LIBRO DE ABSTRACTS
DE LA XL BIENAL DE FÍSICA

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#91 · Poster · Moisture Sources And Downstream Hydroclimatic Contribution Of A Deforested Agricultural Frontier In Rondônia, South-Western Amazonia
#92 · Poster · Drying In The Congo River Basin: Attribution From Atmospheric Moisture Transport
#114 · Oral · The Role Of Mesoscale Ocean Eddies In Global Climate Prediction
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#142 · Poster · Caracterización De La Atmósfera Antártica, En Verano En El Entorno Del Círculo Polar Antártico, Mediante Radiosondeos.
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#191 · Poster · Using AI Weather Prediction Models To Accelerate The Forecast And Attribution Of Climate Change Signals In Extreme Events
#294 · Oral · Reconstructing Climate And Extremes In Extremadura: Insights From Archival Data
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#345 · Poster · From Middle-Earth To Milankovitch: Calendars As Tools For Teaching Earth Physics
#349 · Poster · Ice Monitoring Systems Based On Acoustic Waves. A Comparison Between Plate And Surface Acoustic Waves.
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GEFM - Simposio de Física Médica

#16 · Oral · SEQUOIA: A New Paradigm For Individualised Survival Prediction
#17 · Poster · A 5 Year Review Of The Automatic Exposure Control System In Conventional Chest Radiography.
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#51 · Poster · High-Resolution Temporal Mapping Of Retinal Oxygenation

#52 · Oral · Towards A Consistent I-Value For Water: Insights On Phase Effects From Advanced Modelling And Simulations
#65 · Oral · Compton Cameras For Medical Imaging: MACACO Results And AIDER Perspectives.
#98 · Oral · Hacia Un Modelo Personalizado De Irradiación Sanguínea En Tratamientos De Radioterapia
#111 · Oral · Impact Of Energy-Loss Fluctuations And Secondary Electron Transport On The Radial Dosimetry Of Electron-Emitting Radioisotopes
#186 · Oral · A Workflow For The Extraction Of Simplified Vascular Graphs From Murine Micro-CT Imaging
#187 · Oral · Spatio-Temporal Encoding For High-Resolution Photoacoustic Tomography With Reduced Hardware Requirements
#194 · Oral · Coded-Mask Prompt Gamma Imaging For Proton Range Verification With Pure Cherenkov Crystal Detectors
#196 · Oral · How Do Binding Kinetics And Radiopharmaceutical Design Affect In Vitro Dosimetry?
#204 · Oral · Suspended Microchannel Resonators For Multiplexed Physical Characterization Of Cells
#222 · Oral · Radiobiology With Laser-Accelerated Protons At CLPU – A Status Report
#285 · Oral · Advanced Monte Carlo Simulations For Emission Tomography Imaging
#307 · Oral · Sensitivity Of Proton Microdosimetry In Water To Electron Transport: Evaluation Of The Influence Of PenG4 And Geant4-DNA Models
#350 · Oral · Assessment Of A 4H-SiC PIN Diode For Time-Resolved Proton Beam Monitoring

GEFN - Simposio de Física Nuclear

#3 · Oral · From A Material Developed For The Control Of Optical Properties To Innovative Helium Targets Fabrication For Fundamental Studies Of Nuclear Reactions.
#141 · Oral · High-Precision Nuclear Structure Simulations On NISQ Quantum Devices
#148 · Oral · Two-Neutrino Double-Beta Decay To Excited States At Next-To-Leading Order
#154 · Oral · Shape Coexistence And Deformation Fluctuations From Shape Invariants
#165 · Oral · Study Of Carrier Transport Enhancement In 4H-SiC Radiation Detectors Through Thermal And Optical Excitation
#167 · Oral · Upgrades At CNA HiSPANoS For Continuous And Pulsed (Alpha,N) Measurements Within MANY
#179 · Oral · Commissioning And Perspectives Of The New Moderator For Thermal Neutrons At CNA HiSPANoS
#188 · Oral · Advanced Characterization Of Radiation Sensors At High Temperatures Using The CNA Tandem Accelerator
#197 · Oral · Development Of A Compact Cryogenic Platform For Multi-Penning-Trap Experiments
#210 · Oral · A Passive Extended Range Bonner Sphere Spectrometer For Neutron Measurements At The ALBA Synchrotron Injection LINAC
#225 · Oral · Direct And Indirect Low-Energy Reaction Studies With Light Nuclei At CNA
#230 · Oral · Probing The Structure Of The Two-Proton Borromean Nucleus 17Ne Through Inclusive Breakup Data
#257 · Oral · A Novel Optical Model Protocol For Nuclear Reaction Analyses At Near-Barrier Energies
#276 · Oral · The Nuclear Josephson Effect And γ-Ray Emission
#278 · Oral · 3D Hybrid Kinetic-MHD Modelling Of The Interaction Between Edge Localised Modes And Energetic Particles In The ASDEX Upgrade Tokamak
#284 · Oral · Dynamic Neural Quantum States
#293 · Oral · Study Of Neutron-Rich Beta-Delayed Emitters Relevant For Understanding The Formation Of The R-Process Rare Earth-Peak Around Mass A~160
#330 · Oral · PALOMARES: UN “LABORATORIO NATURAL” PARA ESTUDIOS RADIOECOLOGICOS DEL PLUTONIO
#374 · Oral · ^{146}Nd(N,γ) Activation At N_TOF NEAR: Bayesian-Optimised HPGe Modelling And First Results Of The SACS

#375 · Oral · Origen De La Estadística Espectral Intermedia En Caos Cuántico: Grado De Caos Y Niveles Perdidos

GEFN y GEFM - Simposio compartido de Física Médica y Física Nuclear

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#176 · Oral · Charge Collection And High-Density Ionization Effects In Ultra-Thin 4H-SiC Diodes For FLASH Radiotherapy Dosimetry
#180 · Oral · Development Of A Fast Electrostatic Chopper For FLASH Proton Radiobiology
#211 · Oral · Neutron Spectrometry In Proton Therapy At Clinica Universidad De Navarra
#214 · Oral · Characterization And Biological Validation Of A BNCT Irradiation Field Using PADC Detectors, RCF And Microdosimetric Modelling
#289 · Oral · Integration Of A Pixelated Crystal In A Compton Camera For Dose Monitoring In Boron Neutron Capture Therapy

GEFP - Plasma Physics

#21 · Oral · Spectroscopy-Based Tools For Probing Magnetic Confinement Plasmas In The Stellarator TJ-II
#145 · Poster · Ar/CO2/H2O Plasmas Generated In A Modified Surfatron Device
#166 · Poster · Implementation Of The Thomson Scattering System For The SMART Tokamak: Status & Synthetic Modeling
#192 · Poster · Time Evolution Of The Ns-Laser-Generated Plasma On Steel Samples In Controlled Atmospheres
#205 · Oral · Physics-Informed Neural Network Modelling Of Perpendicular Energy Diffusion In The Scrape-Off Layer Of Nuclear Fusion Devices.
#207 · Poster · Implementation Of The First NBI System For The SMART Tokamak
#219 · Oral · Investigation Of Edge Deuterium Density Profiles With MI-CXRS At ASDEX Upgrade
#228 · Oral · BRIGHT, A Negative Triangularity, Low Aspect Ratio, HTS-Based Tokamak As A Platform For Fusion Enabling Technology Research
#229 · Poster · Status Of The SMall Aspect Ratio Tokamak And Achievements Of The First Experimental Campaign
#234 · Oral · Efecto E Interpretación De Los Parámetros Espaciotemporales De La Re-Excitación De Un Plasma Inducido Por Láser De Femtosegundos Mediante Un Pulso Láser De Nanosegundos
#238 · Poster · Preliminary Design And Initial Heat Load Assessment Of The BRIGHT Tokamak Divertor Using SOLEDGE3X
#239 · Poster · Diagnostics Overview Of The SMART Spherical Tokamak
#251 · Oral · Solution Cathode Glow Discharge Optical Emission Spectrometry: Fundamental Insights And Methodological Approaches
#252 · Oral · Evaluation Of An Artificial Neural Network For Copper Quantification In Optical Emission Spectroscopy Using SCGD-OES
#264 · Oral · Nuevas Perspectivas De PGD-TOFMS Como Herramienta Versátil Para El Análisis Directo De Compuestos Orgánicos
#266 · Oral · Impurity Transport Studies In Magnetically-Confined Using Tracer-Encapsulated Solid Pellet (TESPEL)
#309 · Oral · Control Nanoestructural De Películas Delgadas Nanocolumnares De WOx Mediante Deposición En ángulo Oblicuo Asistida Por Plasma
#311 · Oral · CIEMAT-QI4X: A Reactor-Relevant Stellarator Magnetic Configuration As The Basis For Project WISER
#321 · Oral · Influence Of Barrier Architecture And Effective Discharge Volume On Ammonia Decomposition In DBD Reactors
#332 · Poster · Study On The Role Of Nitrogen In Ammonia Decomposition In A Small Gap DBD Plasma Reactor
#336 · Poster · INFLUENCIA DE PROMOTORES EN LA DISOCIACIÓN DE CO_2 MEDIANTE PLASMA CATALÍTICO EN REACTORES DBD PACKED-BED

#378 · Oral · Merging Plasma Sputtering Deposition And Acoustic Wave Activation For The Deposition Of Materials.
#394 · Poster · Overview Of The Activities On The ITER Fast-Ion Loss Detector
Poster · Finite-β Effects on Energetic-Ion Confinement in W7-X
Poster · Overview of Fast-Ion Physics Studies in Magnetically Confined Fusion Devices from the Plasma Science and Fusion Technology Group
Oral · Overview of the Plasma Science and Fusion Technology Lab

GEITC - Quantum Computing (Theory and Experiment)

#90 · Oral · Anharmonic Lipkin Model: Implementation On A Quantum Device And Quantum Phase Classification.
#121 · Poster · Rigorous Time-Dependent Hamiltonian Learning Via Weak Measurements
#127 · Oral · Thermodynamic Networks: Harnessing Non-Equilibrium Steady States For Computation
#146 · Oral · Rigorous Quantum State Tomography For Distributed Quantum Computing
#150 · Oral · Hybrid Reward-Driven Reinforcement Learning For Efficient Quantum Circuit Synthesis
#199 · Oral · Leakage Propagation And Passive Removal In Tunable Transmon Architectures
#226 · Oral · Simulating Hardware To Optimize Experiments In A Quantum Hybrid Platform
#310 · Oral · Implementing The Quantum Fourier Transform On A Molecular Qudit With Full Refocusing And State Tomography
#328 · Oral · Complexity Of Shor's Algorithm With Qubit Independent Errors
#329 · Oral · Effect Of Isotropic Errors On The Complexity Of Grover's Algorithm
#342 · Oral · Quantum Reinforcement Learning In The Presence Of Thermal Dissipation
#377 · Oral · Quantum Kernel Methods For High-Energy Neutrino Event Classification

GEITC - Quantum Information and Quantum Cryptography

#42 · Oral · Certification Setup For Single Photon Detectors Used In QKD Systems
#63 · Oral · Device-Independent Quantum Cryptography With Input Leakage
#64 · Oral · Theoretic-Informational Study Of Interelectron Correlations In Non-Heavy Atoms In Position And Momentum Space.
#120 · Oral · Measuring Temporal Entropies In Experiments
#122 · Oral · Analytical Security Analysis For Imperfect Decoy-State QKD
#177 · Oral · Finite-Size Quantum Key Distribution Rates From Rényi Entropies Using Conic Optimization
#184 · Oral · Entanglement-Swapping Measurements For Deterministic Entanglement Distribution
#198 · Oral · The Role Of Entanglement In Energy-Restricted Communication And Randomness Generation
#232 · Oral · Quantum State Exclusion For Group-Generated Ensembles Of Pure States
#233 · Oral · Beyond Weak Coherent Pulses In Decoy-State Quantum Key Distribution: Can Practical Single-Photon Sources Enhance Key Generation?
#381 · Oral · Absolute Dimensionality Of Quantum Ensembles

GEITC y GEOCONL - Quantum Simulation and Ultracold Atoms

#24 · Oral · Observation Of String Breaking Dynamics With Rydberg Atoms And Trapped Ions
#37 · Oral · On The Fragility Of Dissipative Time Crystals
#45 · Oral · Global Control Of Spin Crystals Via Single-Site Manipulation: Tracking Of Transport
#74 · Oral · Enhanced Quantum Heat Engines Using Exchange Symmetry Manipulation
#217 · Oral · Does The Stroboscopic Lindbladian Exist? An Analytical Approach
#343 · Oral · Measurement Induced Quantum Ratchet

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

#5 · Oral · "Programming" Quantum Simulators Made Of Atoms And Light

#6 · Oral · Controlling Propagating Photons With Chiral, Multi-Mode Waveguide QED
#18 · Oral · Optimal Control For Dipolar Hubbard Rings
#32 · Oral · Quantum Sensing With Optically Active Spin Defects For Magnon-Based Technologies
#57 · Oral · Strategies Toward Quantum Optics In The Terahertz Regime
#89 · Oral · Quantum Sequential Parameter Testing
#94 · Oral · Quantum Sensing Through Continuous Monitoring Of Open Many-Body Systems
#99 · Oral · Quantum-Enhanced Estimation Of Mode Parameters
#103 · Oral · Indene-C60 Monoadduct As A Single-Photon Emitter
#130 · Oral · Aproximación Semiclásica Al Antiarracimamiento Fotoeléctrico
#149 · Oral · Photon-Counting RGB Cathodoluminescence Imaging In Scanning Electron Microscopy: Prototype Description And First Results
#172 · Oral · Benchmarking Quantum Extreme Learning Based On Gaussian Boson Sampling
#185 · Oral · Topological Phases Of Interacting Driven-Dissipative Lattices
#325 · Oral · Tailoring Quantum Radiation With Giant Atoms For Quantum Metrology

GEM - Mujeres en Física

#61 · Oral · Women In Physics In Spain: Gender Inequalities, Academic Trajectories, And Structural Barriers In The University System
#62 · Oral · Beyond Neutrality In Physics: Integrating Gender Perspectives In Mechanics Education
#67 · Oral · Las Científicas: El Imaginario Social Y La Realidad
#70 · Oral · ¿Es La Física Realmente Neutral? Cultura, Estereotipos Y Desigualdad En La Disciplina
#286 · Oral · ¿Es Posible Reducir La Brecha De Género En Los Estudios De Física? Conclusiones Tras 4 Años De Actividades De Divulgación Científica De Las Estudiantes De La Facultat De Física En Sus Centros De Secundaria
#313 · Oral · Grandes Científicas En Física Aplicada: Un Proyecto De Divulgación Y Reconocimiento Histórico En La Universidad De Granada
#318 · Oral · Programa Autorreferentes: Mujer Y Ciencia. Una Experiencia De Divulgación Con Perspectiva De Género En Centros Educativos De Sevilla.
#368 · Oral · Geometry Of Silence: Women Computers And Engravers In 19th-Century Cartography

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

#19 · Oral · Orbital Angular Momentum Conservation Versus Scaling Laws In High-Order Harmonic Generation Driven By Spatiotemporal Structured Light
#38 · Poster · Vortex Bullets In Guiding And Anti-Guiding Potentials
#40 · Oral · Artificial Intelligence For Multi-Symmetry Topological High-Harmonic Spectroscopy
#43 · Oral · Time-Gated Optical-Parametric-Amplification Of Mid-Infrared Free-Induction Decay Signals
#44 · Oral · Towards Attosecond Pulse Generation In Graphene Via Macroscopic High-Harmonic Generation
#126 · Poster · Achromatic Fourier Optics With Geometric-Phase Lenses Under Supercontinuum Illumination
#136 · Oral · Experimental Observation Of Discrete Time Crystals And Domain-Wall Dynamics In Active Mode-Locked Laser Cavities
#157 · Poster · Polarization Gating Techniques Towards The Characterization Of Structured Attosecond Pulses.
#160 · Oral · Spontaneous Optical Skyrmion Generation By Frequency Doubling In Underdense Plasmas
#163 · Oral · Compact High-Order Harmonic Attosecond Pulse Sources Driven By Hollow Gaussian Beams
#190 · Oral · Adaptive Robotic Laser System For Coating Removal From Aeronautical Components Of Arbitrary Geometry
#221 · Oral · Ultrafast Thermodynamic Characterization Of The Photoinduced Metal-Insulator Transition In Vanadium Dioxide.

#245 · Oral · Selective Up- And Down-Conversion Of Weak Optical Signals By Raman Molecular Modulation In Hydrogen-Filled Hollow-Core Fibres
#248 · Oral · Engineering Classical And Quantum Properties In An Ultrafast Bright Squeezed-Vacuum Source
#255 · Oral · Polarization-Stable Frequency Conversion Via Stimulated Raman Scattering In Birefringent Hollow-Core Fibers
#388 · Oral · Surface Light Localization In Topological Multilayers: Linear And Nonlinear Applications

Resúmenes de charlas de ponentes invitados

Alberto Loarte

The new ITER Baseline: Status of Construction, Research Plan and open R&D issues

ITER Organization, France

Resumen

A new baseline has been adopted by the ITER Project in 2024 to ensure a robust achievement of the Projects' goals, in view of past challenges. The new baseline includes modifications to ITER's tokamak configuration and ancillaries (e.g. change of first wall material from beryllium to tungsten, modification of heating and current drive mix, etc.) as well as additional testing of components (e.g. toroidal field coils) or phased installation (start with inertially cooled first wall before water-cooled one is installed) to minimize operational risks.
In the new baseline, the ITER Research Plan (IRP) is divided into three main phases:
a) Start of Research Operation (SRO), with 40 MW of ECH and 10 MW of ICH, which will focus on the demonstration of 15 MA operation in L-mode, commissioning of all required systems, including disruption mitigation, and the demonstration of H-mode plasma operation in deuterium,
b) DT-1, with 60-67 MW of ECH, 33 MW of NBI and 10-20 MW of ICH, which will demonstrate robust operation in high confinement H-mode plasmas in DT up to Q = 10 for burn durations for 300-500s within an accumulated neutron fluence of ~ 1% of the final goal, and,
c) DT-2, with 60-67 MW of ECH, up to 50 MW of NBI and 10-20 MW of ICH, with the ITER tokamak and ancillaries in their final configuration to demonstrate routine operation in DT plasmas at high Q and the Q = 5 long-pulse and steady-state scenarios to the final neutron fluence.
The presentation will describe the status of ITER tokamak assembly and plant system installation and commissioning, the logic, physics basis and the modelling and experimental evaluations carried out to support the new baseline and the associated IRP. The latter includes the impact of the tungsten wall on plasma scenarios and associated risk mitigation measures, as well as the optimization of the tokamak components and ancillaries to minimize Project risks. Open R&D issues related to these evaluations and mitigation measures will also be described together with experimental, modelling and modelling validation activities required to address them.

Volver al índice

Arantxa Arbe

Vitrimers as Promising Polymeric Materials: Fundamental Aspects

Centro de Física de Materiales (CSIC-EHU), San Sebastián, Spain

Resumen

The incorporation of dynamic bonds into polymer networks has emerged as a promising strategy to address the environmental challenges associated with the pervasive use of polymers and their generally limited recyclability. Vitrimers represent a distinct class of polymeric materials in which dynamic covalent bonds form networks with associative reversible cross-links. In the practice, the usual chemical incompatibility of cross-linker moieties and polymer backbone leads to nano- or micro-phase separation. Understanding the intricate structural and dynamical behavior of these systems is essential for the rational design of this emerging class of materials and represents an exciting challenge from a fundamental perspective. In this talk, model vitrimers will serve as illustrative examples to highlight the rich and diverse phenomenology exhibited by soft-matter systems.

Volver al índice

Beatriz Jurado

Nuclear reactions at heavy-ion storage rings

LP2i Bordeaux, France

Resumen

Reactions induced by neutrons on radioactive nuclei are essential for applications in nuclear technology and in astrophysics. However, the measurement of the cross sections for these reactions is very difficult or impossible due to the difficulty to produce and handle the necessary radioactive targets. In this talk, I will present the innovative method we have developed to infer these cross sections indirectly by using for the first time heavy-ion storage rings.

Volver al índice

Carmen Garcia Garcia

Del descubrimiento a la precisión: ATLAS en la era de la alta luminosidad

Profesora de investigación del CSIC; IFIC - Instituto de Física Corpuscular

Resumen

Desde el inicio de la toma de datos del LHC, el experimento ATLAS ha desempeñado un papel central en la exploración de la frontera de la física de partículas. El descubrimiento del bosón de Higgs en 2012 marcó un hito histórico que culminó décadas de esfuerzos para comprender el origen de la masa de las partículas elementales. Sin embargo, lejos de representar un punto final, este hallazgo inauguró una nueva etapa en la que ATLAS ha evolucionado desde un experimento concebido para realizar descubrimientos hacia una herramienta de precisión sin precedentes.
En esta charla se repasarán algunos de los principales logros científicos de ATLAS a lo largo de las distintas fases de operación del LHC. Se presentarán los avances en el estudio del bosón de Higgs, las medidas de precisión en física electrodébil, cromodinámica cuántica y física del quark top, así como las búsquedas de fenómenos más allá del Modelo Estándar. En conjunto, estos resultados ilustran cómo el creciente volumen de datos y la mejora continua de las técnicas experimentales han transformado ATLAS en un observatorio capaz de someter al Modelo Estándar a pruebas cada vez más exigentes. Finalmente, se discutirá cómo ATLAS se prepara para afrontar el desafío de la Alta Luminosidad del LHC (HL-LHC), una nueva etapa que multiplicará el potencial estadístico disponible y requerirá una profunda renovación del detector, de la infraestructura de computación y de las estrategias de análisis para seguir ampliando nuestro conocimiento de las leyes fundamentales de la naturaleza.

Volver al índice

Eckehard Olbrich

Computational approaches to understand political polarization - How methods and models from sociophysics can help to understand the dynamics of political polarization

Max Planck Institute for Mathematics in the Sciences

Resumen

The modelling of opinion dynamics is a central element in the field of sociophysics and can be told as a success story. In contrast to survey-based studies of public opinion in the social sciences, these models allow for the investigation of dynamic phenomena such as sudden opinion shifts or hysteresis effects. The study of political polarization is a key application domain for these models. At the same time, the representation of opinions in such models remains highly abstract - typically as binary yes/no variables or along a one-dimensional continuous scale - and this limits their empirical applicability. Bridging this gap is particularly challenging when it comes to capturing conceptually distinct forms of polarization, such as diverging opinions on individual issues (issue polarization), the sorting of citizens into ideological camps (issue alignment and ideological polarization), and affective polarization. In my talk, I discuss the challenges that arise when we seek to make our models empirically grounded. This includes questions of how opinions should be represented and measured, and what modelling approaches follow from these choices. I will also highlight the opportunities that large language models have opened up for the analysis of text data as a window into political opinions and their dynamics.

Volver al índice

Jairo Sinova

Unconventional Magnetism: the emergence of altermagnetism and beyond

Johannes Gutenberg University Mainz, Germany

Resumen

Antiferromagnetic spintronics has been a very active research area of condensed matter in recent years. As we have learned how to manipulate collinear antiferromagnets actively and their emergent topology by means of new types of spin-orbit torques, a key problem remained: the inefficiency of relativistic mechanism. The necessity of relativistic effects to manipulate and detect Néel order arises from the spin degeneracy of collinear antiferromagnets in the non-relativistic limit - or at least it was thought. The discovery of d-wave magnetic order in momentum space motivated a closer look at the symmetry classification of collinear magnetic systems. This has emerged as the third basic collinear magnetic ordered phase of altermagnetism, which goes beyond ferromagnets and antiferromagnets. Altermagnets exhibit an unconventional spin-polarized d/g/i-wave band structure in reciprocal space, originating from the local sublattice anisotropies in direct space. This gives properties unique to altermagnets (e.g., the spin-splitter effect), while also having ferromagnetic (e.g., polarized currents) and antiferromagnetic (e.g., THz spin dynamics and zero net magnetization) characteristics useful for spintronics device functionalities. I will cover the basic introductory view to altermagnetism and its consequences to spintronics as well as new emerging exchange driven phenomena akin to spin-orbit coupling effects, such as p-wave magnetism, emerging from the basic concepts that gave rise to the discovery of altermagnetism.

Volver al índice

Manuel Lozano Leyva

Lo que no se debería haber descubierto

Catedrático emérito de Física Atómica, Molecular y Nuclear, Universidad de Sevilla

Resumen

La intuición humana más importante para el devenir de la humanidad, la existencia de los átomos y el vacío, tardó 2400 años en confirmarse. Sin embargo, lo más decisivo fue el hallazgo del desaparecido poema De Rerum Natura de Tito Lucrecio Caro. La fusión en el mismo de la hipótesis de Leucipo y Demócrito con la de Epicuro fue aún más sorprendente: los átomos propiciaban la alegría de vivir. De Rerum Natura, La Naturaleza de las Cosas, fue pieza clave en el Renacimiento y sin duda en la eclosión de la ciencia apagada desde el periodo helenístico. Se mostrará todo el sentido que tiene la conclusión de Lucrecio en el siglo XXI tratando de definir lo más acertadamente posible lo que puede significar esa alegría de vivir y cómo los átomos, las moléculas e incluso —quizás, sobre todo— el núcleo atómico y las partículas subatómicas la pueden favorecer ad infinitum.

Volver al índice

Marie Vidal

Uncertainties in dose calculation and measurement in protontherapy

Head of Medical Physics of Institut Méditerranéen de Protonthérapie, Centre Antoine Lacassagne, Nice, France

Resumen

Proton therapy has emerged as a highly advanced form of radiotherapy, thanks to the unique physical characteristics of proton beams, particularly the presence of the Bragg peak, enable the delivery of high doses to tumors while minimizing exposure to surrounding organs at risk. However, these advantages come with significant challenges in dose calculation and measurement, making the role of the medical physicist essential throughout the treatment process, but also in the developments of research projects related to clinics.
Accurate dose calculation in proton therapy is complicated by uncertainties related to patient anatomy, tissue heterogeneity, and particularly proton range prediction. Small variations in tissue composition, anatomical changes during treatment, or imaging inaccuracies can lead to significant deviations between planned and delivered dose distributions. Furthermore, advanced treatment techniques such as pencil beam scanning require sophisticated dose calculation algorithms.
Dose measurement and quality assurance also present unique challenges. The steep dose gradients and high sensitivity of proton beams to material composition demand the use of highly precise detectors and measurement protocols. Verification of beam parameters, calibration of dosimetric equipment, and validation of treatment planning systems are critical tasks to ensure treatment safety and accuracy. Medical physicists play a central role in addressing these challenges. As proton therapy continues to evolve, by integrating advances in imaging, dosimetry, and computational modeling in collaboration with research laboratories, treatment precision and clinical outcomes are significantly improved.

Volver al índice

Monika Aidelsburger

Quantum simulation - Engineering & understanding quantum systems atom-by-atom

Max-Planck-Institute of Quantum Optics & Ludwig-Maximilians-Universität München, Germany

Resumen

Quantum simulation provides new insights into the complex properties of quantum many-body systems in regimes that are not accessible with state-of-the-art classical numerical methods.
In this talk, I will introduce quantum simulators based on ultracold atoms in optical lattices, where control at the level of individual particles can now be achieved in systems of several thousand atoms. I will discuss how these platforms enable the exploration of topological phases of matter and their interplay with interactions and disorder.
Building on these capabilities, we have recently realized non-equilibrium U(1) quantum spin liquids of Rokhsar-Kivelson type, establishing a direct connection to lattice gauge theories.
Finally, I will highlight recent experimental advances that provide new ways to prepare and probe complex quantum states, opening routes to strongly correlated and out-of-equilibrium many-body physics, where neutral-atom platforms not only emulate but are increasingly enabling the discovery of new quantum phenomena.

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Nazario Martin

Benzene: Discovery and Legacy - The Molecular Origins of Graphene at Atomic Resolution

Departamento de Química Orgánica, Facultad de Química, Universidad Complutense de Madrid; IMDEA-Nanociencia

Resumen

The development of advanced carbon nanomaterials, including graphene, can be traced back to the discovery of benzene, the archetypal aromatic molecule whose unusual properties puzzled nineteenth-century chemists. In 1825, Michael Faraday isolated benzene while studying the liquid produced during the compression of oil gas. He initially named the compound “bicarburet of hydrogen,” and its empirical formula, C6H6, was established several years later. The exceptional stability of benzene challenged the prevailing understanding of unsaturated hydrocarbons until August Kekulé proposed its cyclic structure in 1865. This model was definitively validated in 1925 through X-ray diffraction studies carried out by Kathleen Lonsdale.

This presentation explores the key milestones that led to the discovery and structural determination of benzene and follows the evolution of increasingly complex aromatic architectures derived from it. Attention is given to graphene, the first isolated two-dimensional (2D) material, whose extraordinary electronic, mechanical, and thermal properties sparked the emergence of an entire family of atomically thin materials.

The journey from benzene to graphene can also be appreciated through modern surface-assisted synthesis, which enables the fabrication of atomically precise nanographenes. These molecular nanostructures can be directly characterized using scanning probe techniques such as STM (Scanning Tunneling Microscopy) and nc-AFM (non-contact Atomic Force Microscopy). Remarkably, nc-AFM imaging with functionalized tips provides submolecular resolution, allowing individual benzene rings and even the bonding framework within nanographenes to be visualized in real space. Such capabilities offer an unprecedented connection between the molecular origins of aromaticity and the atomic structure of graphene-related materials. Graphene itself has been celebrated as a “gift from the gods,” reflecting both its scientific significance and its transformative impact on nanoscience.

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Paula Heron

Improving Student Learning: The Dual Roles of Conceptual Understanding and Reasoning Ability

University of Washington, Department of Physics,
Seattle, USA

Resumen

Why do students make errors on physics problems? Errors that directly contradict what they have been taught? Errors that don't arise from the failure to remember the correct formula? For the past several decades, physics education researchers have focused on one compelling explanation: students arrive in the classroom with pre-formed ideas about how the world works. Even though they may blend these ideas with those presented in formal instruction, the prior conceptions often win out. According to these accounts, students' prior knowledge has been built through rational, if imperfect, processes of observation and analysis, and any new or different ideas presented in the classroom must likewise be built, not simply received. Figuring out what ideas students bring with them to the classroom, and how to take them into account, has proven to be a complex, multi-faceted program of research that has significantly influenced physics teaching. However, it is not always the case that students produce incorrect answers through logical inferences based on incorrect or inappropriate premises - often they don't know why they chose a particular answer, just that it seems right. "Dual-process" theories suggest that their answers might not be based on so-called "slow" thinking, which is deliberate and laborious. Instead they might be based on so-called "fast" thinking, which is automatic and effortless. The basic idea is that students immediately and effortlessly form a first-impression of a physics problem. If this impression is found to be satisfactory, it will be adopted. Otherwise, a deliberate and analytical process ensues. It is believed that this sequence cannot be "turned off." That is, a first impression will always be formed. If it is attractive, and the benefits of engaging in more effortful thinking are not obvious, then a student may answer incorrectly, masking their conceptual knowledge. In this talk, I will discuss recent efforts to improve both conceptual understanding and reasoning skills. Examples will be chosen from first-year university-level physics.

Volver al índice

Rafael Bachiller

El Trío de Eclipses “españoles” 2026, 2027 y 2028

Presidente de la Comisión Científica del Trío de Eclipses; Director del Observatorio Astronómico Nacional y del Real Observatorio Astronómico de Madrid (IGN)

Resumen

Los eclipses solares del 12 de agosto de 2026 (total), 2 de agosto de 2027 (total) y 26 de enero de 2028 (anular) que serán visibles desde España constituyen unos acontecimientos extraordinarios que brindan una magnífica oportunidad para la observación del Sol y para la divulgación científica. Esta conferencia ofrecerá información básica sobre la física de los eclipses solares en general, sus tipos y sus ciclos, así como sobre su impacto en las artes, las mitologías y, por supuesto, en la investigación científica. En efecto, la observación de los eclipses no sólo aportó un valiosísimo conocimiento sobre las capas más externas del Sol, sino que permitió, con ocasión del eclipse del 29 de mayo de 1919, realizar la primera validación observacional de la teoría de la Relatividad General que Albert Einstein había publicado tan sólo unos años antes.
Se analizarán las efemérides astronómicas de esta tríada de eclipses, ya llamados “españoles”, se detallarán las mejores zonas para visionarlos y se ofrecerán consejos para disfrutar de una observación óptima.

Volver al índice

Ricardo Garcia Herrera

La predicción meteorológica: de las puertas de Ishtar a la Inteligencia Artificial

Catedrático de Física de la Atmósfera,
Universidad Complutense de Madrid; Instituto de Geociencias (CSIC-UCM)

Resumen

Predecir el tiempo ha sido uno de los desafíos científicos más antiguos, motivado por el impacto severo del tiempo y el clima en el modo de vida y el grado de desarrollo de las diferentes civilizaciones. Esta presentación repasa las diferentes etapas que se han producido en la evolución de la predicción del tiempo gracias al avance del conocimiento científico y el desarrollo tecnológico. Las primeras predicciones se basaron en la climatología y en la pretendida influencia de los astros. La invención de instrumentos capaces de medir las variables meteorológicas a partir del siglo XVII, así como los posteriores desarrollos teóricos de la mecánica y la termodinámica, permitieron plantear la meteorología como una ciencia a principios del siglo XX. Sin embargo, como el comportamiento de la atmósfera está regido por ecuaciones diferenciales no lineales en derivadas parciales acopladas, el uso de modelos meteorológicos con capacidad operativa tuvo que esperar a finales del siglo XX, cuando la supercomputación permitió la resolución numérica de las mismas de manera rutinaria. La presencia del caos determinista en las ecuaciones hidrodinámicas, obligó posteriormente a introducir la predicción probabilista basada en conjuntos. En los últimos años, la irrupción de la Inteligencia Artificial está dibujando un nuevo panorama, cuyos límites están todavía siendo explorados.

Volver al índice

Xavier Moya

Barocaloric materials and systems for sustainable heating and cooling applications

Department of Materials Science, University of Cambridge; Barocal Ltd

Resumen

Half of the world's CO2 emissions can be attributed to heating and cooling. This is primarily due to heating with natural gas and cooling with compression of greenhouse gases, which are neither environmentally friendly nor energy efficient. There is great interest in developing energy-efficient solid-state heat pumps that can replace these environmentally damaging technologies. Barocaloric materials are at the core of novel solid-state heat-pump technologies. During this talk I will describe our work on barocaloric materials and systems driven using pressure for low-carbon heating and cooling applications.

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#4 — Poster

Rayos X, Radiografías Y GVirtualXray Como Su Gemelo Digital

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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3. Instituto de Física Corpuscular (CSIC-UVEG), Paterna, Spain
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Abstract Text:

X-ray radiography is one of the most widely used imaging techniques in medicine and industry due to its speed, low cost, and high spatial resolution for visualizing the internal structure of objects. This article reviews the physical and technological foundations of conventional radiography, including the generation of X-rays in metal-anode tubes, the formation of the emission spectrum, and the attenuation processes described by the Beer-Lambert law. Based on these principles, the concept of virtual radiography is introduced, particularly through the gVirtualXray framework, which enables fast and realistic simulation of radiographic images using geometric models and efficient rasterization-based algorithms. The computational foundations of the simulation are described, highlighting their advantages over traditional approaches and their ability to generate radiographs in near real time. Finally, applications in education, research, technological development, and artificial intelligence training are discussed, emphasizing the value of these virtual environments as a safe and flexible complement to real radiology.

Volver al índice

#7 — Oral

A Breakout Activity For Engineering Students

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

This work presents a gamified activity linked to the Renewable Energy course, which is taught across several engineering degree programs at the University of Burgos.
In the laboratory, the students are divided into teams through the random drawing of colored balls. Each team faces a series of challenges associated with different parts of the course (solar thermal energy, photovoltaics, wind energy, geothermal energy, etc.). To solve these challenges, students must bring into play theoretical knowledge, calculation skills, and reasoning abilities.
The challenges have been implemented using the Genially application, a widely used tool in gamification-based teaching. Each time a team correctly solves a challenge, the application displays a map of the laboratory showing the approximate location of a QR code. Students must find this code, which then directs them to the next challenge.
The activity takes place during the final in-person session of the course and contributes approximately 10% to the final grade. Each team's score is determined by the number of challenges completed and by their ranking relative to the other teams. Additionally, every student must complete a peer-assessment questionnaire designed to clarify the relative contribution of each team member to the problem-solving process.
Students invariably engage enthusiastically in the activity. Although the official duration of the session is two hours, it is common for them to remain in the laboratory until they are literally asked to leave. In the hours that follow, it is not unusual for them to send the instructor the solution to the challenge they were working on at the moment of leaving. For the author, this activity has become an essential component of his Renewable Energy courses.

Volver al índice

#8 — Poster

“Mini Lingotes De Oro” SDA Adaptada Para Alumnas Y Alumnos Ciegos.

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

“Mini lingotes de oro” es una situación de aprendizaje original, realizada mediante una metodología de aprendizaje basada en proyectos. La contextualización es la siguiente: Brenda y Diego son dos alumnos ciegos que han descubierto en un cajón de la casa de sus abuelos unos mini lingotes metálicos, en relieve está escrita la palabra gold (oro). Su reto será determinar si dichos mini lingotes son de oro puro. En este proyecto hemos determinado la densidad de unos mini lingotes de metal, recubiertos de un baño dorado que simulan ser de oro. Para ello, hemos medido experimentalmente la masa y el volumen de los mini lingotes. En la medida de la masa, hemos utilizado una balanza y para la medida del volumen hemos utilizado el método de la balanza hidrostática y también el uso de una probeta. Hemos determinado su comportamiento ferromagnético y realizado un ataque con ácido acético del recubrimiento dorado, deduciendo con todo que su composición es ZAMAK con un baño dorado de latón. El principal objetivo del proyecto, además de determinar la densidad de los lingotes y su composición ha sido adaptar los métodos y materiales, para que el proyecto pueda ser desarrollado de forma autónoma por estudiantes ciegas y ciegos de una forma autónoma.

Volver al índice

#10 — Oral

QuaMtos: Motivational Activities In The Physics Classroom

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

The authors of this proposal are first-year Physics instructors in several Engineering degrees at the University of Burgos. Despite the fundamental importance of a solid grounding in Physics for any engineer, we frequently observe a lack of motivation among our students regarding the subject. For this reason, we intend to enrich our theoretical sessions with a variety of activities —collectively referred to as quaMtos (i. e. quanta of Motivation)— designed to spark students' interest within the context of the concepts that will later be formally introduced. The quaMtos can take multiple forms: live experiments, open-ended questions, video screenings, polls, competitions, and more.
Of course, all instructors include activities of this nature into their classroom sessions. The novelty of this initiative relies on three main pillars. First, whenever possible, we aim to schedule the activities prior to the theoretical content they are intended to clarify, so as to stimulate students' curiosity about those concepts. Second, we seek to make quaMtos a regular feature of the classroom experience, such that every theoretical session includes at least one "different" element. In this sense, we would like students to ask themselves before every session "What performance will we witness today?" Third, we intend to document all our quaMtos through descriptive text files—or preferably through video recordings—and to upload them to the University's Institutional Repository, ensuring they remain indefinitely available to the entire university community.
During the 2025/26 academic year, the authors presented approximately twenty quaMtos in the classroom, a number we hope to double over the course of 2026/27.

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#23 — Poster

Incorporación De Python Como Recurso Didáctico En La Docencia De Física Y Matemáticas Con Aplicación En Distintas Asignaturas De Grado

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

En esta contribución se presenta la implementación completa de la transición del lenguaje de programación MatLab a Python en la asignatura de Métodos Numéricos y Estadísticos, impartida en segundo curso del grado en Física y en tercero del doble grado en Física y Química de la Universitat de València.
A diferencia del estudio preliminar realizado previamente, en este curso académico se ha llevado a cabo la migración total de la asignatura, incluyendo tanto el desarrollo de ejemplos sencillos para su uso en el aula como la adaptación íntegra de las sesiones prácticas. Para ello, se ha optado por el entorno de desarrollo Spyder, seleccionado por su facilidad de instalación y uso en distintos sistemas operativos, lo que facilita su adopción por parte del estudiantado.
Durante el presente curso, el uso de Python ha sido obligatorio en el doble grado en Física y Química, mientras que su implantación como herramienta obligatoria en el grado en Física está prevista a partir del próximo curso académico. La aplicación de este cambio ha mostrado resultados muy positivos tanto en términos de seguimiento como de aprendizaje por parte del alumnado.
Asimismo, la experiencia adquirida ha permitido extender el uso de Python a otras asignaturas del grado. En Introducción a la Física Experimental (primer curso), se ha desarrollado una selección de ejemplos de estadística básica, representación gráfica (incluyendo histogramas) y ajustes sencillos, que el estudiantado puede utilizar de forma opcional. Por otro lado, en la asignatura de Física Nuclear y de Partículas (cuarto curso), se han implementado programas orientados al análisis avanzado de datos y cálculos específicos de la asignatura.
Estos resultados refuerzan el potencial de Python como herramienta docente en el ámbito de la Física, destacando su versatilidad, accesibilidad y proyección en entornos científicos y profesionales.

Volver al índice

#26 — Oral

Aprendizaje De La Física Mediante Un Proyecto De Bioconstrucción Con Impacto Social: Efectos Sobre La Comprensión Conceptual Y El Compromiso Emocional En Educación Secundaria

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

La enseñanza de la física en Educación Secundaria afronta el reto de promover aprendizajes conceptuales sólidos en contextos auténticos y socialmente relevantes. En este marco, se presenta una intervención didáctica basada en Aprendizaje Basado en Proyectos e integración STEM, articulada en torno al diseño y construcción de prototipos de domos mediante la técnica de bioconstrucción Superadobe, vinculada al problema humanitario de la vivienda de emergencia en zonas áridas. La propuesta permitió trabajar contenidos de física relacionados con las propiedades de los materiales, el comportamiento de materiales granulares, las fuerzas de compresión, la distribución de cargas y la estabilidad de estructuras abovedadas. La intervención se desarrolló en contextos reales de aula mediante un diseño cuasiexperimental con medidas pretest-postest. La muestra estuvo compuesta por 111 estudiantes de Educación Secundaria Obligatoria distribuidos en cuatro grupos: un grupo de control, dos grupos experimentales ordinarios y un grupo experimental de Diversificación Curricular. En los grupos experimentales se desarrolló una secuencia completa de experimentación, análisis de datos, diseño y construcción, mientras que el grupo de control abordó los mismos contenidos mediante una aproximación más transmisiva, basada en explicación docente y análisis de registros previamente obtenidos. Los resultados cognitivos muestran mejoras estadísticamente significativas en los grupos experimentales, acompañadas de ganancias normalizadas medias y tamaños del efecto elevados. En contraste, el grupo de control presentó una mejora más moderada. Asimismo, se observaron resultados afectivos positivos en motivación, autoeficacia y colaboración, junto con una reducción de barreras emocionales. De forma especialmente relevante, el grupo de Diversificación Curricular, pese a partir de niveles iniciales inferiores, alcanzó progresos comparables a los de los grupos ordinarios. En conjunto, los hallazgos apoyan el potencial del ABP con integración STEM e impacto social para favorecer simultáneamente la comprensión conceptual, el compromiso emocional y la inclusión educativa en la enseñanza de la física.

Volver al índice

#27 — Oral

Diseñar, Construir Y Explicar: Enseñanza De Fenómenos Físicos En Primaria A Través De Proyectos STEM

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

La enseñanza de la física en Educación Primaria presenta dificultades derivadas del carácter abstracto de muchos fenómenos y de la escasez de experiencias experimentales significativas en el aula. Diversos estudios en didáctica de las ciencias han mostrado que el aprendizaje de fenómenos físicos se favorece cuando el alumnado puede manipular materiales, construir modelos y observar directamente los efectos de sus acciones. En este contexto, los proyectos STEM (Science, Technology, Engineering and Mathematics) ofrecen oportunidades para abordar estos contenidos mediante experiencias de diseño, construcción y experimentación. El objetivo de este estudio es analizar el impacto de proyectos STEM basados en el diseño y construcción de artefactos sobre la comprensión de fenómenos físicos en Educación Primaria. En particular, se examina en qué medida la participación en actividades estructuradas en torno a la secuencia diseñar–construir–experimentar–explicar favorece el aprendizaje de conceptos relacionados con la energía, las máquinas simples, el movimiento, la flotabilidad y los circuitos eléctricos. La investigación se desarrolla mediante un diseño cuasi-experimental con grupo control y medidas pre-test y post-test de variables cognitivas y afectivas, integrado en un estudio de casos múltiples. Participaron 230 estudiantes de Educación Primaria, distribuidos en cinco intervenciones y organizados en grupos experimental y control. Cada intervención constituye un caso centrado en la exploración de un fenómeno físico mediante el diseño y construcción de un artefacto. Los resultados muestran que los grupos que participaron en los proyectos presentan ganancias de aprendizaje superiores a las observadas en los grupos control y una evolución emocional más favorable para el aprendizaje. Asimismo, se identificaron diferencias estadísticamente significativas a favor de los grupos experimentales. En conjunto, los resultados sugieren que el diseño y construcción de artefactos constituye una estrategia didáctica eficaz para favorecer la comprensión de fenómenos físicos en Educación Primaria.

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#39 — Oral

Fenómenos Relativistas Explicados Con Modelos Espaciotemporales

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Los fenómenos relativistas son intrínsecamente cuadridimensionales: son la prueba de que espacio y tiempo se imbrican en el espaciotiempo. Por eso conviene a su explicación prescindir de las categorías separadas de «objeto tridimensional» y «tiempo unidimensional» y sustituirlas por una sola de carácter cuadridimensional que las integre. Es lo que se hace al concebir la realidad física como universo de procesos [1] y considerar los procesos (colecciones de cambios causalmente concatenados) como las entidades físicas básicas.
En esa concepción, las líneas de universo representan procesos de distintas direcciones de cambio. La oblicuidad de dos procesos se percibe como movimiento relativo. La velocidad relativa, vrel, se relaciona con el ángulo, α, que forman sus líneas de universo. En el sistema de referencia en que los dos procesos son simétricos (SRS), la relación entre α y vrel es muy sencilla: senα=vrel/c . Además, el SRS tiene la singular propiedad [2] de que sus representaciones minkowskianas (euclídeas sobre el papel) reflejan fielmente las relaciones pseudoeuclídeas entre las magnitudes representadas. Por todo eso, el SRS es muy útil para la explicación e interpretación de los fenómenos cinemáticos de la TRE.
En esta ponencia oral, con el apoyo de modelos y maquetas, se explicarán el efecto Doppler relativista, el fenómeno de la “dilatación temporal” y el de la “contracción de longitudes”. Se mostrará que la clave de la explicación es que las medidas realizadas con relojes y con metros son direccionales en el espaciotiempo. Las líneas de universo y los planos de simultaneidad de los asistentes serán elementos de la representación explicativa en algún caso.
[1] Tomé, J., Universo de procesos: realidad física cambiante y cuadridimensional, ArtefaCToS, 13-2 (2024), pp 273-279
[2] Tomé, J., Adelantamiento de trenes en el espaciotiempo, Revista Española de Física, 36-4 (2022), pp 10-15

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#41 — Oral

ENCERRADO EN UNA JAULA

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Las investigaciones en el ámbito educativo en la etapa de enseñanza secundaria, ponen de manifiesto la importancia que tiene el bienestar emocional y social para lograr éxito en la educación y en la vida. La inclusión en paralelo de cuestiones vinculadas al currículo de la materia de Física de 2º de bachillerato con preguntas y reflexiones sobre la «pandemia de la soledad», permite activar mecanismos con la idea de conseguir que el alumnado muestre sensibilidad hacia las emociones y experiencias de los demás y que sea consciente de la influencia que ejerce el grupo en las personas. La finalidad última del proyecto es la de consolidar una personalidad empática e independiente y desarrollar la inteligencia.
La propuesta comienza con el video de la canción Lovely de Billie Eilish con Khalid en el que se observa a los dos cantantes atrapados dentro de una caja de vidrio. El uso de obras de arte y de enunciados de física con un cierto componente emocional nos lleva a plantear, por un lado, cuestiones curriculares de la materia y, por otro lado, preguntas relacionadas con la soledad no deseada.
Las actividades «¿es lo mismo sentirse solo que estar solo?» y «¿cuál fue la última vez que te sentiste en soledad?» tratan temas de gravitación. «¿La soledad se «digitaliza? ¿Desapego digital?» aborda el sonido y «encerrado en una jaula» versa sobre el campo eléctrico.

Volver al índice

#46 — Oral

Introducción A La Física Del Estado Sólido A Través De Demostraciones En El Aula

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

La Física del Estado Sólido es una asignatura clave en la formación del alumnado de Física, que integra conceptos de física estadística, cuántica y electromagnetismo para modelizar las propiedades de sólidos cristalinos reales, y constituye la base conceptual de áreas como la Estructura de la Materia, la Materia Condensada o la Ciencia de los Materiales. En este contexto, la utilización de demostraciones experimentales en las clases de teoría resulta especialmente adecuada para mostrar fenómenos físicos accesibles, ilustrar de forma directa conceptos abstractos y facilitar su comprensión.
En este trabajo se presentan diversas demostraciones didácticas que forman parte de la colección de la Facultad de Física de la Universidad de Valencia[1], diseñadas para su implementación en el aula y que permiten visualizar y discutir fenómenos y conceptos relevantes en Física del Estado Sólido. Entre ellas, se incluyen ejemplos que relacionan estructura cristalina y propiedades mediante materiales con memoria de forma (nitinol) y el comportamiento elástico del acero al carbono; modelos de apilamiento compacto mediante esferas rígidas; representaciones de zonas de Brillouin del sistema cúbico; demostraciones de levitación diamagnética en grafito; y experiencias que ilustran la relación entre propiedades ópticas y electrónicas en una unión pn utilizando un LED como emisor y como célula fotovoltaica[2].
Referencias:
[1] https://www.uv.es/fisicademos
[2] Demostraciones 175, 201, 71, 155, 191, 202, entre otras.

Volver al índice

#54 — Oral

Gabinete De Los Errores En La Enseñanza Y La Divulgación De La Física

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

En la enseñanza y en la divulgación de la física es habitual realizar experimentos vistosos, para captar la atención de alumnado y público en general. Entre el repertorio de estas actividades llamativas, hay bastantes que se explican recurriendo a fenómenos, conceptos y fórmulas que no son aplicables a los contextos en los que se llevan a la práctica.
Algunos ejemplos de esta clase de experimentos incluyen el vaso lleno de agua cubierto con una cartulina, que no se derrama al voltearlo; la dificultad para doblar el extremo de una regla que sobresale de una mesa, cuando se golpea estando la mitad de ella sobre la mesa y cubierta con una hoja de periódico; la levitación estable de una pelota ligera sostenida por un chorro de aire; o el vuelo de los aviones, entre otros.
Las demostraciones de física que se explican utilizando leyes y conceptos inaplicables en las condiciones en que se realizan son los elementos de un «gabinete de los errores», cuyos «especímenes» se van enriqueciendo (lamentablemente) con aportaciones de distintas áreas de la física.
En esta presentación se pondrán de manifiesto las inconsistencias que subyacen en las explicaciones habituales de estos experimentos, así como de otros frecuentes en este repertorio didáctico-divulgativo, y se proporcionarán razonamientos más coherentes con los fundamentos físicos de los fenómenos estudiados.

Volver al índice

#55 — Oral

Un Paseo Por La Física De La Mano De La Mitología (O Viceversa)

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

La mitología ha constituido históricamente una herramienta para interpretar el mundo natural mediante relatos protagonizados por dioses, héroes y mortales, en los que se proyectan emociones y conflictos humanos. Frente a ello, la física aborda la comprensión de la naturaleza mediante metodologías racionales, prescindiendo de explicaciones sobrenaturales. No obstante, a pesar de la aparente oposición entre ambos enfoques de conocimiento, la mitología —especialmente la grecolatina y la judeocristiana, por su estrecha vinculación con la cultura occidental— ha dejado una huella apreciable en el lenguaje de la física.

Esta influencia se manifiesta con especial claridad en la astronomía, donde numerosos objetos celestes reciben denominaciones de origen mitológico. Sin embargo, también pueden identificarse, aunque en menor medida, referencias legendarias en la nomenclatura de determinados fenómenos físicos y en la instrumentación científica que despertaron el interés de la comunidad académica hace más de un siglo. En esta conferencia se presentan algunos de estos fenómenos y los instrumentos asociados a su estudio, contextualizando su denominación a través de las leyendas y relatos mitológicos que inspiraron a los eruditos y divulgadores científicos que los bautizaron.

Esta interacción entre física y mitología resulta mutuamente enriquecedora, pues la primera se inspira en el marco narrativo y simbólico de la segunda para humanizar y contextualizar fenómenos naturales de carácter abstracto, mientras que el universo mítico encuentra en los experimentos y fenómenos físicos una vistosa forma para representar sus fábulas ante todo tipo de público.

Volver al índice

#72 — Oral

PORTUGAL: ECLIPSE 2026 EN EL AULA

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

El eclipse solar del 12 de agosto de 2026 constituyó una oportunidad excepcional para integrar fenómenos astronómicos reales en la enseñanza de la Física, también en Portugal. Este trabajo presenta un análisis de actividades experimentales desarrolladas en contextos educativos portugueses, utilizando el eclipse como herramienta para abordar conceptos fundamentales.
Las iniciativas analizadas incluyeron observación solar segura, medición de la intensidad luminosa mediante sensores accesibles, construcción de dispositivos ópticos simples (cámaras estenopeicas) y análisis temporal de la variación de parámetros físicos durante el eclipse. Estas actividades permitieron trabajar, de forma aplicada, conceptos como la propagación de la luz, la formación de imagen, la geometría del sistema Tierra–Luna–Sol y la variación de la irradiancia solar.
Los datos recogidos por el alumnado se emplearon para construir series temporales y compararlos con predicciones teóricas, favoreciendo la conexión entre observación experimental y modelización física. Asimismo, se exploró el potencial del eclipse como contexto para introducir metodologías de adquisición y tratamiento de datos en el aula.
Los resultados evidencian altos niveles de motivación y participación del alumnado, así como una mejora en la comprensión de conceptos científicos. Se discuten también los principales retos encontrados, especialmente en relación con la seguridad en la observación solar y la adaptación de las actividades a distintos niveles educativos.
Este trabajo pone de manifiesto el valor de la experimentación en contextos reales en la enseñanza de la Física, destacando el potencial de los eclipses solares como herramienta didáctica de alto valor científico y pedagógico.

Volver al índice

#79 — Oral

Física Y Tecnología: El Mundo Analógico Transformado En Ceros Y Unos

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

En el laboratorio de física en Enseñanza Secundaria nuestros alumnos aprenden las bases del trabajo experimental usando, por ejemplo, un cronómetro y un péndulo para obtener la aceleración de la gravedad, o midiendo con una regla el alargamiento de un muelle para determinar su constante elástica. Con estas y otras muchas actividades prácticas, que son un complemento imprescindible en la enseñanza de la asignatura, desarrollan habilidades fundamentales relacionadas con la medida y el análisis de los datos.
Pero, en el momento en que salen de clase, los estudiantes se encuentran rodeados de aparatos de medida digitales cuyo uso lleva asociado una serie de conceptos que les son desconocidos: diferencia entre señales analógicas y digitales, curva característica de un sensor, conversión analógico-digital, frecuencia de muestreo, ruido en las medidas... Estos conceptos, que son básicos para el funcionamiento de dispositivos como los sensores de luz que regulan el brillo de la pantalla del móvil o los detectores de partículas del CERN, no se trabajan en el aula de física por razones evidentes: tiempo disponible, material necesario o formación del profesorado, entre otras. Sin embargo, dada la importancia que consideramos que tiene una formación completa e integrada en el campo científico, los departamentos de Física e Informática de nuestro centro hemos diseñado una actividad interdisciplinar para alumnos de Bachillerato en la que, usando el microcontrolador Raspberry Pi Pico y el lenguaje de programación MicroPython, los estudiantes trabajan de manera completamente práctica diversos conceptos relacionados con el uso de aparatos de medida digitales y el análisis de los datos. Con esta actividad, además de preparar a los estudiantes para enfrentarse al uso de herramientas digitales, conseguimos que las aportaciones de la física y la tecnología se beneficien mutuamente.

Volver al índice

#80 — Poster

Lei De Faraday – Fenómeno De Indução Eletromagnética — APSA

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Da lista das aprendizagens essenciais (AE) do subdomínio “Eletromagnetismo e ondas eletromagnéticas” de Física e Química A de 11.º ano consta a AE “Aplicar, na resolução de problemas, a Lei de Faraday […]”.
Considerando que se recomenda a realização experimental do fenómeno de indução eletromagnética, é realizada a atividade laboratorial (AL), em regime de demonstração para a turma, que consiste em deixa cair um íman cilíndrico, que atravessa uma bobina ligada a um sensor de diferença de potencial elétrico, por sua vez ligado a uma calculadora gráfica por uma interface.
Terminada a aquisição automática de dados, efetuando a análise do gráfico da diferença de potencial elétrico em função do tempo, conclui-se que
– os sinais da força eletromotriz induzida quando o íman se aproxima quando o íman se afasta da bobina são diferentes;
– o módulo máximo da força eletromotriz induzida quando o íman se aproxima da bobina é inferior ao módulo máximo da força eletromotriz induzida quando o íman se afasta da bobina (a força eletromotriz induzida depende da velocidade com que o íman se move).
Efetuando a análise do referido gráfico, para um intervalo de tempo em que se possa admitir que a força eletromotriz induzida varia linearmente com o tempo, é possível determinar, para esse intervalo de tempo,
– a força eletromotriz induzida média;
– e, aplicando a Lei de Faraday, a variação de fluxo do campo magnético e a magnitude da variação de campo magnético.
Repetindo o procedimento, deixando cair o íman de diversas alturas em relação à bobina, também se conclui, que a força eletromotriz induzida depende da velocidade com que o íman se move.
Esta AL permite abordar o conceito de fluxo de campo magnético e a Lei de Faraday, além de permitir elaborados enunciados de problemas para ser resolvidos em contexto de sala de aula.

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#81 — Poster

Aplicação Da Indução Eletromagnética: Transformador — APSA

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Da lista das aprendizagens essenciais (AE) do subdomínio “Eletromagnetismo e ondas eletromagnéticas” de Física e Química A de 11.º ano consta a AE “Aplicar, na resolução de problemas, a Lei de Faraday, interpretando aplicações da indução eletromagnética, explicando as estratégias de resolução e os raciocínios demonstrativos que fundamentam uma conclusão”.
Um dos contextos de aplicação da Lei de Faraday é o dos transformadores, cuja abordagem pode ser efetuada realizando uma atividade laboratorial, em regime de demonstração para a turma, que consiste no uso de um modelo escolar de transformador — que funciona como abaixador de tensão elétrica, devido a limitações do sensor de diferença de potencial elétrico —, medindo-se a diferença de potencial elétrico (tensão elétrica eficaz) nos terminais do primário, usando um multímetro em função voltímetro, e a diferença de potencial elétrico nos terminais do secundário, usando um sensor de diferença de potencial elétrico, ligado a uma calculadora gráfica por uma interface.
Terminada a aquisição automática de dados, e exibido o gráfico da diferença de potencial elétrico em função do tempo, efetuando uma análise do gráfico, é possível
– determinar a frequência da corrente elétrica alternada;
– estabelecer a equação da tensão elétrica em função do tempo nos terminais do secundário;
– obter a tensão elétrica eficaz nos terminais do secundário e, se o transformador for considerado ideal, estabelecer a relação entre as tensões elétricas eficazes do primário e do secundário com os respetivos números de espiras.
Esta atividade laboratorial permite identificar a função de um transformador, relacionar as tensões elétricas do primário e do secundário com o respetivo número de espiras e justificar o seu princípio de funcionamento no fenómeno de indução eletromagnética.

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#119 — Oral

Festival Pint Of Science: Difundiendo La Ciencia En Pubs/Bares

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Es muy importante divulgar la ciencia entre la sociedad utilizando todos los medios que actualmente permite la tecnología y la vida social, en particular fuera del propio ámbito científico.
El festival Pint of Science nació en mayo de 2013 en el Reino Unido, impulsado por los neurocientíficos Michael Motskin y Praveen Paul, quienes decidieron acercar la ciencia al público general trasladando a investigadores punteros desde sus laboratorios hasta los bares. Esta iniciativa, sin ánimo de lucro, organizada por voluntarios con el patrocinio y colaboración de diversas instituciones (como la RSEF), se ha expandido globalmente de manera exponencial.
En mayo de 2026, el festival ha constituido un fenómeno internacional celebrado de forma simultánea en más de 25 países y cientos de ciudades de los cinco continentes, siendo España uno de los países con mayor participación, alcanzando un récord de 113 localidades. Como un ejemplo realizaremos una corta presentación representativa denominada: ENTENDIENDO A EINSTEIN, RELATIVAMENTE

Volver al índice

#129 — Oral

MÁS ALLÁ DEL AULA: UNA RADIOGRAFÍA DE LA FÍSICA A TRAVÉS DE LAS PAU Y DE LAS OLIMPIADAS LOCALES

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Sabemos que la PAU (Prueba de Acceso a la Universidad) es un examen obligatorio cuya nota, elaborada junto al expediente y diferentes factores de modulación, ordena y prioriza al alumnado de bachillerato en su acceso a la universidad. Conocemos los porcentajes globales de aprobados (alrededor del 95%) y cada distrito universitario proporciona estadísticas por asignatura que, si bien pulsan globalmente el desempeño del alumnado y/o el acierto de las preguntas, no permiten un análisis fino de los resultados. Desde 2012 y hasta la actualidad, el grupo de especialistas de las PAU de Física de la Comunidad Valenciana ha recopilado y analizado los resultados de las PAU aportados por los correctores: opciones elegidas y notas obtenidas en función de los bloques curriculares o los tipos de pregunta. En esta ponencia se presentará una síntesis de estos resultados y se analizarán y extraerán conclusiones, sobre todo a la luz de los últimos cambios, ligados a un mayor énfasis en aspectos competenciales y la armonización entre comunicadas autónomas. También se abordará brevemente la Olimpiada de Física del distrito universitario de la provincia de Valencia: sus características y especificidad (se desarrolla a través de un curso gratuito de formación en el temario de física internacional para 25 estudiantes preseleccionados previo a la prueba local e impartido por profesorado universitario) y los resultados obtenidos a lo largo de casi 20 años.

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#134 — Oral

Item Response Analysis For A Guided Activity For Spin Visualization And Spin Matrix Algebra Using A Javascript Simulation

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

The concept of spin and the addition of angular momenta are fundamental yet challenging topics in the quantum mechanics curriculum. Students often struggle to build a robust conceptual understanding of these systems, a difficulty well-documented in the Physics Education Research community. In this sense, interactive computer simulations have emerged as a particularly powerful tool, effectively bridging the gap between abstract formalism and physical intuition. Building on this approach, our contribution introduces a specialized simulation designed to demystify the rotations of spin-1/2 systems and the underlying matrix algebra. This tool allows students to visually manipulate quantum states and observe in real-time the corresponding transformations providing a dynamic visualization of the spin state. This simulation is used in an activity with questions to help the student relate the geometric and the algebraic representation (Pauli matrix), thereby fostering a more integrated understanding. Since it is implemented in JavaScript, it is executable across all standard browsers.
An activity was implemented as a collaborative homework task with 70 fourth-year physics students at the University of Córdoba. The educational impact of the simulation was assessed through a pre/post-test design. Student understanding was measured using targeted questionnaires before and after the activity. Item Response Theory (IRT) was employed for a precise quantification of learning gains specific to the concepts addressed. The research question was: Does the guided simulation activity produce a measurable shift in students' ability? Results revealed a substantial increase in latent student ability following the intervention, providing strong evidence for the simulation's effectiveness.

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#135 — Oral

Montajes Para Reforzar El Estudio De La Inducción Electromagnética En Bachillerato: Variante Del Anillo De Thomson Y Modelo De Disco Duro De Laboratorio.

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Se mostrarán dos montajes experimentales creados para reforzar la enseñanza-aprendizaje de la inducción electromagnética en Bachillerato:
En primer lugar, una versión alternativa del anillo de Thomson. El montaje habitual (compuesto por una bobina con un núcleo de ferrita y un anillo de aluminio o de cobre) se usa con corriente alterna y, aunque permite realizar experiencias muy atractivas (p.e., hacer que el anillo levite), resulta menos adecuado para que el alumnado de Bachillerato comprenda completamente la experiencia. El montaje que mostraremos se usa con corriente continua y es idóneo para realizar experiencias, cuya interpretación sí es accesible al alumnado de esta etapa (cuándo hay y cuándo no inducción electromagnética, cómo es la fuerza entre la bobina y el anillo, cómo influyen diversas magnitudes en el proceso, etc.)
En segundo lugar, se mostrará un modelo de laboratorio, fácilmente construible por cualquier profesor, que simula el funcionamiento del disco duro de un ordenador. El disco duro es un sistema de grabación magnética digital, que contiene una serie de platos metálicos apilados que pueden girar a gran velocidad y sobre los cuales se sitúan cabezales encargados de leer o escribir los impulsos. Los platos metálicos están repletos de pequeñas zonas magnéticas o microimanes, cuya orientación codifica cada bit de información. Finalmente, el cabezal lector puede modelizarse como una bobina, en la que se induce una corriente eléctrica cuando cada imán está pasando por debajo de ella. Como se verá, nuestro montaje es idóneo para que los alumnos visualicen e interpreten todos estos aspectos del disco duro, usando conocimientos básicos sobre inducción electromagnética, incluida la obtención de outputs en forma de secuencia binaria. Finalmente se realizarán algunos cálculos básicos con los que el alumnado toma conciencia de órdenes de magnitud en el caso real y su repercusión en la capacidad de almacenamiento del disco.

Volver al índice

#140 — Oral

DESDE EL MIT Y CALTECH A LA UNIVERSIDAD DE VALENCIA: 20 AÑOS DE LA COLECCIÓN DE DEMOSTRACIONES DE FÍSICA

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

La Facultad de Física de la Universidad de Valencia cuenta desde hace 20 años con una colección de demostraciones (“demos”) de física para el aula: un repositorio de dispositivos experimentales que se llevan a las clases de teoría o problemas para mostrar los fenómenos en directo y discutirlos en relación con los principios y modelos físicos. Unos 40-50 docentes las utilizan en sus clases de física de 25 titulaciones diferentes (350 ECTS de grado y máster) o en actividades de relación con secundaria (olimpiadas, visitas a la facultad, etc.) y se realizan 450-500 préstamos por curso.
Las demos son un recurso estrechamente ligado a la historia de la física y de su docencia que abre una ventana a la realidad natural en el aula: interpelan activamente al alumnado y fomentan la discusión y participación sobre evidencias empíricas.
Esta colección es pionera y única en nuestro país y se concibe como una infraestructura docente inspirada en las de universidades reconocidas como el MIT, Harvard o Caltech: hemos generado un catálogo abierto online por temas de física, fichas descriptivas, un almacén donde se ubican las cajas de demostraciones y un sistema de préstamo, así como materiales complementarios como vídeos y cuestionarios. Desde sus inicios, este proyecto se propone superar el uso individual de las demos y establecer las condiciones para su generalización en la docencia, todo ello pese a no contar con los recursos (financiación o personal dedicado) de las universidades de la Ivy League.
Además de una síntesis sobre la colección y de su objetivo de recuperación de un legado específico de la física, esta presentación incide en la viabilidad y reproducibilidad de este proyecto en las condiciones y con los recursos reales de nuestras universidades, en particular las convocatorias de proyectos de innovación (800-1000 €/curso).

Volver al índice

#161 — Oral

Aprender Física A Través De Un Concurso De Aviones De Papel: Una Experiencia Con Alumnado De Secundaria Y Docentes En Formación

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Se presenta un proyecto de innovación docente centrado en la organización de un concurso de aviones de papel en la Facultad de Educación de la Universidad de Zaragoza. La propuesta se ha implementado en el Máster de Profesorado de Secundaria, en la especialidad de Física y Química y de Matemáticas, y constituye una experiencia contextualizada para el desarrollo de competencias científicas y didácticas en la formación inicial del profesorado.
El diseño y experimentación con aviones de papel permite trabajar contenidos propios de la Física y la Química, como la aerodinámica, las fuerzas que intervienen en el vuelo, la estabilidad, el centro de gravedad, la resistencia del aire, las propiedades de los materiales y el análisis experimental de variables. Asimismo, favorece el desarrollo de prácticas científicas vinculadas a la indagación, la modelización, la recogida y análisis de datos y la argumentación basada en evidencias.
El futuro profesorado participa en la planificación y organización de un concurso abierto a la comunidad educativa y a la sociedad, en colaboración con la Escuela-Museo de Origami de Zaragoza (EMOZ). Durante la experiencia, los participantes diseñan y construyen prototipos, realizan pruebas experimentales y registran datos relativos al tiempo y distancia de vuelo, así como a la estabilidad y comportamiento aerodinámico de los modelos. Estos datos permiten analizar la influencia de diferentes variables de diseño y promover la reflexión sobre la enseñanza de las ciencias.
La experiencia ofrece al profesorado en formación la posibilidad de diseñar, implementar y evaluar una propuesta interdisciplinar con enfoque STEM, integrando elementos científicos, tecnológicos y creativos. Además, contribuye a ampliar la concepción de la ciencia escolar mediante actividades lúdicas y culturalmente significativas, favoreciendo una enseñanza de la Física y la Química conectada con situaciones reales y motivadoras.

Volver al índice

#193 — Oral

Historical Maps: A Physicochemical Analysis Of Cartographic DNA

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

During the 19th century, cartography evolved from a primarily illustrative practice into a scientific discipline grounded in technical precision and mathematical rigor. This transformation was driven by significant advances in the collection of geographic data, methods of territorial representation, and the development of increasingly sophisticated printing materials and techniques.
This study analyses the interdisciplinary relationship between materials science, physics, and applied mathematics in the development of modern cartographic production. It takes as a reference the European cartographic traditions associated with figures such as Haack, Delagrave, and De Kampen, whose contributions played a key role in shaping modern geographic thought and in spreading standardized scientific models of spatial representation across Europe and beyond during the 19th and early 20th centuries.
The first part of the analysis examines on the physical and chemical foundations of historical map production. It considers the properties of paper supports, the composition of mineral and organic inks, chromatic pigments, and reproduction techniques such as lithography and engraving. The aim is to understand how the principles of chemistry and physics influenced the stability, legibility, and preservation of cartographic documents.
The second part addresses the mathematical and geometric principles underlying territorial representation. It explores the construction of coordinate systems, geographic grids, and the challenge of projecting the Earth's curved surface onto a two-dimensional plane. Special emphasis is placed on map projections, meridian convergence, and the resulting spatial distortions. Using concepts from spherical trigonometry and geodesy, the study evaluates how these distortions influence the measurement of distances and the calculation of regional areas.
Overall, the research proposes an interdisciplinary approach that integrates cartography, physics, chemistry, and geometry, offering a more comprehensive understanding of the scientific and technological evolution of historical maps and their role in the consolidation of modern cartography.

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#195 — Oral

As Olimpíadas De Física Em Portugal: Um Modelo De Sucesso Para O Fomento Da Cultura Científica No Ensino Secundário

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Esta comunicação apresenta o modelo organizativo e pedagógico das Olimpíadas Portuguesas de Física (OPF), coordenadas pela Sociedade Portuguesa de Física (SPF). Através de um relato de experiência, analisam-se as três fases da competição (Escolar, Regional e Nacional) e a forma como Portugal conseguiu consolidar uma rede de participação massiva que envolve tanto centros públicos como privados.
Serão detalhados os aspetos fundamentais que definem o sucesso do modelo luso:
1. A estrutura por níveis (Escalões A e B): A estratégia de captar alunos logo no 9.º ano para criar uma base sólida de interesse pela ciência.
2. A descentralização académica: O papel das sedes universitárias na dinamização das fases regionais e na ligação dos alunos ao ensino superior.
3. A formação de equipas: O processo de seleção e preparação dos alunos para as competições internacionais (IPhO e OIbF).
4. O Centro de Treino de Coimbra (Escola Quark!): O modelo de preparação intensiva dos alunos selecionados para as competições internacionais (IPhO e OIbF). Este centro destaca-se pela sua metodologia de treino avançado, tanto teórica como experimental, funcionando como um polo de alta performance para os jovens talentos nacionais.
5. Resultados: As medalhas de Portugal em olimpíadas internacionais como prova da eficácia deste centro.
6. Testemunhos: O Impacto na Primeira Pessoa
O sucesso das Olimpíadas em Portugal começa na sala de aula com cada um de vós, mas floresce quando damos aos alunos o espaço para serem cientistas antes de serem universitários. O talento não tem fronteiras, precisa apenas de treino e de motivação.
O objetivo é partilhar estratégias de motivação e logística com os docentes espanhóis, promovendo o diálogo sobre a deteção de talentos e a excelência académica na Península Ibérica.

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#202 — Oral

«El Más Enojoso De Los Peligros Pedagógicos En La Enseñanza De La Física»: Recuperación De Prácticas Y Experiencias Históricas Para El Aprendizaje De La Física

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

La historia de la enseñanza de la ciencia ha recibido una atención creciente en las últimas décadas por parte del profesorado de ciencias y de investigadores en educación e historia de la ciencia. Lejos de la imagen de la enseñanza tradicional como un territorio estéril para la enseñanza y el aprendizaje, la historia de la educación científica dota al profesorado actual de una perspectiva crítica que le permite orientar y mejorar su práctica profesional. Asimismo, la historia de la enseñanza de las ciencias permite recuperar un valioso repositorio de experiencias y prácticas pedagógicas de gran utilidad.
Con el propósito de poner en valor el pasado de la profesión docente como un fértil territorio que no solo conviene conocer, sino también recuperar y valorar, esta ponencia presenta varias intervenciones didácticas realizadas en aulas de ESO, Bachillerato y Ciclos Formativos en torno a la recuperación de experiencias históricas de enseñanza de la física. Dicha recuperación ha permitido abordar diversos saberes curriculares desde un enfoque competencial que apuesta por un conocimiento profundo de los fundamentos de la física, con el fin de enseñar al alumnado a pensar físicamente. Es decir, se busca guiar al alumnado en la conexión de los aprendizajes de física con la realidad, evitando así la desconexión entre el aula y la vida cotidiana del estudiante, considerada por diversos profesores y autores españoles de manuales de Física de principios del siglo XX como un «enojoso peligro pedagógico». Se pretende así recuperar la obra de estos ilustres desconocidos de la historia de la ciencia, cuyo legado puede seguir desempeñando su función educadora original muchas décadas después.
De este modo, la propuesta combina la investigación histórico-didáctica con la docencia en aulas reales, fomentando la investigación-acción como línea de actuación para la enseñanza de la física.

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#208 — Oral

Medida De La Velocidad De Muones Atmosféricos A Partir De La Dilatación Temporal Relativista

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Este trabajo presenta una verificación experimental de la dilatación temporal predicha por la Relatividad Especial mediante el estudio de muones atmosféricos. Estas partículas, generadas en la alta atmósfera como producto de la interacción de rayos cósmicos primarios con núcleos atmosféricos, poseen una vida media en reposo de aproximadamente 2.2 microsegundos, lo que resulta insuficiente para recorrer la distancia hasta la superficie terrestre si no se consideran efectos relativistas. Sin embargo, una fracción significativa de muones es detectada a nivel del mar, lo que constituye una evidencia directa de la dilatación temporal.
El objetivo principal del trabajo consiste en reproducir experimentalmente este fenómeno midiendo el flujo de muones a distintas altitudes en la provincia de Granada, aprovechando su variabilidad geográfica, desde el nivel del mar hasta más de 3000 metros en Sierra Nevada. Para ello, se emplean dos detectores de bajo coste, tipo centelleador en configuración de coincidencia, capaces de discriminar muones frente a otras componentes de la radiación de fondo.
A partir de las mediciones experimentales, se realiza un tratamiento estadístico de los datos y se aplica la ley de desintegración radiactiva para modelizar la atenuación del flujo con la altitud. Mediante la linealización del modelo exponencial, se lleva a cabo un ajuste por mínimos cuadrados que permite estimar la velocidad promedio de los muones. Este análisis se aborda tanto desde un enfoque relativista como no relativista, lo que permite comparar ambos marcos teóricos.
Los resultados obtenidos muestran que únicamente el tratamiento relativista reproduce adecuadamente los datos experimentales, evidenciando la necesidad de considerar la dilatación temporal para explicar la supervivencia de los muones. El trabajo incluye una orientación didáctica, proponiendo una adaptación del experimento como práctica de laboratorio en estudios de grado en Física.

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#209 — Poster

Mapa De Superficies Vegetales Con Alta Captación De Agua Atmosférica-SitckyDropsMap

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

StickyDropsMap es un proyecto de ciencia ciudadana de la Universidad de Granada que busca cartografiar plantas y superficies capaces de capturar agua atmosférica (niebla y rocío) para mitigar el estrés hídrico en regiones semiáridas. Esta iniciativa multidisciplinar integra la botánica, la física e ingeniería de superficies para desarrollar tecnologías de Captación de Agua Atmosférica (CAA) pasivas y sostenibles.
El fundamento del proyecto es la bioinspiración. Mientras algunas superficies vegetales repelen el agua (Efecto Loto), otras presentan una alta adherencia o parahidrofobia (Efecto Pétalo), donde las gotas permanecen "ancladas" hasta que crecen por coalescencia y se deslizan por gravedad. El estudio de estas propiedades, que incluyen conceptos de tensión superficial, histéresis y mojabilidad, permite diseñar materiales avanzados para la recolección de agua sin consumo energético.
La metodología involucra a ciudadanos y centros educativos en la localización y análisis de especies mediante el uso de aplicaciones como iNaturalist. Los participantes utilizan un kit de medida (superficie basculante y transportador de ángulos) para determinar el Ángulo de Deslizamiento (AD) de las gotas sobre las hojas. Este proceso permite crear un inventario científico de la flora local con propiedades humectantes únicas, valorizando los recursos naturales de zonas vulnerables como el sureste ibérico.
StickyDropsMap no solo genera datos científicos, sino que sensibiliza sobre la gestión del agua y promueve el Objetivo de Desarrollo Sostenible 6. A través de estrategias de divulgación como "Ciencia en Cómic", talleres en institutos y la colaboración con jardines botánicos, el proyecto transforma el entorno natural en un laboratorio vivo para el aprendizaje de la física y la resiliencia climática.

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#236 — Oral

Construcción Y Estudio De Un Horno Solar: El Poder Calorífico Del Sol

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Se presenta un proyecto de investigación propuesto a un estudiante de 2º de Bachillerato como parte de las actividades del Bachillerato de Investigación y Excelencia del IES Vaguada de la Palma en Salamanca. Se le planteo el reto de diseñar y construir de un horno solar para analizar el cambio de estado de la sustancia estudiada (chocolate) y comprender de manera práctica las posibilidades que ofrece la energía solar como recurso térmico. El estudiante fabricó un horno solar analizando previamente los materiales adecuados que permitan captar y concentrar la radiación solar, y con ayuda de un instrumental adecuado midió temperatura y tiempo necesario para fundir una muestra de chocolate situado en su interior. Analizó el comportamiento del chocolate en relación a su composición y a la cantidad de superficie expuesta. Durante el proceso registró las condiciones experimentales y la evolución del calentamiento, con el fin de obtener datos que permitan describir el comportamiento del sistema. Además, para identificar fugas de calor, invisibles al ojo humano, se empleará una cámara termográfica de infrarrojos.
Como concusiones, se pudo determinar que la potencia alcanzada de 14 W ha sido inferior a experimentos ya publicados que llegaron a obtener aproximadamente el doble, pero se mantiene dentro del rango esperado. Esta diferencia de potencia se puede deber al momento invernal de la realización del experimento. En este estudio, una mayor superficie de contacto duplicó la absorción de calor. Se ha podido corroborar cómo la composición del chocolate afecta a su capacidad de absorción de calor dado que las muestras con mayor contenido de cacao (85%) alcanzan una temperatura más alta a un mismo tiempo y potencia.
En conjunto, el proyecto contribuye a comprender mejor los principios físicos implicados en la transferencia de calor y a destacar el aprovechamiento de la energía solar como alternativa sostenible.

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#254 — Poster

Aplicación De La Inteligencia Artificial En Asignaturas De Física De Grados De Ingeniería.

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Se ha realizado un estudio longitudinal durante cuatro años en asignaturas de Física de tres grados de ingeniería. La inteligencia artificial (IA) se está utilizando cada vez más por los estudiantes. Para la resolución de problemas, para realizar trabajos o como tutor personalizado para resolver dudas. Este hecho comporta una menor interacción con el profesorado universitario. Normalmente la aplican sin una visión crítica. En este estudio se les ha permitido realizar diversas actividades empleando la IA. Se han realizado interacciones intermedias con el objetivo de favorecer el desarrollo de un enfoque crítico y reflexivo. Constatándose un redactado no específicamente científico-tecnológico, información errónea o problemas en la resolución de problemas que en su resolución exigen aspectos complejos de carácter vectorial, derivadas e integrales. Evidentemente, la evolución de la IA es continua y estos errores se están reduciendo. Por otro lado, está surgiendo IA específica para entornos STEAM. Sin embargo, algunos de los mejores programas en desarrollo no son de libre acceso. Cabe destacar que los estudiantes, aunque tengan experiencia en la aplicación de la IA, son usuarios. Por lo tanto, en la mayoría de los casos ni siquiera son usuarios expertos.
Por otra parte, se ha procedido a realizar una encuesta inicial sobre el grado de uso y sobre la percepción que tienen los estudiantes de la IA. Se constata que suelen utilizar los programas de IA más conocidos y de libre acceso. Respecto a los puntos fuertes de la IA remarcan su facilidad de uso y que permite resolver tareas complejas en poco tiempo. Respecto a los puntos débiles, inicialmente les preocupaba la pérdida de puestos de trabajo, aunque cada vez menos.

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#265 — Oral

QUANTUM COMPUTING EUROPEAN PROJECT

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Resulta complicado explicar conceptos del mundo de la mecánica cuántica en niveles preuniversitarios, ya que se trata de un tema complejo y abstracto. En nuestro Centro hemos formado parte de un proyecto donde varios profesores europeos, han formado pequeños grupos de trabajo con el fin de desarrollar materiales que se puedan aplicar en el aula de los diferentes centros educativos. Los materiales desarrollados se publican en el mes de junio, en un sitio web de Science on Stage (https://www.science-on-stage.eu/quantum-computing) y son de uso libre. Las distintas actividades tratarán sobre conceptos básicos, aplicaciones, algoritmos cuánticos… Para el uso de estos materiales, existen diversos itinerarios que se pueden seguir en función de las necesidades educativas e intereses del docente. No es necesario llevar a cabo todas las actividades de forma secuencial, se pueden seguir diversos caminos y es posible saltar de unas partes del proyecto a otras. El material elaborado cuenta con guías didácticas para el profesorado, fichas para los estudiantes, tutoriales…Además de todo lo anterior, Science on Stage organiza webinars y formaciones gratuitas para el profesorado interesado.
Como ejemplo, en nuestro Centro hemos introducido el concepto cuántico de entrelazamiento de una forma muy intuitiva. Se trata de una actividad interdisciplinar en la que se usaron analogías para poder manipular y visualizar “objetos cuánticos”.
Los estudiantes pueden experimentar cómo estos “objetos cuánticos” interaccionan entre sí y cómo pueden compartir información. Usamos la analogía de los LEDs de la placa microcontroladora micro:bit y la propia micro:bit, que jugarán el papel de “objeto cuántico”.
En esta actividad los estudiantes tienen que resolver distintos retos para averiguar qué objetos cuánticos están entrelazados. Los estudiantes aprenden conceptos complejos de una forma muy manipulativa y motivadora.

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#279 — Oral

024 REALIDAD OBSERVABLE Y "REALIDAD ESCONDIDA" DE LA VIDA

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Los jóvenes de hoy se enfrentan a muchas realidades diferentes, entre otras señalar el creciente aislamiento social, las crisis de identidad y propósitos o los problemas de salud mental. La Organización Mundial de la Salud (OMS) ha reconocido la salud mental de los adolescentes como una prioridad fundamental debido a su impacto significativo en su desarrollo y bienestar. Según la OMS, entre un 10 y un 20 % de los adolescentes experimentan problemas de salud mental en todo el mundo, y la mitad de las enfermedades mentales comienzan antes de los 14 años.
A priori se puede pensar que no es un objetivo de la materia de Física tratar el tema de la salud mental. Sin embargo, si que está entre sus objetivos fomentar la reflexión, evaluar lo que percibimos o ser capaces de dudar de las informaciones hasta darles veracidad o ignorarlas, en definitiva, observar el mundo con pensamiento crítico.
Esta propuesta busca plantear, metafóricamente, algunas cuestiones referidas a la salud mental, mediante una serie de experimentos relacionados con el movimiento ondulatorio.
La caída de una piedra en el agua permite reflexionar sobre la realidad observable (la onda) y sobre el viaje invisible de la piedra y sus posibles repercusiones. La máquina de ondas facilita la relación entre la perturbación y la transmisión de la misma con preguntas como ¿por qué yo?, ¿por qué ahora?, ¿por qué sigue?, ¿qué me ayuda? Experimentos como los péndulos acoplados o el péndulo de longitud variable nos abre un camino para tratar los factores que afectan a la salud mental haciendo especial hincapié en las redes sociales o hablar de los trastornos emocionales.

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#316 — Poster

PÍLDORAS DE FÍSICA: DIEZ AÑOS DE RECURSOS EDUCATIVOS ENTRE DOCENTES

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

La difusión de información con enlaces de interés para los socios desde el año 2014 constituyó una de las líneas programáticas del anterior Grupo Especializado de Enseñanza de la Física (GEEF-RSEF). En la práctica de la enseñanza de la física, se precisa obtener información adaptada al nivel académico al que va dirigida, y acorde con la calidad científica y divulgativa requeridas. De entre el gran volumen de documentación existente en la actualidad, seleccionar recursos educativos de enseñanza y divulgación, eficaces, motivadores o novedosos, requiere mucho esfuerzo y tiempo; por ello nuestro interés fue que la información de dichos recursos pudiera ser usada por muchos docentes si supieran de su existencia. Esta posibilidad de difusión informativa cristalizó en el año 2015 mediante la creación de una nueva sección de intercambio y comunicación con los miembros de dicho Grupo Especializado, con el título de Píldoras de Física (PF). Esta sección se mantiene activa desde 2019 bajo el paraguas de la actual División de Enseñanza y Divulgación de la Física (DEDF-RSEF).
El propósito de esta comunicación es exponer y difundir los recursos y actividades de las Píldoras de Física, que venimos realizando desde el Grupo de Trabajo (constituido por los autores de esta comunicación) como canal de comunicación entre docentes. Se presentará una visión general de las PF, que se publican en “dosis” mensuales. Daremos cuenta de sus requisitos, de la variedad de su tipología y de la temática abordada a lo largo de cerca de ciento veinte entregas (cada entrega con una media de tres píldoras), que han tenido lugar durante diez años de actuación.

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#317 — Oral

La Ruptura Del Vínculo Proceso–resultado En La Enseñanza De La Física En La Era De La IA: Hacia Un Retorno Al Aprendizaje Experimental

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

La incorporación de herramientas de inteligencia artificial generativa en el ámbito educativo está alterando de manera sustancial los procesos de enseñanza-aprendizaje en Física. Más allá de su impacto instrumental, estas tecnologías cuestionan un supuesto fundamental del modelo educativo hasta hace poco vigente: la correlación entre el proceso de aprendizaje del alumnado y el producto final que este genera. La posibilidad de obtener respuestas formalmente correctas mediante IA debilita el valor de las producciones escritas como evidencia de comprensión.
Esta comunicación plantea que dicha transformación incide de manera crítica sobre un proceso cognitivo central en el aprendizaje de la Física: la “textualización” del conocimiento. Aprender Física implica traducir observaciones, intuiciones y experiencias en lenguaje formal, articulando progresivamente el pensamiento a través del texto. Este tránsito desde lo observacional a lo simbólico constituye un momento esencial del aprendizaje. Sin embargo, la IA permite invertir este proceso, situando al alumnado directamente en un plano textual ya formalizado, desde el cual puede generar productos académicos sin haber establecido una conexión efectiva con la realidad física subyacente.
Se argumenta que esta problemática debe abordarse desde las primeras etapas del aprendizaje, donde se configuran los hábitos cognitivos, si bien sus efectos se manifiestan también en otras etapas educativas. En este contexto, se propone una revisión crítica no solo de las prácticas docentes tradicionales, sino también del propio modelo de experimentación de laboratorio. Con frecuencia, estas actividades se conciben como verificaciones de teorías previamente formalizadas y descansan en guiones altamente estructurados, lo que las hace vulnerables a una resolución íntegra mediante IA, generando informes formalmente impecables, pero cognitivamente vacíos. Incluso en contextos experimentales aparentemente abiertos, la introducción prematura de la IA como mediador de la expresión escrita puede sustituir el proceso de verbalización propio del alumno, por lo que su uso debe situarse en fases posteriores del

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#360 — Oral

Nature Of Superconductor-To-Normal Transition In Inversely Proximitized Superconducting Nanowires

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Mesoscopic superconducting nanowires have attracted considerable interest as a platform for topological superconductivity and superconducting quantum devices. In full-shell InAs–Al nanowires [1, 2], recent experiments have reported anomalous metallic behavior [3] and a strong suppression of the critical current [4,5]. However, the role played by the measurement geometry and electrical contacts has remained relatively unexplored.

Here, we show that the superconducting properties of epitaxial Al shells can be strongly modified by an inverse proximity effect induced by normal-metal electrodes. The resulting weakened superconducting regions dominate the current-driven transition to the normal state, leading to switching currents far below the theoretical depairing limit and to the emergence of intermediate-resistance states. Using a Usadel-based model, we account for the different superconductor-to-normal transition behaviors observed in our InAs–Al nanowires. Our results suggest that the reduced critical currents and anomalous metallic behavior previously reported in the literature may instead originate from contact-induced superconducting inhomogeneity and nonequilibrium effects [6]. More broadly, our work highlights the importance of device geometry and measurement configuration for correctly interpreting transport experiments in mesoscopic superconductors, while also providing practical guidelines for the design of superconducting nanodevices.

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#370 — Oral

Propuesta Didáctica Para Enseñar La Caída Libre Con El Videojuego Minecraft Desde Educación Secundaria Hasta La Universidad

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

La utilización de juegos y nuevas tecnologías supone una herramienta eficaz para motivar el aprendizaje de la física, especialmente en Educación Secundaria Obligatoria (ESO), Bachillerato o primeros cursos universitarios. Los videojuegos sacan el aprendizaje del contexto formal y lo acercan a una actividad de ocio ampliamente extendida, actuando como “gancho” y favoreciendo una actitud más positiva hacia la física [1]. Muchos videojuegos incluyen numerosos aspectos físicos en su programación, necesarios para simular el movimiento de los elementos de los mismos. Este es el caso de Minecraft, popular juego en el que los jugadores interactúan con bloques de diversos materiales para construir sus propios mundos y proyectos. Minecraft se ha utilizado para enseñar diferentes aspectos de física [2] y puede resultar útil para explicar conceptos de mecánica.
En esta contribución introducimos una propuesta didáctica para explicar diferentes aspectos de la caída libre a través de la experimentación en el mundo virtual de Minecraft. Dejando caer bloques de diversa naturaleza desde varios niveles de una torre construida por los estudiantes, estos experimentan con el movimiento rectilíneo acelerado en sus diversas variantes. La actividad permite explorar desde una caída libre sin rozamiento apreciable, adecuada para reforzar la enseñanza del movimiento rectilíneo uniformemente acelerado en el segundo ciclo de ESO, hasta situaciones en las que aparece la velocidad límite, útil para cursos más avanzados como Bachillerato. La actividad permite análisis más minuciosos, mediante la resolución de la ecuación del movimiento de caída libre con rozamiento, adecuada para los primeros cursos del Grado en Física. Mostraremos los resultados de la implementación de la actividad en un grupo de 4º curso de ESO y discutiremos las posibilidades que ofrece para niveles formativos más avanzados.

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#376 — Poster

La Historia De La Física Como Recurso Para La Formación Del Profesorado De Física Y Química En Naturaleza De La Ciencia

DEDF - XXXV Encuentro Ibérico para la Enseñanza y Divulgación de la Física

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Abstract Text:

Se analiza el potencial didáctico de la historia de la física para promover la comprensión de la naturaleza de la ciencia (NdC) en la formación del profesorado de Física y Química. Concretamente, se examinan los efectos de una experiencia educativa basada en una controversia histórica del siglo XVIII sobre la naturaleza de la electricidad, protagonizada por Robert Symmer y Benjamin Franklin, en relación con dos aspectos específicos de NdC: los desacuerdos científicos y la autoridad epistémica. Participaron 21 futuros profesores mediante un estudio de diseño pretest–postest. La intervención se desarrolló en tres sesiones e incluyó la lectura crítica de una narrativa histórica, discusión en grupos y debate en gran grupo orientado explícitamente a la reflexión sobre NdC. Para la recogida de datos se utilizaron ítems adaptados del cuestionario COCTS y los resultados se analizaron mediante pruebas de Wilcoxon y tamaños del efecto. Los resultados muestran progresos claros y estadísticamente significativos, especialmente en la comprensión de los desacuerdos científicos, con tamaños del efecto moderados y altos (TE = 0.49–0.69). Antes de la intervención, muchos participantes mantenían visiones empiristas, según las cuales los desacuerdos científicos se explican únicamente por falta de datos o evidencias. Tras la intervención, mostraron una comprensión más sofisticada, reconociendo el papel de marcos teóricos, interpretaciones alternativas y factores contextuales en la construcción del conocimiento científico. También se observaron mejoras en la comprensión de la autoridad epistémica (TE = 0.53), particularmente en el reconocimiento del carácter social y colectivo de la actividad científica.
Los hallazgos respaldan el valor pedagógico de las controversias históricas y de la enseñanza explícita y reflexiva de NdC en la formación del profesorado. Asimismo, sugieren que intervenciones breves basadas en historia de la ciencia pueden constituir una estrategia viable para favorecer visiones más complejas y contextualizadas sobre el funcionamiento de la ciencia.

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#93 — Oral

Co-Doped HfO2 Memristive Synapses: Ionic Pathways, Asymmetric Heterointerfaces, And The Road To Neuromorphic AI

DFMC-GEFES - Artificial Intelligence in Materials Research: Revolution, Evolution, or Illusion?

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Abstract Text:

The rapid advancement of AI algorithms increasingly outpaces the capabilities of underlying hardware, demanding revolutionary innovations in materials design for energy-efficient, brain-inspired computing. Neuromorphic hardware based on memristive synapses offers a compelling pathway, yet the atomic-scale ionic mechanisms governing synaptic behaviour remain insufficiently understood - a gap that limits rational device engineering.

Here, we present a unified materials and mechanistic strategy addressing both challenges. We introduce multi-component p-type Hf(Sr,Ti)O2 thin films, grown by magnetron co-sputtering on TiN/SiO2/Si substrates, forming asymmetrically extended p-n heterointerfaces with an n-type oxygen-rich TiOxNy underlayer. This engineered heterointerface generates a fully depleted space-charge layer, enabling ultra-low switching currents (<10-8 A), hundreds of tuneable conductance levels, and exceptional cycle-to-cycle and device-to-device uniformity - all driven by low-voltage (1.5 V) presynaptic spikes. Both short-term synaptic plasticity and spike-timing-dependent plasticity are demonstrated, satisfying unsupervised learning rules critical for time-dependent AI functionalities.

Crucially, we go beyond electrical characterisation by providing the first direct, cycle-resolved visualisation of the ionic dynamics underpinning these synaptic responses. Through in-operando Raman, photoluminescence, and dark-field spectroscopies, we establish that co-doping stabilises oxygen vacancies and facilitates reversible interfacial oxygen migration - the key mechanism controlling conductance modulation and enabling robust neuromorphic operation. Correlating optical signatures with device performance directly links interface and defect engineering to controllable ionic motion and emergent synaptic plasticity.

Together, these findings demonstrate that combining heterointerface engineering with operando optical tracking provides a powerful, general strategy for designing high-endurance, energy-efficient memristive hardware. This work positions materials innovation - not merely algorithmic progress - as central to realising the true potential of neuromorphic AI, directly addressing whether such hardware revolutions are achievable in practice.

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#155 — Oral

Constraint-Aware Functional Cloning For Stable And Transferable Machine-Learned Density Functional Theory

DFMC-GEFES - Artificial Intelligence in Materials Research: Revolution, Evolution, or Illusion?

Sara Navarro-Rodríguez 1, Alec Wills 2, Kimberly Jennifer Daas 3, María Camarasa-Gómez 4, Marivi Fernández-Serra 5,6

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Abstract Text:

The accuracy of Kohn–Sham density functional theory (DFT) depends on the exchange–correlation (XC) functional. Different XC approximations are ranked in Perdew's Jacob's ladder according to the accuracy and input parameters they use. Functionals on the second rung, known as the generalized gradient approximation (GGA), are widely used for large-scale simulations because they are fast, but their accuracy is not always enough
Machine-learned (ML) functionals trained on highly accurate reference data aim to solve this, yet they struggle with many challenges, including transferability, stability, and physically consistent initialization. To study these problems in a clean way, we present the cloning strategy, where train a neural network (NN) to simply copy a known functional while staying on the same rung. In our case, we stick to GGAs and clone PBE.
This controlled cloning lets us test how choices like network architecture or training data affect accuracy, without mixing in extra complications. We find that enforcing known physical constraints in the network dramatically improves how well it reproduces PBE total energies in self-consistent calculations. Next, we check transferability. A network trained with pseudopotential densities (obtained with SIESTA), cannot reproduce total energies when used in all-electron calculations (PySCF), showing it is sensitive to the type of density used for cloning. However, energy differences remain reliable. Interestingly, a NN cloned using only molecular densities still reproduces PBE results for solid crystals. This shows that molecular training data alone is enough to capture the functional's behavior in solids. Finally, we see how cloning and physical constraints improve full training on high-level data, highlighting the value of a physically grounded initial guess and physical constraints.
Overall, our work offers a simple and clean way to benchmark and build stable, transferable, self-consistent ML functionals on a single rung, providing a solid foundation for next-generation data-driven DFT.

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#206 — Oral

Ab Initio And Not-So-Ab-Initio Machine Learning Models For Atomistic Materials Simulation

DFMC-GEFES - Artificial Intelligence in Materials Research: Revolution, Evolution, or Illusion?

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Abstract Text:

Machine learning models for atomistic simulations have emerged as a transformative tool for predicting materials properties in silico. These models are trained on large datasets of ab initio electronic-structure calculations and can achieve near-ab initio accuracy at a fraction of the computational cost. In this talk, I will discuss applications of this technique to understand how materials form and present new developments my team is pursuing to push the boundaries of the accuracy these models can achieve. First, I will present our studies of crystallization processes at surfaces, from the melt, and from aqueous solution, showing that we can describe complex phenomena that were previously out of reach for atomistic simulations [1,2]. I will then introduce our recently proposed algorithm for training hybrid ab initio and empirical machine learning models. These models are trained simultaneously on datasets derived from ab initio calculations and on thermodynamic or structural data from experiment, enabling an accuracy that significantly exceeds that of purely ab initio models [3]. Finally, I will discuss where the field is heading and how my team plans to contribute to the development of the next generation of machine learning models for atomistic simulations.
[1] Piaggi et al, Proc. Natl. Acad. Sci. 122 (41), e2415663122 (2025)
[2] Zhou and Piaggi, arXiv:2511.13402 (2025)
[3] Peña-Cano and Piaggi, arXiv:2511.14352 (2025)

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#35 — Oral

Topographic Patterning In Perovskite Oxide Membranes For Local Control Of Strain, Nanomechanics And Electronic Structure

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

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Abstract Text:

Single-crystalline perovskite oxide membranes provide a powerful platform to access physical properties that are inaccessible in bulk crystals and substrate-clamped thin films. Within this context, the deliberate fabrication of tailored corrugations provides a reliable mean to impose local curvature enabling deterministic modulation of functional properties. Here, we demonstrate controlled topographic patterning in (00l)-oriented La0.7Sr0.3MnO3 (LSMO) membranes with thicknesses ranging from 4 to 100 nm where they spontaneously form sinusoidal wrinkles with thickness-dependent periodicity and amplitude. The wrinkle morphology directly modulates membrane stiffness and generates exceptionally large local strains exceeding 5% with strain gradients approaching ~ 2.5 x 107 m−1 in the thinnest membranes. These extreme deformations suppress antiferrodistortive octahedral rotations and stabilize polar distortions, evidencing a curvature-driven symmetry transformation. The surface potential variation reinforces the formation of wrinkled-induced polar patterns being strongly modulated with thickness. The variation of Mn oxidation state from ~ 3.2+ to ~ 2.85+ provides a direct chemical signature of a thickness-controlled electronic transition. These results demonstrate that corrugation-induced strain gradients in oxide membranes with different thicknesses can drive coupled structural, nanomechanical and electronic transformations offering a singular route to engineer their functional states for next-generation electronic devices.

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#71 — Oral

Survival Guide To Hafnia Ferroelectrics

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

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Abstract Text:

CMOS-compatible hafnia ferroelectrics hold great promise for the development of devices that take advantage of their permanent and switchable electric polarization, which has made them a focus of attention. But that is not all: these materials are proving to constitute a ferroelectric class of their own, displaying many intrinsic behaviors that seem genuinely unprecedented and certainly lay outside the "standard model" of soft-mode ferroelectricity in perovskite oxides. In this talk I will present first-principles results to discuss and explain some of those surprising properties. For example, I will argue that the polarization of hafnia ferroelectrics cannot be considered a bulk property, showing simulation evidence that the very same polar configuration can behave as either upward or downward polarized. I will also discuss our latest results on polarization switching, showing that – because switching and oxygen diffusion are intimately connected – the coercive and breakdown fields are bound to be close in magnitude. As we will see, when it comes to hafnia, wherever we look we tend to find surprising results that contradict our expectations and question our understanding of ferroelectrics. I will conclude with a personal outlook for (simulation) work in the field, briefly commenting on challenges and opportunities.
Work funded by the Luxembourg National Research Fund (FNR), as of late through grant INTER/NSF/24/18804122/PIEZOHAFNIA. Projects done with X. Diaz de Cerio, B. Mukharjee, I. Robredo-Magro and N.S. Fedorova (LIST), and many other collaborators, chiefly A. Gruverman (Nebraska-Lincoln).

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#104 — Oral

Exploiting First-Order Phase Transitions For Large Electrocaloric Effects

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

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Abstract Text:

Supercritically driven first-order phase transition enabled large electrocaloric effects over a wide range of temperature in multilayer capacitors (MLCs) of Pb(Sc,Ta)O3 (PST) [1]. While prototype heat pumps based on these MLCs [2-4] demonstrate good cooling performance, their operation is restricted to above room temperature due to the Curie temperature of 290 K for PST, limiting sub-ambient applications. I will show how solid solution was made to depress the Curie temperature down to 235 K while preserving a strongly first-order character, thereby enabling large EC effects across room temperature [5]. As an extension, I will also show our attempt to exploit a first-order phase transition in polymer MLCs for large EC effects.
[1] B. Nair et al., Nature 575, 468 (2019).
[2] A. Torelló et al., Science 370, 125 (2020).
[3] Y. Wang et al., Science 370, 129 (2020).
[4] J. Li et al., Science 382, 801 (2023).
[5] M. Guo et al., Nature in press.

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#113 — Oral

Ion Relaxation Dynamics Enable Synaptic Functionality In Ferroionic Van Der Waals Materials

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

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Abstract Text:

Metal thiophosphates such as CuInP2S6 and CuCrP2S6 are an emerging class of 2D van der Waals layered materials in which polar behaviour such as (anti-)ferroelectricity, as well as ionic switching and interfacial redox, co-exist. Ion migration occurs due to the hopping of Cu+ between van der Waals layers, while ferroelectricity arises due to intralayer Cu+ switching between stable upper and lower lattice sites in the presence of an electric field. The mutual dependence of these mechanisms on the Cu+ occupancy opens possibilities for engineering a range of synaptic functions for application in energy-efficient neuromorphic processing. Specifically, the presence of ionic hopping and relaxation (a volatile process) and ferroelectricity (a non-volatile process) can naturally give rise to short-term plasticity and long-term potentiation.

In this work, we explore the resistive switching and ion relaxation dynamics in vertical devices based on paraelectric CuCrP2S6 and AgCrP2S6, and ferroelectric CuInP2S6, and how they give rise to short-term plasticity behaviour. We will demonstrate that by varying the active material and electrodes, the relaxation time constants can be controlled. Subsequently, devices can be fabricated which show paired-pulse facilitation and spike-rate dependent plasticity. Finally, we will discuss how future integration with polar phases of these materials can broaden their functionality for next-generation neuromorphic computing architectures.

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#118 — Oral

Emerging Piezoelectric Polymers: Unraveling Fundamental Mechanisms And Designing Multifunctional Hybrid Composites

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

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Abstract Text:

The transition towards flexible green electronics has positioned piezoelectric polymers as key enabling materials for sensing and actuation, including self-powered systems capable of harvesting energy from their surroundings. They are core elements of novel technologies like wearable electronics, electronic skin, and bio-implanted devices, where polymers are bound to play a pivotal role in the advancement of responsible electronics, as they offer clear benefits over ceramics, which cannot satisfy the increasing demand for flexible devices. A main line of research is the development of piezopolymers and polymer-based hybrid composites formed by functional inorganic fillers within polymeric matrices. While most works today resort to PVDF, a fuel-based, non-biodegradable polymer with associated environmental concern; greener alternatives are emerging, such as biobased polyesters, due to their biodegradable character and biocompatibility.

This talk will first address the fundamentals of piezoelectricity in polymeric systems, emphasizing their different origin in ferroelectric polymers (such as PVDF or polyamides) versus shear-piezoelectric biopolymers (such as PLLA and PHB). The latter exhibit a distinct polar symmetry that avoids the need for high-voltage poling, opening new avenues for device design. Furthermore, we will explore multifunctionality by designing hybrid composites aimed not only to enhance piezoelectric output but also to introduce novel coupling phenomena. We are investigating at ICMM the suitability of biobased polyesters and innovative 3D-printing approaches to fabricate piezoelectric platforms incorporating: lead-free ferroelectric perovskites to enhance response; novel magnetic spinel oxides designed for enhanced magnetostriction to prepare magnetoelectric composites; and mechanoluminescent particles to explore the influence of the polymer's piezopotential on photoemission modulation. Finally, we will address the challenge of adequately characterizing the piezoelectric response, specifically the nuances between open-circuit and short-circuit measurements, and the deconvolution of signals in multiphasic systems.
Research funded by projects PID2021-122708OB-C33 and PID2023-152475OB-100, by MCIN/AEI/10.13039/501100011033; and by the DIGIMATER-CM project (TEC-2024/TEC-102).

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#152 — Oral

Towards Flexible Magnetoelectric Devices: Materials Design And Fabrication Strategies

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

Adriana Barreto 1, Ricardo Jiménez 1, Pablo Ramos 2, Harvey Amorín 1, Iñigo Bretos 1, Miguel Algueró 1, Maria Lourdes Calzada 1

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Abstract Text:

Magnetoelectric (ME) composites, which couple magnetic and electric order parameters through strain-mediated interaction between a magnetostrictive and a piezoelectric phase, constitute a versatile materials platform for multifunctional devices. Their ability to convert magnetic stimuli into electrical signals without an external power source makes them attractive for energy harvesting, magnetic field sensing and wearable electronics. While bulk ME composites have been studied for decades, device miniaturization has driven interest towards film geometries, where higher integration density, improved sensitivity to weak magnetic fields and mechanical flexibility can be achieved.
Obtaining high ME responses in this form, however, poses substantial challenges. The magnetoelectric coefficient is governed by the intrinsic properties of each phase, the volume fraction ratio between them and the efficiency of elastic strain transfer across their shared interface. This coupling is frequently compromised by interfacial degradation during processing, particularly the formation of non-functional oxide interlayers, which reduces polarization and hinders strain transfer. The poling state of the ferroelectric film is also critical, as it establishes a stable remanent polarization that substantially enhances the net piezoelectric response and, consequently, the ME coefficient. Poor polarization retention or high leakage currents therefore directly limit device performance.
Our work has explored these issues using $BiFeO_3$–$PbTiO_3$ (BFO–PTO) perovskite films on magnetostrictive Ni substrates, fabricated by chemical solution deposition (CSD) and aerosol deposition (AD), two low-thermal routes compatible with flexible substrates. The results underscore that high ME performance requires a deliberate design strategy in materials selection, deposition technique, film and substrate thickness, interfaces and poling conditions. Understanding how these factors interact is therefore as important as optimizing each one individually.
Acknowledgements: This work was supported by the Spanish project PID2022-136790OB-I00, PID2021 funded by MCIN/AEI/10.13039/501100011033 and CAM PhD grant from the Comunidad de Madrid (PIPF-2024ECO-33982). The Severo Ochoa Centres of Excellence program is acknowledged through Grant CEX2024-001445-S.

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#178 — Oral

Freestanding Oxide Membranes Beyond Epitaxy: A Polycrystalline Alternative Toward 2D Device Integration

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

Julia Hernandez Ruiz, Ricardo Jimenez, Iñigo Bretos, Lourdes Calzada, Andres Castellanos-Gomez, Jesus Ricote, Carmen Munuera

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Abstract Text:

The integration of ferroelectric oxides with Van der Waals materials has emerged as a promising route for next generation multifunctional devices. Ferroelectric materials are highly desirable for integration into future devices due to their unique properties, such as polarization hysteresis, non-volatility, and/or multiferroicity, which provide new tuning knobs to enhance overall performance. On the other hand, among the remarkable properties that emerge in van der Waals materials when thinned to a few layers, 2D semiconductors stand out as ideal components for optoelectronic applications due to their exceptional optical and electronic characteristics. The combination of both families in hybrid heterostructures could synergistically expand their potential applications, leveraging the unique strengths of each material to achieve functionalities that surpass the sum of their individual contributions.
Until now, most freestanding complex oxides used in such heterostructures have been obtained by epitaxial growth on single-crystal substrates, either by adding sacrificial layers or by remote van der Waals epitaxy, which enable membrane separation but require careful lattice-matching and vacuum-based processing.
In this work, we present a low-cost and scalable route combining chemical solution deposition (CSD) technique for oxide growth, with an electrochemical delamination process to obtain freestanding polycrystalline oxide membranes avoiding lattice matching sacrificial layers. Centering on PbZr0.3Ti0.7O3 (PZT), we show that we can control the thickness of the membranes, quantify it by optical means and investigate their mechanical properties by extracting Young's modulus of the freestanding films. Finally, we assess their functionality by atomic force microscopy (AFM) methods such as Kelvin probe microscopy (KPFM) and piezoresponse force microscopy (PFM) and demonstrate that they can be integrated into devices with 2D materials in an analogous manner to their more common epitaxial counterparts.

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#182 — Oral

The Coupling Of Ferroelectric Polarization And Oxygen Vacancy Migration Enables Electrically Controlled Thermal Memories

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

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Abstract Text:

The coupling between electric, ionic, and thermal phenomena in ferroelectric oxides offers new opportunities for active control of heat transport in solid-state devices. By opening and closing thermal current pathways at will, these devices enable the active route of thermal energy on demand, which is critical for applications such as thermal energy storage and management, solid-state refrigeration–and thermal regulation–technologies, thermoelectric systems for energy harvesting, or even storing and processing information via heat currents. In this work, we demonstrate electrically controlled and non-volatile thermal conductivity switching in ferroelectric Hf0.5Zr0.5O2 epitaxial thin films, positioning hafnia-based oxides as promising platforms for thermal memories and other multifunctional thermal devices. We reveal that the electric-field dependence of the thermal conductivity of ferroelectric Hf0.5Zr0.5O2 epitaxial films exhibits a pronounced hysteresis that closely mirrors the polarization–electric field response, including identical coercive fields. We identify electrically driven oxygen vacancy migration as the dominant process, with vacancies acting as highly efficient active phonon scattering centers. The non-volatility comes from the ferroelectric polarization, which creates an electrostatic barrier that controls the redistribution and retention of these defects, stabilizing non-equilibrium vacancy configurations and giving rise to the observed hysteretic thermal response. This mechanism enables, thus, two non-volatile thermal states, corresponding to high (ON) and low (OFF) thermal conductivity, which remain stable after removal of the external electric field. The reported ON/OFF ratio is approximately 1.6 and switching between states can be achieved using voltages below ±5 V, compatible with thin-film device integration. Both thermal states exhibit excellent robustness over several days, indicating strong suppression of vacancy back-diffusion in the absence of an applied field.

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#258 — Oral

Epitaxial Ferroelectric HfO2 For Multifunctional Neuromporphic Computing

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

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Abstract Text:

Emerging computing paradigms require materials and devices that surpass the limitations of conventional semiconductor technologies. Ferroelectric HfO2 has emerged as a promising platform because its polarization switching occurs without current injection, enabling intrinsically low-power operation while remaining fully compatible with CMOS technology. Although most studies have focused on polycrystalline films, their mixed phases and complex microstructures hinder the understanding of intrinsic switching mechanisms. In contrast, epitaxial ferroelectric HfO2 films provide atomically flat surfaces, sharp interfaces, and controlled phase purity, making them ideal model systems for fundamental studies. These films also exhibit wake-up-free behavior, fast switching dynamics, large remanent polarization, and excellent endurance.
Here, we highlight recent advances in functional characterization of epitaxial Hf0.5Zr0.5O2 heterostructures. Interface or tunneling limited current enable electric modulation of resistance response, providing a route toward multi-state and neuromorphic-like memristive functionalities. These results demonstrate the potential of epitaxial ferroelectric HfO2 as a versatile platform for next-generation low-power multifunctional computing devices.

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#275 — Oral

Synergistic Piezoelectric Response In 3D-Printed ZnO/PLLA Biocomposites

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

Guillermo Vergara 1, Juan Pedro Fernández-Blázquez 2, Pablo Ramos 3, Miguel Algueró 1, Harvey Amorín 1, **Cristina Pascual-González** 1

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Abstract Text:

In poly-L-lactic acid (PLLA), piezoelectricity arises from the chiral helical conformation of the polymer chain that generates a non-centrosymmetric arrangement of dipoles that couples mechanical stress to electrical polarisation through the shear piezoelectric coefficient d_{14}, without requiring the electrical poling needed in state-of-the-art ferroelectric polymers such as PVDF.
Here, we demonstrate that incorporating ZnO rods into an electroactive PLLA matrix processed by fused deposition modelling (FDM) 3D printing, activates a synergetic piezoelectric mechanism that exceeds the simple additive contribution of the two piezoelectric components. ZnO rods contribute directly to the piezoelectric response and simultaneously promote preferential crystallisation of the PLLA matrix through heterogeneous nucleation. The anisotropic rod geometry further enables efficient stress transfer across the matrix–filler interface, that amplifies the electromechanical response. Multi-physics simulations support this coupling and link filler geometry to the macroscopic electrical output.
The cooperative mechanism produces a significant enhancement of d_{14}, from 2.71 pC N^{-1} for pure PLLA to 7.76 pC N^{-1} for the PLLA–ZnO rod composite, which reaches a maximum power density of 781 mW m^{-2} at 90 Hz, exceeding representative PVDF-based composites.

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#304 — Poster

Photovoltaic/Plasmonic Platforms As Hybrid Tools For Nanoplastic Accumulation And Detection

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

Esther Rincón 1,2, Marcos Barraya 1, Fernando Agulló-Rueda 3, Ángel García-Cabañes 1,2, Patricia Haro-González 1,2, Mercedes Carrascosa 1,2

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Abstract Text:

Plastic is a worldwide used material whose utilization has augmented considerably in the last century. About 1.15 – 2.41 million tons of plastic wastes are released into the ocean annually, degrading into micro- and nano-plastics, thus, posing a risk for the environment and human health. With this in mind, detection and identification of plastics in marine and freshwater is a fundamental issue. For this purpose, a recently developed physical method for accumulation of plastic particles based in lithium niobate (LN) platforms was proposed and successfully applied. Focused on plastic particles of micrometric size (1 to 4 micron) suspended in water, accumulation and detection of plastics were achieved from concentrations as low as 1 µg/L. Moreover, preliminary results suggested the viability of the technique for accumulating and detecting nanoplastics.

In this work, we thoroughly investigate the viability of nanoplastic accumulation and sensing in LN platforms by droplet ejection. This method is based on the bulk photovoltaic effect in iron-doped LN crystals, through which visible light induces an electric field that deforms a nearby reservoir droplet, causing the ejection of nano-droplets towards the crystal, thereby concentrating their contained material on its surface. On the one hand, different nanoplastics were tested and the role of key parameters such as plastic concentration, time, and light intensity were characterized. Successful accumulation from water suspensions with concentrations well below µg/L has been achieved. On the other hand, to further increase detection efficiency, the accumulation capabilities were combined with plasmonic enhancement provided by Ag nanoparticle patterns incorporated into the platform. Results show an enhancement in photoluminescence of dyed polystyrene nanoparticles of up to 46% in Ag-pattern fringes compared with the clean LN:Fe surface.

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#361 — Oral

Chiral Polar Textures In Twisted $SrTiO_3$ Membranes

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

Jacobo Santamaría 1, Isabel Tenreiro 1, Víctor Rouco 1, Hugo Aramberri 2, Mariona Cabero 3, Gabriel Sánchez Santolino 1, Fernando Gallego Toledo 1, David Sánchez Manzano 1, ALberto Rivera 1, Federico Mompean 4, Mar García Hernández 4, Jorge Íñiguez 2, Carlos León 1

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Abstract Text:

The emergence of freestanding perovskite-oxide membranes has opened a new route toward moiré engineering in strongly bonded crystalline oxides. Unlike van der Waals systems, twisted oxide homobilayers generate non-coherent atomic registry and long-range interfacial strain fields arising from ionic bonding and lattice reconstruction. In ferroic oxides, these twist-induced strain textures unlock a chiral degree of freedom and provide a powerful platform to engineer topological polar states through flexoelectric coupling.

In this talk, I will discuss the emergence of flexoelectric moiré polar topologies in twisted $SrTiO_3$ bilayers. Although $SrTiO_3$ is a quantum paraelectric with only incipient polarity, the torsional strain fields generated by twisting stabilize robust polar vortex arrays. Combining atomic-resolution experiments with first-principles simulations based on machine-learned force fields, we demonstrate the formation and stability of these vortex textures and identify their origin in a flexoelectric response associated with a negative flexoelectric coefficient. Remarkably, vortex chirality is programmed by the twist angle, while the two layers develop opposite handedness due to the continuous torsional strain across the interface.

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#379 — Oral

Freestanding Ferroelectric Oxide Membranes Integrated With 2D Semiconductors For Optoelectronic Functionalities

DFMC-GEFES - Beyond ferroelectrics: Emerging coupling mechanisms and related phenomena

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Abstract Text:

Freestanding oxide membranes have recently emerged as a promising platform, offering new opportunities to design materials and heterostructures with novel functionalities beyond the constraints of conventional epitaxial systems [1-3]. In particular, the possibility of integrating ferroic oxide membranes with van der Waals semiconductors opens new routes to explore interfacial coupling phenomena and multifunctional device concepts.

In this work, we investigate hybrid architectures combining freestanding $BaTiO_3$ oxide membranes with MoS_2 layers, with particular emphasis on the modulation of the 2D semiconductor optical and optoelectronic response. This talk will provide examples of how these two families of materials can be synergistically integrated, using van der Waals manipulation strategies, to fabricate novel hybrid 2D heterostructures that expand their potential applications. By combining transferable ferroic oxides with atomically thin semiconductors, we explore how polarization, electrostatic boundary conditions and interfacial interactions can be harnessed to control charge transport and light–matter interaction in transistor devices [4,5]. These hybrid systems provide a versatile platform to study the synergy between ferroic functionalities and low-dimensional semiconductors, opening new opportunities for multifunctional oxide/2D optoelectronic devices

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[2] G. Sanchez-Santolino et al., Nature 2024 626, 529
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#29 — Oral

Mechanical Mapping Of Soft Materials And Cells With Colloidal AFM Probes Through Advanced Models

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

Annalisa Calò 1, Beatriz Cantero 2, Mauricio Cano 2, Mohit Kumar 1, Gabriel Gomila 2

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Abstract Text:

Colloidal spherical probes, with radii ranging from 100's nm to 10' um, are ideal for mechanical mapping of soft samples and living cells, as they guarantee minimum sample damage, small pressure, and well-defined indentation geometry. Nevertheless, current theoretical models for data interpretation, including those available in commercial software tools, are not accurate for this probes when large indentations are considered, since they do not properly account for the bottom contact effect. Large indentations occur very often in force curve-based experiments with colloidal probes on very soft materials, like soft polymers, hydrogels, and living cells, and therefore there is the need to develop and test more advanced theoretical models than the existing ones. Here, we present a force indentation analytical model that considers accurately the bottom contact effects for the case of a spherical probe. The model is valid in the full range of indentations and sample thicknesses, as shown by numerical calculations, and has been experimentally validated with the mapping of the Young's modulus of soft hydrogels (Y = 3 kPa) and ultra-soft cells (M0, M1 and M2 macrophages) (Y < 1 kPa). We will also present a software tool integrating this (and other analytical models with bottom effect correction) with the aim to achieve large scale and automatic quantitative mechanical cell phenotyping at high throughput using colloidal probes, approaching on the fly mechanical quantitative analysis.

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#116 — Oral

Atomic Force Microscopy / Ultrasonic Force Microscopy Insights Into The Nanoscale Organization Of PVA-Chitosan-Glycerol Film

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

Understanding the nanoscale organization of PVA–chitosan-based films is essential to explain their physicochemical behavior and potential performance in biomedical and packaging applications. In this work, Atomic Force Microscopy (AFM), Lateral Force Microscopy (LFM), and Ultrasonic Force Microscopy (UFM) were employed to investigate nanoscale morphology and local mechanical heterogeneity in PVA, PVA–CS, and PVA–CS–GLY films, complemented by X-ray diffraction (XRD), Fourier transform infrared (FTIR) spectroscopy, and thermal analysis.
In pure PVA films, Scanning Probe Microscopy (SPM) revealed well-defined ribbon-like crystalline domains at the nanoscale, consistent with a semicrystalline structure. The addition of glycerol (22% w/w) induced a transition from ribbon-like to rounded, while XRD confirmed an increase in crystallinity and reduced structural disorder within the amorphous phase [1].
In pure CS lactate films, the surface consists of rounded clusters (~80–100 nm) and fibrillar structures arranged in preferential orientations, forming band-like patterns with characteristic angles (60°/120°), suggesting a recurrent supramolecular organization.
In PVA/CS blends, with low CS content (15%w/w), XRD evidences increased crystallinity. UFM distinguishes softer clusters (~100 nm) arranged in rows, likely associated with PVA or amorphous PVA/CS domains, interconnected by stiffer fibrillar structures with a “beads-on-a-string” morphology, attributed to chitosan-rich regions.
Although XRD indicates a loss of crystallinity upon GLY incorporation, SPM reveals the persistent supramolecular organization. GLY leads to larger clusters, void formation, and reduced fibril density. At small scan sizes (L < 5 μm), RMS roughness decreases, while fractal analysis reveals a higher Hurst exponent and a lower fractal dimension (Df ≈ 2.23 vs 2.58), indicating more spatially correlated and less complex surface features.
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#125 — Oral

Optoelectronic Properties Of Threading Dislocations In GaN Studied By Light-Assisted Kelvin Probe Force Microscopy

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

The performance of semiconductor devices is strongly governed by point and extended defects, requiring robust nanoscale characterization methods. In this context, scanning probe microscopy enables the classification of dislocations by probing local variations in surface morphology and optoelectronic response. This is particularly relevant for gallium nitride (GaN), a wide band-gap semiconductor (3.4 eV) of increasing interest for vertical power devices. When grown on foreign substrates such as silicon or sapphire, GaN exhibits a high density of threading dislocations (TDs) that strongly affect doping efficiency, carrier transport, and overall device performance. As the electrical properties of dislocations depend on their nature[1], their character and associated carrier dynamics can be probed by combining Kelvin probe force microscopy (KPFM) with above-bandgap illumination.

In this work, TDs in two GaN samples (S1 and S2) are analyzed by ultraviolet (UV)-assisted KPFM. Both samples are grown by metal–organic vapor phase epitaxy on c-plane sapphire substrates and exhibit a typical power device structure, consisting of an ~5 µm n^- drift layer on top of an n^+ ~2 µm drain layer. The key difference between them is a 50 nm n^{++} GaN capping layer in S2, which is absent in S1. We investigate the contact potential difference (CPD) in the dark and under UV illumination, and analyze its dependence on illumination power as well as its transient response for pristine and defect regions. By these means, we have been able to characterize two types of dislocations.

We acknowledge funding from: ECSEL Joint Undertaking (JU) under grant agreement No 101007229. JU receives support from the European Union's (EU) Horizon 2020 research and innovation program and Germany, France, Belgium, Austria, Sweden, Spain, Italy; NextGeneratonEU, PCI2021-121970/ AEI/10.13039/501100011033. Aso supported by grant PID2024-161277OB-I00 financed by MICIU/AEI/10.13039/501100011033/ERDF, EU.

[1] I. Belabbas, J. Chen, G. Nouet, Computational Materials Science, vol. 90, 71, (2014).

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#153 — Poster

ICMAB Advanced Scanning Probe Microscopy Platform At ALBA For Correlative Characterization

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

Advanced characterization of energy and functional materials increasingly requires multimodal and correlative approaches capable of probing structural, electronic, chemical, and nanomechanical properties across multiple length scales and environmental conditions. The In-situ Correlative Facility for Advanced Energy Materials (InCAEM) has been developed in Catalonia as an open-access platform enabling integrated in-situ and correlative Scanning Transmission Electron Microscopy (STEM), Scanning Probe Microscopy (SPM), and synchrotron-based techniques for multiscale characterization of advanced materials, supported by dedicated workflows and advanced data infrastructure. Within this initiative, the Institute of Materials Science of Barcelona (ICMAB-CSIC) contributes to the SPM platform through two specialized laboratories. The UHV laboratory (SM01) is equipped with scanning tunneling microscopy (STM) and non-contact atomic force microscopy (nc-AFM), enabling studies of surface electronic structure, short-range interatomic interactions, and molecular systems under ultra-high vacuum conditions, with direct sample transfer capabilities to ALBA Synchrotron beamlines including LOREA, BOREAS, CIRCE, NCD-SWEET, and NOTOS. The AFM laboratory (SM02–03) hosts atomic force microscopy systems for nanomechanical and electrical characterization in ambient conditions and within an inert-atmosphere glovebox for air-sensitive materials. Automated probe exchange and correlative workflows enable multimodal measurements on the same sample region, facilitating comprehensive nanoscale studies of surfaces, interfaces, and functional materials.

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#170 — Oral

Quantized Dissipation In Single-Polymer Nanomanipulation

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

nderstanding energy dissipation in non-equilibrium processes is arguably one of the last pending challenges of nanoscience. While macroscopic friction is often perceived as continuous, at the nanoscale, dissipation is governed by discrete events. In this work, we combine cryo-forcespectroscopy and non-equilibrium molecular dynamics (NEMD) simulations to investigate the mechanical desorption of a single polymer from a gold surface.
The experimental dissipation traces reveal a unique series of discrete peaks during the "lifting" and "redeposition" cycles, suggesting that energy loss is regulated by specific conformational transitions rather than a smooth viscous process. By applying Crooks Fluctuation Theorem (CFT) locally, we quantify the reversibility of these oscillation cycles and identify the exact "slip-stick" events of molecular subunits. We demonstrate that these dissipation peaks serve as a fingerprint for the molecule’s conformational space, allowing us to propose generalized coordinates for energy dissipation based on simple physical observables. Combined here we provide a new theoretical framework for rationally designing and understanding energy dissipation during desorption processes.

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#171 — Oral

Stereochemical Design Of Superlubricity

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

Superlubricity has traditionally been associated to structural incommensurability between two surfaces, which prevents interlocking and collective slick-slip motion, leading to small frictional forces . A recent work on 2,7-dibromocyclopent[h,i]aceanthrylene (CPAA) chains adsorbed on Au(111) have revealed a distinct and intriguing pathway: the conformational state of the polymer chain — determined by the torsion angle between consecutive monomers (0° or 180°) — appears to uniquely determine the surface registry, and with it, the friction dynamics of the system. This suggests that molecular stereochemistry could serve as a new design lever for achieving robust path for superlubricity in chain-like molecular systems. In this work, we present molecular dynamics (MD) simulations of the pulling of CPAA chains on Au(111), exploring the role of stereochemistry, as well as the chain length, on the adsorption geometry and friction dynamics. By varying conformational isomers, we aim to establish whether a specific conformation consistently leads to a superlubric contact, and to characterize the underlying mechanisms. Beyond this we also aim the role of contact area, how friction scales with it and the interplay between adhesive and bending energies during sliding. Simulation results will be benchmarked against available experimental AFM images to validate adsorption configurations. This study aims to provide an atomic level understanding of how intramolecular degrees of freedom couple to substrate periodicity, extending concepts from flexible superlubric polycycle-aromatic-hydrocarbon (PAH) chains to stereochemically tunable systems and opening new routes to the rational design of ultralow friction molecular interfaces.

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#183 — Oral

Nanorheology And Nanoindentation Revealed A Softening And An Increased Viscous Fluidity Of Adherent Mammalian Cells Upon Increasing The Frequency

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

The mechanical response of a cell depends on the frequency or velocity at which the cell is probed [1,2]. The components of the cell which contribute to this property and their interplay are not well understood. Here, we integrated local deformation methods and theory [3,4] to develop a force microscopy approach to characterize frequency and velocity-dependent properties of living cells. We show that mammalian cells soften and fluidize upon increasing the frequency or velocity of the deformation. This behavior was independent of the method applied to deform the cell and the indentation values (25 or 1000 nm). At low frequencies (2-10 Hz) or velocities (1-10 μm/s), the response was dominated by the mechanical properties of the cell surface. At higher frequencies (> 10 Hz) or velocities (> 10 μm/s), the response became dominated by the hydrodynamic drag of the cytosol. Softening and fluidization did not involve any structural remodeling. It reflected a redistribution of the applied stress between the solid and liquid-like elements of the cell response as the frequency or the velocity was changed [5].

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[5] Victor G. Gisbert, Francisco M. Espinosa et al., Small. (2023) 2304884.

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#201 — Oral

Optomechanical Control And Characterization Of Physical Properties In 2D Materials

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

Since the first successful isolation of graphene, bidimensional (2D) materials have been revealed as excellent platforms for studying different physical phenomena, ranging from single photon emission to straintronics. However, after two decades studying these materials, their full potential has not been already released, being the limitations in reproducibility when fabricating 2D material-based nanosystems one of the major causes reducing the possibilities of these materials. To overcome these problems, in this work we introduce a novel optomechanical technique to facilitate the reproducibility in this kind of systems. More specifically, the proposed technique relies on the optomechanical coupling obtained when suspended membranes made of graphene are analyzed under an optical interferometer. On one hand, we demonstrate this optomechanical coupling can be used for the active control of the stiffness (either linear and cubic) in the suspended membranes. This optomechanical control of the stiffness opens the door to the active tuning of the mechanical response of these devices, which can help to increase the reproducibility in the use of nano electromechanical systems based on 2D materials by compensating the stiffness variability among different samples. On the other hand, the proposed method also allows the multiplexed characterization of physical properties in these materials (as optical absorption or Young´s modulus). To this purpose, we characterize the mechanical response of these suspended membranes under different conditions (as driving amplitude or light intensity), which eventually allows extracting different properties of the suspended membranes as their mass, Young´s modulus or optical absorption.

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#268 — Oral

Atomic-Scale Visualisation Of Interfacial Water Structure And Electrical Behaviour

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

Simone Benaglia 1,2, Jing Zhang 1,2, Harriet Read 1,2, Rene Fabregas 3, Rui Wang 1,2, Mordjann Souilamas 1,2, Ellia Rees 1,2, Pablo Ares 4, Alessandro Prinicipi 1, Andre K. Geim 1,2, Laura Fumagalli 1,2

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Abstract Text:

At a solid-liquid interface (SLI), liquid molecules arrange into quasi-discrete layers extending a few molecular diameters from the surface due to surface-molecule interactions and confinement (1). These interfacial layers influence adhesion, wetting, ion solvation and transport, and (bio)chemical processes (2). Directly probing this structuring and its physical properties remains challenging, as it requires atomic-scale resolution in both the vertical and lateral directions. Techniques including vibrational spectroscopy, the Surface Force Apparatus, and the Atomic Force Microscope (AFM) have been used to probe these effects, with AFM uniquely offering atomic-scale resolution in both dimensions.
Here I will present two complementary approaches based on AFM, Scanning Dielectric Microscopy (SDM) and Three-Dimensional AFM (3D AFM), used to study the physical properties of liquid structuring at interfaces with solid 2D crystals and soft biomolecules. One probes the electrical properties of liquids under nanoconfinement in 2D-material nanochannels (3, 4), while the other allows to image interfacial liquid structure directly with atomic resolution (5–7). Together, these methods reveal interfacial water layers whose electrical response differ markedly from bulk water, offering new insight into natural processes and providing important information for theories of liquid-mediated interactions.
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#270 — Oral

Sifting Interlayer Excitons From Topographic Artifacts In Real-World 2D Heterostructures

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

Alvaro Rodriguez 1, Pablo Hernández López 2, Luka Pirker 3, Astrid Weston 4, Arijit Kayal 3, Rafael Nadas 2, Adrián Dewambrechies Fernández 5, Roman Gorbachev 4, Kirill I. Bolotin 5, Otakar Frank 3, Sebastian Heeg 2

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Abstract Text:

Interlayer excitons (IXs) in transition metal dichalcogenide (TMDC) heterostructures are often identified from room-temperature photoluminescence (PL) measurements. However, real-world heterostructures frequently contain interfacial inhomogeneities, bubbles, and local strain that can generate spectroscopic signatures resembling IX emission. Distinguishing interlayer states from strain-induced artifacts therefore requires spatially resolved characterization beyond conventional diffraction-limited optics.
In this talk, I will present a nanoscale characterization approach combining atomic force microscopy (AFM), hyperspectral PL mapping, and tip-enhanced photoluminescence (TEPL) to address this problem. Using MoS2/WSe2 as a model system, I will show that the widely reported ~1.6 eV feature commonly assigned to a momentum-indirect Γ-K interlayer exciton spatially correlates with topographical irregularities and strained WSe2 nanobubbles rather than with uniformly coupled heterostructure regions. By performing TEPL with ~20 nm spatial resolution, we directly resolve the nanoscale origin of the emission and demonstrate that the redshifted PL emerges exclusively from locally strained and partially decoupled regions. I will finally discuss how correlated AFM and nanoscale optical spectroscopy provide a generally applicable framework for identifying interlayer excitons in van der Waals heterostructures and for disentangling intrinsic excitonic states from strain and topographic artifacts in complex moiré and mixed-dimensional systems

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#290 — Poster

Construction And Characterization Of A High-Speed Atomic Force Microscope (HS-AFM) With Photothermal Excitation

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

This technique is able to visualize dynamic conformational changes of single biomolecules, reaching frame rates that are orders of magnitude higher than conventional AFM while preserving the spatial resolution needed. The main goal was to develop a HS-AFM prototype capable of recording soft biological samples with precision, incluiding a flexoscanner nanopositioner.
The principal adjustement is based on the implementation of a miniaturized cantilever in order to increase the resonance frenquency for the scanning. As a consequence, it is also necessary to reduce the laser spot size used for measuring the deflection of this new miniaturized cantilever. Hence, the final design consists of an inverted AFM head over the cantilever (with its tip directed upwards), positioned just above a system of mirrors and lenses where the laser optical path lays.
Another important consideration is the liquid environment required for measuring the movement of biological samples. To prevent any inconvenience, the cantilever oscillates by means of photothermal excitation. For that purpose, a second laser beam is introduced inside the optical system and is directed into the base of the cantilever, modulated by the software responsible for controlling the microscope.
After its construction, the performance of the HS-AFM prototype is tested observing double DNA strands, which are going to be used for the callibration of the flexoscanner. Once the functioning of the microscope is verified, it can be employed in the recording of more complicated dynamic processes, such as the aggregation of RNA strands in presence of magnesium.

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#299 — Oral

KPFM-Guided Identification Of Contact, Channel And Heterojunction Bottlenecks In TMD-Based 2D Devices

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

Krishna K Yadav 1, El Hadj Abidi 2, Carmen Munuera 3, Jorge Quereda 4, Enrique Díez 5, Ana Pérez Rodríguez 6

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Abstract Text:

As global energy demand continues to rise, the development of high-efficiency, cost-effective, and ultrathin photovoltaic (PV) devices has become essential for the large-scale adoption of renewable energy technologies. Among emerging materials, two-dimensional (2D) Transition Metal Dichalcogenides (TMDs) have attracted strong interest for next-generation photovoltaics due to their mechanical flexibility, strong light–matter interaction and high optical absorption. However, despite their theoretical potential, practical 2D photovoltaic and optoelectronic devices remain limited by the difficulty of rapidly and reliably identifying interfacial charge-transport losses, contact barriers and local electrostatic bottlenecks.
In this work, we present a robust experimental platform for the systematic investigation of the electronic properties of TMD monolayers and stacked heterojunctions using advanced Atomic Force Microscopy (AFM) based techniques. Monolayer-to-few-layer TMD flakes were deterministically transferred onto pre-patterned contact pads with different metallization schemes. Kelvin Probe Force Microscopy (KPFM) was employed to precisely map local surface potentials and quantify contact-related potential drops at the corresponding metal–semiconductor interfaces. These measurements were combined with transport and temperature-dependent Arrhenius analysis to determine whether the extracted effective activation energies arise from metal/TMD contacts, the semiconductor channel, internal electrostatic domains, or interface-related pinning. The KPFM-derived potential profiles were then correlated with local contact resistance, asymmetric barrier formation, and junction band alignment. Finally, photocurrent mapping was used to assess whether the electrostatic fields identified by KPFM also function as active carrier-separation regions. This study provides critical insights into the rapid optimization of both ohmic and Schottky contacts in TMD-based devices. The findings establish a scalable pathway for accelerating the selection of suitable metal contacts and heterostructure combinations, ultimately supporting the development of highly efficient ultrathin TMD-based solar cells.

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#300 — Oral

Multifrequency Atomic Force Microscopy For Organic Electronic Thin Films

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

The performance of organic electronic devices strongly depends on the nanoscale organization of their molecular components. Molecular packing, crystallinity, and structural heterogeneity in organic thin films directly influence charge transport and device operation, particularly in systems such as organic field-effect transistors (OFETs). Considerable efforts have therefore been devoted to developing fabrication methods that improve molecular ordering and electrical performance. In this context, Atomic Force Microscopy (AFM) has become a powerful tool for investigating organic thin films at the nanoscale. Here, we explore the use of multifrequency AFM, combining high-resolution imaging with crystallographic domain mapping. We demonstrate that multifrequency AFM provides valuable information beyond conventional topography, offering insight into the relationship between molecular organization and the functional behavior of organic electronic devices.

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#301 — Oral

Emergent Electrostatic Domain Reconstruction In Large-Area 3R-MoS2

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

Mariana M. Gomes 1,2, Aitor Zambudio 1,2, Carmen Munuera 3, Andrés Castellanos-Gómez 3, Julio Gómez-Herrero 1,2, Pablo Ares 1,2, Álvaro Rodríguez 1,2,3

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Abstract Text:

Rhombohedral transition metal dichalcogenides have recently attracted growing interest due to their broken inversion symmetry and the emergence of reconstructed electrostatic textures associated with interlayer coupling and stacking reconstruction [1]. Here, we investigate large-area bilayer 3R-MoS2 flakes obtained through Au-assisted exfoliation by combining Kelvin probe force microscopy (KPFM), lateral force microscopy (LFM), and Raman spectroscopy.
KPFM reveals complex electrostatic domain patterns extending over tens to hundreds of micrometers, including irregular domains, line-like domain walls, and triangular reconstructed regions coexisting within the same flake. Correlated LFM and topographic measurements indicate that these electrostatic reconstructions strongly depend on local interfacial morphology and sliding-related structural rearrangements. Remarkably, the domain patterns disappear after removing the Au substrate, indicating a critical role of metal-induced strain, shear, and interfacial coupling in stabilizing the reconstructed polar textures. Our results suggest that exfoliation-induced interlayer sliding and heterostrain drive large-scale electrostatic reconstruction in 3R-MoS2. The work highlights the sensitivity of rhombohedral TMDCs to substrate interactions and demonstrates the power of correlated scanning probe microscopies for visualizing emergent interfacial reconstruction phenomena in van der Waals materials.
[1] Shear Strain-Induced Two-Dimensional Slip Avalanches in Rhombohedral MoS2, Nano Letters 2023 23 (15), 7228-7235

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#312 — Oral

Combining Optical Spectroscopy With Scanning Probe Microscopy In The Study Of 2D Materials

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

Nanoscale miniaturization and the integration of hybrid and functionalized materials have significantly increased the complexity of semiconductor technologies. In this context, experimental platforms that integrate optical spectroscopies, such as photoluminescence (PL) and Raman scattering, with scanning probe microscopies (SPM) enable comprehensive insights into local structural, compositional, optical, and electrical properties, and have become essential for further scientific development. Co-localized optical and SPM images, despite providing different spatial resolution, can unravel the behaviour of surfaces and interfaces at the micro- and nanoscale. For optical resolution beyond the diffraction limit, one could take advantage of the plasmonic resonance of a metallised SPM tip, which is the basis of tip-enhanced Raman spectroscopy (TERS), a technique capable of probing local vibrational properties with simultaneous topographic imaging at the nanoscale.
In this contribution, we will present several examples of integrated optical and SPM studies on complex 2D materials. On SPM-produced MoS_2 nanoislands, optical spectroscopies can determine their dimensionality. For graphene derivatives, co-localized Raman scattering or PL maps with different SPM modes are used to assess the reduction of graphene oxide (GO) nanoflakes and to monitor photocarrier dynamics in GO nanohybrids.
TERS is particularly well suited for the study carbon-based 2D materials, including graphene, GO, and molecular self-assembled monolayers, where it offers clear advantages not only in terms of spatial resolution, but also through its enhanced sensitivity. We will also discuss the main bottlenecks of TERS, particularly those regarding data analysis and interpretation resulting from the high degree of disorder, and the modification of the selection rules compared to conventional Raman spectroscopy.

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#322 — Oral

Local Conductance With Scanning Probe Microscopy

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

The advent of Scanning Probe Microscopy (SPM) began with Scanning Tunneling Microscopy (STM), which in its simplest form measures the tunnel current across a vacuum gap. Beyond imaging, STM was already being employed in the early 1990s to fabricate nanocontacts and probe local conductance within Landauer's formalism [1]. Atomic Force Microscopy (AFM) later expanded the SPM toolkit by using tip-sample forces rather than current as the primary imaging signal, offering key advantages over STM — notably the ability to operate on insulating substrates. It was quickly recognized that equipping AFM with metallic tips would also enable local conductance measurements, opening new avenues for nanoscale electrical characterization.
In this talk, I will review a selection of landmark contributions spanning the use of SPM to study electrical transport at the nanoscale: from the formation and characterization of metallic nanocontacts, through conductance measurements of individual molecules and carbon nanotubes, to local conductivity mapping of graphite.
[1] Quantum contact in gold nanostructures by scanning tunneling microscopy . J.I. Pascual et al. Phys. Rev. Lett. 71, 1852, (1993)

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#333 — Oral

Room-Temperature Phonon Interference In Single-Molecule Junctions

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

Wave interference allows unprecedented coherent control of various physical properties and has been widely studied in electronic and photonic materials. However, the interference of phonons, or thermal vibrations, central to understanding coherent thermal transport in all electrically insulating materials, has been poorly characterized due to experimental challenges. In this work, we report the first direct observation of vibrational interference at room temperature, which was measured in two molecular-scale junctions.

This is enabled by custom-developed scanning thermal probes with combined high stability and sensitivity, allowing quantification of heat flow through molecular junctions one molecule at a time. Using isomers of oligo(phenylene ethynylene)3 with either para- or meta-connected central rings, our experiments revealed a remarkable reduction in thermal conductance in meta-conformations.

We make use of quantum-mechanically derived force fields to accurately model the vibrational properties of the molecular compounds within classical non-equilibrium molecular dynamics (NEMD). Our simulations confirm the experimental observations regardless of the specific lead geometry under consideration. Further analysis through Green's junction methods supports the presence of vibrational interference in both species. Fine sampling of the conformations spanned through the dynamics reveal that thermal fluctuations hinder interferences in para-OPE3, thus explaining the difference with respect to meta-OPE3.

This work opens opportunities for studying numerous wave-driven material properties of phonons down to the single-molecule level with the aid of state-of-the-art scanning probe methods.

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#334 — Oral

KPFM Mapping Of Sliding-Induced Electrostatic Domains In Exfoliated ReS_2 Flakes

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

Sliding ferroelectricity generates out-of-plane polarization in van der Waals materials through interlayer registry rather than conventional ionic off-centering [1–3]. Yet identifying its nanoscale signatures in realistic exfoliated flakes is difficult, because strain, trapped charges, ferroelastic reorientation and substrate screening can all produce heterogeneous electrostatic signals. Here we report a correlative study of multilayer ReS_2 flakes combining Kelvin probe force microscopy (KPFM), low-energy and UV-photoemission electron microscopies (LEEM/UV-PEEM), and Raman spectroscopy. KPFM reveals robust contact-potential-difference domain patterns, with contrasts from tens of millivolts to about 100 mV, without topographic counterpart and observed on different substrates. Raman mapping shows that these domains are decoupled from broad vibrational/orientation regions and do not follow strain-sensitive phonon shifts, while DF-LEEM and UV-PEEM detect only a subset of the KPFM boundaries. This partial correspondence indicates that the domains are electronic/electrostatic in nature, but not a single class of rigid structural domains. We further show that the electrostatic landscape can be modified by thermal annealing and by local electric fields applied with a biased AFM probe, producing long-lived reconfiguration beyond the directly contacted region. The observations are consistently explained by stacking-sensitive, sliding-induced ferroelectric polarization in weakly coupled multilayer ReS_2 [1,4]. These results establish KPFM, combined with complementary spectroscopic and photoemission microscopies, as a powerful strategy to access weak, screened polarization textures in low-symmetry two-dimensional materials.

[1] Wan et al., Phys. Rev. Lett. 128, 067601 (2022).
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[4] Jeong et al., Adv. Mater. 34, 2108777 (2022).

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#382 — Poster

Geometry-Dependent Electrostatic Deformation Of Suspended Graphene Membranes For Poisson'S Coefficient Determination

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

Pablo Andrés Romero Proaño 1, Guillermo López-Polín Peña 2, Fernando Calle 3, Jesús García-Arisco 3, Julio Gómez Herrero 1

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Abstract Text:

Among the mechanical properties of graphene, the determination of Poisson’s ratio remains under debate, as previous studies have reported a wide dispersion of values, ranging from positive values predicted by continuum elasticity and phonon-dispersion measurements to effective negative values associated with thermally fluctuating and rippled membranes. Experimentally, the Poisson’s ratio has only been determined indirectly from phonon-dispersion measurements, while previous bulge-test methodologies have shown that the geometry-dependent nonlinear mechanical response of suspended membranes leads to different sensitivities to the Poisson’s ratio. Motivated by this approach, in this work we study the electrostatic deformation of suspended graphene membranes deposited over circular holes and rectangular trenches on Si/SiO2 substrates under different applied gate voltages using Atomic Force Microscopy (AFM). The deflection-voltage curves are analyzed using nonlinear electrostatic membrane models to evaluate the influence of geometry and boundary conditions on the extracted elastic parameters. To improve the clamping conditions of the suspended graphene membranes, ultrathin hBN layers combined with capillary assisted collapse and thermal annealing are explored. The experimental results reveal a measurable dependence of the mechanical response on membrane geometry, highlighting the sensitivity of the extracted elastic parameters to residual strain and clamping conditions.

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#384 — Oral

Unmasking Biomacromolecular Adsorption And Large Conformational Transitions From AFM Images With Multiscale Simulations And Parsimonious ML Models

DFMC-GEFES - Forty years of Atomic Force Microscopy: advances in nanomaterials characterization

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Abstract Text:

AFM has emerged as a transformative experimental platform capable of directly probing biophysical properties such as elasticity, electrostatics, viscosity, among many others, with unprecedented spatial and force sensitivity. Some unique features of force microscopy for biological measurements are the capacity of measuring samples under reconstructed physiological conditions and at the same time ambient conditions that allow studying fomites (bio-material interfaces). In spite of the AFM capabilities in biology and growing AFM advanced operating modes, the interpretability of their images/videos is still mostly done by eye, and/or there are a few “fitting” tools that do not consider proper initial conditions of the biological sample, such as deformation upon adsorption, among others.
Hence, modeling adsorption of biomacromolecules onto substrates is critical for accurately interpreting high-resolution images acquired through tapping, multifrequency, or high-speed AFM modes. This challenge becomes particularly pronounced when proteins exhibit multiple domains with similar length scales but only subtle conformational differences, as observed in the receptor binding domain (RBD) "up" versus "down" states of the SARS-CoV-2 spike protein. In this work, we developed a dynamic mode decomposition (DMD) framework using parsimonious machine learning algorithms to analyze extensive high-speed AFM (HS-AFM) experimental measurements, alongside short molecular dynamics simulations of one spike protein laid over polarizable model substrates. The model is able to sample the most relevant dynamics modes during HS-AFM imaging, as it demonstrated strong agreement with experimental measurements, by matching trends in root mean square deviations (RMSD) and radius of gyration (Rg) metrics. Our analyses reveal accessible conformations during HS-AFM imaging, quantify domain variance, molecular center-of-mass, and identify flexible and rigid regions. Finally, the multi-modal analysis exposes subdomain organization, while microstate detection distinguishes open and closed RBD forms. Together, this approach provides a comprehensive structural and dynamic characterization of the biomacromolecules adsorption.

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#144 — Oral

Mechanical Properties Of Nanoporous W Under Irradiation - Experiments And Modeling

DFMC-GEFES - Frontiers in Fusion Materials Science

Carlos J Ruestes 1, Raquel Gonzalez-Arrabal 1, Miguel Monclus 2, Manuel Avella 2, Lukas Schweiger 3, Daniel Kiener 3, Ulrich Kentsch 4, Jon Molina-Aldareguia 2, Javier Segurado 2

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Abstract Text:

Nanoporous tungsten (np-W) is a class of functional material that exhibits a bi-continuous network of nanoscale pores and solid ligaments, an open-cell porous material. With improved mechanical properties enabled by nanoscale effects, it has a remarkable potential for nuclear applications thanks to the radiation performance of its base material, combined with a large amount of internal surfaces, which act as sinks for radiation-induced defects. Nanoporous W with 35% porosity and an average ligament size of 20-25 nm was manufactured using severe plastic deformation of a coarse-grained W-Cu composite followed by selective dissolution of Cu. The resulting np-W was then implanted with H and He at energies of 82 keV and 160 keV, respectively. The implantation fluence for both cases was selected as 5E20 m^{-2}. Molecular dynamics simulations of radiation damage and FFT-based crystal plasticity simulations were combined to predict the effect of H and He implantation on np-W mechanical properties. The simulations were then validated by nanoindentation and micropillar compression experiments on as-prepared and irradiated samples. Hardness and yield stress increase due to irradiation, and the results are interpreted based on a model accounting for the increased resistance to dislocation glide by helium-implantation-induced defects.

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#200 — Oral

Alternative Plasma Facing Materials For Nuclear Fusion Applications

DFMC-GEFES - Frontiers in Fusion Materials Science

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Abstract Text:

Nuclear fusion represents a promising option for future large-scale energy supply. Two main approaches are being pursued: magnetic confinement fusion (MCF) and inertial confinement fusion (ICF). In recent years, both have achieved significant milestones, strengthening the view that the scientific community is progressing towards the realisation of fusion energy. These advances have stimulated substantial public and private investment in the development of projects focused on the conceptual design of commercial power plants.

Despite these achievements, several challenges still need to be addressed before upscaling to a commercial facility. One of these is the development of plasma-facing materials (PFMs) capable of withstanding the combined effects of high thermal loads and radiation environments present in these reactors.

In this contribution, we compare the radiation environments encountered by PFMs in direct-drive dry-wall ICF and in MCF. We briefly outline the limitations of conventional coarse-grained tungsten as a PFM and present alternative tungsten-based materials, including nanostructured tungsten, with a high density of grain boundaries [1–5], and tungsten nanocolumns, with a large surface area [6–9]. We discuss the potential advantages and limitations of these materials, as assessed through a combination of experiments and multiscale computer simulations.

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#213 — Oral

Ion Beam Techniques At CMAM: From Materials For Fusion To Circular Economy

DFMC-GEFES - Frontiers in Fusion Materials Science

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Abstract Text:

The Center for Micro-Analysis of Materials (CMAM) is an accelerator facility located at the Universidad Autónoma de Madrid (UAM). CMAM features an electrostatic tandem ion accelerator with maximum terminal voltage of 5 MV and a suite of six beamlines for different applications.
In the context of nuclear fusion, ion beam techniques are well suited to simulate radiation-induced damage (from both ions and neutrons), as well as to characterize radiation-induced effects such as segregation, damage, and the behaviour of light species. Furthermore, ion beam methods enable the characterization of impurities contained in proposed breeding blanket materials, such as PbLi.
Within this framework, CMAM collaborates with two key groups in the Spanish research ecosystem: LNF-CIEMAT, primarily focused on magnetic confinement fusion (MCF) studies, and IFN-GV (UPM), mainly oriented towards inertial confinement fusion (ICF). CMAM contributes to the analysis of radiation effects in conventional (coarse-grained W) and alternative plasma-facing materials (PFMs), in structural materials, in multifunctional coatings for breeding blanket applications and in breeding blanket materials themselves.
It is also worth noting that CMAM's recently commissioned pulsed ion source enables the study of pulsed irradiation effects in materials. These effects, which differ substantially from those induced by continuous irradiation, are highly relevant for plasma-facing materials in ICF and for the divertor in MCF.
All these studies, conducted within the EUROfusion consortium, contribute significantly to the advancement of the European fusion programme.
Additionally, CMAM is involved in two European projects: ReMade@ARI (https://remade-project.eu/), which focuses on materials research for Circular Economy, and RIANA (https://riana-project.eu/), dedicated to nanotechnology. These projects provide fully supported user access to more than 50 European analytical infrastructures for both academic and industrial research.

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#315 — Oral

Collision Cascades Interacting With Magnetic Domain Walls In Fe: A Spin-Lattice Dynamics Study

DFMC-GEFES - Frontiers in Fusion Materials Science

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Abstract Text:

Magnetism is often neglected in atomistic simulations of radiation damage in structural materials, despite its potential influence on defect production and microstructural evolution. In this work, we investigate the interaction between collision cascades and magnetic domain walls in bcc Fe using spin-lattice dynamics (SLD) simulations implemented in LAMMPS.
Atomic interactions are described using an EAM potential coupled to a short-range ZBL correction, while magnetic interactions include Heisenberg exchange, dipolar interactions, and uniaxial anisotropy. A Néel-like term is additionally incorporated to enhance spin-lattice coupling.
The system consists of a thin Fe film containing magnetic domain walls. Collision cascades are initiated close to the domain walls, and defect production, recombination, clustering, and the evolution of the magnetic texture during the cascade are analyzed.
Preliminary results show that the total defect production is similar in magnetic and non-magnetic samples during the primary damage stage. However, collision cascades produce noticeable distortions and displacements of the magnetic domain walls. These results suggest that magnetic degrees of freedom could play an important role during the post-cascade evolution of radiation-induced defects and magnetic textures.

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#344 — Poster

From Defects To Thermal Performance: Multiscale Modelling Of Irradiated Tungsten For Fusion Applications

DFMC-GEFES - Frontiers in Fusion Materials Science

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Abstract Text:

Plasma-facing components (PFCs) in future fusion reactors must be able to withstand extreme heat and neutron irradiation, requiring predictive understanding of how plasma conditions lead to material degradation. Tungsten (W) is a leading candidate material due to its favourable thermophysical properties. However, irradiation-induced defects can significantly reduce its performance, particularly thermal conductivity.

We are developing a multiscale modelling strategy to link plasma-facing conditions, neutron irradiation effects, defect evolution, and macroscopic material behaviour. This approach is supported by high-performance multiphysics simulations coupling neutronics, heat transfer, and fluid dynamics. The present study contributes to this larger effort by combining electronic structure calculations, large-scale atomistic molecular dynamics simulations, and data-driven approaches to quantify the impact of irradiation-induced defect structures on material properties. Plasma conditions provide the heat and particle fluxes that drive defect formation in PFCs, motivating a predictive description of defect–property relationships.

At the electronic structure level, training data generated from first principles, using multifidelity and low-scaling density functional theory (DFT), enables the treatment of large dynamic systems through machine learning interatomic potential (MLIPs), providing insight into the atomic-scale properties of defects beyond the limits of quantum mechanical approaches. Additionally, non-equilibrium molecular dynamics simulations with semi-empirical potentials are employed to investigate structure-property relationships linked to thermal transport in irradiated tungsten across a wide range of defect densities, which are introduced using the Creation–Relaxation Algorithm. By coupling molecular dynamics simulations with ML models, quantitative structure-property relationships are established, linking defect characteristics and thermal conductivity degradation. Vacancy density is identified as the dominant factor, and a strong nonlinear suppression of thermal conductivity is observed.

The results presented here provide key atomistic and data-driven building blocks towards multiscale modelling, enabling improved prediction of thermal performance in tungsten plasma-facing components under fusion-relevant conditions.

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#75 — Oral

Microscopic Insights Into Magnetically Doped Topological Insulators

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Magnetic topological insulators (MTIs) constitute a versatile platform to explore the interplay between non-trivial band topology and magnetic order. The introduction of magnetic dopants enables the breaking of time-reversal symmetry (TRS), leading to the opening of a gap in the Dirac-like topological surface states (TSS). This gap is a key requirement for realizing exotic quantum phenomena such as the quantum anomalous Hall effect (QAHE), characterized by dissipationless edge transport. Despite significant progress, achieving robust QAHE at elevated temperatures remains a central challenge [1].
In this talk, I present a comparative study of different approaches to induce and control magnetism in topological insulators, focusing on both intrinsically magnetic systems and externally doped compounds. In particular, we investigate the antiferromagnetic topological insulator Mn2Bi4Te7 [2], as well as rare-earth-doped Bi2Te3 [3] and Sb2Te3. Using a combination of surface-sensitive techniques, including angle-resolved photoemission spectroscopy (ARPES) and scanning tunneling microscopy (STM), we analyze how magnetic order and dopant incorporation influence the TSS. These findings open a viable pathway toward achieving the QAHE and integrating MTIs into spintronic technologies.
References:
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#77 — Oral

Tuning Two-Dimensional Magnetic Van Der Waals Heterostructures Via Twist Engineering

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Two-dimensional (2D) magnetic materials offer unprecedented opportunities for fundamental and applied research in spintronics and magnonics. Of particular interest is the layered metamagnet CrSBr, a relatively air-stable semiconductor formed by antiferromagnetically-coupled ferromagnetic layers (Tc∼150 K) that can be exfoliated down to the single-layer. In this work, the magneto-transport properties of pristine 2D layers of CrSBr integrated into vertical heterostructures are inspected. The results demonstrate the marked low-dimensional character of the ferromagnetic monolayer, with short-range correlations above Tc and an Ising-type in-plane anisotropy, being the spins spontaneously aligned along the easy b magnetic axis. By applying moderate magnetic fields along the a (intermediate) and c (hard) axes, a spin-reorientation occurs, leading to a magnetoresistance enhancement at low temperatures. In multilayers, a spin-valve behaviour is observed, with negative magnetoresistance strongly enhanced along the three directions.[1] Furthermore, we fabricate an artificial magnet by twisting 90º two CrSBr ferromagnetic monolayers, thus forming an orthogonally-twisted bilayer.[2] The magneto-transport properties reveal multistep spin switching with a magnetic hysteresis opening, which is absent in the pristine case. By applying an external magnetic field, we can modulate the remanent state and coercivity, triggering hysteretic and non-hysteretic magneto-resistance states that can be further tuned when stacking different number of layers (keeping a constant twist angle of 90º), observing different magnetic scenarios.[3] These results show that twisted CrSBr layers provide an ideal platform for studying and controlling field-induced phenomena in two-dimensions, offering new insights regarding 2D magnets and opening a fruitful playground for creating artificial magnetic symmetries and manipulating non-collinear magnetic textures their integration into vertical spintronic devices.

[1] Adv. Mater. 34 (2022) 2204940. [2] Nat. Mater. 23 (2024) 212-218. [3] Adv. Mater. 37 (2025) 2415774.

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#100 — Oral

Fabrication And Electrical Property Tuning Of Ni Micro/Nanostructures By Focused Ion Beam Irradiation Of Nickel Acetate Films

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Focused Ion Beam (FIB) technology enables precise modification and patterning of materials at the micro- and nanoscale. While FIB-induced deposition (FIBID) using gaseous precursors offers high resolution, it is typically limited by low throughput. In contrast, the use of spin-coated organometallic films allows high-throughput material transformation under ion irradiation. However, if the precursor material is a spin-coated organometallic film, FIB irradiation provides material growth with a high throughput, as demonstrated for PdAc films.
In this work, spin-coated nickel acetate films were used as solid-state precursors and irradiated with a focused Ga^+ ion beam to induce localized decomposition and the formation of nickel-based nanostructures. The morphology and composition of the irradiated structures were systematically characterized by scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDX), and transmission electron microscopy (TEM).
Two complementary post-processing strategies were explored to further tailor the physical properties of the fabricated structures. In the first approach, He^+ ion irradiation was employed to further modify the nanostructures, enabling fine control over their structural and magnetic properties, which were subsequently investigated by physical property measurement system (PPMS) measurements. In the second approach, post-growth current annealing was applied to enhance electrical conductivity, leading to a significant reduction in resistance, suggesting improved structural connectivity.
The combination of Ga^+-induced growth with He^+ modulation and electrical post-processing provides a versatile platform for tuning both the magnetic and electrical properties of nickel-based nanostructures, highlighting its potential for applications in nanoelectronics and functional nanodevices.

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#108 — Oral

Automated Hubbard Parameters In LCAO DFT+U With SIESTA

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Standard Density Functional Theory (DFT) over-delocalizes charge, giving an inaccurate description of strongly correlated systems such as metal oxides [1]. This stems from the violation of the piecewise-linear constraint with respect to electron number in approximate exchange–correlation functionals [2]. Twenty years ago, a linear-response methodology was proposed to determine the Hubbard U in DFT+U such that this constraint is satisfied [3], so that +U ceases to be empirical and the ab initio character is restored. Implemented in the plane-wave package Quantum ESPRESSO [4], the method was later extended to DFT+U+V [5]. To date, Quantum ESPRESSO has effectively monopolized this procedure [1]. Here we implement this methodology in SIESTA [6], which employs a Linear Combination of Atomic Orbitals (LCAO) basis. This framework offers a more natural localized-basis description, faster calculations in systems with large vacuum regions, and improved scaling with system size [6]. The resulting real-space Hamiltonian can be reused as a tight-binding model, e.g. in quantum-transport simulations. Our implementation follows the original formalism and uses utilities from AiiDA-SIESTA [7]. The obtained values are of the same order as those from Quantum ESPRESSO and reproduce the trend $U(CrCl_3) < U(CrBr_3) < U(CrI_3)$ [8]. Ongoing work benchmarks the approach against Quantum ESPRESSO. The implementation also computes the intersite Hubbard V at marginal additional cost. Making this available in a public SIESTA release would remove the current dependence on Quantum ESPRESSO and enable LCAO-based simulations with automatically computed Hubbard parameters.

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#137 — Oral

Probing Magnetic States Of 2D Materials In Graphene-Based Heterostructures Via Electron Transport Measurements

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Two-dimensional (2D) van der Waals (vdW) antiferromagnets (AFMs) are promising candidates for spintronic applications due to their fast spin dynamics and robustness against external magnetic perturbations. However, their intrinsically low electrical conductivity challenges their integration into electronic devices. A path to overcome this limitation is to form vdW heterostructures with graphene, which can sensitively respond to interfacial magnetic interactions. In this work, we investigate vdW heterostructures composed of single-layer graphene and the antiferromagnet FePS3 (FEPS). In a previous work, electron transport and Raman measurements in a field-effect transistor geometry (GFET) revealed a sharp change in graphene resistance precisely at the Néel temperature of FEPS [1], indicating a distinct interfacial charge transfer driven by the antiferromagnetic ordering Interestingly, magnetic field-dependent low temperature electron transport measurements uncover distinct features in graphene resistance well below FEPS Néel temperature, suggesting secondary magnetic phases or more complex spin dynamics [2] of this particular antiferromagnet. Gate-dependent measurements add insight about the nature of those secondary phases. Altogether, our results highlight the potential of 2D vdW heterostructures as a platform for the detailed study of the properties of all kind of vdW magnetic materials. A strong interplay between magnetism and electron transport in 2D vdW heterostructures is unveiled, paving the way toward integrating antiferromagnetic vdW materials into future electronic and spintronic technologies.

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#220 — Oral

Nanofabrication And Transport Properties Of Topological Insulator Bi2Te3 Thin Films

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Three-dimensional topological insulator Bi2Te3 has attracted much attention due to its exotic property of holding a great conductivity on surface protected by time-reversal symmetry.[1] However, maintaining topological protection during the transition from growth to nanoscale device integration is a significant challenge. Our study systematically investigated the material growth, fabrication and magnetotransport properties of Bi2Te3 thin films prepared by two different processes: molecular beam epitaxy (MBE) and metal organic chemical vapor deposition (MOCVD). The results showed that a 30 nm thick film grown by MBE exhibited a carrier density as high as 1200 cm2/Vs extracted from transport measurements from 300 K to 2 K.
With the long-term goal of device fabrication, we used focused ion beam (FIB) milling to precisely pattern the thin films. To achieve complete milling of narrow lines on the Bi2Te3 layer while minimizing irradiation-induced amorphous damage [2], the optimal Ga+ beam dose is found to be 8.6×1010 ions/cm. We obtain narrow lines with width down to 80 nm. This research lays a solid foundation for future fabrication of nano-superconducting quantum inference devices (nanoSQUIDs) with Bi2Te3 as non-superconducting path within the Josephson junctions[3].

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#250 — Oral

Emergent Hydrodynamics And Geometric Phases In Graphene Superstructures

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

We report the dual emergence of collective hydrodynamic flow and quantum geometric phenomena in ultra-high-quality monolayer graphene patterned with periodic antidot lattices. This lithographically defined platform provides a deterministic route to engineering electronic spectra and transport regimes traditionally difficult to access in van der Waals heterostructures. By systematically tuning the lattice geometry, we reveal a hierarchy of commensurability features and pronounced Brown-Zak oscillations arising from the alignment of the magnetic flux quantum with the superlattice unit cell. Crucially, we demonstrate that the intrinsic geometric phase of the system is directly measurable, with the magnetic field periodicity precisely matching the lithographic patterning. These results show that moiré-like electronic spectra and their associated topological phases can be generated geometrically in single-layer graphene without the need for twist, lattice mismatch, or multilayer stacking.
This structural periodicity simultaneously governs the transition from ballistic to collective transport regimes. The inhomogeneous current flow induced by the antidot geometry facilitates the observation of viscous electron fluids, manifested through an enhanced superballistic effect. We find that this superballistic conduction behaves non-monotonically with the magnetic field, proving that the antidot geometry is a superior architecture for realizing hydrodynamic flow.
Our findings establish nanopatterned graphene as a clean, tunable, and scalable platform where deterministic real-space design governs both the fundamental geometric phase of the wavefunction and the emergent many-body dynamics of the electron fluid.

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#256 — Oral

Resistive Switching In A Mott Insulator Initiated By Topological Defects

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Avalanche resistive switching is the fundamental process that triggers the sudden change of the electrical properties in solid-state devices under the action of intense electric fields. Despite its relevance for information processing, ultrafast, electronics, neuromorphic devices, resistive memories and brain-inspired computation, the nature of the local stochastic fluctuations that drive the formation of metallic regions within the insulating state has remained hidden.
Here, using operando X-ray nano-imaging, we have captured the origin of resistive switching at low temperatures in a V2O3-based device under working conditions. V2O3 is a paradigmatic Mott material, which undergoes a first-order metal-to-insulator phase transition together with a lattice transformation that breaks the threefold rotational symmetry of the rhombohedral metallic phase [1]. We reveal a new class of volatile electronic switching triggered by nanoscale topological defects appearing in the shear-strain based order parameter that describes the insulating antiferromagnetic phase [2]. Our results pave the way to the use of strain engineering approaches to manipulate such topological defects and achieve the full dynamical control of the electronic Mott switching. Topology-driven, reversible electronic transitions are relevant across a broad range of quantum materials, comprising transition metal oxides, chalcogenides and kagome metals

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#273 — Oral

Cubic Edge Dispersion In A Semi-Dirac Chern Insulator

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Topological edge states in Chern insulators are typically characterized by a linear dispersion relation inherited from the Dirac structure of the bulk Hamiltonian. Here we show that this paradigm can be fundamentally altered in systems with anisotropic semi-Dirac band structures. We introduce a minimal two-band lattice model realizing a semi-Dirac Chern insulator and determine its topological phase diagram analytically. Using a mass-domain-wall approach in a semi-infinite geometry, we derive an explicit expression for the chiral edge states and find that their low-energy dispersion scales cubically with momentum, E(k)~ k^3. Numerical diagonalization of the corresponding tight-binding ribbon confirms the analytical prediction. Our results demonstrate that unconventional bulk band structures can produce qualitatively different boundary excitations, providing a route to engineering nonstandard chiral edge dynamics in topological materials and synthetic quantum systems.

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#297 — Oral

Substrate-Driven Structural Coherence In Epitaxial Hematite Thin Films For Spintronics

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Unlike conventional spintronic devices based on ferromagnets, antiferromagnetic materials offer intrinsic advantages such as robustness against external magnetic perturbations, zero stray fields, and ultrafast spin dynamics.[1] Among antiferromagnetic insulating oxides, hematite is particularly attractive due to its robust antiferromagnetic order at room temperature (TN~950K) even for thin films. Also, its weakly canted antiferromagnetic structure gives rise to a small net magnetization, enabling external control of the Néel vector orientation. α-Fe2O3 thin films have demonstrated long-distance spin transport mediated by spin waves,[2] pronounced spin Hall magnetoresistance,[3] and potential for current-induced information storage.[4]

To date, most studies have focused on hematite grown on isostructural Al2O3 substrates.[2-4] However, integrating it with functional perovskite oxides offers new opportunities, such as the spin current injection by spin pumping when coupling it with ferromagnetic manganites, or integrating it with high spin–orbit coupling metallic oxides to build new full oxide-based spintronic devices.

Here, we report the successful growth of high-quality epitaxial hematite thin films on (0001)-oriented Al2O3, and on (111)-oriented SrTiO3 and LaAlO3. Structural characterization confirms epitaxial growth across all substrates, while synchrotron X-ray diffraction reveals that the films exhibit systematic in-plane lattice variations driven by substrate-induced strain. Notably, films grown on perovskite substrates display superior structural quality compared to those on Al2O3.[5]

Harmonic Hall measurements were performed on Pt/α-Fe2O3 bilayers grown on the three substrates to characterize the spin-orbit torques. Significant differences in the signal amplitude were observed among the samples, with films grown on (111)-SrTiO3 exhibiting the largest field-like torque.

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#306 — Oral

High-Tc Superconducting Nanostructures For Single Photon Detectors And Quantum Devices

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Superconducting nanowire single-photon detectors (SNSPDs) are key devices for quantum communication, sensing, and information processing due to their high detection efficiency, low noise, and ultrafast response. While state-of-the-art SNSPDs rely on low-Tc superconductors and deep cryogenic operation, cuprate high-Tc materials offer key advantages, including intrinsically faster quasiparticle relaxation dynamics, tuning through carrier doping, and the potential for operation at elevated temperatures, enabling simpler cryogenic platforms. Their implementation, however, is severely limited by nanofabrication challenges arising from strong sensitivity to oxygen stoichiometry and chemical contamination [1]. Here we present two complementary nanofabrication approaches for YBa2Cu3O7-x (YBCO) nanostructures relevant to SNSPDs and other high-Tc devices. First, we develop a fully water-free photolithography and etching process based on PMMA resist with a photoinitiator, enabling the fabrication of well-defined and reproducible nanostructures while preserving superconducting properties. Second, we demonstrate a maskless direct laser writing technique that enables grayscale patterning, allowing continuous and local tuning of oxygen stoichiometry and superconducting properties within arbitrarily shaped sub-micrometer structures. Transport and magneto-optical measurements reveal spatial control of the critical temperature and carrier density [2]. Together, these approaches provide a versatile platform for fabricating and functionally controlling YBCO nanostructures for quantum technologies and photon-sensitive superconducting devices.

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#308 — Oral

Charge Density Wave In Transition Metal Tellurides

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Transition metal dichalcogenides (TMDC) feature a wide range of physical and electronic properties that range from semiconducting to metallic. Moreover, they can host many-body correlated states such as superconducting phases, Mott insulator phases and charge density waves (CDW) which have brought a lot of excitement to the scientific community.
Thanks to the development of new growing techniques, it is possible to grow large samples of these structures that present different polytypes that present different physical properties.
Although sulphur and selenium compounds have been thoroughly studied in the past years, tellurium based have been less studied. Interestingly, group V Te-based single-layers are catching attention lately since the absence of Te-Te interlayer interactions changes the electron transfer compared to the bulk or multi-layer cases and new structures and electronic properties can be found.
In the past years, we have performed a comprehensive study of the structural and electronic properties of two group V TMDC, TaTe2 and NbTe2, combining STM/STS and ARPES experiments with first-principles calculations. We find that these materials present a large number of possible structures which are very close in energy. Furthermore, in the case of the Nb compound we an unexpected CDW appeared. We study in detail the formation of these structures and give a possible mechanism for their formation.

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#339 — Poster

Magnetoelectric And Resistive Switching Effects In Functional Oxides

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

Strongly correlated oxides are at the forefront of emerging electronic technologies due to their complex interplay of charge, spin, lattice, and orbital degrees of freedom, which enable phenomena such as ferroelectricity, magnetoresistance, and superconductivity. Recent advancements in oxide electronics underscore resistive switching and magnetoelectric coupling as pivotal functionalities for non-volatile memories, neuromorphic systems, and multifunctional devices. However, achieving reproducible control and a comprehensive understanding of their underlying mechanisms remains a significant challenge. Here, we present a systematic study of charge transport and electro-responsive behavior in functional oxides using advanced electrical characterization. Magnetotransport measurements are performed on micro-patterned devices with varied geometries and contact schemes to disentangle interface and bulk contributions. Resistive switching and magnetoelectric responses are probed via voltage pulses across a broad range of amplitudes and frequencies, enabling identification of switching dynamics and coupling mechanisms.
By correlating electrical responses with structural and device parameters, this work contributes to clarifying the microscopic origins of resistive and magnetoelectric effects. The insights obtained provide guidelines for the rational design and optimization of oxide-based devices, advancing their integration in next-generation applications including memory, sensing, and energy-efficient electronics.

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#340 — Oral

Twisted Planar La0.7Sr0.3MnO3 Junctions

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

The recent realization of membranes of transition metal oxides has enabled their mechanical assembly in twisted bilayers opening avenues towards oxide twistronics. The ferroic orders hosted by transition metal oxides, many of which are stable at room temperature, offer exciting opportunities for the search of chiral ferroic properties in twisted oxide membranes. In this work we present the growth, fabrication and characterization of twisted stacks made of La0.7Sr0.3MnO3 (LSMO), a half-metallic ferromagnetic perovskite with highly tunable properties.
We have studied the temperature dependent magnetotransport across the interface of two twisted LSMO membranes for different twisting angles. These samples exhibit a large low temperature magnetoresistance MR up to 32% which switches abruptly at small (10 mT) magnetic fields. These MR values are well above the 0,01% AMR typically observed in single LSMO flakes. This approach allows exploring material combinations which are not possible in epitaxial heterostructures and opens promising avenues towards oxide based CMOS compatible spintronic devices.

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#363 — Oral

Twist-Engineered Moiré Nanodevices From SrRuO3 Membranes

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

Fernando Gallego 1, Sandra López 1, Rafael Fuster 1, Alejandro Martín Merodio 1, David Sánchez Manzano 1, Víctor Zamora 1, Víctor Rouco 1, Mariona Cabero 2, Sergio Valencia 3, Federico Mompeán 4, Mar García Hernández 4, Carlos León 1, Jacobo Santamaría 1

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Abstract Text:

Since the isolation of monolayer graphene in 2004 and the subsequent observation of moiré superlattices in twisted graphene bilayers in 2011, twistronics has developed into a broad platform for engineering electronic states through controlled rotational misalignment. [1] In its simplest form, twistronics exploits the relative twist angle—together with thickness and composition—to imprint long-wavelength moiré fields that reshape coupling across freestanding layers. Transition-metal oxides (TMOs) are now emerging as compelling moiré materials [2] because strong correlations intertwine their electronic, magnetic and lattice degrees of freedom, giving rise to collective responses such as ferroelectricity, ferromagnetism and superconductivity. Here we explore how twisting and thickness tune the magnetic and electronic properties of bilayer devices based on twisted SrRuO3 (SRO) membranes. As a spin–orbit-coupled oxide with pronounced ferroelasticity, SRO provides a natural route to couple moiré-imprinted strain textures to the magnetic ground state. [3] Controlling magnetism through twist-engineered strain landscapes could thus open new directions for oxide twistronic devices, including concepts for magnetic memory.
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#369 — Oral

Structural And Electrical Characterization Of Twisted Nickelate Membranes

DFMC-GEFES - Phase transitions, electronic transport and emergent phenomena in strongly correlated s

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Abstract Text:

The discovery of superconductivity in magic-angle twisted bilayer graphene launched twistronics, showing that relative rotation between layers can engineer flat bands and quantum phases absent in the parent materials [1]. This concept is expanding beyond van der Waals systems to complex oxides, where coupled charge, spin, lattice and orbital degrees of freedom provide routes for tuning functional properties [2]. Rare-earth nickelates are attractive correlated oxides because of their metal–insulator transitions and relationship to superconductivity in infinite-layer nickelates. $LaNiO_3$ is different: it remains metallic and paramagnetic in bulk, but its electronic behavior is highly sensitive to dimensional confinement, strain and interfaces [3]. Making it a platform for exploring how dimensionality and moiré interfaces modify itinerant transport.

Here, we report freestanding $LaNiO_3$ films and twisted bilayers by epitaxial lift-off. $LaNiO_3$ heterostructures were grown by pulsed laser deposition on water-soluble $Sr_1Ca_2Al_2O_6$ sacrificial layers deposited on $SrTiO_3$ substrates, following established approaches [4,5]. X-ray diffraction and atomic-resolution HAADF-STEM confirm the crystalline quality of the as-grown heterostructures and released membranes, while transport measurements show that metallicity is preserved after exfoliation.

Twisted freestanding bilayers were then investigated for twist angles between 0° and 45°. Compared with single-layer membranes, the bilayers show a marked reduction in longitudinal resistivity, indicating enhanced metallic behavior. This enhancement is strongest at low twist angles below 12°, whereas at larger angles the transport response approaches that of single-layer membranes. These results establish twisted nickelate membranes as a versatile platform for exploring emergent transport phenomena in correlated oxides.

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#131 — Oral

Comparative Structural Dynamics And Lipid Fingerprints Of Complete Flavivirus Particles From Coarse-Grained Simulations

DFMC-GEFES - Physical Virology: from virus function to materials science

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Abstract Text:

Flaviviruses are enveloped RNA viruses of major medical relevance whose mature particles share a conserved icosahedral architecture but differ in stability, antigenic accessibility and sensitivity to neutralization. How sequence variation and local protein organization modulate whole-particle dynamics and protein–membrane coupling remains difficult to address experimentally because viral envelopes are crowded, nanoscale and highly dynamic systems.
Here, we present a comparative coarse-grained molecular dynamics study of complete virus-like particles from Zika virus, dengue virus, Japanese encephalitis virus, West Nile virus and tick-borne encephalitis virus. Using a standardized multiscale workflow and the SIRAH force field, we performed multi-microsecond CG-MD simulations of complete flaviviral envelopes with identical membrane composition, temperature and ionic conditions. This design allows us to evaluate virus-specific dynamical signatures emerging from the protein shell and membrane confinement, rather than from lipid-composition differences.
Our analysis integrates protein-centered and membrane-centered descriptors. At the protein level, we quantify envelope and membrane protein dynamics, with emphasis on viral breathing, transient fusion-loop exposure and geometric rearrangements of antibody-relevant epitopes. At the membrane level, we evaluate area per lipid, thickness, curvature fluctuations and leaflet organization. In parallel, residue-resolved coordination-number maps and two-dimensional lipid-density fingerprints reveal preferential interactions between lipid headgroups, glycerol/backbone regions, acyl chains and specific domains of E and M, including stem and transmembrane regions.
Across the five flaviviruses, our simulations suggest that globally similar viral architectures can generate distinct dynamical and protein–lipid interaction fingerprints under equivalent membrane conditions. These differences highlight protein–lipid hotspots and symmetry-dependent environments that may contribute to particle stability, fusion-loop accessibility and conformational landscapes targeted by broadly neutralizing antibodies. Overall, this work supports a view of the flaviviral envelope as an integrated protein–membrane assembly, in which the viral membrane is not a passive scaffold but an active modulator of virion stability and functional accessibility.

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#272 — Oral

Immunotherapy, Viral Vectors And Electrostatic Interactions: Atomistic Simulations

DFMC-GEFES - Physical Virology: from virus function to materials science

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Abstract Text:

Immunotherapies are cellular therapies based on the enhancement of the patient's immune system and are considered a vital pillar of modern oncology by the World Health Organization (WHO). Among them, chimeric antigen receptor (CAR) T therapy is one of the most promising approaches, and it has shown unprecedented results in clinical practice, including long term complete responses. This therapy is based on the extraction of immune cells (T-cells) from the patient and their ex-vivo enhance ment to program them to target and destroy specific cancer cells. The T-cell enhancement is done by a genetic modification, the chimeric antigen receptor (CAR), introduced to the T-cells by an engineered viral vector. In the current hospital practice, the interaction between the viral vector and the T cells takes place in liquid solution, leading to a random (Poisson) process which is highly inefficient. This can be improved by designing porous materials that simultaneously trap the viruses and provide an appropriate environment for the cells. Our calculations, combining Poisson-Boltzmann electrostatics and Molecular Dynamics simulations show that an appropriate strategy for the capture of the CAR gene carrier virus is to take advantage of the strong electrostatic interactions arising from highly charge proteins that cover most enveloped viruses. This capture can then be realized by incorporating highly charged natural polymers present in human cells (such as heparin) into the structure of porous materials like hydrogels. This strategy, supported by our calculations, has been successfully implemented [1,2].

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#281 — Oral

Probing The Role Of Post-Translational Modifications In The Structural Integrity Of Plum Pox Virus Via Atomic Force Microscopy

DFMC-GEFES - Physical Virology: from virus function to materials science

Adrián Cámara-Ballesteros 1, Sandra Martínez-Turiño 2, Bernardo Rodamilans 2, Pedro J. De Pablo 1, Carmen Simón-Mateo 2, Mercedes Hernando-Pérez 1

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Abstract Text:

Plum pox virus (PPV) is a member of the Potyvirus genus, the largest group of plant RNA viruses, and is the causative agent of sharka, a devastating disease affecting stone fruit trees. Structurally, PPV is characterized by flexuous tubular virions approximately 11–15 nm in diameter and nearly 900 nm in length [1]. Beyond their relevance as pathogens, helical plant viruses like PPV are currently being exploited in biotechnology as versatile scaffolds for the production of heterologous proteins, drug delivery systems, and vaccine development.

The viral capsid protein (CP) is subject to various post-translational modifications (PTMs), including phosphorylation and O-GlcNAcylation, which play critical roles in regulating protein stability and virion assembly. To understand how these modifications influence the physical integrity of the virus, this study focuses on two specific mutants: SEC-b2, a transgenic line with down-regulated O-GlcNAc transferase activity, and 7TA, a mutant where seven O-GlcNAcylation target threonines are replaced by alanines [2]. We used Atomic Force Microscopy (AFM) [3] to evaluate whether these alterations in PTM patterns affect the mechanical structure and stiffness of the virus, and also to try to elucidate the disassembly process of the virions. Our results reveal a clear hierarchy in virion rigidity: the wild-type (WT) virus was found to be the softest, followed by the SEC-b2 mutant, while the 7TA mutant exhibited the highest stiffness. These findings suggest that O-GlcNAcylation plays a significant role in modulating the mechanical flexibility of the PPV capsid, potentially influencing its functionality during the viral infection cycle.

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#326 — Oral

Interplay Between Chemical Stress And Genome Uncoating Of Adenovirus Under The Effect Of Urea As A Denaturing Agent

DFMC-GEFES - Physical Virology: from virus function to materials science

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Abstract Text:

Viruses are microscopic infectious agents that hijack the metabolic machinery of their hosts to replicate. They consist of genetic material, DNA for adenovirus, enclosed within a protein shell called a capsid. Adenoviruses are associated with respiratory diseases, gastroenteritis, conjunctivitis, and urinary tract infections [1]. In this work, we investigate the denaturation of the viral capsid in the presence of urea as a chemical denaturant and analyze how increasing urea concentration affects capsid stability. To model the experimental system in simulations, we propose a coarse-grained representation of viral DNA based on a Kratky–Porod chain, which allows us to incorporate solvent conditions and obtain realistic length scales [2]. Additionally, we model the capsid as a spherical confinement composed of discrete beads and introduce openings of various sizes to map changes in urea concentration to the simulation environment. Our findings indicate that the lag time observed in intensity curves can be explained by differences between partial and complete capsid opening.

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#327 — Oral

Allosteric Conformational Switching Coordinates Genome Encapsidation And Viral Capsid Assembly

DFMC-GEFES - Physical Virology: from virus function to materials science

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Abstract Text:

Icosahedral capsid assembly and genome encapsidation are paradigmatic problems in biological self-organization, yet the physical mechanisms governing symmetry selection and coordinated shell formation around nucleic acids remain incompletely understood. We develop a coarse-grained molecular dynamics model that incorporates protein diffusion, genome flexibility, and an allosteric conformational switch that alters subunit elastic properties upon binding, thereby reshaping the assembly free-energy landscape during encapsidation. For the first time, we demonstrate spontaneous co-assembly of proteins and genome into icosahedral capsids with triangulation numbers $T > 1$, including $T = 3$ and $T = 4$, the most prevalent geometries in nature. Our results identify allosteric conformational switching as a key physical mechanism coordinating genome encapsidation, symmetry selection, and the robust assembly of complex viral shells.

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#337 — Oral

From Structure To Vaccine: Cryo-EM Structure Of African Horse Sickness Virus VP2 For Nanoparticle Vaccine Design

DFMC-GEFES - Physical Virology: from virus function to materials science

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Abstract Text:

African horse sickness virus (AHSV) is a highly lethal equine pathogen which is endemic to sub-Saharan Africa and has caused epizootics across Europe, North Africa, the Middle East, Asia and most recently in Thailand, highlighting its potential for global spread. Currently, no safe and widely approved vaccines are available, beyond live-attenuated virus strains that pose significant safety concerns. Therefore, we aimed to develop a rationally designed vaccine capable of providing safe and effective protection in horses. To this end, I will present the 3.1 Å cryo-electron microscopy structure of the full-length VP2 protein from AHSV serotype 4; the receptor-binding protein and primary target of neutralizing antibodies. Our structure reveals its native triskelion architecture and uncovers a previously uncharacterized α-helical domain, a feature not observed in other orbiviruses. Through structure-guided mapping, we identified an immunogenic VP2 subdomain as promising vaccine candidate. In order to assess its efficacy, we engineered nanoparticles to display the selected antigen using the SpyTag/SpyCatcher technology. We showed that a prime-boost immunization with these particles conferred complete protection from viral challenge infection in mice and elicited strong and durable immune responses in horses, the target species of AHSV. Together, our results demonstrate how high-resolution cryo-EM informs vaccine design and directly supports the development of safe, next-generation recombinant vaccines against AHSV and related orbiviruses.

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#354 — Oral

Atomic Force Microscopy For Nanomechanical Sensing Of Single Viral Proteins Under Mutation-Driven Evolution

DFMC-GEFES - Physical Virology: from virus function to materials science

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Abstract Text:

Understanding how viral mutations influence the nanoscale mechanical properties of proteins is essential for revealing fundamental structure–function relationships and supporting the development of new antiviral strategies. In rapidly evolving viruses, such as SARS-CoV-2, point mutations in spike proteins can significantly modify intermolecular interactions, mechanical stability, and functional behaviour at the single-molecule level.
This presentation discusses an atomic force microscopy (AFM)-based nanomechanical sensing framework for probing the mechanical properties of individual viral proteins. Using dynamic force–distance spectroscopy in combination with amplitude-modulation AFM, it becomes possible to extract key nanomechanical parameters at the single-protein scale, including Young's modulus, local stiffness, adhesion forces, van der Waals interactions, and energy dissipation.
The AFM-based approach enables direct mapping of how mechanical properties evolve in response to mutation-induced structural changes. As a representative application, SARS-CoV-2 spike protein variants are used to demonstrate how nanomechanical signatures vary across different mutation profiles, highlighting a direct link between viral evolution and nanoscale mechanics.
Overall, this AFM-driven methodology provides a general platform for single-protein viromechanics, offering a powerful route to study mechanically functional changes in viral proteins and their implications for infectivity, stability, and molecular recognition in a wide range of viral systems.

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#356 — Poster

Coarse-Graining The Finer Structure Of RNA Interactions At The Interface With Macromolecular Assemblies

DFMC-GEFES - Physical Virology: from virus function to materials science

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Abstract Text:

RNAs are remarkably versatile molecules that form functional three-dimensional structures and can store valuable genetic information. Viruses exploit this versatility, using RNAs that simultaneously translate into proteins via ribosomes and can fold into dynamic cell regulatory structures. These RNA fragments interact with viral and/or other macromolecular assemblies (i.e. ribosomes) to regulate critical processes, such as: translation, genome packaging, among others. However, the properties of confined RNAs inside diverse proteinaceous viral geometries remain largely unexplored due to challenges associated with their high-resolution characterization and multiple interactions. Similar limitations in understanding mRNA during translation exist. To overcome these RNA modeling-challenges, we used tractable coarse-grained models to tackle both: first, the electrostatic interactions as the driving force of RNA-protein association, which are regulated during viral assembly/disassembly processes; and second, the spatial architecture and mechanical rigidity of polysomes (mRNA+ribosomes). On one hand, our methods for electrostatic interactions show how RNA secondary-structure regulates the adsorption onto proteinaceous substrates (flat, spherical, icosahedral) and scaling-laws of these observations for archetypical small RNAs fragments to longer RNAs, in the case of flat substrates. On the other hand, we investigate the conformational statistics of an mRNA backbone decorated with varying-densities of ribosomes using large-scale, extensive molecular dynamics simulations based on the Kremer-Grest bead-spring model. Our results demonstrate that the excluded volume of massive ribosomes induces a significant and robust expansion of the scaling exponent v from 0.59 to approximately 0.7. In the conformation of mRNA, this shift translates to a self-induced dimensional reduction from a three-dimensional random coil toward a stretched, quasi-two-dimensional architecture at biologically relevant scales. The latter findings reveal that the geometric crowding of ribosomes itself provides a robust physical prerequisite for the formation of higher-order polysome architectures, bridging the gap between polymer physics and structural properties of mRNA during translation.

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#358 — Poster

Seeing And Touching Human Adenovirus: Complementary Approaches For Understanding Assembly And Disassembly Of A DNA Virion

DFMC-GEFES - Physical Virology: from virus function to materials science

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Abstract Text:

Understanding adenovirus assembly and disassembly poses many challenges due to the virion complexity. A distinctive feature of adenoviruses is the large number of virus-encoded proteins packed together with the dsDNA genome. Cryo-electron microscopy (cryo-EM) structures are broadening our understanding of capsid variability along evolution, but little is known about the organization of the non-icosahedral nucleoprotein core and its influence in adenovirus function. On the other hand, Atomic force microscopy (AFM) probes the biomechanics of virus particles, while simultaneously inducing and monitoring their disassembly in real time (1). Synergistic combination of AFM with EM shows that core proteins play unexpected key roles in maturation and entry, and uncoating dynamics are finely tuned to ensure genome release at the appropriate time and place for successful infection (2).
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(2) de Pablo,P.J. and San Martin,C. (2022) Seeing and touching adenovirus: complementary approaches for understanding assembly and disassembly of a complex virion. CURRENT OPINION IN VIROLOGY, 52, 112–122.

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#380 — Poster

Electrostatic Forces Driving Protein-Glycan Interactions During Adsorption

DFMC-GEFES - Physical Virology: from virus function to materials science

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Abstract Text:

Respiratory viruses transmit via airborne microdroplets that adhere to fomites, yet the mechanisms governing glycoprotein adsorption onto polarizable surfaces remain poorly understood. Using molecular dynamics simulations, we investigate how N-glycans and protein conformers modulate long and short-range interactions at the interface with modeled material surfaces. We tested our approach with two variants of concern of the SARS-CoV-2 Receptor Binding Domain (RBD) glycoprotein to reveal distinct adsorption mechanisms depending on the initial loci of the glycan within the protein wall. Hydrophobic surfaces facilitate stable adsorption for both RBD conformations. Conversely, hydrophilic surfaces exhibit reduced adsorption, particularly for the closed-RBD, where glycans predominantly form hydrogen bonds. Complementary electrostatic analysis quantifies protein–glycan interactions across three representative N-glycan types with distinct charge profiles: FA2G0 (charged), A2G2S1 (partially highly charged), and FA2G2S2 (highly charged). Nonlinear Poisson–Boltzmann calculations consistently reveal stronger electrostatic forces for the positively charged Omicron variant, particularly for highly charged glycans. We statistically selected highly charged glycan conformations exhibiting polarity inversion events, where glycan electrostatic interactions with respect to the protein transition between attractive and repulsive states. These transitions emerge across structurally distinct glycan conformations spanning RMSD differences from 1.74 Å to 11.28 Å, suggesting that both subtle reorientations and large-scale conformational rearrangements can alter protein–glycan electrostatic interaction states. Our findings elucidate glycan-mediated adsorption phenomena at virus–fomite interfaces and inform understanding of glycoprotein recognition at biological surfaces.

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#385 — Oral

Lipid Multi-Scale Engineering Approach: AI Design, Screening, And Assembling

DFMC-GEFES - Physical Virology: from virus function to materials science

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Abstract Text:

Generative Lipid AI is a computer-based platform that combines automated molecule design, machine learning, and molecular simulations to speed up the discovery of ionizable lipids for RNA carrying nanoparticles. It invents millions of virtual lipids and rapidly filters them for how easy they are to make, their shapes and charges, and their behavior in simulated nanoparticles. In a first run, the system cut a pool of about twelve million candidates down to sixteen top molecules that models predict can match or surpass the lipids now used in leading vaccines. Several of these winners have unusual chemical features that ordinary search methods would miss. By shrinking the time from idea to lab test, Generative Lipid AI opens new chemical space for the next generation of RNA medicines.

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Oral

Epithelial Geometry and Membrane Mechanics Govern Multivalent Viral Attachment

DFMC-GEFES - Physical Virology: from virus function to materials science

Irem Demir1†, **Federico Amadei**1†, David B. Gomes1†, Elisabetta Avizzano2, Danica Sutherland3, Victor Gisbert1, Xi-Lei Zeng4, Roman Truckenmüller2, Mary K. Estes4, Terence S. Dermody3, David Alsteens1,5*

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Abstract Text:

Viral attachment is often described as a molecular recognition process governed by receptor-ligand interactions.
Yet, in vivo, viruses encounter highly structured epithelial surfaces where geometry and membrane mechanics
shape the physical landscape of binding. Here, we show that epithelial architecture acts as a key physical regulator
of viral attachment across multiple spatial scales. Using single-virus force spectroscopy, we quantify reovirus
interactions with epithelial models ranging from flat monolayers to curved and tissue-like architectures. Epithelial
differentiation enhances viral binding by increasing receptor availability and promoting multivalent interactions.
At the microscale, local curvature creates receptor-enriched hotspots that bias attachment toward fully multivalent
binding regimes. At the tissue scale, viral attachment cannot be explained by receptor density alone; instead, both
binding probability and mechanical stability scale with membrane fluidity, revealing a direct coupling between
epithelial geometry and membrane mechanics. Together, these findings establish a physical virology framework in
which viral attachment emerges not only from biochemical affinity, but also from the mechanical and architectural
constraints imposed by epithelial organization.

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#78 — Oral

Emergent Magnetism Beyond Altermagnetism In 2D MnTe

DFMC-GEFES - Spin orbit and altermagnetism

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Abstract Text:

MnTe has recently emerged as a prototypical altermagnet, a novel class of magnetic materials combining compensated antiferromagnetic order with spin-split electronic bands [1,2]. However, whether altermagnetism survives in the two-dimensional (2D) limit remains an open question. Here, we investigate the structural, electronic, and magnetic properties of atomically thin MnTe, focusing on monolayers (ML) and bilayers (BL) grown on graphene/Ir(111). By combining scanning tunneling microscopy (STM) with X-ray photoelectron spectroscopy (XPS) and synchrotron-based X-ray absorption spectroscopy and X-ray magnetic circular dichroism (XMCD), we provide a comprehensive experimental characterization of these systems, supported by density functional theory (DFT) calculations. XPS measurements confirm the stoichiometry and Mn^{2+} oxidation state in both ML and BL phases, while XMCD reveals their distinct magnetic responses. We find that, despite MnTe being a canonical altermagnet in bulk, both ML and BL adopt structures whose symmetry is incompatible with altermagnetism. Instead, the BL exhibits a robust layered antiferromagnetic state with in-plane anisotropy, whereas the ML shows behavior consistent with a frustrated, nearly compensated magnetic phase compatible with spin-glass-like characteristics at low temperature . These results demonstrate how reduced dimensionality and symmetry changes can drive the emergence of unconventional magnetic states, providing new insights into the evolution of altermagnetism in the 2D limit [3].

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#96 — Poster

First-Principles Calculations Of Magnetic Defects In Rare-Earth-Doped Bi_2Te_3

DFMC-GEFES - Spin orbit and altermagnetism

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Abstract Text:

Magnetic interactions at the surface of topological insulators (TIs) provide an effective route to manipulate the electronic structure and induce exotic quantum phases by breaking time-reversal symmetry (TRS). Opening a Dirac gap in the topological surface state (TSS) of Bi_2Te_3 is a critical step toward realizing the quantum anomalous Hall effect (QAHE) [1–3]. This study investigates the microscopic origin of TRS breaking induced by submonolayer erbium (Er) deposition on Bi_2Te_3, combining STM/STS, XPS, ARPES, XMCD, and quasiparticle interference (QPI) mapping.

STM and XPS reveal the formation of substitutional defects and an additional Bi 5d component, signaling Er–Bi bonding. ARPES shows a dramatic transformation of the Fermi surface from a hexagonal "snowflake" to a "Star-of-David" geometry, accompanied by a Dirac-point gap opening and p-type doping, while XMCD confirms out-of-plane magnetic anisotropy of the Er moments. DFT calculations using the SIESTA code [4] identify that Er atoms preferentially substitute Bi sites in the first quintuple layer, reproducing the STM topographic contrasts and explaining the associated spectroscopic changes.

The combined experimental and theoretical results demonstrate that local magnetic moments from Er adatoms couple strongly to the spin-polarized TSS, inducing a Zeeman-like symmetry breaking and electronic reconstruction, consistent with theoretical models of magnetic doping in TIs [5–7]. These findings, detailed in Ref. [8], establish a direct microscopic mechanism for the magnetic modification of topological states, confirming that rare-earth surface doping provides a robust and precise strategy to engineer magnetic topological phases.

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#117 — Oral

Engineering Altermagnetism In Metal-Organic Frameworks

DFMC-GEFES - Spin orbit and altermagnetism

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Abstract Text:

Altermagnetism has recently emerged as a new class of spin compensated magnetic materials that exhibit momentum dependent spin splitting despite having zero net magnetization. The origin of these electronic signatures lies in symmetry operations that connect opposite spin sublattices while allowing spin splitting in momentum space. While most candidate materials identified so far belong to inorganic crystals with fixed lattice symmetries, the realization of altermagnetism ultimately requires platforms in which magnetic symmetry can be deliberately engineered. In this presentation, I will introduce how metal-organic frameworks (MOFs) provide a unique chemical platform to address this challenge. [1] I will first place altermagnetism in the broader context of magnetic and electronically active metal-organic networks, highlighting how reticular chemistry enables precise control over lattice geometry, dimensionality and electronic structure. Then, I will discuss how these features position framework materials as promising candidates for realizing altermagnetism and highlight the key challenges that must be addressed to translate theoretical proposals into experimentally accessible systems. [2]
[1] D. López-Alcalá, A.M. Ruiz, A. Shumilin, J.J. Baldoví, J. Am. Chem. Soc. (2026) Under review; arXiv:2512.14623.
[2] D. López-Alcalá, A. Shumilin, J.J. Baldoví, J. Am. Chem. Soc. (2026) Under review; arXiv:2603.05112.

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#224 — Oral

Crystal Growth And Physical Properties Of MnTe-Based Altermagnetic Materials

DFMC-GEFES - Spin orbit and altermagnetism

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Abstract Text:

Altermagnetism has emerged as a distinct magnetic phase characterised by compensated antiparallel magnetic order and momentum-dependent spin splitting. The apparent contradiction of these properties can be reconciled within an extended symmetry framework describing spin configurations in crystalline structures. In recent years, α-MnTe has emerged as a prototypical altermagnetic material. Structurally, α-MnTe crystallises in the hexagonal $P6_3/mmc$ space group and exhibits a collinear A-type antiferromagnetic order assigned to $P6_3'/mmc'$ for in-plane Néel vector orientation, with Mn moments aligned within the basal (001) planes and coupled antiferromagnetically along the c axis. Its Néel temperature of approximately 307 K makes α-MnTe a near-room-temperature platform to investigate the interplay between crystal symmetry, Néel-vector orientation, and mesoscale magnetic domains.
Encouraged by recent literature, we have grown single crystals of nominal Fe-doped $Mn_{1-x}Fe_xTe$ (x = 0.0, 0.1, 0.5) by chemical vapour transport (CVT). The synthesis of high-quality crystals is essential for the reliable investigation of intrinsic electronic, magnetic, and thermal transport properties, since structural disorder, crystal defects, and secondary phases can strongly affect symmetry-dependent phenomena associated with altermagnetism and magnetic domain configuration.
Single-crystal X-ray diffraction confirms the formation of high-quality α-MnTe domains. Magnetotransport characterisation reveals an increase in the net magnetisation with increasing Fe content, accompanied by the emergence of an anomalous Hall contribution associated with magnetic disorder and partially uncompensated Fe-derived moments across antiferromagnetic domains. The interplay between Mn and Fe magnetic moments is further investigated as a function of magnetic field and temperature in order to elucidate the origin of the anomalous transport response.

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#259 — Oral

Orbital Moment And K-Edge Dichroism Of Oxygen In Magnetite

DFMC-GEFES - Spin orbit and altermagnetism

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Abstract Text:

Magnetite shares the spinel structure with other mixed ferrites such as cobalt or nickel ferrite. As the oldest known magnetic material, it is highly relevant to geophysics, condensed matter physics, and spintronics. We have studied its magnetic properties using spin-polarised low energy electron microscopy and x-ray magnetic circular dichroism in photoemission microscopy (XMCD-PEEM), mapping magnetic domains in single crystals with (100) and (110) orientations [1-3]. In XMCD-PEEM, spectra acquired at the Fe L_{23} absorption edges combined with sum rules allow to estimate the spin and orbital moments of iron [2,3]. Analogously, the O K-edge XAS spectrum can be acquired and the sum rules applied to estimate the oxygen orbital moment. We have used O K-edge XMCD-PEEM to image magnetic domains in several spinels, finding that the oxygen contrast has the same sign as iron in octahedral positions [3]. However, the estimated orbital moment magnitude is substantially larger than DFT predictions, and in magnetite(110) we observed a reversed magnetic contrast relative to octahedral iron [3].
Here we present further XMCD-PEEM observations on magnetite (100) and (111) that resolve the contrast discrepancy seen in our previous experiments, and discuss what the O K-edge XMCD-PEEM results imply for the oxygen orbital magnetic moment.
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#271 — Oral

Interplay Between Superconductivity And Altermagnetism In Hybrid Heterostructures

DFMC-GEFES - Spin orbit and altermagnetism

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Abstract Text:

We study the interplay between superconductivity and altermagnetism in hybrid heterostructures using recently derived quantum kinetic transport equations. From this framework, we derive a Ginzburg–Landau free energy for superconducting altermagnets that contains, couplings between altermagnetic order and spatial variations of the superconducting condensate.
Using this Ginzburg–Landau theory, we analyze thin films hosting superconducting and collinear d-wave altermagnetic orders in the presence of external magnetic fields and in-plane supercurrents. We demonstrate that the interplay between superconductivity and altermagnetism gives rise to characteristic fourfold anisotropies in the parallel critical field and critical current. This provides experimentally accessible signatures of the coexistence of both orders.
We further show that the coupling between altermagnetism and spatial gradients of the superconducting order parameter leads to two distinct phenomena. First, a nonlinear magnetoelectric effect, in which a supercurrent induces a spin polarization; this contribution is quadratic in the superconducting phase gradient. Second, when the magnitude rather than the phase of the superconducting order parameter varies in space, a finite real-space magnetization emerges, inheriting the symmetry of the underlying altermagnetic order. We also show that in Josephson junctions these effects lead to 0–π transitions. Our results establish a unified theoretical framework for superconducting altermagnets and identify experimentally accessible signatures.

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[2] A. A. Mazanik, R. de las Heras, and F. S. Bergeret, “Superconductivity as a Probe of Altermagnetism: Critical Temperature, Field, and Current”, arXiv:2603.06188 (2026).

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#323 — Oral

Unified Theory Of Electronic Transport In Spin-Orbit Coupled, Altermagnetic, And Superconducting Systems

DFMC-GEFES - Spin orbit and altermagnetism

Sebastian Bergeret

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Abstract Text:

Spin and charge transport in systems with strong spin-orbit coupling and unconventional magnetic order are central topics in modern spintronics. In this talk, I will present a unified theoretical framework for diffusive quantum transport in normal and superconducting materials with generic spin-orbit and magnetic interactions. The approach is based on symmetry-constrained quantum kinetic theory and nonlinear sigma models, which yield generalized transport equations capable of describing spin-charge conversion phenomena in a broad class of materials, and arbitrary temperature.
I will discuss how crystal and spin-space symmetries govern effects such as the spin Hall effect, spin-galvanic response, spin-current swapping, and spin-splitting phenomena. Particular emphasis will be placed on altermagnets. I will show how altermagnetic order manifests in diffusive systems and hybrid structures, including nonlocal spin valves and modified Hanle responses.
Finally, I will discuss the interplay between altermagnetism and superconductivity, which gives rise to nonlinear magnetoelectric effects, proximity-induced magnetization, and symmetry-dependent anisotropies in superconducting films and heterostructures. I will discuss experimentally accessible fingerprints of the underlying altermagnetic ordering and symmetry. Altogether, these results provide a comprehensive framework for understanding nonequilibrium spin transport and spin-charge interconversion in altermagnetic and spin-orbit coupled materials.
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Sigales, Nicolás, et al. "Spin splitter and inverse effects in altermagnetic hybrid structures." arXiv preprint arXiv:2602.07779 (2026).
de las Heras, Rodrigo, et al. "Interplay between superconductivity and altermagnetism in disordered materials and heterostructures." Physical Review B 113.14 (2026): 144516.
Mazanik, A. A., Rodrigo de las Heras, and F. S. Bergeret. "Superconductivity as a Probe

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#365 — Poster

Spectromicroscopic Study Of Emergent Magnetic Textures In Permalloy/Hematite Bilayers

DFMC-GEFES - Spin orbit and altermagnetism

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Abstract Text:

Magnetic heterostructures combining antiferromagnets (AFM) and ferromagnets (FM) provide a versatile platform with rich functional magnetic phenomena for spintronic applications. Hematite (α-Fe_2O_3) is particularly attractive due to its temperature-driven Morin transition, where the AFM moments reorient from an in-plane to an out-of-plane configuration when lowering the temperature. In hematite/permalloy bilayers, AFM/FM coupling has been shown to induce enhanced coercivity across the Morin transition and persistent exchange bias upon further cooling [1,2]. Here, we investigate epitaxial hematite [001]/permalloy bilayers grown on sapphire substrates by magnetron sputtering using XMCD-PEEM imaging of the FM magnetic domains above the Morin transition. The permalloy layer shows uniaxial anisotropy induced by the underlying AFM layer. After applying in-plane magnetic field pulses, the remanent FM state exhibits magnetic textures with different morphologies depending on the field direction. Pulses applied along the hard axis result in complex multidomain configurations, including spiral-like and closed magnetic textures. In contrast, pulses applied along the easy axis favor isolated closed magnetic textures with characteristic diameters ranging from a few micrometers to tens of micrometers. Interestingly, the reconstructed vector maps reveal a 360° magnetization rotation with preferential alignment across concentric ring textures, where the inner and outer regions of the ring are predominantly antiparallel and tend to follow the underlying AFM Néel vector orientation of the hematite layer, suggesting that their stabilization is influenced by the complex interplay between interfacial exchange with the underlying AFM spin structure and magnetic anisotropy. MOKE microscopy reveals the generation of new concentric magnetic rings as the magnetization is reversed when changing the direction of the applied in-plane magnetic field. Our results reveal a influence of the hematite Néel order on the orientation and the morphology of non-trivial emergent magnetic textures.

[1] Wang et al., JMMM 597, 172024 (2024)
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#367 — Poster

Low-Energy Electron Microscopy Study Of The Growth Of M2Mo3O8 (M = Mn, Fe) By Single Cation Deposition On Mo(110)

DFMC-GEFES - Spin orbit and altermagnetism

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Abstract Text:

The M2Mo3O8 ternary molybdenum oxides (M = 3d transition metal) are a family of polar magnets that exhibit diverse multiferroic properties. Depending on the identity of the cation M, the compounds show collinear or non-collinear magnetism, ferri – antiferromagnetic transition near the TC, tunable magnetoelectric effect (by external field or doping), and pyroelectricity – to name a few. Recently, the family has been identified as a candidate for altermagnets, and it is a promising rare-earth free OER catalyst. Here, we present a high-temperature oxygen-assisted molecular beam epitaxy growth of Mn2Mo3O8 and Fe2Mo3O8 microstructures on a Mo (110) single crystal. During the synthesis, we deposit only the metal M, and let the Mo4+ cations be incorporated from mobile MoOx clusters that form upon exposure of the Mo (110) surface to molecular oxygen (10-6 mbar) at high temperatures (~800ºC). While this phenomenon has been previously observed in the case of MBE growth of oxides on a tungstate crystal[1,2], to our knowledge it has never been reported for molybdenum.
The growth was followed in real space and time by low-energy electron microscopy (LEEM). Low-energy electron diffraction (LEED) was used to determine the surface structure. Preferential growth along the [001] and [111] directions of the substrate was observed, with the (001) plane of the molybdate facing upwards in most cases. We used ex-situ photoemission electron microscopy (PEEM) to elucidate the chemistry of the samples through spatially resolved X-ray photoemission (XPS) and X-ray absorption (XAS) spectroscopies. Raman spectroscopy aided in identifying the structures as belonging to the polar P63mc space group and confirmed their high crystallinity. Finally, atomic force microscopy (AFM) was used to obtain detailed information on the sample morphology.
[1] T. Skála et al., Phys. Chem. Chem. Phys. 13, 7083 (2011). https://doi.org/10.1039/C0CP03012K.
[2] K. Fornal et al., J. Mater. Chem. C (2025). https://doi.org/10.1039/D5TC02639C.

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#373 — Poster

Static And Dynamic Properties Of Magnetic Configurations In A Room Temperature Van Der Waals Ferromagnet

DFMC-GEFES - Spin orbit and altermagnetism

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Abstract Text:

Two-dimensional (2D) van der Waals (vdW) materials have attracted attention as they provide a versatile platform to explore low-dimensional physics in hybrid heterostructures. Recent studies have revealed the possibility of long-range magnetic ordering in 2D, even in the monolayer limit. A representative example is Fe3GeTe2; however, its Curie temperature (Tc) falls far below room temperature (approximately 200 K), which hampers its direct implementation in practical devices [1].
Recently, Fe3GaTe2, where Ga replaces Ge, has emerged as a promising alternative exhibiting a Tc above room temperature. As such, this material offers a robust platform for studying spintronic phenomena such as current-driven magnetic switching and wall motion at practical device operation temperatures [1]. In addition, while skyrmion-hosting vdW materials are scarce, it has been reported that Fe3GaTe2 is capable of nucleating stable zero-field skyrmions under certain conditions [2].
Here, we fabricate and characterize Fe3GaTe2 devices to study the static and dynamic properties of their magnetic domains and textures. By employing a combination of magneto-optic Kerr effect (MOKE) microscopy, magnetic force microscopy (MFM), magnetotransport measurements, and synchrotron-based Photoemission Electron Microscopy (PEEM), we demonstrate efficient manipulation of magnetic domains, domain walls, and skyrmions at room temperature. These findings highlight the potential of Fe3GaTe2 for future high-performance spintronic applications.
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#390 — Oral

Building Unconventional Magnetic Phases On Graphene By H Atom Manipulation: From Altermagnets To Lieb Ferrimagnets

DFMC-GEFES - Spin orbit and altermagnetism

Beatriz Viña-Bausá 1, Manuel Antonio García-Blázuez 1, Simran Chourasia 1, Roberto Carrasco 1, Diego Expósito 1, Iván Brihuega 1,2, Juan José Palacios 1,2

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Abstract Text:

Engineering all magnetic phases within a single material platform would mark a significant milestone in materials science, simplifying device fabrication by eliminating the need for the integration of different materials. Here [1], we demonstrate that graphene can host all nonrelativistic magnetic phases—diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferrimagnetism, altermagnetism, and fully compensated ferrimagnetism—using single H atoms as building blocks [2,3]. Their magnetic character is confirmed by density functional theory and mean-field Hubbard calculations. Notably, altermagnetism [4] can be realized, exhibiting directionally spin-split bands coexisting with zero net magnetization due to spatial symmetries. Furthermore, fully compensated ferrimagnets can be created, lacking these symmetries and presenting unrestricted spin-splitting, with vanishing net magnetization protected by Lieb's theorem [5]. We take this idea to the laboratory and, through the precise manipulation of H atoms by scanning tunneling microscopy, experimentally create isolated unit cells of all magnetic phases. These findings open the door to the bottom-up design of magnetic phases via symmetry selection.

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[2] H. González-Herrero et al., Science, 352, 437 (2016)
[3] B. Viña-Bausá, et al., Nat Commun, doi: 10.1038/s41467-026-72624-0 (2026)
[4] L. Šmejkal, J. Sinova, T. Jungwirth, Phys. Rev. X, 12, 040501 (2022)
[5] E. H. Lieb, Phys. Rev. Lett., 62, 1201-1204 (1989)

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#247 — Oral

Study Of Damping In Ferromagnet-Superconductor Hybrids With Spin Orbit Coupling And Symmetry Filtering

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

Recently, it has become clear that spin orbit coupling (SOC) is crucial in mediating the interactions in superconductor/ferromagnet (S/F) hybrid heterostructures, otherwise antagonistic materials where exotic interfacial quantum phenomena have been discovered over the last decade. Building on recent advances in studies of various V/MgO/Fe(100)-based junctions [1-4], this talk highlights the critical role of a crystalline MgO barrier in selectively transmitting specific electronic states between V(100) and Fe(100) and how interfacial SOC enables symmetry mixing, allowing for the interaction between ferromagnetic and superconducting orderings though MgO(100). This mutual interaction, mediated by interfacial SOC, facilitates the conversion of spin-singlet to spin-triplet Cooper pairs. The goal is to provide key insights into designing SOC based superconductor-ferromagnet hybrid structures for advanced superconducting spintronic functionalities.

In S/F systems, the experimental investigation of spin supercurrents by spin pumping has been proposed as an important tool to probe the generation of long-range spin-triplet (LRT) spin supercurrents. Through dynamic FMR measurements in epitaxial V/MgO/Fe heterostructures with varying MgO thickness, we observe a strong increase in FMR linewidth and Gilbert damping below TC. Contrary to this, in V/Fe and V/Cr/Fe junctions we do not find any change in FMR linewidth with temperature. These observations together with FMR measurements along both the easy and hard axis of Fe, allow us to conclude that an additional contribution to spin pumping from LRT formation appears below TC through the interfacial SOC provided by the Fe/MgO interface [5].

[1] I. Martínez et al., Phys. Rev. Appl. 13, 014030 (2020).
[2] C. González-Ruano et al., Phys. Rev. B 102, 020405(R) (2020).
[3] P. Tuero et al., Phys. Rev. B 110, 094504 (2024).
[4] C. Gonzalez-Ruano, et al., Nat. Commun. 16, 9524 (2025).
[5] P. Tuero, et al., J. Phys. D: Appl. Phys. 59, 133003 (2026).

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#282 — Oral

Superconducting Signatures Of Altermagnetism: From Critical Anisotropies To Nonreciprocal Vortex Response

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

We present a unified theoretical study of superconducting films and heterostructures hosting collinear d-wave altermagnetic order. Using a Ginzburg-Landau description, we show that the interplay between superconductivity and altermagnetism produces characteristic fourfold anisotropies in the critical temperature, parallel critical field, and critical current density under external magnetic fields and in-plane supercurrents. We further demonstrate that, in the vortex state, altermagnetism transforms conventional circular Abrikosov vortices into elliptical ones, with their orientation controlled by the sign of the magnetic-field component parallel to the Néel vector. As a consequence, superconducting films with pinning defects or geometrical constraints can exhibit nonreciprocal magnetization curves arising from different vortex-vortex interaction energies for opposite field orientations. These effects originate from an altermagnetism-induced effective-mass anisotropy generated by the coupling between the external field and the Néel vector. Together, these results identify a broad set of experimentally accessible superconducting signatures of altermagnetism, relevant both to intrinsic altermagnetic superconductors and to superconductor/altermagnet hybrid structures.

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#295 — Oral

Anomalous Spin-Pumping Behavior Of Half-Metallic Ferromagnet/D-Wave Superconductor Heterostructures

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

Spin-pumping experiments in superconductor/ferromagnet heterostructures, which probe spin-sinking by the superconductor, have revealed a variety of complex behaviors. Most studies have focused on conventional s-wave superconductors combined with metallic or insulating ferromagnets. In this talk, I will discuss the spin pumping phenomena in d-wave superconductor YBa2Cu3O7-d paired with a half-metallic ferromagnet La0.7Sr0.3MnO3. I will compare heterostructures with two crystalline orientations: one in which YBCO is c-axis oriented, and the other in which YBCO grows along the (103) direction. Using ferromagnetic resonance (FMR), we probe the temperature-dependent Gilbert damping coefficient α. For (103) heterostructures, α(T) initially decreases below Tc, but then increases at lower temperatures, exceeding normal-state levels. This behavior can be understood in terms of the opening of the superconducting gap and spin transport via nodal quasiparticles, which dominate when the ab-plane of YBCO is exposed at the interface. In stark contrast, c-axis heterostructures exhibit a pronounced enhancement of α(T) below TC, peaking at ~0.65–0.7TC before decaying. This anomaly suggests the dominance of interface-bound Andreev states, arising from a locally suppressed superconducting order parameter due to proximity effects with the half-metallic LSMO.

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#298 — Oral

High-Tc Superconductivity In Perovskite-Like Hydrides At Ambient Pressure

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

Hydrides have emerged as one of the most promising candidates for achieving room-temperature superconductivity, yet the high pressures required remain a major challenge for their practical application. Recently we predicted a series of perovskite and perovskite-like hydrides exhibiting high-Tc superconductivity at ambient pressure. Here, we propose an unreported family of ambient-pressure high-Tc superconductors by assembling H2 molecules into a perovskite framework ABH3 (A = group 1 and 2 metals, B = group 9-12 transition metal), forming AB(H2)3 (ABH6). High-throughput screening of this family identified six high-Tc candidates KNiH6, RbNiH6, CsNiH6, KPdH6, RbPdH6, and CsPdH6 with predicted Tc values ranging from 75-143 K at ambient pressure. Notably, RbNiH6, CsNiH6, and CsPdH6 are thermaldynamically stable down to 3.2-5.2 GPa. In these compounds, electrons donated by the bimetals reside in the antibonding states of H2 molecules, elongating the H-H distance to around 1 Å, which increases both the density of states at the Fermi level and the mid- to high-frequency phonon modes associated with H2 molecules, thereby enhancing the electron-phonon coupling. These findings offer a promising route toward the design of molecular hydrogen-based superconductors at ambient pressure.

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#320 — Poster

Probing Superconductivity In Suspended $NbSe_2$ Microdrum Resonators

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

Micro and nanoresonators based on 2D materials, with their flexibility, ultralow mass and high responsivity to external perturbations, have emerged as promising platforms for sensing [1]. In this work, we design and manufacture an optical cavity suspending a NbSe2 flake onto a circular well, forming a microdrum resonator in a SiOx/Si substrate. The device can be electrically addressed via electrodes. Since $NbSe_2$ is semi-transparent, it enables optical driving in a Fabry–Pérot-like configuration. Additionally, given the highly doped nature of the Si layer, a parallel plate capacitor-like device is created vertically. In this way, the mechanical resonance frequency can be modified by a strain filed, driven via a DC bias. We can tune the cavity mode to the resonance condition of an incoming CW laser. The radiation pressure exerted by the laser results in an optomechanical mode: the photons within the cavity transfer their momentum to the membrane, causing it to oscillate around its equilibrium position. In other words, we can induce self-sustained oscillations in the system by CW optical pumping. Moreover, by applying a RF signal, we can induce an electromechanical mode at the driven frequency [2]. NbSe2 is superconductive, so the aim of this work is to study how superconductivity is affected both by the material being suspended and by the resonant excitation of the membrane's modes. Furthermore, we investigate whether the combination of the radiation pressure, mechanical oscillation and superconducting properties amplify the light sensitivity of the resonators, or if the superconducting properties can be tunned or controlled by the optomechanical or electromechanical modulation. This system may open new routes toward radiation sensors, with potential applications in space exploration and quantum technologies.
[1] Hao Jia et al., Sci. Adv.12, eads5668 (2026). DOI: 10.1126/sciadv.ads5668
[2] Julia García-Pérez et al., Mater. Res. Express, 12 075002 (2025). DOI: 10.1088/2053-1591/adec40

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#324 — Oral

Emergent Topology From Landau Level Mixing In Quantum Hall-Superconductor Nanostructures

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

We reveal the emergence of unconventional topological phases in quantum Hall–superconductor hybrid structures driven by Landau-level mixing and spin–orbit coupling. For a narrow superconducting stripe atop a two-dimensional electron gas, hybridization of chiral Andreev edge states yields a rich phase diagram, including the unexpected realization of the long-sought p-wave superconducting state at even filling factors, thus allowing its detection at lower fields. These phases feature quantized nonlocal conductance from electron cotunneling at filling factor $\nu = 1$, coexisting with quantized crossed Andreev reflection at $\nu = 2$. Notably, this results in the excitation of a neutral mode with remarkable thermoelectric response, offering new means to probe correlated transport. Numerical simulations and effective modeling reveal how spin–orbit coupling and geometry control these transitions, enabling realistic routes to engineer topology in proximized quantum Hall devices.

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#338 — Oral

Carrier Doping Control As A Route To Electronic And Spin Transport Engineering In Cuprate Superconductors

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

High-temperature cuprate superconductors exhibit an exceptionally rich phase diagram in which superconductivity, correlated metallic states, charge ordering, and insulating behaviour are governed by hole doping, predominantly controlled through oxygen stoichiometry. Achieving scalable, spatially resolved, and reversible control of carrier density therefore remains a central challenge for both fundamental investigations of strongly correlated quantum matter and the development of superconducting and spin-based devices.
Here we demonstrate controlled access to distinct regions of the cuprate phase diagram in epitaxial $YBa_2Cu_3O_{7-x}$ thin films by locally tuning the carrier density. Using maskless direct laser writing, we induce spatially controlled oxygen depletion with sub-micrometre resolution, enabling continuous modulation of the superconducting critical temperature, critical current density, and normal-state transport [1]. Building on these engineered oxygen landscapes, we investigate electric-field-induced electronic phase transitions in YBCO-based heterostructures. We identify two distinct regimes: a high-temperature electrochemical process dominated by oxygen vacancy migration, and a low-temperature electrostatic transition driven by hole redistribution within an oxygen-depleted interfacial layer. The latter enables stable, low-voltage, multilevel resistance states that persist well below the superconducting transition, demonstrating that carrier-controlled cuprates can support non-volatile, analogue electronic states relevant for cryogenic memory and in-memory computing architectures.[2] Finally, magnetotransport measurements near the superconducting transition reveal large in-plane anisotropic magnetoresistance and pronounced planar Hall effects, confined to a narrow temperature window around Tc and strongly dependent on carrier density. Their dependence on the relative orientation between current and magnetic field is consistent with spin-polarised quasiparticle transport, pointing to an emergent spin–orbit landscape in cuprate superconductors.
[1] Biancardi et al. arXiv:2601.09513 (2026), [2] T Günkel et al. Small, 2411908 (2025)

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#364 — Oral

Anomalous Josephson Effect In YBCO/LSMO/YBCO Junctions.

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

We investigate Josephson coupling in planar junctions combining the half-metallic manganite LSMO and the cuprate superconductor YBCO. The proximity effect extends over micrometre length scales at temperatures of tens of kelvins, consistent with transport mediated by triplet pairs. Under in-plane magnetic fields, the junction features the hallmarks of Josephson effect, including Shapiro steps and a Fraunhofer pattern dominated by a second-harmonic current–phase relation [1]. Strikingly, applying the field out of plane produces an anomalous, asymmetric Fraunhofer pattern that depends on both current direction and magnetic history. At low temperatures, the modulation separates into a fast oscillation superimposed on a long-period contribution that tracks the domain structure of the ferromagnetic weak link. To elucidate the microscopic origin, we image the magnetic texture under in-plane and out-of-plane fields using XMCD-PEEM and compare the observations with theoretical analysis of the Fraunhofer asymmetries. Together, these results point to a Josephson coupling channel mediated by magnetic domain walls within the ferromagnetic barrier.

[1] Sanchez-Manzano, et al. Nat. Mater. 21, 188–194 (2022).

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#389 — Poster

Superconducting Density Of States And Vortex Lattice Of LaRu2P2 And Superconducting Gap Of SrBi2Se4

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

Marta Fernández-Lomana, **Paula Obladen Aguilera**, Beilun Wu, Edwin Herrera Vasco, Hermann Jesús Suderow Rodríguez, Isabel Guillamón Gómez

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Abstract Text:

We provide the superconducting density of states of the pnictide superconductor LaRu2P2, measured using millikelvin scanning tunnelling microscopy. From the tunnelling conductance, we extract a density of states which shows the opening of a s-wave single superconducting gap. The temperature dependence of the gap also follows BCS theory. Under magnetic fields, vortices present Caroli de Gennes Matricon states, although these are strongly broadened by defect scattering. $SrBi_2Se_4$ can be viewed as a structurally and electronically derived system from Bi_2Se_3, where the fundamental Bi–Se building blocks found in the layered topological insulator Bi_2Se_3 are reconfigured into a quasi-one-dimensional framework, leading to anisotropic properties and potentially modified topological behaviour compared to the parent 3D compound. Contrary to Bi_2Se_3, $SrBi_2Se_4$ is superconducting and could host correlations, due to its low-dimensional structure, and potential topological properties. Here we present first measurements of the superconducting gap of $SrBi_2Se_4$ as a function of temperature.
[1] Marta Fernández-Lomana et al 2025 J. Phys.: Condens. Matter 37 025604

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#391 — Oral

Local Control Of Parity And Charge In Nanoscale Superconducting Lead Islands

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

Small superconducting islands can exhibit charge quantization, where Coulomb interactions compete with Cooper pairing. Using scanning tunneling spectroscopy, we probe this interplay by measuring the charging energy (EC) and the pairing energy (Δ) of individual Pb nanoislands. Below a critical island size, where EC > Δ, we observe a crossover between even and odd parity ground states. By applying controlled voltage pulses, we continuously tune the island's electrostatic potential and map the full charge-parity landscape. These results demonstrate tunable superconducting ground states, offering a potential platform for qubit design and control.

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#393 — Oral

Superconducting Transport In Hybrid LSMO/NbSe2 Devices

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

We study hybrid superconducting–ferromagnetic heterostructure devices combining free-standing thin membranes of LSMO with exfoliated NbSe2 van der Waals superconducting flakes. Transport measurements are performed in various geometries to investigate the interplay between the competing ferromagnetic and superconducting orders as a function of temperature and magnetic field. Under in-plane magnetic fields we observe oscillatory behaviour of the critical current with magnetic field resembling the Fraunhofer pattern characteristic of Josephson junctions. The modulation of the superconducting transport response observed by applying current and measuring voltage across the NbSe2 layer suggests a weak link behaviour driven by the local depression of the superconductivity by proximity interaction with the ferromagnet. We are currently exploring devices, geometries and orientations to clarify the origin of this behaviour, considering the possible emergence of superconducting proximity effects within the locally coupled ferromagnetic thin film.

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#398 — Oral

Levitating Superconductor As An Ultralow-Dissipation Probe For Testing Quantum Gravity

DFMC-GEFES - Superconductivity: Emerging Materials and Quantum Phenomena

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Abstract Text:

We report the progress in implementing a device designed to probe superfluid 3He and 4He by magnetically levitating and manoeuvring a superconducting lead sphere. A variety of motion patterns have been achieved including simple harmonic oscillations, uniform linear motion and circular motion. We have developed a precise electromagnetic detection system, allowing us to track the position of the probe in real time. This has allowed us so far to probe the decay of oscillations of an untethered sphere in superfluid 4He down to millikelvin temperatures.
Preliminary experiments at millikelvin temperatures in vacuum revealed that the levitating ball presents a tunable-frequency harmonic oscillator with an exceptionally long dissipation time constant on the order of several days. This coherence time opens opportunities for experimentation at the boundary of quantum and classical mechanics, e.g. building apparatus for exploring quantumness of gravity

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#12 — Oral

Unconventional Chemical Bonds In Topologically-Active Thermoelectric Materials Based On Phase Change Materials

DFMC-GEFES - Termoelectricidad en España: retos, capacidades experimentales y teóricas, y oportunida

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Abstract Text:

Today, the most used thermoelectric materials in the low-temperature range (300-550 K) are tetradymites (Sb2Te3, Bi2Te3, and Bi2Se3), while those in the medium-temperature range (550-900 K) are PbTe and SnSe. These semiconductors belong to the AX (A = Ge, Sn, Pb; X = Se, Te) and B2X3 (B = As, Sb, Bi; X = Se, Te) families, which are also related to topologically non-trivial materials, with applications in spintronics and quantum computation, and to phase change materials, where also AB2X4 compounds (A = Ge, Sn, Pb; B = As, Sb, Bi; X = Se, Te) can be formed, and are not only used in thermoelectrics, but also in data storage.

Why do all materials within these two families fail to exhibit effective thermoelectric, topological, or phase-change properties? What do the above-mentioned thermoelectric, topological, and phase change materials have in common? To answer these questions, we must first identify the common trends in the materials of these families with excellent properties. Materials with non-trivial topologies, phase change behavior, and thermoelectric properties are based on the heaviest atoms of the two families. They exhibit crystalline structures with a large atomic coordination (violating the 8-N rule for covalent bonding) and a large symmetry (orthorhombic, rhombohedral, or even cubic). Underlying these features is an unconventional type of chemical bond: the multicenter bond [1]. Here, we will present the multicenter bond and its relation to the unified theory of multicenter bonding [2], and will explain why multicenter bonds provide special properties to materials that cannot be understood in the framework of conventional covalent, ionic, and metallic bonds.

[1] H. H. Osman et al., J. Mat. Chem. C 13, 18780–18795 (2025).
[2] H. H. Osman et al., J. Mater. Chem. C 13, 3774−3803 (2025).

Volver al índice

#28 — Oral

High-Entropy Skutterudites As Thermoelectrics: Potential Synthesizability, Enhanced Stability And Band Convergence Via The Cocktail Effect

DFMC-GEFES - Termoelectricidad en España: retos, capacidades experimentales y teóricas, y oportunida

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Abstract Text:

High entropy materials offer a promising avenue for thermoelectric materials discovery, design, and optimization. However, the large chemical spaces that need to be explored hamper their development. In this work, a large family of high-entropy skutterudites is explored as promising thermoelectric materials. Their potential synthesizability is screened and rationalized using the disordered enthalpy-entropy descriptor through high-throughput density functional theory calculations. In the case of high-entropy skutterudites, the thermodynamic density of states and the entropy gain parameter appear to be key factors for their stabilization. Electronic band structure analyses not only show a reduction in the band gap, which enhances carrier concentration and electrical conductivity, but also a band convergence phenomenon for some specific compositions, which is related to the "cocktail effect". Analyzing atom-projected band structures shows how band convergence is due to the simultaneous presence of Fe, Ni, and Co in the compound. The presence of Rh or Ir, while not contributing to this band convergence effect, can be directly linked to an increase in system's entropy, which enhances the thermodynamic stability of these materials. Transport properties are computed for the most promising compositions, and their dynamical, mechanical, and thermal stability are addressed. Our results demonstrates that these types of compounds open new avenues, not only to enhance thermoelectric efficiency but also to reduce costs by utilizing more abundant elements and also improving their durability.

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#50 — Oral

Instruments For Rapid, Affordable And Accurate Characterization Of Thermoelectric Materials

DFMC-GEFES - Termoelectricidad en España: retos, capacidades experimentales y teóricas, y oportunida

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Abstract Text:

Progress in thermoelectric research is often constrained by the high cost, complexity, limited accessibility and stringent size requirements of commercial characterization platforms. We present a pair of low cost, modular laboratory instruments designed for rapid, accurate, and reproducible room temperature characterization of thermoelectric materials, built entirely from readily available components and 3D printed parts and controlled by fully documented open source software. The first instrument combines a controlled temperature gradient with a four point probe geometry to enable simultaneous measurement of the Seebeck coefficient and electrical conductivity on bar and pellet shaped samples, minimizing contact resistance and wiring complexity while supporting fast sample exchange. The second instrument implements a Van der Pauw configuration on regular bulk 3D specimens and integrates an external magnetic field to determine electrical conductivity, Hall coefficient, charge carrier concentration, and mobility from a single mounting. Particular attention is paid to thermal and electrical shielding, contact design, and calibration procedures to ensure reliable measurements and traceability to reference standards. We validate both instruments against established commercial systems and demonstrate agreement within experimental uncertainty, confirming that precise thermoelectric assessment can be achieved at room temperature without specialized proprietary equipment. As a showcase, we apply the instruments to study anisotropic electrical transport and Seebeck coefficient behavior in doped polycrystalline SnSe, highlighting their capability to resolve direction dependent properties and dopant induced changes in carrier type and mobility. Beyond this case study, the presented designs are material agnostic, highly configurable, suitable for a wide range of bulk thermoelectric materials and capable of working under various atmosphere including vacuum. By lowering the cost and complexity barriers, these instruments enable more research groups and teaching laboratories to perform quantitative thermoelectric characterization and to iteratively optimize materials and device architectures.

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#68 — Oral

Sustainable Thermoelectric Materials: From Classical Systems To Earth-Abundant Alternatives

DFMC-GEFES - Termoelectricidad en España: retos, capacidades experimentales y teóricas, y oportunida

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Abstract Text:

Thermoelectric materials enable the direct conversion of heat into electricity (and vice-versa), offering a pathway toward sustainable energy. With approximately 60% of global primary energy lost as waste heat, Thermoelectric technologies have strong potential to improve energy efficiency and support decarbonization. Their performance is given by the dimensionless figure of merit (zT), which depends on optimizing electrical transport while minimizing thermal conductivity.
This presentation first reviews the evolution of thermoelectric materials, from classical systems, such as Bi_2Te_3, PbTe, and Si-Ge alloys. While these materials achieve good performance in specific temperature ranges, their broad use is limited by toxicity, scarcity of key elements and high prices.
Then, it is introduced the phonon-glass electron-crystal (PGEC) concept, which enables independent control of heat and charge transport through structural complexity and multi-scale phonon scattering. This approach has led to significant thermoelectric performance improvements in materials such as skutterudites and half-Heusler compounds. Emphasis is finally placed on sustainable, earth-abundant alternatives: i) Tetrahedrites ($Cu_{12}Sb_4S_{13}$), which exhibit intrinsically low thermal conductivity and can reach $zT \approx 1$ through compositional tuning; ii) Magnesium-based materials, including α-MgAgSb and $Mg_2(Si,Sn)$, which also show competitive performance, non-toxicity, and low cost, making them strong candidates for applications.
At the end, key challenges and future directions are outlined, including materials optimization, device integration, contact engineering, and long-term stability.

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#82 — Oral

From Waste Heat To Functional Power: Recent Advances And Opportunities In Thermoelectric Generators For Automotive Systems And Wearable Applications

DFMC-GEFES - Termoelectricidad en España: retos, capacidades experimentales y teóricas, y oportunida

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Abstract Text:

Thermoelectric generators (TEGs) are emerging as key enabling technologies for sustainable energy harvesting, converting low-grade waste heat into useful electrical power. In the context of increasing electrification, energy efficiency demands, and the growth of autonomous and wearable electronics, TEGs offer unique advantages due to their solid-state operation, reliability, and scalability.
This presentation reviews recent advances in thermoelectric materials, device design, and system-level integration, developed within the Spanish research group FINDER. The discussion focuses on applications in automotive exhaust heat recovery and body-heat-powered wearables, addressing realistic operating conditions relevant to industrial and biomedical environments.
Recent work carried out in Spain is highlighted, including experimental characterization, device-level optimization, and modeling approaches aimed at improving performance under moderate temperature gradients. Emphasis is placed on issues such as thermal management, mechanical robustness, and integration constraints, which are critical for real-world deployment.
These results illustrate the growing experimental and theoretical capabilities in thermoelectric research in Spain and point to future opportunities for TEGs in sustainable mobility, health monitoring, and distributed energy systems.

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#97 — Oral

Beyond Solid-State Thermoelectrics: Soft Matter Approaches For Thermal Energy Conversion

DFMC-GEFES - Termoelectricidad en España: retos, capacidades experimentales y teóricas, y oportunida

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Abstract Text:

Thermoelectricity is traditionally associated with solid-state semiconductors, where electronic charge carriers convert temperature gradients into electrical power or enable active cooling. However, recent advances in soft matter are expanding this framework towards materials in which ions, redox species, polymer networks and hydrated interfaces play an active role in thermal energy conversion. In this talk, we will discuss hydrogel-based thermoelectrics as an emerging platform that complements conventional solid-state materials by offering mechanical compliance, tuneable composition, low-temperature processing and compatibility with flexible or biocompatible devices.
The first part of the talk will introduce the main mechanisms involved in soft thermoelectric systems, including thermogalvanic conversion based on temperature-dependent redox reactions. Special attention will be paid to thermogalvanic hydrogels, where the polymer network is not merely a passive electrolyte holder but an active component that can regulate ion transport, redox accessibility and heat flow. We will present recent results from our group showing that electrostatic interactions between charged hydrogel networks and redox couples can be used to enhance thermogalvanic performance, highlighting the importance of network design, redox chemistry and mechanical stability.
Finally, we will discuss emerging opportunities and open challenges for soft thermoelectrics, considering their potential integration in flexible, wearable, or building-related platforms. The talk will highlight how hydrogels and hybrid soft materials provide a versatile framework to explore different scenarios where low-grade heat, thermal gradients and soft interfaces are relevant. This perspective aims to connect materials design, transport mechanisms, characterisation and device concepts, identifying possible future directions for thermoelectric research.

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#102 — Oral

Marangoni And Natural Convection In Phase Change Materials For Enhanced Thermoelectric Micro-Energy Harvesting From Ambient Thermal Fluctuations

DFMC-GEFES - Termoelectricidad en España: retos, capacidades experimentales y teóricas, y oportunida

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Abstract Text:

Phase Change Materials (PCM) exploit the latent heat of the solid/liquid phase transition to store and release thermal energy. In addition to ground applications, the temperature cycles of spacecraft in microgravity are well suited to exploit the latent heat during PCM melting and solidification [1]. Coupling PCMs with thermoelectric generators (TEG) increases the electric energy output well beyond conventional designs. For thermal conditions in satellites, thermocapillarity enhances the TEG/PCM micro-energy harvesting efficiency, and the greatest efficiency gain occurs during the heating phase when Marangoni flows are strongest [2].
Under terrestrial conditions, natural convection and Marangoni convection both enhance convective heat transfer in the liquid phase of the PCM. Grounded in fundamental physical principles — temperature-driven density variations and surface tension gradients — their combination is robust. Through 3D simulations, we show that combining both mechanisms enhances thermoelectric efficiency in converting day-night temperature swings into electricity [3].
Using a TEG coupled to a heat storage unit filled with hexadecane, the combined convective driving yields average power densities of 29.7, 16.2, and 27.2 μW/cm² for Central Europe, Western Europe, and Brazil, respectively, with a 16 cm³ unit. Marangoni convection approximately doubles the harvested energy for the European profiles compared to natural convection alone, providing sufficient power to continuously operate environmental sensors measuring humidity, pressure, and temperature [3].
[1] S. Madruga. Modeling of enhanced micro-energy harvesting of thermal ambient fluctuations with metallic foams embedded in Phase Change Materials. Renew. Energy, 168:424-437, 2021.
[2] S. Madruga and C. Mendoza. Introducing a new concept for enhanced micro-energy harvesting of thermal fluctuations through the Marangoni effect. Appl. Energy, 306:117966, 2022.
[3] S. Madruga and C. Mendoza. Thermoelectric energy harvesting from day-night temperature swings with latent heat storage: Enhancing the efficiency by combining natural and Marangoni convection. Appl. Energy, 391:125880, 2025.

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#109 — Oral

Synergistic La, Ca-Double Filling In High-Pressure Synthesized CoSb3 Skutterudites

DFMC-GEFES - Termoelectricidad en España: retos, capacidades experimentales y teóricas, y oportunida

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Abstract Text:

LayCaxCo4Sb12 double-filled skutterudites were synthesized by a one-step high-pressure route as promising medium-temperature thermoelectric materials. Synchrotron X-ray diffraction confirms the cubic Im-3 skutterudite structure, with Ca and La occupying the 2a filler sites within the CoSb3 framework. Rietveld refinement reveals substantial Ca incorporation, exceeding typical filling limits reported for ambient-pressure synthesis, while Sb positional parameters and Oftedal analysis indicate only moderate distortion of the [Sb4] rings, consistent with weak Ca–framework interactions. Thermoelectric characterization shows that single Ca filling strongly perturbs electronic transport, reducing the Seebeck coefficient and increasing resistivity. In contrast, La-Ca co-filling restores favourable carrier transport, reaching Seebeck coefficients up to −134 μV K-1 and power factors of 1.5 mW m-1 K-2. Weighted mobility analysis suggests dominant acoustic-phonon scattering in the best co-filled compositions. Simultaneously, La-Ca co-filling strongly suppresses heat transport, yielding total thermal conductivity values as low as 1.3 W m-1 K-1 at high temperature. This ultra-low thermal conductivity is attributed to synergistic resonant scattering, mass/strain-field fluctuations, and microstructural phonon scattering. These results demonstrate La–Ca double filling as an effective strategy to tune electronic transport while suppressing lattice thermal conductivity in CoSb3 skutterudites, advancing their potential for medium- and high-temperature thermoelectric applications.

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#124 — Oral

Thermoelectric Modules For Active Heating And Cooling In Building Envelopes: Opportunities And Challenges

DFMC-GEFES - Termoelectricidad en España: retos, capacidades experimentales y teóricas, y oportunida

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Abstract Text:

The building sector accounts for approximately 40% of global energy consumption, with heating and cooling representing a dominant share. Although vapour-compression systems remain the most efficient and widely adopted solution for building climate control, they present inherent limitations, including reliance on refrigerants with environmental impact, mechanical complexity, and reduced suitability for decentralised thermal management. Solid-state thermoelectric (TE) devices operating on the Peltier effect offer a fundamentally different solution: silent, compact, refrigerant-free, and capable of reversible heating and cooling by simply reversing current polarity.
TE device performance is characterised by the dimensionless figure of merit ZT, which relates the Seebeck coefficient, electrical conductivity, and thermal conductivity. Commercially available bismuth telluride (Bi_2Te_3) modules with ZT ≈ 1 near room temperature are the most accessible candidates for integration into building envelopes. Advances in nanostructuring, phonon engineering, and emerging oxide and half-Heusler materials continue to push ZT higher, with clear implications for the feasibility of building envelope-integrated TE systems.
A key challenge in evaluating building-integrated thermoelectric systems is characterising COP under realistic boundary conditions, where ambient fluctuations and envelope heat fluxes differ substantially from those in standardised laboratory setups. Our experimental characterisation of a thermoelectric prototype tested under real building conditions yields COP values of 1.0–2.1 and module-level thermal outputs of 67–274 W, establishing a performance baseline for applications in window frames and ventilated façade assemblies.
While opportunities are significant, modularity, execution costs, zone-level control, maintenance costs and compatibility with photovoltaic sources, issues remain in scaling COP competitiveness, managing thermal bridging, and developing standardized integration procedures within building energy regulations. This work contributes to the broader advancement of building-integrated thermoelectrics as an emerging solid-state thermal technology, identifying priority directions across materials development, real-world metrology, and regulatory readiness.

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#203 — Poster

Photoinduced Local Symmetry Breakage In SrTiO3 And Potential Venues To Ferroelectricity

DFMC-GEFES - Termoelectricidad en España: retos, capacidades experimentales y teóricas, y oportunida

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Abstract Text:

Recent advances in photovoltaics have plateaued due to the intrinsic voltage limitations of traditional p–n junction solar cells, motivating the search for alternative mechanisms such as the bulk photovoltaic effect in ferroelectric materials. Among these, oxide perovskites, and particularly Strontium Titanate (STO), stand out for their strong polarization, stability, and tunable electronic structure, despite their wide band gap. STO has been the subject of extensive studies exploring the phase transitions it undergoes from paraelectric to ferroelectric or antiferrodistortive phases, induced by electromagnetic radiation such as lasers. This ability to exhibit photoinduced ferroelectricity has strong implications for its potential applications in photovoltaic and optoelectronic devices. Additionally, STO exhibits a rich dielectric behavior under UV irradiation in the presence of an electric field.
In this work, we explore the nature of the photoinduced enhancement of the STO dielectric constant under UV irradiation. Analyzing the STO potential energy surface (PES), the first excited states exhibit a local breaking of symmetry due to the displacement of the Ti atom off the center of the unit cell. Furthermore, two key variables linked to the ferroelectric phase transition in STO, namely, pressure and oxygen vacancies, are investigated. Pressure can modify the ground state and excited state PES, tailoring the depth of the excited state well or reducing the energy gap between the ground and excited states. The distribution of oxygen vacancies in the STO bulk was also explored, revealing preferential configurations and the presence of aligned Ti3+-Ovac-Ti3+ or Ti3+-Ovac complexes. These configurations can lead to a small polarization of the material, which could serve as a driving force to align the off-center photoexcited Ti polarons.

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#101 — Oral

Kretschmann-Otto Plasmonic Cavities For Ionic-Liquid Sensing And Electrochemical Integration

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Prism-coupled surface plasmon resonance (SPR) sensing is commonly implemented in the Kretschmann or Otto geometries, each offering different advantages in simplicity and tunability. Here, we investigate the hybrid Kretschmann-Otto (KO) configuration using ionic liquids as the intracavity analyte. In this structure, the finite dielectric thickness acts as an additional control parameter and enables coupled surface plasmons (CSPs), extending the sensing capabilities of conventional prism-coupled SPR systems. Compared with the standard Kretschmann geometry, the KO configuration provides access to thickness-dependent information and enhanced sensitivity to the optical properties of each metal boundary, which can favor asymmetric metal combinations. This is especially relevant for ionic liquids, whose interfacial organization near metal surfaces may differ from their bulk optical response and may not be equivalent at the two cavity interfaces. Reflectance maps calculated for different cavity thicknesses and selected metal combinations show how the resonance pair evolves as the system becomes optically asymmetric. The results suggest that asymmetry can be used as a design parameter to tailor linewidth, angular position, and interface sensitivity. This makes KO microcavities a promising platform for SPR studies of ionic liquids under confinement and for future electrochemical devices in which interfacial ordering and optical response can be monitored simultaneously.

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#151 — Oral

Co-Crystallization And Charge-Transfer Complex Formation In Thin Films: A Strategy For NIR Sensing Applications

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Charge-transfer complexes (CTCs) formed by the co-assembly of small conjugated molecules, typically an electron donor and acceptor, enable organic semiconductors with enhanced electrical and optical properties compared to their individual components, while avoiding complex synthetic routes [1–3]. Understanding and controlling co-crystallization in thin films is critical to exploit their properties in devices. Here, we investigate the formation of co-crystalline thin films comprising 2,7-bis(octyloxy)[1]benzothieno[3,2-b]benzothiophene (C8O-BTBT-OC8) and 1,3,4,5,7,8-hexafluoro-tetracyanonaphthoquinodimethane (F6TCNNQ) by sequential deposition of F6TCNNQ on C8O-BTBT-OC8 films, both vacuum sublimated. Grazing-Incidence Wide-Angle X-ray Scattering (GIWAXS) during acceptor deposition reveals the emergence and growth of the (001) Bragg peak associated with co-crystal formation. Atomic Force Microscopy (AFM) and Kelvin Probe Force Microscopy (KPFM) performed after acceptor growth confirms a morphological change in the films and an increase of the local work function. UV–vis spectroscopy demonstrates the formation of the CTC with a new absorption band in the near-infrared (NIR) absorption. We show that this approach is a viable strategy to grow uniform co-crystalline thin films, with potential application in NIR sensing applications.

References:

[1] L. Sun et al. Adv. Mater. 31, 1902328 (2019).

[2] W. Wang et al. Chem. Eur. J. 27, 464 (2021)

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#237 — Oral

High-Entropy Alloying Of Halide And Chalcohalide Semiconductors

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Around twenty years ago, the term “high-entropy alloy” was coined by Yeh and co-workers1 to describe metallic alloys with significant configurational entropy and outstanding thermal and mechanical properties. Today, the concept of high-entropy materials has grown well beyond this field and is being applied to different advanced or multifunctional materials for different purposes such as catalysis or thermoelectrics.2 In the field of optoelectronics, halide perovskites have gathered an incredible attention over the last decade. Among their relevant properties, the soft crystal lattice and the possibility of accommodating different species makes them rather uniquely tuneable. In that sense, it is foreseeable that high-entropy alloys thereof may be formed to yield interesting emerging and non-linear properties such as pronounced bandgap bowing. Nevertheless, experimental evidence of high-entropy halide perovskites remains very scarce.3,4 In parallel, a growing interest is being directed towards chalcohalide semiconductors,5,6 where some parallelism with halide perovskites can be drawn, including the potential for high-entropy alloying. In this talk I will briefly introduce high-entropy materials and discuss existing literature and unpublished results related to halide and chalcohalide semiconductors alloys.
References:
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(2) Han et al., Multifunctional High-Entropy Materials. Nat. Rev. Mater. 2024, 1–20.
(3) Folgueras et al., High-Entropy Halide Perovskite Single Crystals Stabilized by Mild Chemistry. Nature 2023, 621 (7978), 282–288.
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(5) Palazon, F. Metal Chalcohalides: Next Generation Photovoltaic Materials? Sol. RRL 2021, 2100829.
(6) Sebastiá-Luna et al. Chalcohalide Antiperovskite Thin Films with Visible Light Absorption and High Charge-Carrier Mobility Processed by Solvent-Free and Low-Temperature Methods. Chem. Mater. 2023, 35 (16), 6482–6490.

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#244 — Oral

Simultaneous In-Situ Measurement Of Surface Potential And Heat Capacity Of Organic Semiconductors

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Organic semiconductors exhibit complex polarization phenomena that strongly influence charge generation, transport, and recombination processes in optoelectronic devices. In particular, the spontaneous orientational ordering during thin-film deposition of polar organic semiconductors can generate a surface potential that modifies the energetic landscape of the material. These polarization effects can also influence excitonic processes, such as exciton polarization quenching, where local electrostatic environments modify exciton dissociation and non-radiative decay pathways, ultimately affecting device efficiency and stability. Although molecular dipoles and spontaneous orientational ordering are known to play a central role in defining the internal electrostatic landscape of thin films the relationship between molecular orientation, thermodynamic transitions, and polarization dynamics remains insufficiently understood due to the lack of experimental techniques capable of probing these properties simultaneously and in situ.
In this work, we propose a methodology for the simultaneous in-situ measurement of surface potential and heat capacity in organic semiconductor deposited thin films. The approach combines fast-scanning nanocalorimetry [1,2] with capacitor-based electrical measurements, enabling direct correlation between thermal signatures and the evolution of polarization. Organic molecules possessing permanent dipole moments can spontaneously orient during film growth, leading to macroscopic polarization and measurable surface potentials. By integrating the film into a capacitor geometry while simultaneously monitoring heat capacity, it becomes possible to identify how orientational ordering and phase behavior are linked to polarization changes.
This combined experimental platform provides a direct route to study the coupling between molecular arrangement, dipolar ordering, and phase transition processes in organic semiconductors. The ability to monitor simultaneously both thermodynamic and electrostatic properties offers new insight into polarization-induced phenomena and could support the development of more efficient organic electronic and photovoltaic devices.
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#274 — Oral

Controlling Optoelectronic Properties Of Halide Perovskites Through Deposition Geometry

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Halide perovskites (HPs) have emerged as outstanding materials for optoelectronic applications due to their exceptional optoelectronic properties, including high absorption coefficients, long carrier lifetimes, tunable bandgaps, and strong photoluminescence. Beyond compositional engineering, controlling the structural anisotropy at the nanoscale provides an additional degree of freedom to tailor light-matter interaction in these materials. In particular, low-dimensional HP nanostructures such as nanowires and nanorods exhibit anisotropic optical and electronic responses arising from their geometry, quantum confinement, and directional carrier dynamics, enabling unique functionalities for photonic and optoelectronic devices. In this work, we explore Glancing Angle Deposition (GLAD) as a versatile vacuum-based technique to engineer anisotropic HP nanostructures with controlled morphology, orientation, and crystallographic texture. GLAD relies on oblique incidence deposition, where shadowing effects and limited surface diffusion drive the formation of highly anisotropic nanostructures. Our approach consists of a two-step fabrication route, involving the deposition of PbI2 at glancing angles, followed by conversion to different perovskite compositions by the exposition to a second halide salt (e.g., MAI, FAI, or CsI). By tuning deposition geometry, we achieve a high degree of structural anisotropy, leading to a broad range of nanostructured architectures.

This geometrical control enables polarization-dependent absorption and photoluminescence, arising from the structural anisotropy of the nanostructures. Such an approach provides a powerful platform to tailor optoelectronic properties beyond conventional compositional tuning. Furthermore, the compatibility of GLAD with scalable fabrication methods highlights its potential for device integration. Overall, this work establishes deposition geometry as a key design parameter for halide perovskites, enabling control over nanoscale structure and light-matter interaction, and opening new pathways for the emergence of previously inaccessible optical and optoelectronic functionalities.

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#280 — Oral

Indium-Free Metal–Organic Graphene Analogues For Scalable And Sustainable Flexible Electronics

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Indium Tin Oxide (ITO) remains the industry standard for transparent conductors, yet its inherent brittleness, supply-chain vulnerabilities, and energy-intensive vacuum processing present significant barriers for flexible electronics and next-generation wearables. While current alternatives frequently compromise either performance or stability, this work introduces Metal–Organic Graphene Analogues (MOGs) as a high-performance, vacuum-free alternative. By eliminating the reliance on scarce elements and high-energy fabrication methods, we demonstrate a scalable, eco-friendly approach that effectively balances optical transparency with mechanical resilience. Our findings advance MOGs from a laboratory concept to a viable industrial platform, demonstrating that high-performance optoelectronics can achieve both sustainability and flexibility.

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#372 — Oral

Carbon Dots As Multifunctional Materials For Applications In Electronics

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Carbon dots (CDs) represent a sustainable class of carbon based nanomaterials with tunable structural and optoelectronic properties. Their adjustable composition, degree of graphitization, and surface chemistry enable control over photoluminescence, charge transfer behavior, and electronic communication. We investigate synthetic routes—thermal and hydrothermal—to access either graphene quantum dots with dominant sp^2 domains or molecularly derived CDs where crosslinking and partial graphitization modulate solubility and fluorescence quantum yields.
Post-synthetic surface engineering expands the functional landscape of CDs. The incorporation of electron rich aromatic units through covalent attachment provides a platform to probe charge transfer interactions in hybrid systems. When introduced into conventional hole transporting matrices, these modified CDs exhibit behaviors suggestive of altered electronic dynamics. Although still at an exploratory stage, these observations point to the broader potential of CDs within emerging optoelectronic architectures.
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#396 — Oral

Tailoring Strong Light-Matter Coupling In Perovskite Quantum Dot Solids Via Capping Ligand Engineering

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Recently, the integration of lead halide perovskite quantum dot (QDs) films into optical cavities has opened the door to exploring the strong light-matter coupling regime in soft semiconductor materials [1]. This has been possible only due to the development of a novel synthetic approach that makes use of zwitterionic ligands, which allows the creation of highly concentrated QD dispersions [2,3].
In this study, we demonstrate that we can modulate the strength of the exciton-photon coupling via capping ligand engineering for lead halide perovskite QD solids (CsPbBr3). By using different zwitterionic alternatives, namely lecithin [2], C12C16-PEA [3], and C8C12-PEA [3], we successfully manipulate the interparticle spacing at the nanoscale. This structural adjustment allows us to gradually tune the QD density in the films, preserving their uniformity and optical quality.
When embedding the QD solids inside Fabry-Pérot resonators, angle-resolved absorptance maps provide unequivocal evidence of the strong coupling regime through the anti-crossing of polaritonic branches. Crucially, the variation in packing density results in a gradual, predictable tuning of the Rabi splitting. These results validate ligand engineering as a robust and scalable approach to the rational design of polariton dispersion, establishing a clear pathway toward advanced polaritonic optoelectronic devices [4].
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#397 — Oral

Machine Vision For Automated Diffraction Analysis In Nanoscale Synchrotron Imaging

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Understanding structure–property relationships in emerging semiconductors requires techniques that can resolve structural and chemical heterogeneity at the nanometre scale. Synchrotron scanning X-ray microscopy provides this capability by combining nano-X-ray fluorescence, nano-X-ray diffraction and nano-X-ray absorption near-edge structure measurements to map composition, lattice structure and local electronic environment. We have used these correlative nanoscopy tools to study performance-limiting mechanisms in halide perovskites and transition metal dichalcogenides. However, such experiments generate extremely large, high-dimensional datasets: at each scan position, a full two-dimensional diffraction image is recorded, producing millions of megapixel patterns. Conventional manual or semi-automated analysis is therefore impractical, particularly for weakly scattering systems such as atomically thin materials, where Bragg peaks occupy only a small detector region and are frequently obscured by noise, background scattering and detector artefacts.

Here, we present a machine-vision framework for automated analysis of synchrotron diffraction datasets acquired at the I14 beamline of Diamond Light Source. The workflow combines physics-informed preprocessing with deep-learning-based denoising to suppress background contributions and enhance weak diffraction features. We then apply computer-vision strategies, including object-detection neural networks, to localize Bragg reflections directly in two-dimensional detector images. This enables robust peak detection under low signal-to-noise conditions and allows structural information, including strain-sensitive diffraction signatures, to be extracted automatically across large nanoscale scans with minimal user intervention and improved reproducibility across samples, acquisition conditions and detector configurations.

As a representative application, we discuss strain imaging in transition metal dichalcogenides, where local structural distortions are linked to quantum light emission. By converting diffraction-image analysis into a scalable machine-learning task, the approach reduces a major bottleneck in synchrotron nanoscopy and enables high-throughput correlative workflows during advanced operando and in situ experiments. Overall, this work demonstrates how integrating X-ray nanoprobes with machine vision can accelerate quantitative, automated and physically interpretable characterization of next-generation optoelectronic materials and devices.

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#399 — Oral

Mechanochemical Design Of Multi-Cation Vacancy-Ordered Double Perovskites For Advanced Optoelectronics

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Halide perovskites based on the ABX3 structure have recently gained significant attention for emerging optoelectronic applications, including low-dimensional phases of this family, double perovskites (A2BB'X6), and vacancy-ordered derivatives (A2BX6). In this context, vacancy-ordered double perovskites (VO-PVSKs) offer an alternative by replacing lead with high-Z elements, which are potentially less toxic while still preserving strong X-ray absorption properties. Their fully inorganic composition suggests enhanced resilience under high-energy radiation compared to hybrid halide perovskites, and their A2BX6 framework provides wide compositional flexibility, allowing access to a variety of tetravalent B-site cations. This study investigates a scalable wet mechanochemical route for the preparation of vacancy-ordered halide perovskites as a platform for compositional screening in systems based on high-Z cations such as Hf4+, Zr4+, and Te4+. We used pair distribution function (PDF) analysis and Raman spectroscopy to probe the local order of these compositions, revealing structurally complex local environments that may be relevant to achieving enhanced stability via high-entropy mixing. In situ synchrotron measurements were used to analyze the stability of the samples under aggressive conditions, such as elevated temperature, humidity, and prolonged X-ray exposure. By studying composition, local disorder, and structure-property relationships, this work advances the understanding and engineering of lead-free perovskite-inspired materials.

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#400 — Poster

Self-Gelation Of MOFs

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

Metal-organic frameworks (MOFs) are highly porous materials composed of organic ligands coordinated to metal ions or metal clusters, which form a network that containing potential voids. Traditionally, the properties and applications of these materials are characterized in the form of microcrystalline powders; however, this form is not manageable for large-scale applications and existing forms such as pelletizing it or adding binders clog its porosity. For this reason, MOF gels have emerged as a functional alternative to microcrystalline powders. In this talk we are going to propose a way to gel with light. To do this, we use a molecule that acts as a transducer of light in heat, thanks to which sufficient temperature can be reached to promote MOF synthesis (Figure 1). We analyse this gelling in situ with the Small Angle X-ray Scattering (SAXS) technique and laboratory techniques such as SEM, TEM and UV-Vis spectroscopy among others. This opens up a lot of new applications as it combines the advantages of gelling with light and the intrinsic advantages of MOFs, especially it is very useful for biomedical applications, applications in which MOFs stood out for being good drug deliveries.

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#402 — Poster

Strong Light-Matter Coupling In 2D Perovskites Integrated In Porous Optical Cavities

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

In recent years, metal halide perovskites (ABX3) have attracted significant attention owing to their outstanding optoelectronic properties. However, conventional three-dimensional perovskites present important limitations, particularly their low environmental and thermal stability. In this context, low-dimensional perovskites have emerged as promising alternatives, exhibiting improved stability while maintaining excellent optical properties1. Furthermore, these materials have large exciton binding energies, making them particularly attractive for investigating strong light-matter coupling when integrated into optical cavities2,3.

Under the strong light-matter coupling regime, hybridization between excitonic transitions and confined photonic modes occurs, leading to the formation of new hybrid quasiparticles known as polaritons. These systems are highly relevant not only for tuning the optical properties of perovskite-based materials but also as platforms for exploring complex physical phenomena, such as polariton Bose-Einstein condensation4,5. Here, we report an alternative strategy to achieve strong light-matter coupling in Ruddlesden-Popper 2D perovskites integrated into Fabry-Perot optical cavities using mesoporous scaffolds with a narrow pore size distribution. This architecture enables precise control over the structural quality and phase purity of the confined perovskites while promoting strong excitonic resonances. Additionally, the thickness of the mesoporous scaffold can be accurately controlled, allowing fine tuning of the cavity thickness and resonant photonic modes.

The resulting system exhibits pronounced anticrossing and a Rabi splitting value exceeding 200 meV, demonstrating efficient exciton-photon coupling. In conclusion, our nanoporous scaffold-based approach provides enhanced tunability, stability, and higher coupling strength compared to previously reported low-dimensional perovskite cavity systems.

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#403 — Oral

Investigating Förster Resonance Energy Transfer Mechanisms In Quantum Dot Solids Via Spectrally-Resolved TRPL

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

The development of efficient optoelectronic materials is essential for the advancing of sustainable energy technologies. In this context, semiconductor quantum dots (QDs) are particularly attractive due to their size-tunable optical properties. Among them, lead halide perovskite QDs (PQDs) have emerged as promising candidates for next-generation solar cells and light-emitting devices, offering exceptional photoluminescence quantum yields (PLQYs) and remarkably large exciton diffusion coefficients compared with conventional QDs [1] For all these applications, colloidal PQDs must be casted as optical quality solid films.

In such QD solids, carrier transport is strongly influenced by the insulating organic ligands capping the nanocrystalline QDs. As a result, Förster Resonance Energy Transfer (FRET), which depends on dipole-dipole interactions between neighboring QDs, becomes the dominant mechanism for migration. In this context, previous studies have shown that exciton diffusion in PQD films exhibits distinct temperature-dependent regimes. As temperature increases, a pronounced reduction in exciton diffusion is commonly observed above 100 K, which is nowadays the subject of an interesting debate. [1,2].

In this work, we employ Time-Resolved Photoluminescence (TRPL) to systematically investigate the factors controlling the temperature dependence of FRET in PQD films [3]. By analysing the exciton decay dynamics in both the donor and acceptor spectral regions over a range of temperatures, we extract the FRET efficiency and correlate its evolution with key parameters. Our results indicate that the temperature dependence of the oscillator strength plays a central role in determining the energy-transfer efficiency [4]. These findings provide insight into the mechanisms governing exciton transport in PQD assemblies and may contribute to the design of QD-based devices with improved performance under different operating conditions.

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#404 — Oral

Squaraine Dye Thin Films As A Platform For Strong Light-Matter Coupling In Optical Microcavities

DFMC-GEFES y GENAM - Soft materials for Emerging Optoelectronics

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Abstract Text:

In recent decades, organic dyes have been successfully implemented in a wide range of applications, from optoelectronic devices such as dye-sensitized solar cells (DSSCs) [1] to biosensors employed in bioimaging [2]. These materials are characterized by their molecular orbitals that enable the formation of tightly-bound excitons. When integrated into optical microcavities as absorbent materials, the energy of the photons trapped inside the microcavities can match the transition energy of the dyes' excitons. This matching gives rise to the strong light-matter coupling regime and new hybrid quasiparticles known as polaritons. In this regime, the original absorption band of the dyes is split into two distinct bands, which are shifted from the original spectral position of the absorption. Consequently, the absorption band of dyes can be easily tuned through their implementation in optical microcavities [3].
In this research, we focus on squaraine dyes - derivatives of squaric acid - which are photostable, easy to synthesize and exhibit strong absorption and emission bands in the red region of the visible spectrum [4]. Thin films of these materials were prepared and a thorough characterization was carried out. The optical constants of the films, needed to design the optical cavities, and their dependence on dye concentration were determined. Time-resolved photoluminescence together with emission quantum yield measurements were used to identify the presence of concentration quenching. Finally, transient absorption spectroscopy (TAS) measurements allowed us to explore the different mechanisms involved in exciton recombination by tracking the temporal evolution of the ground-state bleach and excited-state absorption features. These results provide an excellent foundation for the subsequent design and fabrication of optical microcavities based on these materials.

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#14 — Oral

Enhancing Predictions Of WIMP Annihilation Spectra: Modeling Propagated Gamma Rays With CRPropa

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

Weakly interacting massive particles (WIMPs) remain one of the most compelling candidates for dark matter. Although these particles cannot be directly detected, they are expected to produce a non-negligible number of annihilations when they encounter each other in dense environments such as haloes of galaxy clusters. The products of these annihilations include high-energy gamma rays, which can be detected with current instruments. To reliably associate a gamma-ray signal with a WIMP annihilation spectrum, it is crucial to understand how this spectrum is modified during propagation through intergalactic space, particularly due to interactions with the background radiation of the Universe. Current models typically account only for pair production, neglecting the subsequent interactions undergone by the secondary particles produced in this process. In this work, we investigate the impact of inverse Compton scattering on gamma-ray spectra from WIMP annihilation using CRPropa simulations that consistently include interactions with both the cosmic microwave background and the extragalactic background light. We simulate the propagation of ~10^6 gamma-ray events using a Monte Carlo approach, exploring WIMP masses between 1 and 100 TeV and propagation through distances up to several hundred Mpc. The resulting propagated spectra are compared with those obtained when ignoring these electromagnetic cascades.

Our results show that inverse Compton scattering can enhance the gamma-ray flux by up to three orders of magnitude in the GeV energy range for large WIMP masses and long propagation distances. This discrepancy with respect to current models in this regime leads to a shift in the inferred constraints on the WIMP parameter space, particularly in the mass and annihilation cross-section derived from dark matter limits, as illustrated using the Perseus cluster as a case study. These findings have important implications for the interpretation of gamma-ray observations and for indirect searches for dark matter.

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#22 — Oral

Spanish Tier-2 Contribution To ATLAS Computing: Consolidating Run 3 Achievements And Preparing For The HL-LHC Era

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

This work presents the consolidated contributions of the Spanish Tier-2 centers to the ATLAS experiment's computing infrastructure. As of late 2025, our focus spans the final phase of Run 3, preparations for Long Shutdown 3 (LS3), and strategic planning for the High-Luminosity LHC (HL-LHC) era. Our GRID infrastructures undergo continuous optimization, encompassing robust storage, efficient processing, and active involvement in experiment software development.
Our fundamental objective is twofold: first, providing stable, 24/7 data processing with reliability exceeding 95% for Tier-2s. Second, we are addressing the complex computing challenges inherent to the 2022–2026 period. Central to these efforts is a commitment to R&D, preparing for the demanding HL-LHC phase. Annually, we generate billions of simulated events for diverse physics processes, leveraging national High-Performance Computing (HPC) resources, including MareNostrum 5 within the Spanish Supercomputing Network. We extensively utilize the Data Lake paradigm, essential for managing the massive datasets crucial for ATLAS physics analyses. Our centers remain integral to the core GRID infrastructure, housing critical data and offering first-line support to local physicists at IFIC, UAM, and IFAE.
A key development is the implementation of the "Facility for Interactive Distributed Analysis" (FIDA). This innovative initiative streamlines workflows by orchestrating distributed initial analysis with subsequent interactive exploration of reduced data files. FIDA aims to accelerate the production of publishable results and conference contributions.
In conclusion, the Spanish ATLAS computing sites continue to provide substantial R&D contributions. By evaluating emerging models to enhance performance, optimize resource utilization, and expand storage capacity, we are ensuring the Spanish community is ready to meet the unprecedented demands of the forthcoming High-Luminosity LHC era, maintaining our position as a reliable pillar of the international collaboration.

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#25 — Oral

Search For Lepton Flavour Violating Decays Of Higgs Boson With CMS Run-3 Data

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

Lepton flavour violation (LFV) searches are of particular interest since the observation of LFV processes would constitute clear evidence of Beyond the Standard Model (BSM) physics, such as that predicted by supersymmetric or composite Higgs models. In particular, the violation of lepton flavour in the Higgs sector would imply the presence of non-zero off-diagonal terms in the Yukawa matrix, in contradiction with Standard Model predictions. These terms can be measured through the decays of the Higgs boson into two leptons of different flavour, such as μτ, eτ or eμ.
In this study, we present the current status of an ongoing search for LFV Higgs boson decays into μτ or eτ. The main backgrounds for these channels arise from Drell-Yan processes, top-antitop quark pair production and processes in which jets are misidentified as leptons (QCD multijet and single W events). The data corresponds to proton-proton collisions collected during the Run-3 period by the CMS experiment at the LHC. As the analysis is in progress, the focus is on the development of the analysis techniques and validation of the background modelling.
Advanced machine learning techniques and reconstruction methods are employed in order to improve Run-2 results already published. In particular, a mass regressor is used for an improved estimation of the Higgs boson's mass. In addition, deep neural networks are developed to separate events into categories according to the Higgs boson production mechanism, either vector boson fusion or gluon gluon fusion, and to extract the signal from the background exploiting differently shaped distributions of features with enhanced discriminatory power.
The goal of the analysis is to provide the most stringent limits on the Branching Fractions of the Higgs boson decays into a pair of different flavour leptons and on the corresponding off-diagonal Yukawa couplings.

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#31 — Oral

SAETASS: An Open-Source Solver For Astrparticle Transport In Spherical Symmetry

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

Understanding the transport of cosmic rays is a central problem in high-energy astrophysics and astroparticle physics, as it connects the microphysics of particle acceleration with the large-scale non-thermal emission observed across the Universe. Accurate modeling of these processes requires flexible numerical tools capable of solving the cosmic ray transport equation under realistic physical conditions. SAETASS (Solver for Astroparticle Equation of Transport Analysis in Spherical Symmetry) is a recently developed open-source Python package designed to solve the cosmic ray transport equation in spherical symmetry, allowing transport coefficients to depend on space, momentum and time. This flexibility enables the exploration of a wide range of astrophysical environments where particle diffusion, advection and energy losses interplay to shape the resulting particle populations and their observable signatures. In this talk, we will introduce the mathematical formulation and numerical strategy underlying the SAETASS framework, highlighting the physical assumptions and computational design that make the code both robust and versatile. We will present the first scientific applications carried out with the package and discuss its potential for modeling high-energy phenomena such as stellar clusters, supernova environments and other cosmic ray accelerators. Finally, we will outline planned developments aimed at expanding the capabilities of the code and fostering its use within the astroparticle community.

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#34 — Oral

Measurement Of Top Quark Production Ratios And Determination Of The Strong Coupling Constant And The Top Quark Mass.

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

The ratio R32 of the three-jet to the two-jet inclusive differential cross sections is a well-established tool to study perturbative QCD. In this work, this observable is adapted to top-quark physics by considering the ratio of the tt+jet to the tt cross sections as a function of different kinematic variables. Theoretical predictions are provided at next-to-leading order using the Powheg generator matched to the Pythia parton shower, and its dependence with the top-quark pole mass and the strong coupling are investigated, as well as its theoretical uncertainties. New theoretical work from independent groups have recently incorporated NNLO QCD corrections to this observable, with the consequent reduction on the scale uncertainties. First experimental studies of this observable at CMS are presented, showing a good level of agreement with the theoretical predictions. All things considered, these results show promising trends for the determination of both parameters at the CMS Experiment.

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#36 — Oral

Probing The Topology Of The Early Universe Using CMB Temperature And Polarization Anisotropies

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

TeV string-mass-scale strings have been excluded experimentally at colliders, as their effects have not been observed at the Large Hadron Collider (CERN). On the other hand, higher-scale string theory, with mass scales typically close to the Planck scale, is often regarded as experimentally inaccessible due to the enormous energies required for direct tests, and far beyond the reach of present or foreseeable particle accelerators. Nevertheless, the early Universe may provide an indirect observational window for high-string scale through imprints left on the Cosmic Microwave Background (CMB). In this work, building on our previous studies, we reexamine temperature and polarization angular correlations as probes of the geometry and topology of the pre-inflationary Universe. Finally, we extend our framework to B-mode polarization, highlighting its potential as a sensitive probe in forthcoming ground-based and space-borne experiments with unprecedented precision

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#49 — Oral

Monitoring Power Consumption At ATLAS Tier 2 Computing Centre

DFTP - Simposio de la División de Física Teórica y de Partículas

Alejandro Pérez García 1, Francisco Javier Sánchez Martínez 1, Daniel Rosique Egea 1, Miguel Villaplana Pérez 1, Josu Cantero García 1, Emma Torró Pastor 1, Helena Burriel Navarro 1, Jose Salt Cairols 1, Santiago González De La Hoz 1, José Enrique García Navarro 1, Roberto Andreeas Uzum 1, Pablo Collado Soto 2, Jose Del Peso Malagón 2

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Abstract Text:

The computing model of the Large Hadron Collider experiments is undergoing a strong evolution as it prepares for the High-Luminosity HL LHC era, in which data volumes and processing demands are expected to increase by up to an order of magnitude. In this context, improving the accuracy of energy consumption estimates is important the sustainability of large scale scientific computing and a correct assignment of such consumption to jobs. Current estimations often rely on simplified assumptions, such as constant machine load, and do not reliably take into account variations in CPU usage throughout the execution.

We present a proposal to improve the estimation of energy consumption at the job level, reading current technologies (RAPL, IPMI, DCMI, and HWMon). To achieve this, we perform a comparative study of these power monitoring interfaces, evaluating their accessibility, granularity, and reliability. To facilitate its deployment, we develop a simplified version of prmon, a tool used in LHC distributed computing to monitor the resource usage of jobs, that incorporates these power metrics via Prometheus exporters. The prototype has been tested at ATLAS Tier 2 sites, with the expectation of integrating these features into the official prmon release for wider use. Implementation guidelines and a Grafana based monitoring dashboard are also provided. Our results show that using these technologies can improve energy usage estimations in distributed computing environments, in particular at correctly assigning consumption to individual jobs.

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#56 — Oral

Clebsch-Gordan Decomposition Of Unitary Representations Of Compact Groups Using Quatum States

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

Quantum tomography is a picture of quantum mechanics that consists in reconstructing the quantum state of a system by means of linear combinations of unitary representations of the underlying symmetry group of the system where the weights can be obtained indirectly from measurements of observables of the system. Since this theory allows the reconstruction of quantum states using unitary representations, a good question is if we can obtain information about the symmetry group if we know the quantum states of the system. In response to this question, we present a numerical algorithm composed of concatenations of unitary transformations that allows to get the Clebsch-Gordan decomposition of any representation of any compact group by constructing two random quantum states of a system restricted to that group. This work was published in 2017 in the American Institute of Physics:
A. Ibort, A. López Yela and J. Moro. A new algorithm for computing branching rules and Clebsch-Gordan coefficients of unitary representations of compact groups. J. of Math. Phys. 58, 101702 (2017) [doi.org/10.1063/1.5004259] [handle/10115/ 28543]

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#73 — Oral

Searching For New Physics With ATLAS: Anomaly Detection In Multilepton Final States

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

This talk presents the latest results from a competitive search for Beyond the Standard Model (BSM) physics in multilepton final states with four or more light leptons using data from the ATLAS detector at the LHC. Employing a novel anomaly detection strategy, this analysis identifies potential signals of BSM physics. We establish exclusion limits for a variety of benchmark BSM scenarios, utilizing a template fit method applied to discriminating variables sensitive to anomalous events. Using the full ATLAS Run 2 dataset, this analysis demonstrates a level of sensitivity in constraining the parameter space of these models that approaches that of comparable dedicated searches optimized for each scenario. Furthermore, the derived model-independent limits underscore the versatility of this approach, demonstrating broad sensitivity to a range of potential new physics signals within the multilepton final state, thus offering a powerful tool for identifying unexpected phenomena.

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#84 — Oral

Exploring Liquid Fine-Grained Detectors (LFGD) For The Upcoming Neutrino Detector ND280++

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

Long-baseline neutrino (LBNO) experiments investigate neutrino oscillation phenomenon and other properties with neutrino beam coming from proton accelerators. These experiments employ a two-detector approach: a near detector, located close to the production point, measures the unoscillated neutrino beam, and a far detector, placed at a long distance, studying the oscillated neutrino spectrum.
T2K (Tokai-to-Kamioka) is one of the current leading LBNO experiment, located in Japan. The Near Detector, ND280, is located 280m away from the beam generation in Tokai at J-PARC. The Far Detector named Super-Kamiokande (SK), located 295 km away, is the largest water Cherenkov detector in the world with 50 kton of water.
This work focuses on ND280, which has recently undergone a major upgrade. This upgrade consisted of the installation of three new subdetectors : a Time-of-Flight detector (ToF), two High-Angle Time Projection Chambers (HA-TPCs) and the Super Fine-Grained Detector (SuperFGD) which is a scintillator-based tracker. The goal of this upgrade was to reduce the systematic uncertainty from 7% to 4%.
This improvement is essential for the next generation of LBNO experiments, in particular Hyper-Kamiokande (HK), the successor of Super-Kamiokande, with a fiducial volume 8.4 times larger and currently under construction. To fully meet the expectations of HK, ND280 needs to be upgraded to N280++. This consists in replacing the remaining non-upgraded subdetectors to improve the measurement of vertex activity and electron neutrino cross sections, aiming to reduce systematic uncertainty to 3%.
Several detector concepts are being explored for ND280++. One of them is the Liquid Fine Grained Detector (LFGD).
This presentation focuses on the development of this 8–10 tons tracking detector based on LiquidO-type technology. After discussing the technical advantages of this design for both ND280++ and HK, we will present simulation results and the plan for a forthcoming small-scale prototype.

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#88 — Oral

Search For A Resonance Decaying Into A Scalar Particle And A Higgs Boson In The 4b-Quark Final State In The Boosted Regime With The ATLAS Detector

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

A search for a new heavy resonance X decaying into a scalar particle S and a Standard Model Higgs boson H, with both bosons decaying into bottom quark pairs, is presented. The analysis will focus on the boosted regime, where each b-quark pair is reconstructed as a single large-R jet. Later, advanced jet substructure techniques and b-tagging algorithms are used to identify the H→bb and S→bb candidates. Data driven techniques are used to estimate the dominant background coming from QCD multijet production. The search is performed using LHC Run 2 (2015-2018) + partial Run 3 (2022-2024) data collected by the ATLAS detector

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#110 — Oral

MPPC Characterization For FCC Calorimetry

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

The ALLEGRO detector concept for the Future Circular Collider (FCC) envisions a robust, high-performance hadronic calorimeter inspired by the ATLAS Tile Calorimeter (TileCal) design. Within the DRD Calo Work Package 3, this concept leverages the operational experience of TileCal at the LHC while integrating state-of-the-art technologies in photodetectors, electronics, and signal reconstruction to meet the stringent requirements of future high-rate, high-precision collider experiments. Among the proposed innovations, Silicon Photomultipliers (SiPMs) stand out as a promising alternative to traditional photomultiplier tubes, offering high gain, excellent detection efficiency, fast response, superior time resolution, and a broad spectral sensitivity range.
Multi-Pixel Photon Counters (MPPCs), a type of SiPM, are considered well suited for high-granularity calorimetry, such as in the ALLEGRO case. The aim of this study is to characterize different MPPCs to evaluate their performance and assess their suitability within this class of photodetectors. These devices can detect extremely low light levels at the photon-counting scale, making them attractive candidates for future calorimeter designs. Using a custom experimental setup, pulse-height spectra have been acquired to evaluate key performance parameters such as gain and dark count rate and their dependence with the temperature.
This contribution focuses on presenting the complete characterization framework: the experimental setup, including hardware components and the online and offline software tools developed for data acquisition and analysis. The methodology is discussed together with the results obtained so far.

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#115 — Oral

Physics In Coefficients: From Differential Decays To EFT Measurements In ATLAS

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

This talk presents a general analysis framework based on finite basis expansions of fully differential decay rates, with an application to effective field theory (EFT) measurements in single top-quark production. The method is designed to efficiently capture the full multidimensional structure of collider observables while avoiding the limitations of traditional high-dimensional template approaches.
The framework relies on expressing the quadruple-differential decay rate of the (t \to Wb \to \ell \nu b) process in a set of orthogonal basis functions. In this representation, the full kinematic information is encoded in a finite number of coefficients, which provide a compact and complete description of both the shape and normalisation of the distribution. These coefficients are extracted directly from data via projection, with well-defined statistical uncertainties and correlations.
As a first application, the method is used to perform a simultaneous fit of multiple EFT Wilson coefficients affecting the production and decay of single top quarks. The coefficient-based representation allows the combination of differential information and event yields in a unified way, leading to improved sensitivity compared to conventional approaches. The analysis is performed using proton–proton collision data at (\sqrt{s} = 13) TeV collected by the ATLAS detector, corresponding to an integrated luminosity of 140 fb(^{-1}).
Beyond this specific measurement, the framework provides a flexible and scalable tool for precision studies at the LHC. Its ability to encode complex multidimensional information in a small set of observables makes it well-suited for a wide range of applications, including future differential measurements and interpretations in extended theoretical frameworks.

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#128 — Oral

Search For Long-Lived Particles Coupled To Top Quarks With The ATLAS Detector At The Large Hadron Collider (LHC) At CERN.

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

The Standard Model (SM) of Particle Physics accurately describes most of the observed phenomena in High Energy Physics. However, it fails to explain observations like Dark Matter, the matter-antimatter asymmetry, or neutrino masses. These evidences point to the need for an extension of the SM, which is being extensively searched for at the Large Hadron Collider (LHC) experiments at CERN. More than a decade after the LHC started taking data, no clear hint of New Physics has been observed. One possibility for the lack of a discovery so far is the low sensitivity of standard searches to unconventional signatures, particularly those involving long-lived particles (LLPs). LLPs are predicted in many extensions of the SM and should be considered a serious possibility for uncovering New Physics. ATLAS and CMS have ongoing search efforts for LLPs leading to different signatures. The CalRatio+top analysis team proposes to exploit the preferential coupling of Axion-Like Particles (ALP) to third generation quarks, particularly top quarks, in scenarios where the ALP's lifetime enhances its decay within the ATLAS detector, leading to displaced jets. This approach aims to explore, for the first time in ATLAS, a specific region in the parameter space of ALP models, potentially leading to the discovery of New Physics.

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#156 — Poster

Progress In The Framework For The Application On ML/DL To Physics Analysis On Massive Data In ATLAS Experiment

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

The application of Machine Learning to physics analysis in the ATLAS experiment is having a significant impact. The methods applied and the different workflows (which we will call itineraries) involve phases that can be automated. Therefore, we have developed a Framework and are testing it with different datasets. In this contribution, we have applied it to the extraction of the ttbar resonance signal (Z') from the background using simulated data from the Darkmachines repository (https://arxiv.org/pdf/2002.12220). These results can be compared with previous results obtained with other datasets that included high-level discriminant variables, from the University of California, Irvine (UCI) repository. We will highlight the good discrimination with low-level variables when using Boosted Decision Trees (BDTs) and Random Forests (RF) applied to the fully hadronic channels from ttbar.
When we focus on the semileptonic channel (l + jets), we have access to the differences and similarities in discriminations, confusion matrices, correlations between variables, etc., for the two dataset repositories: the one used in this work and the one referenced in previous contributions. We also include results from extracting the ttbar resonance signal using Artificial Neural Networks with varying hyperparameters. Finally, we will include the progress made in incorporating different analysis paths with Machine Learning, referencing various machine learning methods and the importance of discriminant variables.

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#189 — Oral

Top-Quark Tomography And Orbital–spin Entanglement In Single-Top Decays At ATLAS

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

The top quark, due to its extremely short lifetime, decays before hadronisation and thus provides direct access to its quantum properties. This makes it a unique laboratory to explore quantum effects in high-energy particle physics.
This contribution presents a novel analysis within the ATLAS experiment that performs a quantum tomography of the top-quark decay t→Wb in t-channel single-top-quark production using proton-proton collision data from the LHC. The approach is built upon a previously established quadruple-differential angular analysis [1], which fully exploits the kinematic phase space by projecting reconstructed angular distributions onto a set of orthonormal basis functions constructed from Wigner D-functions. This projection allows for a Fourier-based decomposition of the angular distributions, facilitating the direct extraction of the angular coefficients and capturing the intricate helicity structure of the tWb vertex. This method allows for the model-independent extraction of a complete set of angular coefficients through a direct averaging procedure that provides their uncertainties and correlations.
By combining these experimentally accessible coefficients with recent theoretical developments [2], it becomes possible to reconstruct the joint quantum state of the decay products. This enables a direct experimental investigation of quantum entanglement between orbital and spin components in a fundamental particle decay. The analysis uses LHC Run2+Run3 data and established reconstruction techniques, providing a concrete and feasible path towards the first observation of orbital–spin entanglement in high-energy physics and opening a new window to probe the quantum structure of the Standard Model.

[1] The ATLAS Collaboration. Constraints on effective field theories via quadruple-differential angular decay rates from t-channel single-top-quark production at $\sqrt{s}$ = 13 TeV with the ATLAS detector, 2025, arXiv: 2510.23372 [hep-ex]. https://arxiv.org/abs/2510.23372.
[2] J.A. Aguilar-Saavedra. Full quantum tomography of top quark decays. Phys.Lett.B 855 (2024) 138849. https://doi.org/10.1016/j.physletb.2024.138849.

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#218 — Oral

The Four-Gluon Vertex In General Kinematics

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

We present a nonperturbative lattice QCD study of the four-gluon vertex in general kinematics, extending previous analyses restricted to collinear configurations. Our investigation focuses on soft kinematics, spanning the same phase space as the fully general three-gluon vertex. The analysis relies on large-volume lattice simulations and on the assumption of planar degeneracy, which allows different kinematical configurations to be classified by a single invariant, s^2, and meaningfully averaged, thereby significantly improving the statistical quality of the data.
The resulting form factor provides a reliable approximation to the tree-level structure of the full four-gluon vertex, and shows good agreement with corresponding results obtained from continuum Dyson–Schwinger calculations.

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#296 — Oral

Thermal Resonances And Their N_c Behaviour Near Chiral Symmetry Restoration.

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

We study the dependence on the number of colors N_c of the pole parameters of the $f_0(500)$ resonance at finite temperature within the framework of unitarized Chiral Perturbation Theory, extending previous analyses performed at zero temperature. In particular, the Inverse Amplitude Method is used to compute the $f_0(500)$ pole, including the expected linear N_c scaling of the chiral low-energy constants. Our results show that, near the chiral phase transition, the N_c dependence of both the mass and the width differs from that found at zero temperature. In this regime, the observed scaling remains incompatible with that expected for a conventional $q\bar q$ state, consistent with a mixed and non-ordinary nature of the $f_0(500)$. We also analyse the N_c dependence of the scalar susceptibility, χ_S, within an approach in which this quantity is saturated by the thermal $f_0(500)$ state.
References

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#314 — Oral

CMS Muon Detector: Drift Tubes Analytical Method Algorithm Efficiency And Synchronisation

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

One of the most important parts of the CMS detector are the muon detectors. They are used to measure charged particles tracks that escape the inner barrel zone of the detector using the particles ionization capability. In particular the Drift Tubes use the rather constant drift veolcity within a gas volume to detect charged particles tracks (mainly muons). In this talk, two aspects of the phase-2 upgrade online trigger algorithm (Drift Tubes Analytical Method), which will be used during the High Luminosity LHC, will be addressed: the determination of the algorithm's efficiency and the mitigation of the different detection delays in the measured particles' paths.

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#331 — Oral

Experimental Prospects For Decoherence Of Fermion Qubit Pairs From Radiation At Colliders

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

Entanglement (the inability to define a state from a system independently of the state of the order, even at really large distances) constitutes one of the defining features of quantum mechanics (QM) and the heart of the disparity of QM from classical mechanics. For the last century, its study has evolved from an exclusively fundamental physics question to a key topic in technological progress, central for metrology (the science that determines the consensus in units' definition), quantum information, and, notably, quantum computation.
The simplest two-level quantum system is provided by fermions in the Standard Model, spin-1/2 particles, with the entanglement being characterized by correlations in the spin state of pairs of these. Particularly, top-quark pairs have been studied extensively in this matter. The top quarks have a very short lifetime that their spin information is transferred to their decay products. Experimental observation for correlations and, most recently, quantum entanglement between top-quark pairs was reported at the LHC.
For this work, we study heavy fermion pairs as open systems, assessing the process through which entanglement can be lost. Particularly, we study the impact of final-state radiation on fermion-pair quantum systems produced at colliders. We present predictions for several processes, specifically $t\bar{t}(g)$ and $\tau^+\tau^-(\gamma)$, showing that hard radiation can induce decoherence and significantly reduce the entanglement of the elementary fermion pairs. We investigate the feasibility of observing this effect experimentally in exclusive samples with hard radiation. Likewise, we conclude that a statistically significant signal can be obtained with current data in $pp \to t\bar{t}(g)$ production at the LHC and in $e^+e^- \to \tau^+\tau^-(\gamma)$ production at Belle-2. Future electron-positron colliders operated at the Z pole or well above the $t\bar{t}$ production threshold will extend these prospects further.
Based on arXiv:2604.16268.

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#383 — Oral

Optical Characterization And R&D For The DUNE Photon Detection System

DFTP - Simposio de la División de Física Teórica y de Partículas

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Abstract Text:

The Deep Underground Neutrino Experiment (DUNE) is a next-generation international experiment that aims to advance our understanding of neutrinos. By combining a powerful wide-band neutrino beam and a high-performance Near Detector complex at Fermilab with a massive Far Detector (FD) located 1,300 km away at the Sanford Underground Research Facility (SURF), DUNE will be able to determine the neutrino mass ordering, measure potential CP violation in the lepton sector, and test the completeness of the three-flavor paradigm.
In particular, the FD will consist of four large Liquid Argon Time Projection Chambers (LArTPCs), equipped with a novel Photon Detection System (PDS), capable of detecting liquid argon scintillation light at 128 nm with high efficiency and large-area coverage at a reasonable cost. This talk focuses on the R&D and characterization efforts led by the Institute of Corpuscular Physics (IFIC) within the DUNE PDS consortium. We will discuss several optical measurements, including transmittance and reflectivity studies of key detector materials, as well as photon collectors performance evaluation. These results are fundamental for maximizing light collection efficiency and timing resolution, ultimately ensuring the physics goals of the DUNE program.

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Oral

Search for Pair-Produced Charged Long-Lived Particles Decaying to Muons at CMS with $\sqrt{s}$ = 13.6 TeV

DFTP - Simposio de la División de Física Teórica y de Partículas

Martín Alcalde Martínez

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Abstract Text:

The CMS detector is one of the general-purpose detectors at the LHC at CERN, designed to discover the Higgs boson and to study Standard Model (SM) physics at previously unexplored energy scales. It achieves excellent performance in reconstructing particles originating from decays occurring within a few millimeters of the collision point (prompt decays), particularly muons. These are measured both in the innermost detector, the Tracker, and in the outermost detector, the Muon System. The standard reconstruction algorithm imposes a constraint on the interaction vertex, improving the measurement of these “prompt” muons by effectively adding an additional data point. However, not all muons originate from the interaction point; such muons are referred to as “displaced” muons. While the SM predicts the existence of long-lived particles (LLPs) that can decay into muons, similar signatures may also arise from exotic LLPs associated with physics beyond the SM (BSM). In this work, I study the decay of pair-produced charged exotic LLPs into muons. Compared to previous searches, this new analysis is sensitive to LLP decays beyond the CMS pixel detector, which improves the sensitivity, especially at large lifetimes. This study represents the first CMS analysis targeting this class of signals using proton-proton collision data at a center-of-mass energy of 13.6 TeV, collected between 2022 and 2024.

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#1 — Oral

Breakdown Of Hydrodynamics In A Quasi-Two-Dimensional System

DIFENSC - Sistemas Complejos

Daniel Téllez Calle, María Isabel García De Soria, Pablo Maynar, José Javier Brey

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Abstract Text:

We study a hydrodynamic description of a dilute gas of hard spheres confined between two parallel plates separated by a distance of the order of the particle diameter. In particular, for a separation smaller than two diameters, the particles cannot pass over each other and the system is effectively quasi-two-dimensional. A Boltzmann-like equation for a height-averaged distribution function was obtained through a BBGKY hierarchy, justifying its validity to first order in the density [1]. Starting from this equation, we perform a Chapman-Enskog expansion, yielding an effective Navier-Stokes hydrodynamic description for the density, velocity and temperature fields with explicit transport coefficients as functions of microscopic parameters. In particular, a diverging bulk viscosity is found when the separation tends to zero, which shows how confinement can strongly affect the transport coefficients.
This divergence is found to be due to the predominance of head-on collisions in narrow systems, which inhibits energy transfer between horizontal and vertical degrees of freedom. Indeed, the kinetic mode associated with per-axis energy anisotropy becomes as slow as desired (in particular, as slow as the hydrodynamic modes) as the plate separation becomes smaller. By including one extra temperature anisotropy field, the divergence is regularized and the pure 2D limit (gas of hard disks) is recovered under certain conditions.
The theoretical predictions are validated through molecular dynamics simulations of sound propagation, in which the bulk viscosity shows up through the sound damping coefficient. The results show a very good agreement and demonstrate how confinement strongly affects transport coefficients in a simple and intuitive system.
[1] Brey, J. J., García de Soria, M. I., Maynar, P., Dynamics and kinetic theory of hard spheres under strong confinement, Physical Review E 110, 034127, 2024.

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#30 — Oral

Fate Of Boltzmann’s Breathers: Stokes Hypothesis And Anomalous Thermalization

DIFENSC - Sistemas Complejos

Pablo Maynar 1, María Isabel García De Soria 1, David Guéry-Odelin 2, Emmanuel Trizac 3

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Abstract Text:

Boltzmann showed that in spite of momentum and energy redistribution through collisions, a rarefied gas confined in a isotropic harmonic trapping potential does not reach equilibrium; it evolves instead into a breathing mode where density, velocity and temperature oscillate. This counter-intuitive prediction is upheld by cold atoms experiments [1]. Yet, are the breathers eternal solutions of the dynamics even in an idealized and isolated system? We show by hydrodynamic arguments and also by kinetic theory that an original dissipative mechanism is at work, where the minute and often neglected bulk viscosity eventually thermalizes the system, that thus reaches equilibrium [2, 3].
[1] D. S. Lobster, A. E. S. Barentine, E. A. Cornell, and H. J. Lewandowski, Observation of a persistent non-equilibrium state in cold atoms, Nat. Phys. 11, 1009 (2015).
[2] M.I. García de Soria, P. Maynar, David Guéry-Odelin, and Emmanuel Trizac, Fate of Boltzmann’s Breathers: Stokes Hypothesis and Anomalous Thermalization, Phys. Rev. Lett. 132, 027101 (2024).
[3] P. Maynar, M.I. García de Soria, David Guéry-Odelin, and Emmanuel Trizac, Fate of Boltzmann’s breathers: Kinetic theory perspective, Phys. Rev. E 110, 044105 (2024).

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#58 — Oral

Structural Dynamics Of Liquids Across Timescales: Microscopic Insight Into Atomic Motion During Vitrification

DIFENSC - Sistemas Complejos

Eloi Pineda

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Abstract Text:

Structural dynamics control fundamental aspects of liquids and glasses, such as the crystallization kinetics, the aging rate or the rheological/mechanical behaviour. These structurally disordered systems show a highly non-exponential relaxation, constituted by a broad spectrum that covers many orders of magnitude in timescales. With the current extraordinary combination of beam stability, high brilliance, coherence and new detector technologies available in some synchrotron facilities, the X-rays Correlation Spectroscopy (XPCS) technique gives us access to the intermediate scattering function of glasses at different q-values for times going from microseconds to hours. In terms of time and length scales, this is a unique information which cannot be obtained by any other technique, not even simulations.
This work reviews recent findings on the dynamics of metallic glass-formers. We firstly summarize the main features of their complex relaxation spectrum, encompassing □-relaxation as well as secondary processes [1], and we survey what we currently know about how the relaxation spectrum evolves during cooling - from the supercooled liquid through the glass transition - and during physical aging of the glass [2]. Subsequently, we contrast macroscopic results with the microscopic dynamics explored by XPCS. While macroscopic and microscopic observations appear consistent in the super cooled liquid, a notable divergence emerges in the glass state, with the emergence of compressed non-exponential relaxation functions. We discuss the possible origins of these differences in view of recent microscopic observations [3].

References
[1] Y. Tong et al., Strain-driven Kovacs-like memory effect in glasses, Nature Comm. 14, 8407 (2023).
[2] Y.J. Duan et al., Connection between Mechanical Relaxation and Equilibration Kinetics in a High-Entropy Metallic Glass, Phys. Rev. Lett. 132, 056101 (2024).
[3] M. Frey et al., Liquid-like versus stress-driven dynamics in a metallic glass former observed by temperature scanning X-ray photon correlation spectroscopy, Nature Comm. 16, 4429 (2025).

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#59 — Poster

Fluctuation-Induced Effects Change The Direction Of Selection In Exploit-Escape Dilemmas

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Eduardo Nieto Vargas 1,2, Alicce Doimo 3,4, Lorenzo Fant 5,4, Miguel A. Muñoz 1,2

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Abstract Text:

Dispersal in patchy environments mediates a fundamental exploitation–evasion trade-off: individuals benefit from staying in favorable patches, yet local crowding and kin competition can erode returns and favor movement. While previous theory has clarified how spatial heterogeneity shapes dispersal evolution through deterministic selection gradients, a complementary question is how fluctuations—demographic noise and temporal variability—feed back on nonlinear population dynamics to alter the effective forces acting on dispersal. Here we introduce a minimal discrete-time stochastic metapopulation model that cleanly separates time-persistent (quenched) and time-fluctuating (dynamic) components of environmental heterogeneity, and we develop an analytic coarse-graining based on a second-order moment expansion. This yields explicit fluctuation-induced correction terms (noise-induced drift) and a variance-corrected effective dynamics that accurately predicts long-run behavior and stationary states observed in stochastic simulations, outperforming naive mean-field theory. Using the corrected dynamics to evaluate competing dispersal strategies, we find that heterogeneity and finite-population noise can induce a shift in the evolutionarily favored dispersal effort, switching between low-dispersal exploitation and high-dispersal evasion regimes as a function of measurable disorder statistics. Our results provide a physics-inspired, mathematically tractable route from landscape statistics to dispersal outcomes, and generate testable predictions for finite-size signatures and management interventions that tune variability to tip populations between dispersal regimes.

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#76 — Oral

Noise-Driven Phases And Barrier Crossing In A Two-State System Under Stochastic Fields

DIFENSC - Sistemas Complejos

Raul Toral

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Abstract Text:

We study how stochastic external forcing, combined with thermal fluctuations, modifies the behavior of a bistable system out of equilibrium. As a minimal framework, we consider the Ising model coupled to a heat bath and subject it to spatially uniform magnetic fields that fluctuate randomly in time. In this setting, the two ferromagnetic states play the role of the two wells of an effective double-well potential, allowing us to analyze both non-equilibrium phase transitions and barrier-crossing dynamics within a single theoretical model. This perspective also provides a direct link to experiments on two-state systems driven by noisy fields.

Although the model is conceptually simple and related variants have been examined before in other settings, it displays a surprisingly rich phenomenology. The random time-dependent field replaces the usual symmetry-breaking transition of the equilibrium Ising model by a noise-induced transition between a broad-paramagnetic phase and a broad-ferromagnetic phase. In the latter, the magnetization remains broadly distributed around nonzero values, retaining a finite spread and finite peak height even in the thermodynamic limit. At the same time, the stochastic driving dynamically restores the symmetry between the two equivalent ferromagnetic states.

For weak field amplitudes, the onset of this transition occurs at the critical temperature of the zero-field Ising model. At lower temperatures, however, we identify a second transition from the broad-ferromagnetic regime to a genuine ferromagnetic phase, in which the dynamics selects one of the two symmetry-related ordered states. This regime is further characterized by a divergence of the typical transition time between states. Our results highlight the nontrivial interplay between thermal noise and stochastic fields, and they open the way to further theoretical and experimental studies of barrier hopping and non-equilibrium critical behavior.

S. Oliver-Bonafoux, A. Chakrabarti and R. Toral. Phys. Rev. E113, 044110 (2026).

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#85 — Oral

The Alcon Levitator: A Magnet Hovers Over Two Rotating Conducting Cylinders

DIFENSC - Sistemas Complejos

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Abstract Text:

The Alcon levitator is an experimental setup that produces the levitation of a bar magnet above two counter-rotating metal cylinders. Stable levitation is achieved only above a critical angular velocity—about 9000 rpm in our setup. In this work, we present a theoretical and numerical analysis of the magnetic forces at work. By examining the interplay between lift and braking forces, we clarify the physical mechanism that enables stable levitation. We demonstrate that the critical angular velocity emerges from the distinct scaling behaviors of these forces as a function of the angular velocity of the cylinders.

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#112 — Oral

Multiple Pareto-Optimal Solutions Of The Dissipation-Adaptation Trade-Off

DIFENSC - Sistemas Complejos

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Abstract Text:

Adaptation refers to the ability to recover and maintain “normal” function on perturbations of internal or external conditions and is essential for sustaining life. Biological adaptation mechanisms are dissipative, i.e., they require a supply of energy such as the coupling to the hydrolysis of ATP. Via evolution the underlying biochemical machinery of living organisms evolved into highly optimized states. However, in the case of adaptation processes two quantities are optimized simultaneously, the adaptation speed or accuracy and the thermodynamic cost. In such cases one typically faces a trade-off, where improving one quantity implies worsening the other. The solution is no longer unique but rather a Pareto set—the set of all physically attainable protocols along which no quantity can be improved without worsening another. Here we investigate Pareto fronts in adaptation-dissipation trade-offs for a cellular thermostat and a minimal ATP-driven receptor-ligand reaction network. We find convex sections of Pareto fronts to be interrupted by concave regions, implying the coexistence of distinct optimization mechanisms. We discuss the implications of such “compromise-optimal” solutions and argue that they may endow biological systems with a superior flexibility to evolve, resist, and adapt to different environments.

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#143 — Oral

Information Flows In Bipartite Systems

DIFENSC - Sistemas Complejos

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Abstract Text:

Stochastic thermodynamics describes the energetics of small systems operating far from equilibrium, where thermal fluctuations play a central role. Within this framework, information thermodynamics has emerged as a key concept for understanding the interplay between information and the energetics of a system. Molecular machines constitute a paradigmatic example of these systems, where energy and information are tightly coupled and cannot be treated independently. Bipartite systems play a fundamental role in the modelling of these machines, making their analysis essential to understand a wide variety of biological processes. In this project, we aim to investigate information flows between the different parts of a bipartite system. Previous studies [1] have established, under minimal assumptions, a lower bound on the information flow that depends only on the net output work and the temperature of the thermal baths. While these results are valuable, their general assumptions prevent them from offering detailed insight into the specific mechanisms governing information transfer. Here, we seek to bridge this gap by exploring how information flows are connected to intrinsic properties of the system. Our approach is based on the analysis of simple, discrete, and analytically tractable models, which allow us to identify and discuss generic features of information exchange in bipartite systems and to assess how such features depend on the system's internal structure and dynamics.
[1] Leighton, Matthew P., Ehrich, Jannik, Sivak, David A., "Information Arbitrage in Bipartite Heat Engines" Physical Review X 14, 4 (2024)

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#175 — Oral

Análisis Topológico De Datos En Interacciones De Grupo En Piragüismo De Fondo

DIFENSC - Sistemas Complejos

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Abstract Text:

En piragüismo de fondo, en particular en la modalidad de maratón de piragüismo, los atletas interaccionan para formar grupos mientras luchan por la victoria. Dichos grupos cambian su estructura a lo largo de la regata y muestran una dinámica muy rica. Este desplazamiento grupal, o colectivo, es un fenómeno que se desarrolla a muchas escalas, en este caso macroscópica. A esta escala ha sido observado en numerosas especies animales, incluida la nuestra. En este sentido el deporte de fondo no es más que una manifestación de desplazamiento colectivo en humanos. Nuestro trabajo presenta un análisis de las redes de interacción que aparecen en regatas de este tipo. Mostramos como la estructura topológica de los grupos es un buen descriptor de la cohesión y estructura táctica en piragüismo de fondo, especialmente cuando la conectividad se define siguiendo un criterio físico, el patrón de olas generado por un kayak, en lugar de un criterio basado únicamente en proximidad geométrica. A partir de datos sintéticos de un grupo de 13 kayaks, creado a partir de la estructura geométrica del patrón de olas de estas embarcaciones, demostramos como un criterio basado únicamente en la proximidad geométrica no captura de manera correcta la riqueza topológica del grupo que se observa sustituyendo este por otro basado en dicho patrón de olas. Cotejamos este resultado con datos de campo, obtenidos en el Campeonato del Mundo de Maratón de Piragüismo. En ambos casos se observa como a medida que aumenta la distancia de filtración lo hace la complejidad topológica hasta alcanzar un punto, con la aparición de símplices de dimensión 3 (tetraedros), que identificamos con estructuras de toma de ola de orden 3. Esta perspectiva abre la puerta a nuevas métricas para las interacciones en deportes de fondo y en sus analogías con el desplazamiento colectivo en animales

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#216 — Oral

A Simple Preference Aggregation Rule Explains How Multidimensional Identities Shape Social Networks

DIFENSC - Sistemas Complejos

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Abstract Text:

Social categories, such as race, gender, or socioeconomic status, are core driving forces of social tie formation. They shape our identities, determining our social behavior and our connection preferences. Homophily, the preference for connecting with similar others, is one of the most common and widely studied interaction patterns; however, the dynamics driving multidimensional connection preferences remain largely unexplored. The key unresolved question is: how do individuals integrate multidimensional identity information when forming social ties? Answering this question is important for understanding how segregation and inequality emerge in networks and for designing interventions that promote integration. Here, we develop a principled theoretical framework for modeling multidimensional tie formation. The framework represents group-based preferences as partial probabilities of connection associated with each social dimension and formalizes alternative rules for aggregating these preferences into a single probability of forming a tie. This enables direct tests of competing hypotheses, ranging from tolerant mechanisms in which high preference in any one dimension is sufficient to connect, to selective mechanisms in which preferences must align across dimensions for a tie to form.
We apply the framework to two empirical systems: high-school friendship networks and marriage ties. We fit competing model variants to each dataset and use systematic model comparison to evaluate which aggregation rule is best supported. Across both systems, the data favor a simple mechanism: individuals tend to evaluate each identity dimension independently and form ties only when all relevant evaluations are favorable, consistent with a “picky chooser” rule. Beyond selecting the best-supported mechanism, the model yields interpretable estimates of group-based preferences in each dimension and provides principled measures of identity salience, quantifying which dimensions matter most for tie formation in a given setting. Together, these results provide a tractable, theory-driven approach for studying how intersecting identities translate into social choices and network structure.

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#231 — Poster

Conditioned Dynamics And Large Deviations In Chaotic And Random Maps

DIFENSC - Sistemas Complejos

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Abstract Text:

The characterization of rare dynamical fluctuations in chaotic systems is a central problem in nonequilibrium
statistical physics. In deterministic maps, atypical trajectories are exponentially suppressed and typically require
finely tuned initial conditions. A natural framework to study these fluctuations is provided by large-deviation theory, where trajectory ensembles are biased through suitable tilting procedures. Within this framework, conditioned dynamics can be constructed via a generalized Doob transform, leading to an effective map that is topologically conjugate to the original one and whose typical trajectories reproduce
the statistics of the biased ensemble (Gutiérrez et al., 2023). This construction provides both a practical and conceptual tool to access rare events and analyze dynamical phase transitions in chaotic systems. In this contribution, we extend this formalism to random maps, focusing on the Pelikan map (Yan et al., 2024), which combines deterministic expansion with stochastic selection. We show how the Doob transform can
be consistently implemented in this hybrid setting, yielding an effective conditioned dynamics that retains a clear
dynamical interpretation while encoding the large-deviation properties of the original system. These results place deterministic and random maps within a unified framework based on trajectory ensembles
and the spectral properties of tilted operators, providing further insight into the structure of fluctuations and conditioning in nonequilibrium dynamical systems.

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#241 — Oral

Emergence Of Complexity In The Origin And Early Evolution Of Life.

DIFENSC - Sistemas Complejos

Jacobo Aguirre

Centro de Astrobiología (CAB), CSIC-INTA, Madrid, Spain
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Abstract Text:

Unraveling the origin of life, and how the road to life was punctuated by transitions toward complexity, from astrochemistry to biomolecules and eventually to living organisms, remains one of the greatest challenges that humanity faces. Since Oparin's groundbreaking article a century ago, various scientific disciplines have approached this problem from isolated perspectives. Despite the remarkable progress made, achieving these ambitious goals still entails significant difficulties, and disruptive and more interdisciplinary, holistic approaches have been advocated recently as the way forward.
In this talk, I will first address the main unresolved difficulties associated with the field of the origin and early evolution of life and explore how complexity science, in harmony with recent advances in data science, can play a pivotal role in tackling them [1]. Second, I will briefly describe several approaches under development in our research group, outlining the opportunities for complexity theory and network science in different scenarios of increasing complexity related to the origin of life. Finally, I will focus on a theoretical and computational framework named EarlyWorld to model the non-enzymatic polymerization of ribonucleotides and the template-dependent replication of primordial RNA molecules [2]. Our results demonstrate that systematic polymerization and replication of single-stranded RNA polymers were feasible under these conditions. Crucially, this process required a physico-chemical environment characterized by large-amplitude oscillations with periodicity compatible with spring tide dynamics, suggesting that large moons may have played a role in the emergence of life on planetary bodies.
[1] C. Alejandre, M. Fernández-Ruz, R. Guantes and J. Aguirre, Toward a systems view of life's origins: Modeling the emergence of complexity across chemical, informational and ecological levels, Current Opinion in Systems Biology 44:100588 (2026).
[2] C. Alejandre, A. Aguirre-Tamaral, C. Briones and J. Aguirre, Polymerization and replication of primordial RNA induced by clay-water interface dynamics, Communications Chemistry 8(1), 236 (2025).

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#242 — Oral

Topology, Dynamics And Parameter Sensitivity Of The Interstellar Medium Reaction Network

DIFENSC - Sistemas Complejos

Paulo Domínguez López 1, Izaskun Jiménez Serra 1, Mario Castro 2, Marina Fernández Ruz 1, Raúl Guantes 3, Jacobo Aguirre 1

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Abstract Text:

The interstellar medium (ISM), composed of gas and dust between stars, hosts a rich chemical environment that underpins star and planet formation. Understanding the vast web of chemical reactions that drive ISM evolution is a central challenge in astrochemistry.
In this work, we explore the ISM's chemical reaction network using tools from network science and dynamical systems to uncover both its structural and dynamical properties. Our topological analysis reveals a modular structure connected to the underlying physical-chemical processes, where most modules are dominated by a single chemical element, reflecting chemical homogeneity and functional coherence. Building on this topological analysis and recent work by our group [1], we analyze the temporal evolution of molecular abundances and assess the system's sensitivity to the model parameters, i.e. the reaction rate coefficients. This analysis reveals a strong parameter hierarchy, that is, many parameter combinations exhibit negligible influence on model outcomes, while a few dominate the system's behavior. Our findings aim to guide the future refinement of astrochemical models by identifying the key reactions that require precise kinetic rate determinations through further experimental or theoretical work. This effort could significantly simplify the ISM's chemical reaction network while preserving its usefulness, thereby contributing to a deeper understanding of chemical complexity in space.
As take-home messages, our work highlights that (1) the ISM's chemical reaction network shows modularity linked to chemical function; (2) it exhibits a broad degree distribution and a disassortative pattern; (3) the system's behavior is highly sensitive to a small subset of reaction rate coefficients, while the majority have negligible influence; (4) model simplification is possible without losing accuracy; and (5) our work can guide experimental efforts.
[1] M. Fernández-Ruz et al., Strong parameter hierarchy in the interstellar phosphorus chemical network, Front. Astron. Space Sci. 12, 1570525 (2025).

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#246 — Oral

Dynamical Heterogeneities In Complex Systems: From Soft Matter To Econophysics

DIFENSC - Sistemas Complejos

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Abstract Text:

Heterogeneities in the dynamics have been observed in different complex systems, without any corresponding structural inhomogeneities. This behaviour is characerized by the existence of regions within the system with different mobilities, but also with a characteristic time scale where the heterogeneities are maximal, both requiring a high degree of cooperativity. These features have been reported in supercooled liquids (atomic, molecular or soft matter) or in granular matter, but also in more complex systems, such as active matter or living cells, or even in financial markets.
In this presentation, we will discuss the dynamical heterogeneities in two systems: a dense suspension of colloidal spheres with a tracer of different size to probe the heterogeneities at different length scales, studied with computer simulations, and the New York Stock Exchange, taking the price of stocks as the position of particles. In the physical system, we note that that a tracer slightly smaller than the bath particles presents the strongest indications of the bath heterogeneities, both using the non-Gaussian parameter and dynamical susceptibility. The results are confirmed by theoretical calculations using mode coupling theory, but regions where the tracer shows different mobility are also detected. On the other hand, the stock market studied over the last twenty years shows similar dynamical heterogeneities, with a maximum in the non-Gaussian parameter and dynamical susceptibility, but also with scale-free avalanches.

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#260 — Oral

Imbalance In Gut Microbial Interactions: A Marker Of Health And Disease

DIFENSC - Sistemas Complejos

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Abstract Text:

The human gut microbiome plays a crucial role in maintaining overall health. Although imbalances of the microbiome (dysbiosis) have been linked to a wide range of diseases, the general mechanisms underlying these imbalances remain poorly understood. Moreover, existing biomarkers to identify dysbiosis, such as diversity indices, often yield inconsistent results and fail to accurately reflect the complex ecological mechanisms that distinguish healthy microbial community states from diseased ones. We fill this gap by proposing a general biomarker for dysbiosis. This metric is inspired by the emergent phenomenology observed with our novel theoretical model for the gut microbiome. The model incorporates a large community of bacterial types, migration, nutrient dynamics, metabolic preferences and pathways, and the potential for crossfeeding, thereby generating intricate dynamical interaction networks like the ones expected in the gut microbiome. The emergent communities show two distinct collective states that we interpret as healthy and dysbiotic states, respectively, with the latter resulting from a transition from competition-dominated to cooperation-driven microbial networks. Building on these insights, we used interaction-network inference and analysis to develop our metric for dysbiosis, which effectively and robustly differentiates healthy states from dysbiotic ones not only in the model but also in real data across diverse diseases. Moreover, this metric strongly correlates with disease progression, as demonstrated in colorectal cancer datasets, underscoring its potential as an early diagnostic tool. Our findings advance the understanding of gut microbial dynamics and pave the way for early disease detection and targeted therapeutic interventions.

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#261 — Oral

The Latent Simplicity Of Microbial Ecological Interactions

DIFENSC - Sistemas Complejos

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Instituto de Biología Funcional y Genómica, Salamanca, Spain
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Abstract Text:

Ecological interactions between microorganisms give rise to the functions of microbial communities. The potential number of these interactions and their complexity pose a major challenge towards predicting the behavior and ultimately designing microbial consortia. Here, we experimentally and theoretically show that pairwise and higher-order interactions are often dependent on each other, following simple linear relationships. This statistical dependency is a hallmark of low-dimensional collective behavior, where the function of a microbial community is explained by one or two emergent variables. Using consumer-resource models, we show that these collective variables can be directly connected to species traits, such as their metabolic efficiency. We validate this empirically, and show that these results are maintained over time and robust to community dynamics. Our work provides a quantitative theoretical framework to study, predict, and ultimately engineer emergent functions in microbial communities.

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#262 — Oral

The Saturation Effect On Information Diffusion On Socila Media

DIFENSC - Sistemas Complejos

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Abstract Text:

In an era where social media shapes public opinion, understanding information spreading is key to grasping its broader impact. This work explores the intricacies of information diffusion on Twitter, emphasizing the significant influence of content saturation on user engagement and retweet behaviors. We introduce a diffusion model that quantifies the likelihood of retweeting relative to the number of accounts a user follows. Our findings reveal a significant negative correlation where users following many accounts are less likely to retweet, suggesting a saturation effect in which exposure to information overload reduces engagement. We validate our model through simulations, demonstrating its ability to replicate real-world retweet network characteristics, including diffusion size and structural properties. Additionally, we explore this saturation effect on the temporal behavior of retweets, revealing that retweet intervals follow a stretched exponential distribution, which better captures the gradual decline in engagement over time. Our results underscore the competitive nature of information diffusion in social networks, where tweets have short lifespans and are quickly replaced by new information. This study contributes to a deeper understanding of content propagation mechanisms, offering a model with broad applicability across contexts, and highlights the importance of information overload in structural and temporal social media dynamics.

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#288 — Oral

Capillary Torque On Multipolar Particles At Dynamically Deformed Liquid Interfaces

DIFENSC - Sistemas Complejos

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Abstract Text:

Colloidal particles trapped at fluid interfaces exhibit capillary interactions that can drive migration, alignment, and self-assembly through coupling between particle-induced interfacial deformations and host-interface curvature [1,2]. In this work, we investigate the rotational dynamics of a single dented disk-shaped particle adsorbed at a liquid interface pre-deformed by a cylindrical pillar, which provides a controlled symmetry-breaking curvature field and can be modelled as a capillary monopole, while the particle contributes higher-order multipolar deformations. This problem is motivated by earlier theoretical and experimental studies showing that curved or anisotropically deformed interfaces can induce orientation-dependent capillary interactions and ordered structures through quadrupolar or higher-order coupling [3,4]. Because the particle aligns more rapidly than it translates, the rotational degree of freedom can be isolated, enabling direct measurement of the capillary torque arising from monopole–multipole coupling. To probe this regime, we use an actively controlled pillar platform combined with force sensing and holographic imaging to resolve both the global curvature field and local interfacial undulations under static and time-varying deformations. Our goal is to establish a quantitative framework for capillary torque on multipolar particles at dynamic liquid interfaces and to clarify how imposed curvature fields select preferred orientations and govern interfacial reconfiguration. These results are relevant to the design of responsive interfacial materials and to directed assembly in soft-matter systems with spatially heterogeneous and time-dependent curvature.

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[4] D. S. Ershov, J. H. B. Sprakel, J. Appel, M. A. Cohen Stuart, and J. van der Gucht, Proc. Natl. Acad. Sci. U.S.A. 110, 9220–9224 (2013)

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#291 — Oral

The Nanoparticle Corona As A Complex System: Glassy Dynamics And Machine Learning Bridging Experiments And Theory.

DIFENSC - Sistemas Complejos

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Abstract Text:

Nanoparticles have the potential to cross even the most formidable biological barriers, such as the blood–brain barrier, thereby delivering drugs for treating currently incurable diseases. However, the complexity of the biomolecular corona they form once in our body limits our design. While the composition of the hard corona, including tightly bound proteins, can be characterized relatively well through experiments, understanding its structural evolution remains challenging. Additionally, the highly dynamic soft corona, composed of loosely associated biomolecules, is difficult to analyze experimentally.
We introduce an integrated experimental–computational framework to address these challenges. Firstly, we propose a computational model that simulates the behavior of both the hard [1] and soft coronas [2], capturing their temporal evolution and glassy dynamics. Secondly, we develop a machine learning (ML) method to analyze complex, multi-component spectroscopic data—including UV Resonance Raman, Circular Dichroism, and UV absorbance—to quantify protein conformational changes upon adsorption [3]. Our unsupervised ML framework overcomes the limitations posed by high-dimensional spectral datasets and enables the integration of multiple experimental probes. Together, modeling and data-driven analysis form a comprehensive strategy for understanding the dynamic organization of the corona and the structural response of proteins at nanoparticle interfaces. Employing a complex-systems perspective, this work bridges significant experimental and theoretical gaps, advancing our fundamental understanding of the corona's impact on nanoparticle safety and the development of nanomedical applications.
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#292 — Poster

One-Dimensional Diffusion Of Tethered Walkers

DIFENSC - Sistemas Complejos

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Abstract Text:

We study a one-dimensional system of N identical random walkers with diffusivity D subject to single-file dynamics and an additional constraint where the maximum separation between adjacent walkers cannot exceed a threshold Δ [1]. These ``tethered walkers'' behave as if connected by inextensible strings, causing the system to eventually reach equilibrium. Here, we analyze the system's diffusional relaxation and characterize its equilibrium state using an approximate ansatz for the N-particle probability distribution. This approach allows us to compute single-particle distributions for central and edge walkers, which we benchmark against Monte Carlo simulations and an exact solution derived for the $N=2$ case in both continuum and on-lattice spaces. For $N>2$, the approximation accurately predicts single-particle distributions, though it fails to capture the long-time relaxation of the first- and second-order positional moments.

The Δ-constraint drastically alters the system's long-time behavior compared to the unconstrained case. For all N, edge particles diffuse with an effective diffusivity of D/N, contrasting with the much slower $1/\ln(N)$ decay found when $\Delta = \infty$. Furthermore, numerical results show that the system relaxes exponentially toward equilibrium with a characteristic time scaling as $(N\Delta)^2/D$, which differs from the power-law decay predicted by our ansatz. Finally, we compute the equilibrium system length distribution and its entropy, revealing that the entropic force required to alter this length is linear with a spring constant equal to $$k = \frac{6k_BT}{N\Delta^2}$$ meaning the system macroscopically behaves like an ideal polymer.

[1] Santos B. Yuste, A. Baumgaertner, E. Abad, J. Chem. Phys. 162, 224114 (2025)

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#319 — Poster

Complex Networks In Finance: Applications To Portfolio Optimization And Risk Management

DIFENSC - Sistemas Complejos

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Abstract Text:

Diversification is a fundamental principle of risk-adjusted portfolio construction, yet it has often been underexplored in pairs trading strategies. Pairs trading is a quantitative approach that exploits temporary deviations in the historical relationship between two assets by simultaneously taking long and short positions, assuming that prices will eventually revert to equilibrium. Traditional methods typically prioritize the most highly cointegrated pairs, which can result in overexposure to assets driven by similar market factors and therefore increase systematic risk.

To overcome this limitation, we propose a network-science framework designed to improve diversification in pairs trading portfolios. Financial assets—including stocks, commodities, and cryptocurrencies—form interconnected systems in which assets cluster according to shared dynamics. Capturing this structure is essential for constructing diversified and resilient portfolios. We therefore build a structural asset network based on cointegration relationships and use filtered graph methodologies to obtain an effective representation of the market.

Our findings demonstrate that selecting pairs according to their position within the network significantly improves portfolio performance compared with strategies based solely on the strongest cointegration values. In particular, portfolios composed of pairs containing at least one peripheral asset and connected within the filtered network consistently outperform portfolios built from the top cointegrated pairs, especially in terms of risk reduction. Moreover, peripheral pairs exhibit better performance than pairs formed exclusively by central assets.

We also find that pairs acting as bridges between communities are generally less profitable and involve greater risk. Although these weak ties facilitate information and shock transmission across disconnected market sectors, they are simultaneously exposed to heterogeneous influences and market signals. Consequently, price dynamics between communities may fail to preserve the mean-reverting behavior required for successful pairs trading. These results suggest that identifying and avoiding such bridging pairs is crucial for constructing diversified, stable, and profitable trading portfolios.

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#341 — Oral

Mechanisms Of Self-Chemophoresis

DIFENSC - Sistemas Complejos

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Abstract Text:

A frequent experimental realization of a microswimmer relies on self-chemophoresis. Chemophoresis (also called diffusiophoresis) denotes the motion of a particle immersed in a fluid solution due to a composition gradient. And self-chemophoresis pertains to the case that the gradient is generated by the particle itself through catalytic activity on its surface.
Conceptually one can write phoretic velocity = phoretic coefficient x chemical gradient, whereby the phoretic coefficient captures the mechanism that drives the phoretic motion. In the "classic picture" of chemophoresis, the phoretic coefficient follows from linear response theory and is controlled by the interaction potential between the phoretic particle and the solute. Under the assumption that the only role of the activity is the generation of gradients, the paradigm arises that "self-phoresis is classic phoresis but in a self-generated gradient". It has been shown [1-3], however, that this paradigm may break down, because the activity can also alter the response significantly, leading to a phoretic coefficient dominated by the solute-solute correlations [3-7].
We will discuss these two mechanisms and their relative importance. We will also touch briefly on the recently found [8], unexpected connection with the self-propulsion of an intruder immersed in a shaken granular bath.
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[2] M. De Corato, X. Arqué, T. Patiño, M. Arroyo, S. Sánchez, I. Pagonabarraga, Phys. Rev. Lett. 124, 108001 (2020).
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#351 — Poster

Effect Of Applied Magnetic Fields On The Morphology Of Nematic Nanobridges In Slit Pores

DIFENSC - Sistemas Complejos

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Abstract Text:

In this Communication, we report a molecular dynamics study of the effect of the application of magnetic fields on the morphology of nematic nanobridges of 32,000 oblate Gay-Berne particles in slit pores favouring homeotropic anchoring. In absence of magnetic fields, previous studies show that there are different conformations of the nanobridge, depending on the slit pore width D and the wettability of the walls [1]. Under the application of uniform magnetic field cycles, in which the intensity of the field is increased stepwise until a maximum value and then decreased at the same rate, switching between different nanobridge conformations can be observed if the magnetic field is applied in a perpendicular direction to the global nematic director of the nanobridge. However, there are situations in which the initial bridge conformation is recovered after the magnetic field application, indicating that the switching can only be observed if there are different locally stable nanobridge conformations under the same thermodynamic conditions. Moreover, magnetic fields can destabilise the nanobridge, leading to its breakdown into isolated nanodroplets attached to a single wall.

[1] J. M. Romero-Enrique, Orientational transition in nanobridges of nematic liquid crystals in slit pores, Liq. Cryst. 50 (2023) 1215.

[2] Pablo Romero-Llorente and J.M. Romero-Enrique Effect of applied magnetic fields on the morphology of nematic nanobridges in slit pores, Mol. Phys. 122 (2024) e2428818.

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#359 — Oral

Opinions Inference And Polarization Metrics In Bipolar And Multipolar Political Systems

DIFENSC - Sistemas Complejos

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Abstract Text:

Based on the idea that a population is perfectly polarized when divided in two groups of the same size and contrasting opinions, we propose a general methodology to study and measure the emergence of polarization from social interactions. In particular, we propose the polarization index for bipolar systems. The maximum value of this metric is only achieved when the two conditions (groups of the same size and with contrasting opinions), are fulfilled. It was applied to measure the political polarization in several dichotomous Twitter conversations finding a good agreement with offline data.
In multipolar systems we present the trace of the covariance matrix as a global polarization metric. This metric achieves the maximum value when there are only extreme opinions and they are uniformly distributed among all poles. Similarly, to the polarization index it not only measures how extreme the opinions are but also how evenly is the population divided into the considered factions. We have identified the directions of maximum polarization in tetra polar and pent polar electoral campaigns by principal components analysis, showing that this framework unveils the natural ideological axes of the system. We also present a method to infer opinions in multidimensional contexts through networks of interactions based on an extension of the DeGroot learning process. First, we introduce a generalization to the ideological space of multipolar systems placing each of the n-poles (parties in a multi-party democracy) at the vertex of a regular simplex of dimension $n-1$. By applying this methodology to Twitter data from multi-party Spanish general elections, we find that the main axis of polarization is the left-wing/right-wing split. However, our most striking finding comes from the secondary axes of polarization, as they reveal non-trivial tensions specific to each system. These tensions can be understood in terms of the underlying socio-political context.

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#387 — Oral

Sincronización Explosiva En Redes Adaptativas Y Redes De Alto Orden

DIFENSC - Sistemas Complejos

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Abstract Text:

La sincronización explosiva, transiciones abruptas entre estados incoherentes y sincronizados, acompañadas de biestabilidad e histéresis, es uno de los fenómenos más llamativos en la dinámica de sistemas complejos en red. En esta charla presentamos dos mecanismos distintos capaces de generar este comportamiento. En primer lugar, mostramos cómo redes de osciladores heterogéneos pueden auto-organizarse como "bombas de sincronización": mediante un proceso de percolación competitivo guiado por una regla local que maximiza la coherencia de fase con información descentralizada, la red desarrolla correlaciones estructura-dinámica que precipitan una transición explosiva al añadir o eliminar un único enlace. Este mecanismo, analíticamente caracterizado mediante las técnicas de Coordenadas Colectivas y el ansatz de Ott-Antonsen, unifica bajo un mismo marco conceptual la percolación explosiva y la sincronización explosiva.
En segundo lugar, exploramos cómo la organización microscópica de las interacciones de alto orden, más allá de las interacciones por pares, determina la naturaleza de las transiciones colectivas. Introducimos una métrica, el solapamiento intra-orden de hiperaristas, que cuantifica en qué medida los grupos de interacción del mismo tamaño comparten nodos. Mediante modelos de contagio complejo y sincronización de Kuramoto sobre hipergrafos sintéticos y reales, demostramos que un bajo solapamiento favorece transiciones explosivas con biestabilidad, mientras que un alto solapamiento conduce a transiciones continuas. Estos resultados revelan que no basta con la presencia de interacciones de alto orden para garantizar comportamientos abruptos: la estructura microscópica de dichas interacciones es igualmente determinante.

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#395 — Oral

Modeling Political Polarization As Nonlinear Collective Phenomenon

DIFENSC - Sistemas Complejos

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Abstract Text:

In [1] we proposed a new mechanism for opinion polarization phenomena based on positive or negative social feedback on expressed opinions. We showed that the opinion dynamics can be described as reinforcement learning in a coordination game and derived the structural condition on the network - the existence of more than one cohesive set - for the co-existence of different opinions in the network. Despite simple microscopic update rules, the system exhibits macroscopic phenomena familiar from complex systems physics, including symmetry breaking, bistability, path dependence, and persistent polarization. Importantly, polarization can arise even in the absence of negative influence or bounded-confidence mechanisms.

In my talk I will present the basic model together with two extensions within the same framework: The first addresses the dynamics of public opinion expression [2] and demonstrates how socially reinforced expression can generate spirals of silence and discrepancies between privately held and publicly expressed opinions. The second considers competition between social media platforms [3], where users adaptively choose communication environments that maximize social reward. This leads to segregation dynamics, coexistence of multiple stable equilibria, and hysteresis effects resembling phase transitions in driven nonequilibrium systems.

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[3] Banisch, Sven, Jacob, Dennis, Willaert, Tom, & Olbrich, Eckehard (2026). The social dilemma of online segregation: A dynamical model of platform choice. Rationality and Society, 10434631261428850.

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#401 — Oral

Phase Transitions In The Decision-Making Of Social Animal Groups

DIFENSC - Sistemas Complejos

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Abstract Text:

Collective decision-making in social animal groups often emerges from simple local interactions and can give rise to abrupt transitions between distinct behavioral states. In this talk, we explore how coordination, information transfer, and environmental constraints shape these transitions in animal collectives. Using controlled experimental systems combined with quantitative analysis, we investigate how groups integrate sensory information and social interactions to reach consensus and coordinate movement, particularly in constrained or heterogeneous environments.
Our results highlight the key role of group interactions and sensorial cues in driving collective outcomes, revealing how small changes in environmental conditions or information accessibility can trigger qualitative shifts in group behavior, akin to phase transitions in physical systems. We further discuss how the interplay between individual behavior, group cohesion, and environmental structure governs the efficiency of collective decisions and navigation. These findings contribute to a broader understanding of active and living matter, bridging physics and biology, and provide new perspectives on how collective intelligence emerges in natural systems.

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#33 — Oral

The Exact Solution Of The KWI Model

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

We show how a broad class of two-component square-gradient models of wetting may be solved exactly and clarify how the presence or absence of critical point wetting, in binary and ternary mixtures, is related to universality and symmetry principles at critical end points. We begin by solving a model of fluid interfaces, first introduced by Koga and Widom, in ternary mixtures showing three phase coexistence. Numerical studies had revealed interesting wetting transitions, as well as curious geometrical properties of the component density profiles and led these authors to conjecture expressions for the surface tensions. These conjectures were extended by Koga and Indekeu and predicted that partial wetting may persist up to the line of critical end points, i.e.\ critical point wetting was, unexpectedly, absent. Here, we obtain the exact density profiles and surface tensions for the Koga-Widom-Indekeu (KWI) model using complex analysis and drawing on the theory of algebraic curves. The exact solution determines the location and order of wetting transitions in the surface phase diagram, confirming that critical point wetting is absent. Due to the local component isotropy, the model also displays the remarkable property that microscopic density profiles are mapped by a conformal transform onto the shape of a macroscopic drop whose tensions satisfy the Neumann triangle (the analogue of Young's equation for three fluid interfaces). Critical point wetting seems to be present if the order-parameter components of the mixture describe Ising-like criticality, but is absent if there is a local XY symmetry.

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#48 — Oral

Self-Assembly Of Magnetic Nanocubes: Structural Diversity And Phase Transitions In Finite Clusters

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

Javier Hernández-Rojas 1, Florent Calvo 2

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Abstract Text:

Magnetic cubic nanoparticles, such as hematite and magnetite nanocubes [1,2], are known to self-assemble into a variety of ordered structures driven by dipolar interactions. We present a minimal coarse-grained model for their self-assembly, combining short-range corner-corner cohesion (simple Lennard-Jones potential), steric center-to-corner repulsion (Weeks-Chandler-Andersen component), and long-range magnetic dipolar interactions at the cube centers. Two dipole orientations are studied, along the face normal (001) or pointing at a corner (111).
Using basin-hopping global optimization and parallel tempering Monte Carlo simulations, we map structural phase diagrams for clusters of 8 and 12 particles as a function of dipolar strength μ* and cohesive strength ε. Strong magnetic interactions favor face-bound chains and compact cubic lattices; strong cohesion yields corner-bound columnar rings. Intermediate regimes produce edge-bound, cubatically ordered assemblies [3].
At finite temperature, cubatic ordering peaks near zero temperature while magnetic ordering requires thermal activation. Most clusters show a single first-order-like melting transition, but compact cubic packings first rearrange into entropy-favored, one-dimensional chains before experiencing disorder. Finite-size effects are especially pronounced for 7–9 particle clusters, where multiple sequential transitions appear in the heat capacity with specific signatures on structural order parameters [3].
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#53 — Poster

Phase Stacking Diagrams In Polydisperse Hard Rounded Rectangle Fluids

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

We analyze the sedimentation behavior of a polydisperse two-dimensional liquid-crystal fluid using a local density-functional theory based on scaled particle theory. Polydispersity is incorporated through variations in the roundness of hard rectangular particles interacting solely via excluded area effects. Despite its simplicity, the model displays a rich phenomenology. In bulk, the fluid exhibits isotropic, nematic, and tetratic phases. In sedimentation, we obtain complex phase stacking diagrams featuring multiphasic stacking sequences with up to four stacks of different bulk phases, inverted stacking sequences such as top isotropic and bottom nematic together with top nematic and bottom isotopic, as well as stacking sequences with reentrant stacks such as tetratic and nematic stacks floating between two isotropic stacks. This phenomenology arises as a result of an intricate coupling between particle polydispersity and the effect of gravity. Our approach can be easily adapted to investigate the sedimentation behavior of other polydisperse colloidal systems.

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#83 — Oral

Hydrodynamic Interactions In A Binary-Mixture Colloidal Monolayer

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Colloidal monolayers embedded within a bulk fluid experience long-ranged, effectively compressible hydrodynamic interactions. Far from boundaries, these couplings induce a breakdown of Fick's law beyond a characteristic length scale, yielding anomalous, scale-dependent collective diffusion [1-3]. We extend this framework to bidisperse monolayers comprising two particle species with distinct mobilities [4]. Our analysis shows how interspecies hydrodynamic coupling reshapes collective transport and reveals a new regime in the limit of strongly dissimilar particles. In this regime, the "large(slow)" species' collective diffusivity is not just set by its own properties, but gets instead modified by the diffusivity of the "small(fast)" species via hydrodynamic coupling. This phenomenon can be characterized with the help of scale-dependent Peclet numbers Pe_b and Pe_s for the "big" and "small" particles, respectively, that quantify the relevance of hydrodynamic advection compared to diffusion. The adjoint figure shows how the effective diffusion of the "big" particles is modified according to the the quotient Pe_s/Pe_b, which only depends on the diffusivities and concentrations of the two types of particles. This identifies a robust mechanism by which the transport of slow components can be tuned indirectly by a fast component, despite the overall non-Fickian nature of the monolayer. Our results provide testable predictions for colloidal mixtures and membrane-like systems, and suggest practical strategies for controlling multicomponent transport in soft interfaces by engineering the hydrodynamic contrast

References:
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#86 — Poster

Msptools For GPU-Accelerated Study Of Collective Dynamics Of Plasmonic Nanoparticles Under Optical Excitation

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Optofluidics combines optics and microfluidics to manipulate micro- and nanoscale particles through light–matter interactions. In optical fields, colloidal systems exhibit spontaneous pattern formation, swarming, and self-organization driven by optical binding from coherent multiple scattering, beyond what external fields alone predict explain 1–3. These optical forces arising from coherent scattering 4,5 imply calculation that requires solving the computationally intensive Multiple Scattering Problem (MSP).
We introduce msptools, an open Python package for modeling optical forces in nanoparticle assemblies by solving the Multiple Scattering Problem (MSP). The package provides a rigorous formulation and practical tools to compute particle polarizabilities, scattering fields, optical properties, and resulting forces in many-body configurations. To make large-scale simulations tractable, msptools includes GPU-accelerated workflows and iterative solvers that avoid explicit dense operators constructions, enabling substantial speed-ups.
As an application case study, we consider nanospherical particles illuminated by counterpropagating laser beams. We analyze emergent motion and equilibrium structures, showing that the observed self-organization follows directly from coherent multiple-scattering interactions rather than simple external-field approximations.
These findings have significant implications for advanced optical manipulation systems and understanding self-assembly processes at the nanoscale. Furthermore, by combining GPU acceleration with iterative MSP solvers, our framework makes full multiple-scattering simulations practical at larger scales, providing a foundation for exploring more complex scenarios involving diverse particle compositions, geometries, and optical field configurations.

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#87 — Poster

Neuromorphic Reservoir Computing With Memristive Nanofluidic Diodes

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Memristive systems show conductance states modulated by past electrical stimuli acting as artificial synapses. Most neuromorphic computing systems are based on solid-state memristive devices that use physical environments and electrical carriers different from the ionic solutions characteristic of biochemical and bioengineering applications. Here, we use membranes with multiple nanopores showing different conductance states in an aqueous electrolyte as a model for reservoir computing (RC). To this end, the different membrane conductances obtained with distinct sequences of voltage pulses in the millisecond range are used for the identification of 10-digit inputs in the case of both correct and corrupted inputs. Using the current rectification of the nanofluidic conical diodes, we explore two additional options: (i) the use of the current and its sign instead of the conductance in the digit identification and (ii) the use of an antiparallel arrangement of two membranes instead of the single-membrane unit.

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#95 — Oral

Water Self-Dissociation In Slit Pores Displays Non-Monotonic Behavior As A Function Of Water Filling

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Although nanofluidics and chemistry in nanoconfined liquids has emerged as an exciting field, the quantitative impact of confinement on fundamental properties remains often unclear [1, 2]. Currently, there is not yet consensus on the impact of slit pore confinement on water self-dissociation [1, 2], namely if this ubiquitous elementary reaction is enhanced, unaltered or suppressed by nanoconfinement. We address this question for well-defined water/graphene slit pore systems that allow us to carefully establish the appropriate thermodynamic conditions for different pore fillings, specifically pressure [4, 5]. Anticipating our key results, we show that the energetics of the self-dissociation reaction is very sensitive to even subtle changes of the confinement conditions, leading even to non-monotonic behavior depending on water filling.

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#106 — Oral

Collisional Cooling Induces Phase Separation Of Active Particles

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Motility-induced phase separation (MIPS) is a central collective phenomenon in active matter, theoretically established in the overdamped regime. However, the role of inertia remains poorly understood, despite the large variety of active systems observed at macroscopic scales. Here, we show that inertia fundamentally alters the dynamical origin of MIPS by introducing an effective cooling mechanism that is absent in overdamped active matter. This conclusion is supported by an inertial extension of the direct simulation Monte Carlo method and by a kinetic theory for self-propelled inertial hard spheres derived directly from the microscopic dynamics. In contrast to the overdamped case, both approaches reveal that inertial MIPS does not rely on impenetrability, but instead on a collective cooling mechanism coupling density, polarization, and temperature fields. This mechanism arises from the competition between self-propulsion and a density-dependent collision rate induced by spatial correlations between colliding particles. Our results establish a direct conceptual bridge between inertial active matter and granular physics, opening new perspectives for both fields.

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#138 — Poster

GRAIN SHAPE DEPENDENCE OF THE REVERSE JANSSEN EFFECT IN GRANULAR COLUMNS

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

German engineer Janssen showed that pressure in granular columns does not increase linearly with height as it does in liquids [1,2]. Instead, it reaches saturation due to internal friction and a supportive force-chain structure. In narrow containers, there is an overshoot in the mass of the granular column before reaching saturation. This is hypothesized to be caused by compressive force chains [3]. Here, we revisit these experiments using grains of different shapes—spherical, oblate (lentils), and prolate (mung beans)—within cylindrical containers of varying diameters under the influence of gravity. For all grain types, we recover the classical saturation behavior. In narrow containers, we also observe an overshoot for intermediate heights. This overshoot decreases as the container diameter increases [3]. Interestingly, this decrease is faster for non-spherical grains, likely because their additional degrees of freedom lead to the increase of available system configurations with container size. Among these configurations, those with a force-chain structure favoring the regular Janssen effect would become progressively more dominant, reducing the occurrence of the overshoot.

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#139 — Oral

Correlations In Active Nematic Defects

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

In equilibrium statistical physics, the fluctuation-compressibility theorem states that the variance of the number of particles, in a region of space with size R , scales as σ_N~R^d, with d the spatial dimension. Active systems, however, often exhibit giant number fluctuations (GNF), where σ_N~R^d, with β>d. In contrast, when β < d, the system is classified as hyperuniform (HU). In reciprocal space, hyperuniformity implies that the structure factor scales as S(q)~|q|^α, with α=d-β and q the scattering wavevector, so that S(q)→0 as q→0.

We study an active nematic liquid crystal of microtubules at an oil/water interface, driven out of equilibrium by ATP-fueled kinesin–streptavidin complexes. In the active turbulent regime, the system continuously creates and annihilates ±1/2 topological defects. Previous results in our group showed that β<2 for the system of active defects, for values of R as large as the system size. The system of active defects is thus HU. Using both hydrodynamics and particle-based simulations, we unravel how defect-defect correlation and their creation/annihilation processes all conspire to result in this behavior (Hidden order in active nematic defects, PNAS, 2025).

Recent experiments, however, using larger active nematic cells allow accessing smaller q. In this regime, we observe that S(q) does not vanish at the lowest accessible q, but that instead it decays and saturates to a finite non-zero value. This suggests a crossover from hyperuniform to uniform behavior beyond a characteristic length scale. Uniformity suggests that at sufficiently large length scales random noise, akin to thermal effects, dominates over activity-induced fluctuations. To assess this, we compare our results with those of electric charges in equilibrium, finding that the relation between partial structure factors in this system holds for active nematic defects, thus confirming the transition from HU to uniform behavior.

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#147 — Oral

Spontaneous Convection In Granular Gases In An Arbitrary External Potential

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

The steady states of a granular gas subjected to an energy injection and a time-independent external force are analyzed using a hydrodynamic description. The focus is on the existence of quiescent states, i.e., states with a zero velocity field. We identify the conditions under which quiescent states exist, which involve the system's symmetries through the explicit form of the external force plus the container. When these conditions are not met, the asymmetry induces a steady convective state that can be theoretically described using a perturbation approach. Beyond this limit, some interesting configurations are explored numerically using an event-based molecular dynamics algorithm. The implications of the results for other related systems, such as diffusiophoresis of catalytically active particles and active matter, are discussed.

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#159 — Oral

Relaxation Dynamics Of Small Molecule Ultrastable Glasses

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Vapor deposition provides access to a unique class of organic glasses with exceptional thermodynamic stability. Unlike conventional glasses formed by cooling a liquid to avoid crystallization, these ultrastable glasses (UGs) can be prepared within minutes while reaching stability levels comparable to liquid-cooled glasses aged for millions of years. UGs exhibit remarkable properties, including suppressed two-level systems, a reduced boson peak, anomalous transformation dynamics, enhanced stability in organic electronic devices, and slower crystallization kinetics.
Thin films of vapor-deposited UGs transform into the supercooled liquid through a liquid front that typically propagates from free surfaces or weakly bonded interfaces at constant velocity. This front-mediated transformation can be suppressed by capping the free surface with ultrathin organic layers of higher glass transition temperature (Tg), leading instead to an anomalous bulk transformation characterized by the nucleation and growth of isolated liquid-like regions through kinetic facilitation.
While membrane-based nanocalorimetry provides a macroscopic view of the transformation dynamics [1,2], surface-sensitive probes reveal the local mechanisms governing the process [3,4]. We recently demonstrated that in-situ atomic force microscopy can directly track transformation kinetics by detecting nanoscale surface wrinkles associated with liquid-like regions [3]. In parallel, we developed complementary in-situ electrostatic force microscopy and Kelvin probe force microscopy methods, capable of monitoring changes in surface potential as the glass transforms above Tg into the supercooled liquid [4].
In this presentation, I will show transformation kinetics over a broad temperature range and highlight how surface-sensitive techniques provide unique insight into glass stability and liquid-front evolution in ultrastable organic glasses.
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#215 — Oral

Self-Propulsion At The Nanoscale: Exploiting Molecular Energy Relaxation Mechanisms

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Controlling the dynamics of nanoparticles in liquids is a problem of fundamental interest, with the potential to have an impact in different emerging technologies. Here, we show that the interaction of externally excited anisotropic molecules with the surrounding solvent can give rise to nanoparticle propulsion. We use all-atomic models of excited nanoparticles and of the solvent to investigate with molecular dynamics simulations the emergent particle propulsion as the excess energy is dissipated into the solvent. We report results in liquid water from: (i) nanoparticles functionalized with excited fluorophores; (ii) high energy vibrationally excited molecules. In both cases we find a marked energy flux anisotropy during relaxation which results in a temperature gradient across the nanoparticle and in a net propulsion that leads to significant enhanced diffusion when periodic excitations are applied. In contrast to most models of self-phoresis, we find that propulsion occurs via short impulses after the propelling nanoparticle is excited. From our all-atomic description and a hydrodynamic model we identify the source of propulsion as a transient momentum exchange with the surrounding solvent when hydrogen bonds are broken as a result of the prescribed molecular excitations. Finally, strategies to direct the motion of functionalized nanoparticles using confined environments are also discussed.

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#223 — Oral

Memory-Assisted Acceleration Of Orientational Dynamics In Nanoparticle Suspensions

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

The relaxation of stochastic systems after sudden perturbations is constrained by speed limits and often reveals memory effects that hinder attempts to accelerate their dynamics [1]. Here we demonstrate Kovacs-type relaxation in the electro-orientation of nanoparticles and show how this memory effect limits simple acceleration protocols. Experimentally, the orientational dynamics is monitored optically through field-induced birefringence, which is proportional to the nematic order parameter. When an AC electric field is first set to an extreme value until the birefringence reaches its target and is then switched to the target field (matched two-step protocol), the relaxation exhibits a characteristic Kovacs shoulder [2]. We interpret this behavior within a theoretical framework based on the Smoluchowski equation for the orientational probability density. In the high-frequency AC regime, orientational relaxation is governed by induced dipoles, and the observed memory effect originates from polydispersity, which generates a spectrum of rotational diffusion coefficients and hence multiscale relaxation. Experiments on nanoparticle suspensions with different properties confirm these mechanisms. Building on this insight, we design protocols that mitigate the detrimental effect of memory by sequentially suppressing the slowest active relaxation mode, and we demonstrate substantial reductions in relaxation time compared with single quenches and matched two-step protocols with clay suspensions [3]. More broadly, these results illustrate how memory effects emerge when many degrees of freedom are steered with a single control parameter and provide an experimentally accessible strategy for controlling multiscale stochastic dynamics.
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#227 — Oral

Light-Driven Aggregation Of Microparticles Via Negative Thermophoresis

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Thermophoresis describes the motion of matter under temperature gradients and can give rise to complex nonequilibrium interactions at the microscale. In suspensions of light-absorbing particles, localized heating at the single-particle level generates self-induced thermal gradients in the surrounding electrolyte, leading to thermophoretic interactions that are absent under homogeneous thermal conditions.
Here we report a laser-driven and reversible aggregation process in aqueous suspensions of hybrid polystyrene–magnetite microparticles. Upon irradiation, light absorption by individual particles locally heats the electrolyte solution, creating temperature gradients that induce electrokinetically mediated uphill (negative) thermophoresis. As a result, neighboring particles are driven toward the irradiated region, leading to the formation of dense and dynamic aggregates. The aggregation process can be switched on and off by controlling the laser illumination.
By quantifying the cluster growth dynamics, we show that the effective attraction strongly depends on the electrolyte concentration. Increasing ionic strength progressively weakens the aggregation and eventually suppresses it, consistent with electrokinetic screening effects that reduce the Soret coefficient at high salt concentrations.
To gain further insight into the microscopic origin of these interactions, we directly measure pair interaction forces using optical tweezers. In this configuration, absorbing particles exhibit hot Brownian motion, since the trapped particles remain hotter than the surrounding fluid and generate local temperature gradients that influence nearby particles. Interestingly, the measurements reveal a reversal in the sign of the Soret coefficient, leading to a transition from attractive to repulsive interactions, in agreement with previous reports.

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#240 — Oral

Curvature-Guided Dynamics And Persistence-Induced Localization In Active Soft Matter

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Active soft matter converts local energy injection into motion, stress, and self-organization. Most minimal models describe this process in flat space through propulsion, alignment, and steric interactions. However, many biological and synthetic active systems move on curved, deformable, or internally structured interfaces. In these settings, geometry and topology are not passive backgrounds: they reshape the equations of motion, organize defects, and control transport.
I will present recent work showing how curvature and persistence provide two complementary routes to localization in active soft matter. For active particles confined to curved surfaces, the Levi-Civita connection enters the orientational dynamics as a geometric torque. This torque makes isolated particles follow geodesics and allows heterogeneous curvature to lens, trap, or disperse active trajectories. For active semiflexible filaments, geometric guidance competes with bending elasticity: activity promotes geodesic alignment, whereas stiffness can drive deviations that reduce elastic bending costs. In dilute suspensions, this competition produces curvature-guided rotating bands and density-dependent trapping on necked surfaces.
I will then discuss a distinct localization mechanism in dense active–passive mixtures. Dilute active dopants can fluidize an amorphous host, but sufficiently persistent forcing reorganizes relaxation rather than simply acting as an effective temperature. Persistence allows stress to accumulate and overlap over mesoscopic regions, nucleating voids and localizing rearrangements at their boundaries. The resulting mosh-pit-like regime gives active and passive particles comparable mobility because transport becomes confined to self-generated cavities.
Finally, I will connect these active phenomena to frustrated soft interfaces. In spherical crystals, topology enforces defects whose organization can be tuned between compact clouds and extended scars. In interfacially frozen Pickering emulsions, geometric frustration drives robust sphere-to-icosahedron transformations. In active Janus vesicles, membrane reconfiguration generates run-and-tumble-like dynamics. Together, these results identify geometry, topology, elasticity, and persistence as control parameters for programming nonequilibrium soft matter.

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#243 — Oral

Adaptive Motion Of Janus Rod-Like Colloids In Porous Media Via On-Demand Chirality Switching

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Navigating porous environments is a fundamental challenge for the deployment of artificial microswimmers in applications ranging from soil remediation to targeted drug delivery. In this work, we present a strategy to program the transport of rod-like Janus microswimmers driven by AC electric fields. By leveraging the swimmers' frequency response, we utilize a pre-alignment step that effectively decouples particle orientation from swimmer activity.
Through a stepwise decrease in frequency starting from a static pre-aligned state at 1 MHz, we enable the swimmers to maintain a persistent orientation while triggering active motion at lower frequencies. This method suppresses the inherent chirality typically observed under single-frequency actuation, transforming circular trajectories into persistent motion. Combining experiments with Active Brownian Particle simulations, we demonstrate that this pre-alignment allows for dynamic switching between a 'scanning mode' and a 'traveling mode.' Our findings, quantified via first-passage time statistics, reveal how this approach prevents circular trapping and optimizes transport efficiency within complex porous networks. This dual-mode capability provides a versatile framework for future applications, where the actuation can be chosen or switched to transition between thorough local exploration and rapid long-range transport, depending on the specific target and environmental constraints

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#263 — Oral

Maximising The Mpemba Effect In Granular Fluids

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

The Mpemba effect, commonly described as the phenomenon where an initially hotter system cools faster than a colder one, has become a paradigmatic example of anomalous relaxation and memory effects in nonequilibrium statistical mechanics. Its existence highlights that, in general, the relaxation dynamics of a system cannot be fully characterized by its temperature alone but may also depend on additional variables encoding information about the previous state of the system. Granular gases provide a suitable framework to investigate these effects, since their nonequilibrium nature naturally leads to non-Gaussian velocity distributions and memory effects. We investigate how to prepare non-stationary states in a uniformly heated granular gas in order to maximize the Mpemba effect. Within the first Sonine approximation, the system is characterized by the granular temperature and the excess kurtosis of the velocity distribution. Since the cooling rate depends on the excess kurtosis, we design control protocols that optimize this quantity by tuning the temperature of the stochastic thermostat. We consider protocols with free final time, so that the objective is to determine the optimal control independently of the protocol duration. Using Pontryagin's maximum principle, we show that the optimal preparation protocols are of bang-bang type. We further analyze how the optimal solution depends on the control bounds and on the system parameters, with particular emphasis on the restitution coefficient of the gas.

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#267 — Oral

COVALENT FRAMEWORKS FOR WATER PURIFICATION OF PHARMACEUTICAL CONTAMINANTS

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Pharmaceutically Active Compounds (PhACs) are increasingly detected in aquatic environments, where their persistence and biological activity can affect ecosystems even at low concentrations. Conventional wastewater treatments often remove them only partially, making the development of adsorbent materials able to capture these molecules under aqueous conditions an important challenge. In this context, covalent organic frameworks (COFs) are promising candidates: when immersed in water, they can behave as hydrated soft porous matrices with hydrogel-like features, combining chemical tunability, porosity and compatibility with aqueous media.
Here we use all-atom molecular dynamics simulations with GROMACS to study PhAC adsorption inside hydrated COFs from a soft-matter perspective. Drug--framework contacts and hydration statistics are employed to quantify the affinity of naproxen and propranolol for two related imine-linked COF platforms: TAPB-PDA, formed from TAPB and p-phthalaldehyde, and TAPB-DBBA, a brominated analogue in which two aromatic hydrogens of the PDA linker are replaced by bromine atoms. For each drug, we consider two ionization states representative of pH conditions: neutral and deprotonated naproxen, and neutral and protonated propranolol.
The simulations show that adsorption is governed not only by contact number, but also by chemical anisotropy, hydration and molecular charge. In TAPB-DBBA, bromine atoms break the local symmetry of the framework and induce a preferential orientation of neutral naproxen, whereas the more symmetric TAPB-PDA environment allows both orientations. Hydration analysis indicates that DBBA has a slightly smaller water--framework hydrogen-bond population than PDA, with part of the interfacial contribution redistributed towards brominated sites.
Ionization provides an additional control parameter. Neutral naproxen maintains stable contacts with DBBA, while carboxyl deprotonation hydrates the molecule and suppresses direct COF contacts. Similarly, neutral propranolol remains confined within the pore, whereas protonated propranolol shows intermittent excursions outside the COF region. These results identify hydrated COFs as soft-matter adsorbents whose selectivity emerges from framework chemistry, water structure

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#269 — Oral

Insect Dynamics: Motion And Fluctuations

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Understanding the collective dynamics of living systems composed of many interacting individuals remains a central problem in active matter and biological physics. With this goal, we investigate insect dynamics through a set of controlled experimental systems focusing on ants and moths.
For ants, we study dense collectives confined in quasi–two-dimensional arenas. Under these conditions the system exhibits activity cycles in which it alternates between low-activity states, characterized by the formation of long-lived stationary clusters, and highly active states where most individuals move simultaneously. By analysing spatial number fluctuations within subregions of the system we observe giant number fluctuations characterized by $\langle(\Delta N)^2\rangle \sim \langle N\rangle^{\alpha}$, con $\alpha \approx 1.6–1.7$, in both regimes. Although the scaling behaviour is similar, we hypothesize that the underlying physical mechanisms are different. In the low-activity regime the large fluctuations appear to originate from the spatial heterogeneities introduced by clustering, whereas in the highly active state they may be related to alignment interactions between individuals and the possible emergence of a collective-motion state. This interpretation, however, remains tentative.
Also with ants, we are beginning to explore how the geometry of the substrate influences insect dynamics. To this end, we perform experiments with ants in curved arenas produced by 3D printing, including spherical and toroidal surfaces. In these systems, which are not yet in the dense regime, we vary the total number of individuals and use image analysis to reconstruct trajectories and characterize insect dynamics on curved spaces.
In parallel, we study moths in a cubic cell where individuals typically walk on the flat walls of the system. In this case our aim is to understand and model the encounter dynamics associated with sexual communication by varying the female–male ratio and analysing the resulting trajectories and interaction patterns.

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#277 — Oral

Hydration And Protein Sequestration Into Biomolecular Condensates

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Biological processes such as the sequestration of superoxide dismutase 1 (SOD1) into biomolecular condensates, including fused in sarcoma (FUS) and stress granules, are vital for understanding disease mechanisms, including amyotrophic lateral sclerosis (ALS). Moreover, protein–crowder interactions within these condensates are recognized as fundamental to cellular phase separation and disease-related processes. However, the specific role of the hydration environment in governing SOD1's behavior and transition dynamics within these condensates remains poorly understood, limiting our ability to accurately model these critical biological systems [1]. We incorporate explicit water into an implicit solvent model (OPEP) to investigate how water influences SOD1's behavior, residence times, and transition rates among associative states. We employ the advanced CVF water model, which accurately captures hydrogen-bond networks at the molecular level [3, 4]. While the OPEP model indicates that bovine serum albumin (BSA) crowders reduce SOD1's partition coefficient (PC) into FUS condensates primarily through non-specific interactions, our explicit-water approach points to hydration entropy in BSA as a key contributor to the observed PC reduction. This result offers a new perspective on the system's free-energy landscape, complementing those obtained from OPEP alone. Our research supports the notion that explicitly modeling water can enhance our understanding of protein–crowder interactions and their biological implications, further emphasizing the potential role of water in cellular phase separation and disease-related processes [5].

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#283 — Poster

Self-Diffusion In Confined Systems

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

The self-diffusion process of a hard sphere fluid confined by two parallel plates separated by a distance on the order of the particle diameter is studied. The starting point is a closed kinetic equation for the distribution function that takes into account the effects of the confinement and that is valid in the low-density limit. From it, the Boltzmann-Lorentz equation that describes the dynamics of some tagged particles when the whole system is in equilibrium is derived. An equation that describes the diffusion in the directions parallel to the walls is deduced by applying the Zwanzig-Mori projection technique to the Boltzmann-Lorentz equation, obtaining an explicit expression for the self-diffusion coefficient that depends on the height of the system. A very good agreement between its theoretical prediction and Molecular Dynamics simulation results is obtained for the whole range of heights.

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#287 — Oral

Amyloid Elasticity Through Thermal Fluctuations

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Amyloid fibrils are proteinaceous aggregates in which peptides assemble into extremely long, stable chains with a well-defined supramolecular architecture. They are involved in several neurodegenerative diseases, including Parkinson's and Alzheimer's, although their precise pathological roles remain hotly debated. Beyond disease, amyloid fibrils have emerged as promising biofunctional nanomaterials due in part to the ease with which they can be synthesized in vitro and to their exceptional mechanical properties and stability. These qualities have enabled the creation of a wide range of amyloid-based technologies such as hybrid membranes for water purification and scaffolds for tissue engineering.
Although new amyloid-based technologies are constantly emerging, the relationship between the structure and mechanical properties of amyloid fibrils at the atomic level still leaves room for exploration. This structure-mechanics relation is central both to the rational design of amyloid-based materials and to our understanding of the energetics and dynamics of aggregation in biological environments. Experimental techniques such as AFM and optical tweezers can probe bulk elastic properties but offer limited insight into molecular-level deformation mechanisms.
In this study, we investigate experimentally deposited structures of Aβ40 and Aβ42 fibrils, closely associated with Alzheimer's disease, using atomistic molecular dynamics simulations. We establish a protocol for obtaining fibril conformations that remain stable on the microsecond timescale and, adopting a DNA-inspired local Cartesian coordinate system, characterize their equilibrium structural parameters. Thermal fluctuations away from these equilibrium configurations are then used to extract elastic moduli governing bending, twisting, and stretching deformations.
We apply this analysis to amyloid fibrils with a variable number of residues and filaments, thus examining the role of different regions of the fibril in the elastic behavior and how the elastic moduli change with the number of constituent filaments. We gain quantitative insight into the energetics underlying the hierarchical assembly of fibrils from smaller subunits.

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#302 — Oral

Numerical Simulation Of AC Electrified Jets In A Flow-Focusing Micro-Device

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Electrokinetics is the study of the mechanically driven motion of charged particles and fluids under the influence of an applied electric field. Electric forces applied in liquids are especially relevant in small length scales, making electrokinetics a very active research field for the control of fluid flows and the manipulation of particles in microfluidic devices. It bridges physics, chemistry, and fluid dynamics, powering technologies from environmental soil cleanup to biological cell sorting.
In this work, we present results of a numerical simulation reproducing previous experiments with AC electrified micro-jets in micro-devices directed to produce water-in-oil droplets. The continuous phase is a dielectric mineral oil, while the dispersed phase is a conducting aqueous KCl solution. The viscosity of the outer liquid is one hundred times greater than the viscosity of the inner liquid. In the absence of an electric field, the flows are chosen so that small droplets of the continuous face are produced close to the junction of the flows. An external AC electric field is applied placing metallic electrodes parallel to the channel walls, while the conductive phase is grounded. In this way, a net electric charge appears at the interface of the liquids. The AC electric field acting on this surface charge stretches the jet. The length of the jet increases with increasing applied AC voltage and with decreasing frequency.
Numerical studies allow us to access physical magnitudes that are difficult or impossible to measure in experiments. In particular, we are interested in the structure of the electric potential and field. We compare the results with experimental data, checking the dependence of the breakup length with the applied electric field via the electric Bond number BoE, and the frequency of the applied AC.

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#305 — Poster

Reconciling XPS Simulations And Experiments: New Standards To Quantify And Minimize Discrepancies

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

X-ray photoelectron spectroscopy is a cornerstone technique for materials characterization, providing crucial insights into elemental composition and chemical states. Accurately acquiring and interpreting XPS spectra remains challenging. Theoretical predictions can be a powerful tool to address some of these issues, but their accuracy and robustness need to be well quantified. This work introduces a novel approach to tackle this need by quantifying errors in theoretical core-level binding energy predictions, enhancing the synergy between theoretical and experimental XPS analysis. By employing internal references, experimental noise is minimized, and systematic errors and method uncertainties are differentiated. This error quantification facilitates the optimization of computational methods and opens the door to the detection of inconsistencies in experimental data, ultimately leading to more accurate signal assignments and a deeper understanding of chemical environments.

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#335 — Oral

Molecular Simulation Of CO2 And CH4 Hydrate Dissociation Conditions In Salty Water Using TIP4P/Ice And Madrid-2019 Models

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

This study utilizes molecular dynamics simulations to investigate the cryoscopic effect of NaCl concentration on the dissociation conditions of carbon dioxide (CO2) and methane (CH4) hydrates. The three-phase coexistence temperatures (solid hydrate–aqueous phase–liquid guest) were evaluated at a constant pressure of 400 bar across a range of aqueous NaCl concentrations spanning from 0.0 to 4.0 m. The simulations were performed employing both the direct-coexistence and equilibrium direct-coexistence methodologies.

Water molecules were modeled using the well-established TIP4P/Ice force field, while CO2 and CH4 molecules were represented by the TraPPE force field and a single Lennard-Jones center, respectively. The ion-water interactions were described via the Madrid-2019 force field, maintaining the standard ion-water Lennard-Jones parameters originally developed for combination with the TIP4P/2005 water model to ensure a straightforward implementation.

As anticipated, the results show that increasing the NaCl concentration in the initial aqueous phase leads to a distinct decrease in the dissociation temperature for both hydrate types. The simulated phase equilibria data demonstrate excellent agreement with experimental values reported in the literature. These findings underscore that combining the TIP4P/Ice water model with the Madrid-2019 salt force field accurately captures both the temperature depression trend and the exact three-phase dissociation temperatures, proving to be a robust framework for modeling gas hydrate systems in saline environments.

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#346 — Oral

Molecular Simulation Study Of The Pressure Dependence Of The THF Hydrate–water Interfacial Free Energy.

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

In this work, the tetrahydrofuran (THF) hydrate–aqueous interfacial free energy, γhw, is evaluated along the univariant two-phase coexistence line of the THF hydrate using molecular dynamics simulations. Specifically, γhw is calculated at 100, 250, and 1000 bar, together with their corresponding coexistence temperatures. The interfacial free energy is obtained directly from simulation through the Mold Integration-Host methodology, an extension of the original Mold Integration approach. Water and THF molecules are modeled using the widely employed TIP4P/Ice model and a rigid version of the TraPPE model, respectively. This study extends our previous work, where the same combination of models was used both to describe the univariant two-phase dissociation line of the THF hydrate over a broad pressure range [J. Chem. Phys. 160, 164718 (2024)] and to determine the THF hydrate–water γhw at 500 bar and the corresponding coexistence temperature [J. Chem. Phys. 161, 064701 (2024)]. The values obtained here are in excellent agreement with the only experimental estimate available in the literature, 24(8) mJ/m². To the best of our knowledge, this is the first study reporting predictions of the THF hydrate–water γhw along the entire univariant two-phase dissociation line of the THF hydrate. Our findings indicate the presence of a minimum in γhw at intermediate-low pressures, while overall the interfacial free energy exhibits only a weak dependence on pressure within the studied range. These results further confirm that the Mold Integration-Host methodology provides a direct and reliable route for predicting hydrate–water γhw in hydrates with sII crystallographic structure.

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#347 — Oral

Thermal Action At A Distance In Hydrodynamically Coupled Colloids

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Local temperature gradients profoundly reshape the behavior of colloidal suspensions, altering transport, interactions, and fluctuations in ways that challenge classical isothermal descriptions. While the hot Brownian motion framework successfully captures the dynamics of individual heated particles, the coupled dynamics between a heat-generating colloid and a nearby probe remains largely uncharted. We address this gap by studying the stochastic dynamics of two optically trapped microspheres under a steady thermal gradient. One particle is locally heated through laser absorption, producing an inhomogeneous temperature field that extends to a loosely trapped neighboring bead. We track the three-dimensional trajectories of both particles simultaneously and at high temporal resolution, sweeping across inter-trap distances and heating powers.
A data-driven analysis based on conditional moments allows us to reconstruct the overdamped Langevin equations governing the pair without assuming any functional form in advance. Within the explored range, the dynamics is well described by a linear Langevin model. Exploiting this structure, we infer the drift and diffusion matrices from the self- and cross-correlations of the two-particle fluctuations. Our results reveal how the interplay between thermophoresis and hydrodynamic coupling gives rise to measurable asymmetries in the system's dynamics. Beyond single-particle and force-based descriptions, our work shows how localized thermal gradients can influence the fluctuations of nearby colloidal particles, offering a route to investigate energy transmission, asymmetric response, and fluctuation engineering at the microscale.

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#353 — Oral

Experimental Observation Of Thermal Memory Effects In A Thin Vibrated Granular Layer

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Memory effects such as the Mpemba and Kovacs effects have recently generated a substantial and growing literature across a wide variety of fields, owing to their tendency to appear in diverse physical systems. As we have recently shown, however, these effects are typically confined to brief fast transients, which places stringent demands on the accuracy and time resolution of the experimental methods required for their detection and characterization.
In this work we describe the technical details of the experimental setup that enabled us to report the first experimental observation of thermal memory effects in granular matter. The setup consists of a thin granular layer subject to vertical sinusoidal vibration at frequencies of order 100 Hz. The granular material is composed of identical stainless-steel spheres of diameter $\sigma \simeq 2.38$ mm. The layer thickness is kept below two particle diameters, so that the dynamics is effectively quasi-two-dimensional. A high-speed camera operating at frame rates exceeding 1000 fps tracks the horizontal particle positions, from which the horizontal components of the particle velocities—and hence the horizontal granular temperature—are obtained.
As we will show, following a quench or a sequence of quenches in the driving acceleration, the granular temperature exhibits clear thermal memory effects (Mpemba, Kovacs, and related phenomena). The quenches are synchronized with the camera's internal clock via a digital oscilloscope, providing frame-level temporal precision. This accurate time characterization allows the duration of each memory effect to be determined with high resolution, resolving the short transient intervals over which such thermal memory persists.
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#355 — Oral

Mobility-Induced Phase Separation In A Binary Mixture Of Active Brownian Particles

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

We report a Brownian dynamics simulation study of the mobility-induced phase separation [1] that occurs in a two-dimensional binary mixture of active soft Brownian particles, whose interactions are modeled by non-additive Weeks–Chandler–Andersen potentials inspired by Lennard-Jones potentials used for glass-forming passive mixtures [2]. The analysis of structural properties, such as the radial distribution functions and the hexatic order parameter, shows that the high-density coexisting state in the binary case is spatially disordered, unlike the solid-like state observed for the monocomponent system. The characterization of the mean-square displacement of the active particles shows that both the low- and high-density coexisting states have diffusive behavior for long times. Therefore, the high-density coexisting states are liquid-like in the binary cases. Moreover, diffusive behavior is also observed in the high-density solid-like state for the monocomponent system, which is driven by the presence of active topological defects [3].
[1] M. E. Cates and J. Tailleur, “Motility-induced phase separation,” Annu. Rev. Condens. Matter Phys. 6 , 219–244 (2015).
[2] W. Kob and H. C. Andersen, “Scaling behavior in the β -relaxation regime of a Supercooled Lennard-Jones mixture,” Phys. Rev. Lett. 73 , 1376–1379 (1994).
[3] D. Jiménez-Flores, A. Rodríguez-Rivas and J. M. Romero-Enrique, J. Chem. Phys. 164 , 044901 (2026).

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#357 — Oral

Three-Phase Equilibria Of Hydrogen Sulfide Hydrates From Molecular Dynamics

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

Hydrogen sulfide (H$_2$S) hydrates are relevant in natural gas processing, flow assurance, and energy-related applications involving sour gases. Despite their practical importance, molecular-level predictions of their phase equilibria remain scarce. In this work, the three-phase coexistence line of H$_2$S hydrate was determined from molecular dynamics simulations using the direct coexistence methodology. Simulations were performed in the \textit{NPT} ensemble using the GROMACS package. Water and hydrogen sulfide were modeled with the TIP4P/Ice and TraPPE 4-3 force fields, respectively. Initial configurations consisted of coexisting hydrate, aqueous, and H$_2$S-rich liquid phases within the same simulation box. The hydrate dissociation temperature was identified from the temporal evolution of the potential energy by monitoring hydrate growth or melting over a pressure range from 40 to 800 bar. The simulations reproduce the hydrate--aqueous--liquid H$_2$S coexistence curve with good agreement with available experimental data over the entire pressure range considered. Results show a weak pressure dependence of the coexistence temperature at low pressures and a progressive stabilization of the hydrate phase as pressure increases.
The present results demonstrate that the combination of the direct coexistence approach with the TIP4P/Ice and TraPPE 4-3 models provides a reliable description of H$_2$S hydrate phase equilibria. To the best of our knowledge, this is the first molecular dynamics determination of the H$_2$S hydrate three-phase coexistence line.

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#362 — Oral

Revisiting CO2 Hydrate Dissociation With Large-Scale Molecular Dynamics

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

The thermodynamic behavior of CO2 hydrates has been widely explored using molecular simulation techniques, although comparisons between previous studies are often complicated by the use of different force fields, simulation methodologies, and system geometries. In addition, many reported hydrate dissociation conditions may still be influenced by finite-size effects and by the truncation of intermolecular interactions due to the relatively small systems and short cutoffs commonly employed. In this contribution, we determine the three-phase coexistence temperature, T3, of CO2 hydrates using molecular dynamics simulations specifically designed to minimize these artifacts. The calculations were performed using systems containing more than 3000 molecules together with a long-range cutoff distance of 1.6 nm. The hydrate–aqueous–liquid CO2 equilibrium conditions are obtained through the solubility method, in which the CO2 solubility in water is independently evaluated in equilibrium with a hydrate phase and with a bulk liquid CO2 phase across a range of temperatures at fixed pressure. The intersection between both solubility curves provides the corresponding three-phase coexistence temperature. This methodology, which has recently emerged as an alternative to direct coexistence simulations, is applied over pressures ranging from 100 to 5000 bar. Furthermore, the unlike CO2–water interactions are refined to achieve quantitative agreement with experimental dissociation data. We show that introducing a scaling factor of $\xi = 1.085$ into the Berthelot combining rule accurately reproduces the experimental coexistence line while also capturing the qualitative trend of the dissociation enthalpy. Finally, the simulations provide insight into the anomalous reentrant behavior of the CO2 hydrate dissociation curve. We demonstrate that this phenomenon is associated with a pressure-driven change in the sign of the reaction molar volume, mainly arising from the significantly larger compressibility of the liquid CO2 phase compared with the hydrate and aqueous phases.

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#371 — Oral

Molecular Pathways And Kinetics Of CO_2 Hydrate Nucleation: From Spontaneous Events To Experimentally Relevant Rates

DIFENSC y DFMC-GEFES - Trends in soft condensed matter

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Abstract Text:

We investigate the homogeneous nucleation of carbon dioxide hydrates from aqueous CO2 solutions by means of molecular dynamics simulations using the TIP4P/Ice water model and TraPPE CO2. Simulations are performed at 400 bar over a broad range of temperatures and CO2 concentrations, combining brute-force molecular dynamics at deep supersaturation/supercooling with seeding calculations under less extreme conditions.

A key aspect of this work is the consistent identification of critical hydrate nuclei. For a representative state point, brute-force and seeding approaches yield excellent agreement when the critical clusters are characterized through a linear combination of the local order parameters q3 and q12. This allows us to estimate a nucleation rate of approximately 10^25 m-3s-1 for a CO2-saturated solution at 255 K, corresponding to a supercooling of 3.5 K.

Comparison with our previous results for methane hydrates reveals that CO2 hydrates nucleate several orders of magnitude faster, in line with a lower hydrate–solution interfacial free energy. By combining our nucleation calculations with an independent estimate of the interfacial free energy at coexistence, we predict the temperature dependence of nucleation rates for experimentally relevant CO2-saturated solutions. Our results suggest that direct comparison with experiments becomes feasible at supercoolings above roughly 25 K, whereas homogeneous nucleation is essentially inaccessible below about 20 K, indicating that low-supercooling experiments are likely governed by heterogeneous nucleation pathways.

Finally, we examine whether the solution–CO2 interface promotes hydrate formation by comparing two-phase and single-phase spontaneous nucleation simulations. At the deep supercoolings explored here, no measurable interfacial enhancement or suppression is observed. Overall, this work provides a molecular-level picture of the thermodynamic and kinetic factors controlling CO2 hydrate nucleation, with direct implications for carbon capture, flow assurance, and hydrate-based technologies.

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#105 — Oral

Thermal Analysis And Calorimetry For The Kinetic Study Of Complex Solid-State Processes

GECAT - Análisis térmico y Calorimetría

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Abstract Text:

Thermal analysis and calorimetry has been recently defined as an “interdisciplinary field of science at the intersection of analytical chemistry, physical chemistry, applied physics, and materials science, dealing with thermal and caloric aspects of evolving material systems” [1]. Thermal analysis and calorimetry methods are of paramount relevance for studying complex solid-state processes (solid-solid reactions, gas-solid reactions, decomposition) significant in many practical applications such as materials or energy. Solid-state reactions are heterogeneous processes determined by structure and microstructure. Kinetic studies of these solid-state processes are quite relevant as they provide a model of the behaviour of the process and allow predicting the evolution of the system even under conditions different from those used in the laboratory for extracting the kinetic parameters. Determining the kinetic parameters for these processes is challenging and different procedures have been proposed in literature. Some examples will be provided. Acknowledgments: funded by METHCESFUEL project (funded by the European Union by means of Horizon, the EU framework Programme for Research and Innovation under Grant Agreement no. 101235215) and grant PID2022-140815OB-C22 funded by MCIN/AEI/10.13039/501100011033 and ERDF A way of making Europe
[1] Rotaru and Perez-Maqueda, J. Therm. Anal. Cal. 150(2025) 15229

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#107 — Oral

Advances In CaO-Based Materials For High Temperature Thermochemical Energy Storage: From Fundamental Reactivity To Emerging 3D Printed Architectures

GECAT - Análisis térmico y Calorimetría

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Abstract Text:

The transition towards carbon neutrality requires large-scale, efficient, and cost-effective solutions for storing renewable energy. Among the different thermochemical energy storage (TCES) technologies under development, the Calcium Looping (CaL) process has emerged as a promising candidate for high-temperature energy storage due to the abundance, low cost, and environmental compatibility of CaO-based materials, as well as their high theoretical energy density and suitability for integration into concentrated solar power and industrial waste-heat recovery schemes. Over the past decade, our research group has contributed extensively to understanding and improving CaO-based sorbents for TCES, with particular emphasis on reaction mechanisms, multicycle stability, and material design strategies.
This contribution provides an overview of the current state of CaL-based TCES materials, highlighting key advances in sorbent stabilization, microstructural engineering, and performance optimization under realistic operating conditions. Special attention is given to the role of dopants, synthetic routes, and textural control in mitigating sintering and enhancing long-term cyclability. Beyond powdered sorbents, the field is now moving toward structured CaO-based architectures that enable improved heat transfer, mechanical robustness, and reactor integration. In this context, we present our recent progress in developing three-dimensional CaO-based structures tailored for TCES applications. These architectures open new possibilities for controlling mass- and heat-transport phenomena, enabling more efficient and compact reactor designs.
Acknowledgments: funded by METHCESFUEL project (funded by the European Union by means of Horizon, the EU framework Programme for Research and Innovation under Grant Agreement no. 101235215) and grant PID2022-140815OB-C22 funded by MCIN/AEI/10.13039/501100011033 and ERDF A way of making Europe
[1] PE. Sanchez-Jimenez et al, Applied Energy. 235(2019) p. 543
[2] A. Castro-Chincho et al, J. Energy Storage 138(2025) p. 118603

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#158 — Oral

Heat Capacity And Phase Transitions In Low-Dimensional Materials

GECAT - Análisis térmico y Calorimetría

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Abstract Text:

Heat capacity is one of the most fundamental thermodynamic properties of matter, yet also one of the most challenging to measure with sufficient accuracy as sample dimensions approach the nanoscale. The challenge becomes increasingly severe as the sample mass is reduced, making calorimetric measurements on nanometer-thick materials exceptionally rare. Such measurements are, however, uniquely valuable because they provide direct access to thermodynamic quantities such as entropy changes, latent heat, and critical fluctuations, often inaccessible through other experimental techniques.
In this talk, I will briefly present our group's journey toward pushing calorimetry to ever smaller length and mass scales: from conventional calorimetry to microfabricated membrane-based fast scanning nanocalorimetry operated under ultrahigh vacuum [1], and more recently to microsecond pulse-heating calorimetry [2]. These developments have progressively improved sensitivity and temporal resolution, enabling thermodynamic measurements on samples ranging from thin films down to micron-sized monolayers with masses approaching the 100 fg regime.
I will illustrate how these platforms are opening new opportunities to study phase transitions in systems where thermodynamic measurements were previously out of reach. Examples include the anomalous transformation kinetics of ultrastable organic glasses into their supercooled liquid state [1], phase transitions in ferroelectric oxide membranes [3], and the thermodynamics of emerging low-dimensional magnetic materials [2]. Together, these results highlight how ultrafast membrane-based calorimetry is becoming a powerful tool to directly probe phase transitions, dimensionality effects, and emergent phenomena in nanoscale materials.
[1] A. Vila-Costa et al. Nucleation and growth of the supercooled liquid phase control glass transition in ultrastable glasses, Phys. Rev. Lett. 124(7) 076002 (2020).
[2] Hugo Gomez et al., Microsecond-Pulsed Nanocalorimetry: A Scalable Approach for Ultrasensitive Heat Capacity Measurements, arXiv:2509.18019.
[3] Tapas Bar et al. Domain-induced control of latent heat in freestanding BaTiO3 membranes, arXiv:2604.26089

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#253 — Oral

Aleaciones Heusler Con Efecto Magnetocalórico: Influencia Del Ciclado, Simulación

GECAT - Análisis térmico y Calorimetría

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Abstract Text:

Este trabajo presenta y analiza resultados de aleaciones de Heusler que exhiben el efecto magnetocalórico, específicamente aleaciones nanoestructuradas y libres de tierras raras basadas en Ni-Mn. Los materiales magnéticos magnetocalóricos se caracterizan por su respuesta a campos magnéticos externos. Un proceso cíclico de calentamiento-enfriamiento ocurre dentro de un rango de temperatura de trabajo que idealmente incluye una transición magnética (ferromagnetismo a paramagnetismo), la cual puede combinarse con una transformación estructural con histéresis térmica (austenita a martensita). Una pequeña variación composicional, por ejemplo, del 1% atómico, puede desplazar las temperaturas de transformación en varias decenas de grados. Una opción es la adición controlada y minoritaria de un cuarto elemento a las aleaciones tipo Heusler. En consecuencia, la composición de la aleación puede seleccionarse y ajustarse para un intervalo de temperatura de trabajo específico. Los mayores cambios se han detectado en las aleaciones dopadas con Ti y con Pd.
En cuanto a su aplicabilidad a sistemas de refrigeración magnética, un requisito fundamental es la estabilidad de la respuesta magnetocalórica tras múltiples ciclos. Se han realizado experimentos con diversas aleaciones, observándose que, en algunos casos, no se observa variación, mientras que en otros se produce una disminución de alrededor del 25 % en la respuesta termodinámica y en el efecto magnetocalórico (en los primeros ciclos). Respecto, la histéresis térmica, suele disminuir al acomodarse la fase austenítica.
También se han llevado a cabo estudios de simulación en sistemas integrados donde se aplican campos magnéticos alternos a sistemas formados por material magnetocalórico. Estas simulaciones permiten comprobar la concordancia entre la simulación y el experimento.

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#11 — Oral

Multicenter Bonds Hidden For Almost A Century: The Missing Link Between Strong And Weak Chemical Bonds Leading To A Unified View Of Chemical Bonding And A Better Understanding Of Materials Properties

GEDH - Física, Educación y Sociedad: Aportes desde la Didáctica, la Historia y la Comunicación de la

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Abstract Text:

Condensed matter physicists and chemists seek to understand and control material properties for technological advancement. Central to this effort is a deep comprehension of the chemical bond. However, a century after the birth of Quantum Mechanics, a unified theory of chemical bonding remains elusive because no single quantum operator can be applied to define the chemical bond. We believe that this lack of a cohesive framework hinders our ability to fully grasp the properties of key technological materials. When G.N. Lewis introduced the electron-pair bonding in 1916, two irreconcilable views dominated chemical science: organic chemistry supported shared-shell interactions (covalent view), while inorganic chemistry considered closed-shell interactions (ionic view). In 1981, a similar division in chemistry between molecular chemists and solid-state chemists was described by H.G. von Schenering. In 2026, the situation is even worse since we are experiencing a hyperinflation of chemical bonds and, at the same time, we have forgotten the multicenter bonds, i.e., bonds among more than two atoms, which were proposed in the early days of Quantum Mechanics.

Around 1950, two types of multicenter bonds were defined: the electron-rich multicenter bonds (ERMBs), mainly known as three-center-four-electron (3c-4e) bonds, and the electron-deficient multicenter bonds (EDMBs), e.g., three-center-two-electron (3c-2e) bonds. At present, very few chemists and almost no physicists in Spain know about multicenter bonds because these two bonds have not been properly incorporated into the curriculum of physics and chemistry degrees.

We present, from a historical perspective, the unified theory of multicenter bonding, which addresses the origin and formation mechanism of multicenter bonds and offers a unified view of chemical bonding since multicenter bonds (exhibiting an intermediate strength) are the missing link between strong chemical bonds, like covalent, ionic, and metallic bonds, and weak chemical bonds, like the hydrogen and van der Waals bonds.

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#181 — Oral

La Historia De La Física En Educación Y Divulgación: Experiencias, Recursos Y Retos

GEDH - Física, Educación y Sociedad: Aportes desde la Didáctica, la Historia y la Comunicación de la

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Abstract Text:

La historia de la física constituye un recurso de gran potencial para la enseñanza y la divulgación de la ciencia al permitir contextualizar la construcción del conocimiento científico, mostrar la dimensión cultural de la física y favorecer una comprensión más crítica de sus saberes y prácticas. En consonancia con diversas investigaciones recientes en didáctica e historia de la ciencia, esta ponencia analiza las posibilidades educativas de integrar la historia de la física en la enseñanza y la divulgación de esta ciencia. La comunicación presentará diversas experiencias didácticas desarrolladas en aulas de ESO, Ciclos Formativos y Bachillerato basadas en el uso de episodios históricos, modelos científicos, reconstrucciones experimentales y artefactos históricos, mostrando cómo estos recursos favorecen la modelización, la argumentación y el aprendizaje conceptual. Asimismo, se prestará especial atención al valor educativo de los gabinetes históricos de física y de la cultura material de la ciencia, a partir de estudios sobre la obra pedagógica de actos históricos como Modesto Bargalló, José Estalella y otros ilustres protagonistas de la educación científica en España, cuya obra no ha sido suficientemente divulgada. Finalmente, se facilitarán diversos recursos y materiales de interés para promover la enseñanza y divulgación de la física a través de su historia; invitando a la reflexión sobre los retos actuales para la incorporación efectiva de la historia de la física a la educación STEM y la comunicación social de la ciencia, la formación del profesorado, la presencia de narrativas históricas distorsionadas en libros de texto, las dificultades de la transposición didáctica o la necesidad de enfoques interdisciplinares, inter alia.

Volver al índice

#212 — Oral

ITER: Un Escenario De Aprendizaje Para La Enseñanza Integrada De La Física

GEDH - Física, Educación y Sociedad: Aportes desde la Didáctica, la Historia y la Comunicación de la

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Abstract Text:

El ITER (International Thermonuclear Experimental Reactor) es un proyecto internacional de investigación científica destinado a demostrar la viabilidad de la fusión nuclear como fuente de energía limpia y prácticamente ilimitada. Ubicado en el sur de Francia, reúne la colaboración de la Unión Europea, Estados Unidos, Rusia, China, India, Japón y Corea del Sur. Actualmente el ITER cuenta con un Programa de Visitas para Profesores financiado por la Comisión Europea. Durante dicho programa, docentes de diversos países pueden visitar las instalaciones del ITER, donde además de poder recorrer algunas de las principales infraestructuras, reciben formación especializada de la mano de científicos e ingenieros que trabajan en el proyecto.
Esta ponencia aborda las potencialidades didácticas de hacer uso del ITER en las aulas de Física de enseñanza secundaria, especialmente en Bachillerato. Los ponentes, docentes españoles seleccionados en el Programa de Visitas del ITER en 2026, presentarán distintas propuestas para convertir el ITER en un escenario de aprendizaje STEM de gran interés no solo para abordar contenidos propios de la física nuclear. Como se mostrará, llevar el ITER al aula permite el abordaje didáctico de múltiples saberes del currículo de Física de forma integrada y contextualizada; además de ofrecer un caso real de gran interés educativo para abordar las relaciones entre ciencia, tecnología y sociedad.

Volver al índice

#235 — Oral

The Teaching Of Physics And Astronomy La Enseñanza De La Física Y La Astronomía

GEDH - Física, Educación y Sociedad: Aportes desde la Didáctica, la Historia y la Comunicación de la

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Abstract Text:

La Astronomía es un campo de estudio muy amplio, y de gran interés entre la sociedad en general y el alumnado en particular. En el siglo XXI, los ciudadanos necesitan en su educación las 4 ces: comunicación, creatividad, cooperación y espíritu crítico.
La astronomía puede ser un hilo conductor en cualquier situación de aprendizaje, contribuyendo a la enseñanza de la física venciendo la primera barrera: el interés y la motivación del alumnado.
En este siglo se están desarrollando multitud de misiones espaciales que constituyen grandes proyectos de investigación, y para los que la sociedad debe contribuir y financiar. La enseñanza de la astronomía, como parte de un proyecto de investigación inmerso en las situaciones de aprendizaje del currículo, es la propuesta que se plantea.
Desde el estudio de la luz de las estrellas, al átomo o las misiones Artemis y la asistencia gravitacional para introducir el campo gravitatorio, constituyen ejemplos del uso de la astronomía en el aula en la enseñanza de la Física en todos los niveles de la E.S.O y el bachillerato.
Astronomy is a vast field of study that generates significant interest within society in general and among students in particular. In the 21st century, citizens require the "4 Cs" in their education: communication, creativity, collaboration, and critical thinking.
Astronomy can serve as a common thread in any learning situation, contributing to the teaching of physics by overcoming the first major barrier: student interest and motivation.
In this century, a multitude of space missions are being developed that constitute massive research projects, which society must support and fund. The proposal presented here is the teaching of astronomy as part of a research project embedded within the learning situations of the curriculum.
From the study of starlight and the atom to the Artemis missions and gravitational assist (slingshot

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#366 — Oral

Symbiosis Of Precision: From Bessel'S Geometry To Antropoff'S Chemistry

GEDH - Física, Educación y Sociedad: Aportes desde la Didáctica, la Historia y la Comunicación de la

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Abstract Text:

This study synthesizes the radical transformation of global cartography between 1850 and 1930, a period during which the discipline consolidated as an exact science through the crucial, multidisciplinary convergence of optical physics and industrial chemistry.
The physical infrastructure was firmly established by mathematical geodesy, prominently highlighting Friedrich Bessel's reference ellipsoid, which allowed cartographers to correct the Earth's curvature with strict metric rigor in the complex projections of prestigious European publishing houses such as Justus Perthes. Likewise, critical technological innovations, such as the strategic use of invar, an advanced alloy with near-zero thermal expansion, and the continuous refinement of optical instruments like geodetic theodolites and heliotropes, guaranteed field angular measurements of unprecedented precision worldwide.
In parallel, the chemistry of materials completely revolutionized map production, aesthetics, and overall legibility. The rapid transition from unstable natural pigments to synthetic dyes derived from aniline and transition metals (including chromium, cadmium, and cobalt) enabled a strict chromatic standardization vital for strategic military mapping and educational purposes.
In this context, the text analyses the profound influence of Andreas von Antropoff, whose vision of atomic periodicity and his innovative spiral periodic table provided a deeper understanding of the stability and chemical purity of the reagents necessary to engineer stable, lightfast printing inks. The widespread adoption of photolithography, based on the specialized chemistry of dichromate and organic colloids, completed this evolution by allowing the direct, error-free transfer of complex optical data to the physical medium.
Finally, the study addresses how prominent figures such as Hermann Haack and Albert von Kampen successfully integrated these technical advancements into large-format wall maps and high-fidelity historical atlases.
It concludes the cartographic map of this period is not merely a geographical representation, but a highly complex physicochemical document where laboratory precision and field measurement permanently merge to preserve human knowledge eternally.

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#386 — Oral

Promoviendo La Cienca De La Microgravedad En Vuelo Parabólico Acrobático Con Perspectiva De Género

GEDH - Física, Educación y Sociedad: Aportes desde la Didáctica, la Historia y la Comunicación de la

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Abstract Text:

Las oportunidades para realizar investigación científica en condiciones de microgravedad son escasas y muy competitivas. En esta charla hablamos sobre la plataforma de microgravedad con vuelos parabólicos en avioneta acrobática de la Universidad Politècnica de Catalunya UPC y el Aeroclub Barcelona-Sabadell. Mediante una técnica innovadora se vienen realizando campañas de microgravedad en el Aeropuerto de Sabadell desde hace 15 años con un doble objetivo: científico y divulgativo. Por un lado la plataforma está abierta a experimentación científica. Y mediante el concurso internacional 'Barcelona ZeroG Challenge' se han realizado ya cinco ediciones de un concurso en el que los estudiantes foman equipos multiculturales y multidisciplinares para volar sus propios experimentos científicos con la condición de que la gravedad alterada debe ser el vector principal. En la edición de 2026 de esta campaña de vuelos parabólicos UPC en Sabadell se ha puesto el foco en la perspectiva de género. Las participantes del vuelo parabólico han sido seis mujeres, cinco de ellas integrantes de la asociación 'Hypatia Mars' y se han recogido datos para tres experimentos científicos. La campaña ha tenido una importante repercusión mediática y se ha realizado un concurso en las escuelas entre niñas y niños de 6-12 años para diseñar una mascota que voló a su vez en el vuelo parabólico como indicador de microgravedad. Discutimos desde el marco conceptual del aprendizaje basado en retos y desde esta experiencia de más de 10 años cuáles son los factores que contribuyen al éxito de estas campañas científicas y divulgativas. El reto de la investigación espacial con la vuelta de los vuelos espaciales a la Luna atrae el interés y es una oportunidad para divulgar estudios científicos y valores humanos.

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#66 — Oral

Nanoscale Imaging Of Anode-Free Plating/Stripping

GEE y DFMC-GEFES - Energía, Almacenamiento y Seguridad de Suministro en la Era de la IA

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Abstract Text:

Achieving reversible anode-free solid-state batteries critically depends on controlling alkali-metal nucleation, growth, and dissolution at buried solid-electrolyte/current-collector interfaces. However, the nanoscale mechanisms governing plating and stripping remain largely inaccessible to conventional operando probes. Here, we introduce virtual-electrode low-energy electron microscopy (VE-LEEM), combined with photoemission electron microscopy (PEEM) and atomic force microscopy (AFM), to directly visualize anode formation and dissolution with nanoscale resolution. Using this platform, we resolve the early stages of Li and Na plating, showing that both systems converge toward common dynamic scaling regimes once a continuous metal layer is established, despite following distinct coarsening pathways governed by surface energetics. In contrast, stripping proceeds through asymmetric mechanisms dominated by grain-boundary unzipping and cluster decay, leaving behind a persistent interfacial residual layer. These observations reveal interfacial and cohesive energetics as fundamental constraints on reversibility in anode-free architectures.
Building on this approach, we discuss ongoing experiments exploring how ultrathin metallic interlayers and temperature modify the earliest stages of anode formation. VE-LEEM observations indicate that both parameters tune interfacial energetics and diffusion pathways, potentially reshaping nucleation density and early coalescence modes. Overall, this work establishes VE-LEEM as a versatile platform to resolve buried electrochemical interfaces at the nanoscale and provides an energetic framework to guide the rational design of durable, high-energy anode-free solid-state batteries.

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#123 — Oral

Optimization Of Energy Production In Concentrated Solar Power With Advanced Optical Sensors

GEE y DFMC-GEFES - Energía, Almacenamiento y Seguridad de Suministro en la Era de la IA

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Abstract Text:

This work presents advancements in the development of an optical sensing system to monitor, supervise and control the operation of Concentrated Solar Power (CSP) plants with the purpose of optimizing energy production. This relies on the fine adjustment of extreme solar radiation and thermal conditions achieved at tower receivers, dealing with concentrated solar fluxes up to 1.5 MW/m2 and temperatures with peaks of 1000 ºC. The key challenges for these measurements include calibrating sensors under extreme conditions, ensuring sensor durability, accounting for environmental factors and managing cost considerations. To accurately quantify these magnitudes, a precise and deterministic measurement system is being researched within the framework of the European research project ASTERIx-CAESar (https://doi.org/10.3030/101122231).

State-of-the-art solutions, such as radiometers and camera-based techniques, seem suitable for this scenario. However, strict requirements associated to their maintenance and assembly constraint their practicality and usability in compact and high-resolution stations. To solve these limitations, a novel optical fiber-based sensing system is proposed in this work, as a feasible, passive and robust alternative for the measurement of concentrated solar flux and high temperatures. First, special ad-hoc optical fibers have been designed as direct solar radiation collectors. Coupling them with photodetectors and power meters, the system provides the measurement of the concentrated solar flux in a minimum invasive way. Secondly, arrays of femtosecond Fiber Bragg Gratings (fs-FBGs) were fabricated to measure the high-temperature surface distribution in the central receiver by calculating the relationship between the fiber thermal expansion (when exposed to heat) and its optical properties. Both technologies were successfully tested at the High Flux Solar Simulator (HSSS). This facility, based on Xenon arc lamps, served as an experimental scenario for the optical sensors resulting in the demonstration (TRL4-5) of efficiency, adaptability and precision of both methodologies.

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#162 — Oral

Modelado Físico De Un Sistema De Disco Parabólico Para La Producción De Combustibles Solares: Hacia La Seguridad Del Suministro Y El Almacenamiento Químico

GEE y DFMC-GEFES - Energía, Almacenamiento y Seguridad de Suministro en la Era de la IA

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Abstract Text:

La descarbonización de la economía mundial y la seguridad de suministro requieren sistemas de almacenamiento masivo que transformen la energía solar intermitente en vectores químicos de alta densidad energética. En este escenario, la producción de combustibles solares a partir de biomasa residual, procedente de residuos orgánicos y no de cultivos energéticos, destaca por su capacidad de cerrar el ciclo del carbono y garantizar el suministro sin comprometer recursos alimentarios. El uso de tecnologías de concentración solar, como los discos parabólicos, permite alcanzar las altas temperaturas necesarias para activar estos procesos termoquímicos de conversión.
En este trabajo se presenta el modelado de un sistema de disco parabólico de 44 m2 acoplado a un receptor volumétrico poroso presurizado, diseñado para suministrar calor de alta temperatura a procesos termoquímicos. La metodología combina un análisis óptico mediante trazado de rayos con un estudio térmico basado en balances de masa y energía. Los resultados muestran que el sistema puede proporcionar calor de proceso a temperaturas cercanas a 907ºC y una potencia de 22kWth en condiciones de diseño, parámetros idóneos para alimentar la gasificación de biomasa.
Un hallazgo relevante del estudio es que los valores de rendimiento térmico encontrados para Salamanca (España) y Ouarzazate (Marruecos) son muy similares, en torno al 80.2%. Este resultado sugiere que el despliegue de esta tecnología en latitudes del sur de Europa es viable, lo que facilitaría la seguridad de suministro local y la soberanía energética regional mediante el aprovechamiento de recursos autóctonos.
Por último, este modelo basado en principios físicos fundamentales podría constituir un primer paso hacia el desarrollo de un gemelo digital del sistema, sentando una base útil para explorar futuras estrategias de operación inteligente.

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#164 — Oral

Scaling Up The Production Of Mesoporous Graphene Through Atmospheric Pressure Plasma Technology For The Improvement Of Metal-Sulfur Batteries.

GEE y DFMC-GEFES - Energía, Almacenamiento y Seguridad de Suministro en la Era de la IA

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Abstract Text:

None of the traditional methods for graphene synthesis offers a single-step, low-cost approach. However, plasma technology represents a significant advance in this field. Microwave plasma torches (i.e. TIAGO torch) exhibit high reactivity, being capable of inducing precursors decomposition reactions with high efficiency (~100%), surpassing traditional chemical processes.
Since it is deeply engaging to optimize this technique, a process refinement has been conducted based on two key parameters: the amount of ethanol considered [1] and the applied power [2]. It was discovered that microwave power is the optimal parameter for upscaling the process, without compromising material properties and quality. It has also been discovered that the inclusion of a metallic shielding around the TIAGO reactor reduces energy loss by radiation, significantly increasing the efficiency of the graphene synthesis process [3].
Recently, plasma-synthesized graphene has been successfully used in different high-impact applications. It has been demonstrated that the porosity properties of this graphene [3] can fight the shuttle effect, a phenomenon taking place in Li-S batteries resulting in a loss of battery capacity and faster degradation of performance over time. The integration of graphene in sulfur-graphene composite cathode has been proven to be a suitable strategy for the design of Li-S batteries with ultralong cycle life [4].
[1] A. Casanova et al, Fuel Processing Technology, 212 (2021) 106630.
[2] J. Toman et al, Fuel Processing Technology, 239 (2023) 107534.
[3] F. J. Morales-Calero et al, Chemical Engineering Journal., 498 (2024) 155088.
[4] J.M. Blázquez-Moreno et al, Journal of Power Sources, 630 (2025) 236173.
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#173 — Oral

Operando Study Of The Anode/Electrolyte Interface Formation In Li And Na Solid State Batteries

GEE y DFMC-GEFES - Energía, Almacenamiento y Seguridad de Suministro en la Era de la IA

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Abstract Text:

Solid state batteries (SSB), expected to be in the market in a short future, are advanced energy storage devices in which the usual flammable liquid electrolyte is replaced by solid materials, polimers or ceramics, offering higher energy density, improved safety and faster charging. But SSB's are still facing challenges similar to the current batteries technology like the usual dendrite formation after charge-discharge cycling. We have study Li/LiLaZrTaO and Na/NaGdSiO SSB systems in the so called zero-excess or anode-free configuration, where the anode is formed in situ at the interface between the solid-state electrolyte and the anode current collector during the first charging cycle, but instead of a current collector we have used surface electron flooding with an electron gun to promote the Li diffusion allowing in this way (i) the study of the anode growth evolution in operando conditions and (ii) the chemical anode characterization. The study of the early stages of this anode nucleation can help to identify the conditions (anode surface morphology, chemical changes, nucleation sites,...) that favours battery degradation due to consecutive cycying. We have used synchrotron spectroscopic techniques (XAS, XPS) with lateral resolution (XPEEM) to get insights into the early stage chemistry (different chemical species present at the interface) of the anode growth nucleation, revealing as well the influence of the various experimental conditions impacting the anode morphology, conditions like the use of different interlayer materials to modify the anode growth conditions. We have implemented this spectromicroscopy method for two solid electrolytes, LLZTO and NaGdSiO, to characterize in operando conditions the initial anode formation and the crucial electrolyte-anode interface which is otherwise not easily accessible with other surface science techniques.

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#249 — Poster

Nickel-Based Cathodic Catalysts Prepared By Magnetron Sputtering For Anion Exchange Membrane Water Electrolysis

GEE y DFMC-GEFES - Energía, Almacenamiento y Seguridad de Suministro en la Era de la IA

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Abstract Text:

Green hydrogen, obtained through electrolysis processes, constitutes a viable alternative to both traditional energy vectors (fossil fuels, methane) and reducing agents in numerous industrial processes. This transition is justified by its high calorific value per unit mass and its capacity to minimized negative environmental impacts, such as CO_2 emissions into the atmosphere derived from industrial and energy-related processes. Moreover, there are relevant geopolitical reasons that support advancing toward a new paradigm based on hydrogen, progressively replacing fossil fuels and natural gas.
An emerging technology for the production of green hydrogen is low-temperature water electrolysis based on anion-exchange membranes. This technology does not present limitations associated with the cost and availability of catalysts (as it is not based on the use of critical raw materials such as platinum group metals) and operates with aqueous solutions containing low electrolyte concentrations, which provides greater process stability and overall durability of its components.
A key element of the present research project is the use of dry physical deposition processes, in particular reactive magnetron sputtering in an oblique-angle deposition (MS-OAD) configuration. This approach allows, in a single step, to fabricate and deposit the active phase (i.e., the electrocatalyst) incorporated in the electrolyzer stacks.
To date, most research and optimization efforts following this approach have focused on water oxidation reactions boosted at anodic catalysts deposited on suitable porous transport layers used as current collectors and distributors of reactants (water electrolyte) and products (oxygen gas). On the other hand, water reduction at the cathode side of the membrane electrode assemblies have been much less explored. Thus, in this work, we will present preliminary results of the physico-chemical characterization and electrochemical performance of recently developed nanostructured nickel based cathodic catalysts prepared by MS-OAD, aimed to replace Pt-based catalyst traditionally used for this purpose.

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#348 — Oral

Solar PV Expansion And System Flexibility In Spain: Ramping Challenges Under Limited Interconnection

GEE y DFMC-GEFES - Energía, Almacenamiento y Seguridad de Suministro en la Era de la IA

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Abstract Text:

The rapid expansion of solar photovoltaic (PV) capacity proyected in Spain's National Energy and Climate Plan (NECP) raises critical questions regarding the system's ability to maintain stability under high shares of variable renewable energy sources. Building on our previous analytical framework applied to Germany, this study evaluates whether the Spanish electricity system possesses sufficient flexibility to accommodate the pronounced ramping requirements induced by solar PV, particularly during sunset periods. Using hourly generation and demand data, we compute seasonal duck curves and estimate ramping needs, comparing them with the available flexibility provided by key technologies such as combined-cycle gas turbines, hydro reservoir plants, and pumped-storage facilities.
The analysis highlights that Spain's higher solar irradiation leads to deeper midday reductions in residual load and steeper evening ramps than those observed in Germany. While Spain benefits from a relatively significant hydro capacity, the results suggest that existing storage and dispatchable resources may be insufficient to fully absorb future ramping requirements as PV capacity scales up. In contrast to the German case—where cross-border electricity flows play a central role in balancing the system—Spain faces structural limitations due to its relatively low level of interconnection, particularly with France. This constraint reduces the ability to rely on external flexibility and increases dependence on domestic sources.
The findings point to a critical trade-off between solar expansion and system flexibility, emphasizing the need for accelerated deployment of storage technologies, enhanced demand-side management, and further development of interconnection infrastructure. The Spanish case thus provides a relevant benchmark for understanding how geographically constrained systems can address the challenges of large-scale renewable integration in the absence of strong cross-border support, offering insights for energy policy and market design in similar contexts.

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#392 — Oral

Continuous Production Of Hydrogen By High-Temperature Electrolysis, From Renewable And Intermittent Energy Sources

GEE y DFMC-GEFES - Energía, Almacenamiento y Seguridad de Suministro en la Era de la IA

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Abstract Text:

Between 2021 and 2025, CIEMAT, IMDEA Energía, UCM, and CEU San Pablo collaborated on the design, construction, operation, and characterization of an integrated and manageable system for the continuous production of hydrogen by high-temperature electrolysis, using renewable and intermittent energy sources. This collaboration falls within research line 3 (LIA3) of the Community of Madrid's Strategic Positioning in R&D&I for Green Hydrogen and Fuel Cells, within the Complementary Plan for Energy and Green Hydrogen under the Recovery, Transformation, and Resilience Plan funded by the European Union – Next Generation EU. To achieve this objective, the research activity covered all stages and scales, from the synthesis and characterization of materials to the production and characterization of cells, stacks, and ultimately, electrolyzers at a scale of 10 kWe.
UCM and CEU USP, in coordination with the Institute of Nanoscience and Materials of Aragon (CSIC-INMA) and the National Renewable Energy Centre (CENER), have focused on the development of new materials such as SOEC electrodes, initially at laboratory scale and subsequently transferring the technology for industrial development.
CIEMAT has developed and validated an experimental testing unit for solid oxide cells, both at the single-cell and stack levels, as well as developing materials for fuel electrodes intended for the co-electrolysis of water and CO_2, in order to optimize synthesis gas production.
Finally, IMDEA Energy has worked on the analysis and development of an integrated system composed of a solar steam generation system, thermal and electrical storage systems (flow battery), and a balance of plant with a solid oxide electrolyzer. This paper will present the main results obtained and the scientific challenges addressed.

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#9 — Poster

Reorganización Multifractal Del Régimen De Precipitación En Las Cuencas Internas De Catalunya Bajo Escenarios Climáticos Futuros

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

La precipitación en regiones mediterráneas se caracteriza por una elevada intermitencia y una organización compleja a múltiples escalas temporales. Evaluar cómo estas propiedades pueden modificarse bajo escenarios de cambio climático es fundamental para comprender la evolución futura de los regímenes de lluvia y sus posibles implicaciones hidrológicas. En este trabajo se analiza la evolución proyectada de la estructura multifractal de la precipitación en las cuencas internas de Catalunya a partir de simulaciones climáticas regionales bajo los escenarios RCP4.5 y RCP8.5 procedentes del proyecto RESCCUE.

Se analizaron series mensuales de precipitación correspondientes a 326 estaciones mediante el método Multifractal Detrended Fluctuation Analysis (MFDFA). A partir de los tres parámetros principales del espectro multifractal (α_0, W y γ) se definió un índice de complejidad normalizado (CI), que permite sintetizar las propiedades multifractales del régimen de precipitaciones. Para reducir la dependencia de cada modelo se construyó un ensemble climático del que se obtuvieron campos espaciales interpolados de CI para el periodo histórico y los escenarios futuros.

Los resultados muestran patrones espaciales coherentes de complejidad multifractal en la región de estudio, con un gradiente territorial asociado en parte a la distancia al litoral mediterráneo. En comparación con el periodo histórico, gran parte del territorio presenta una disminución futura del CI, especialmente bajo RCP8.5. El análisis de los cambios en los parámetros multifractales indica que esta reorganización está dominada por variaciones en el parámetro γ, lo que sugiere un aumento relativo de la asimetría del espectro multifractal y, por tanto, un aumento de la intermitencia y de la irregularidad del régimen de precipitaciones.

Estos resultados ponen de manifiesto el potencial de los indicadores multifractales para detectar cambios estructurales en los regímenes de precipitación bajo forzamiento climático y aportan una nueva perspectiva sobre la evolución futura de la complejidad de la lluvia en regiones mediterráneas.

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#15 — Oral

Impact Of Mesoscale Eddies And Dynamics On AMOC And Its Drivers

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

Ocean mesoscale eddies play a critical role in shaping large-scale ocean circulation, yet their influence on the Atlantic Meridional Overturning Circulation (AMOC) and its response to climate change remains uncertain. Most current climate projections rely on low-resolution models that do not fully resolve mesoscale processes, potentially introducing systematic biases in future AMOC projections. Using an ensemble of 14 models combining eddy-rich (~8 km grid spacing) and low-resolution models from EERIE and HighResMIP (5 pairs and 3 only eddy-rich versions), alongside observations, we assess how resolving ocean mesoscale dynamics affects AMOC behaviour over the period 1950-2050. Our results show that eddy-rich models tend to produce stronger AMOC weakenings and a more pronounced shoalings of the Labrador Sea mixed layer depth than their low-resolution counterparts. This enhanced response is associated with a greater surface freshening trend and stronger salinity control over density variability in the Labrador Sea. Eddy-rich models also show better agreement with observed AMOC trends during the instrumental period. Together, these findings suggest that low-resolution models may systematically underestimate future AMOC weakening, with important implications for CMIP-based climate projections and associated risk assessments.

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#60 — Poster

Moisture Source Contributions To North Atlantic Tropical Cyclone Precipitation Under Future Warming Scenarios

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

While intensification of North Atlantic (NATL) tropical cyclone (TC) rainfall is projected under future climate scenarios, the underlying changes in moisture source contributions have not been fully examined. Using high-resolution FLEXPART-WRF simulations driven by a downscaled, bias-corrected CMIP6 dataset, we quantified regional and basin-wide future changes in moisture supply for TC-related precipitation under the SSP2-4.5 and SSP5-8.5 scenarios throughout a Lagrangian approach. Our analysis reveals that 6-hourly moisture uptake is projected to increase by 9–20% across the basin, driving a corresponding intensification in storm-related precipitation of 1.8% to 12.5%. The relationship between warming and TC rainfall appears complex and non-linear; specifically, although mid-century follows the Clausius–Clapeyron scaling rate, the sensitivity of precipitation to warming decreases significantly toward the end of the century. Local moisture supplies near TCs are identified as the primary driver for this intensification, whereas the relative importance of remote moisture origins declines. Additionally, localised rising in moisture transport from the western NATL, the Caribbean Sea, and the Gulf of Mexico substantially supports increases in rainfall totals for landfalling TCs in the southeastern United States. These results emphasise the role of TCs in moisture transport from the ocean to land as the climate warms, with critical consequences for regional flood vulnerability.

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#69 — Oral

An Update On Stratospheric Contraction And Impacts Of Climate Change In The Stratosphere

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

Stratospheric contraction is a key fingerprint of climate change, which presents many advantages when determining trends compared to other variables. However, the assessment of stratospheric contraction has been traditionally precluded by lack of observational data to estimate it. Here using reanalyses and TIMED/SABER satellite data we evaluate the trends in stratospheric thickness and height evolution of the critical layers that define it for 1980–2022, the tropopause and the stratopause. The results suggest that stratospheric contraction trends are significantly greater than previously estimated from models and that contraction has been even faster for the last decades. Variations in the position of the stratopause are the main driver of the changes in stratospheric thickness. Also we find significant inter-reanalyses dispersion when evaluating the results.

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#91 — Poster

Moisture Sources And Downstream Hydroclimatic Contribution Of A Deforested Agricultural Frontier In Rondônia, South-Western Amazonia

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

The region of Rondônia, in south-western Amazonia, has undergone intense land-use change since the 1980s, characterised by widespread deforestation and the expansion of agricultural areas, particularly soybean and maize croplands. These transformations may affect evapotranspiration, atmospheric moisture recycling and the hydroclimatic connectivity between Amazonian landscapes and downstream regions of South America. In this study, we analyse the evolution of dry conditions in Rondônia during 1980–2023 and examine its dual role as both a receptor and a source of atmospheric moisture. Using a Lagrangian moisture-tracking framework, we identify the main moisture sources that contribute to precipitation over Rondônia and quantify where moisture exported from this area is subsequently released as precipitation. Backwards and forward trajectories were computed using a 10-day residence time, allowing annual and seasonal moisture uptake and downstream moisture contribution to precipitation to be assessed. Dryness was evaluated using drought-related hydroclimatic indicators such as the standardised precipitation index (SPI) and the standardised precipitation-evapotranspiration index (SPEI). The results reveal that the most important moisture sources for this region are the southeastern Amazon, Cerrado, and tropical eastern South Atlantic Ocean. An intensification of dry conditions in Rondônia is consistent with the precipitation decline, less moisture supply from the terrestrial sources, and agricultural expansion. At the same time, the region remains strongly connected to broader South American moisture pathways, contributing water vapour to regions located further downstream. These contributions also help sustain precipitation-dependent vegetation, highlighting the importance of Rondônia in regional atmospheric moisture redistribution and land–atmosphere interactions.

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#92 — Poster

Drying In The Congo River Basin: Attribution From Atmospheric Moisture Transport

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

The Congo River Basin, located in central-equatorial Africa, is one of the most important hydroclimatic regions, encompassing major river systems and extensive tropical forests. It is also one of the key rainfall regions in the tropics, supporting ecosystems, river discharge, and millions of people. In this study, we identify an area within the basin that has experienced a marked drying trend during the 1981–2023 period. For this region, we used global outputs from the Lagrangian model FLEXPART to diagnose the main moisture sources contributing to precipitation. Our results show that precipitation over the target region has decreased and potential evapotranspiration has increased, explaining the aridification trend. The Lagrangian analysis reveals that precipitation over the Congo River Basin is supplied by three oceanic moisture sources: the Atlantic Ocean, the Indian Ocean, and the Red Sea and three continental sources: local recycling within the study region, the surrounding Congo region, and external terrestrial areas. Moisture-source diagnostics indicate that local recycling and the rest of the Congo basin dominate the climatological moisture supply, making terrestrial sources the major responsible for supplying moisture. However, the trend analysis reveals a weakening in the absolute contribution of moisture to precipitation from all sources, while relative trends show that locally recycled moisture inputs decline less rapidly than the rest.
A Ridge-based trend attribution suggests that the observed negative precipitation trend is more strongly associated with weakening oceanic moisture contributions than with changes in continental sources, although the surrounding Congo region emerges as the leading individual contributor. Additional analysis of vertically integrated moisture flux divergence further indicates that the drying hotspot lies within a climatologically convergent moisture regime that has weakened over time, consistent with increasingly unfavourable atmospheric conditions for rainfall.

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#114 — Oral

The Role Of Mesoscale Ocean Eddies In Global Climate Prediction

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

Climate predictions are essential tools for socio-economic decision-making and the development of effective adaptation strategies. Yet, while current climate models can achieve notable skill for predicting sea surface temperatures in key regions like the North Atlantic, their ability to accurately forecast the atmospheric circulation and the continental climate is limited. This gap stems from structural model deficiencies rooted in the misrepresentation of critical ocean-atmosphere processes.
In this contribution, we present the methodological basis and first results of the ERC project PREDDYCT, whose main working hypothesis is that mesoscale ocean eddies — turbulent rotating structures that are unresolved in climate prediction models — are the key missing ingredient to bridge this gap. The major workhorse of the project is IFS-NEMO, a state-of-the-art coupled ocean-atmosphere model whose eddy-resolving configuration offers an unprecedented opportunity to explicitly simulate mesoscale dynamics in a climate prediction framework. Specifically, we present the ongoing tuning of this configuration, which seeks to correctly represent key climatological aspects critical for the atmospheric teleconnections bridging the highly predictable ocean basins, such as the Tropical Pacific and North Atlantic, with the European climate. These first steps lay the groundwork for a new generation of climate predictions capable of delivering more realistic and trustworthy forecasts at regional to global scales.

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#132 — Oral

Impact Of High-Vertical Resolution Simulations In The UTLS On The Representation Of Climate Change Around The Tropopause

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

This study investigates the impact of enhanced vertical resolution on the representation of the tropopause region in the CESM2.1.3 model. We employ the WACCM6 (Whole Atmosphere Community Climate Model) configuration, a comprehensive atmospheric model with interactive chemistry extending from the surface to the lower thermosphere.
The primary objective is to assess whether a refined vertical grid improves the representation and reduces biases in chemical species and dynamical processes that are inadequately captured at standard vertical resolutions within the tropopause region. To this end, we conduct a comparative analysis under Pre-industrial and Historical conditions to evaluate the robustness of the results across different climate forcing regimes.

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#133 — Oral

Stratosphere, Stratopause, And Lower Mesosphere In The JRA-55 And JRA-3Q Reanalyses: Insights And Discrepancies

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

The representation of the stratosphere in reanalyses is crucial for various issues such as atmospheric transport, sudden stratospheric warmings, the polar vortex, and understanding the impact of climate change. The high-top and latest reanalyses are designed with the aim of being able to reproduce the high stratosphere better than the previous generation of low-top reanalyses, thus being better equipped to capture issues such as elevated stratopause events. JRA-3Q is a latest generation reanalysis that has been designed as an improvement over its predecessor, JRA-55. In this study, we examine how temperature, geopotential height, and ozone mixing ratio behave in both reanalyses, showing notable differences when comparing various parameters such as correlations and trends. We show that JRA-3Q exhibits substantial differences in its representation of the middle and upper stratosphere compared to JRA-55. Global and low-latitude zone are compared, and negative correlations in stratopause height are observed in the subtropical zone between both reanalyses. Moreover, negative correlations with JRA-3Q and high correlations with JRA-55 have been observed when compared with observational data from MLS, on board of the AURA satellite. Also, we compare our results to SABER data.

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#142 — Poster

Caracterización De La Atmósfera Antártica, En Verano En El Entorno Del Círculo Polar Antártico, Mediante Radiosondeos.

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

La base antártica argentina de Marambio se encuentra en la isla Marambio-Seymour frente al mar de Weddell, en la Península Antártica, en una meseta de 200 m de altitud y en las coordenadas 64,24° S, 56,63° O. Se trata de una base permanente donde El Grupo de Óptica Atmosférica de la Universidad de Valladolid (GOA-UVa) ha instalado una variedad de instrumentos atmosféricos (cámara de cielo para determinar nubosidad, fotómetro solar CIMEL para la obtención de propiedades de aerosoles y radiómetros infrarrojos para mediciones de temperatura de la superficie terrestre y radiancia del cielo. Durante la campaña antártica del verano austral de 2024, la Fuerza Aérea Colombiana llevó a cabo 2 sondeos atmosféricos diarios, con colaboración científica del personal del GOA, a lo largo de febrero y parte de marzo. En todos los casos, los sondeos superaron la tropopausa. Este estudio presenta una caracterización de la atmósfera antártica en las proximidades del Círculo Polar Antártico, incluyendo la determinación de parámetros de vorticidad (basados en componentes horizontales del viento) y el número de Richardson para la evaluación de la turbulencia atmosférica.
Además, el conjunto de datos de reanálisis ERA5, producido por el Centro Europeo de Predicción a Medio Plazo (ECMWF), proporciona un reanálisis atmosférico global que combina observaciones (incluyendo radiosondas, satélites y estaciones de superficie) con un modelo numérico de predicción meteorológica. ERA5 forma parte del Servicio de Cambio Climático de Copernicus de la Unión Europea; proporciona perfiles atmosféricos reconstruidos con cobertura global, continua y homogénea, disponibles en niveles de presión estándar, lo que permite una comparación directa con observaciones convencionales de radiosonda.
En este trabajo se presenta una comparación entre los sondeos atmosféricos realizados en la base antártica y los productos de reanálisis ERA5, incluyendo el cálculo previo de parámetros de vorticidad a partir de los campos del reanálisis.

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#174 — Oral

Oleaje Extremo Frente A Las Costas De Perú: Patrones De Circulación Atmosférica Y La Huella Del Cambio Climático

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

Los fenómenos de oleaje extremo representan una amenaza recurrente para la infraestructura costera y la seguridad marítima de Perú. Su origen varía estacionalmente: se generan en el Pacífico Sur durante el invierno austral y en el Pacífico Norte occidental en verano. Este estudio analiza los patrones de circulación atmosférica asociados a estos eventos extremos, con énfasis en la dinámica de la corriente en chorro en altura y la influencia del cambio climático. Usando datos de reanálisis ERA5, se examinan eventos "muy fuertes" del hemisferio sur (HS) y "fuertes" del hemisferio norte (HN), siendo estos últimos generalmente más débiles por las mayores distancias de disipación. El análisis mediante compuestos revela estructuras hemisféricas diferenciadas: los eventos del HS están impulsados por un dipolo ciclónico-anticiclónico con intensos vientos del suroeste, mientras que los del HN se asocian a sistemas ciclónicos profundos. Ambos presentan estructuras verticales barotrópicas y chorros latitudinalmente confinados. No obstante, en el HS destaca el chorro del frente polar, mientras que en el HN predomina un chorro subtropical reforzado. Para evaluar el impacto antropogénico sobre los vientos superficiales, se aplicó el método de análogos. Los resultados muestran que los patrones de circulación del HS generan hoy vientos más intensos que en el pasado, tendencia atribuida en parte a la fase positiva del Modo Anular del Sur, impulsada por la reducción del ozono estratosférico y las emisiones de gases de efecto invernadero. En el HN, en cambio, la señal antropogénica queda enmascarada por la elevada variabilidad interanual e interdecadal, produciendo cambios inconsistentes entre análogos. Estos hallazgos esclarecen las dinámicas hemisféricas que gobiernan el oleaje extremo en la costa peruana y sientan las bases para mejorar los sistemas de alerta temprana, las evaluaciones de riesgo costero y las estrategias de adaptación climática a largo plazo.

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#191 — Poster

Using AI Weather Prediction Models To Accelerate The Forecast And Attribution Of Climate Change Signals In Extreme Events

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

Artificial intelligence weather prediction (AIWP) models have rapidly emerged as powerful forecasting tools trained mainly on reanalysis data. They show predictive skill comparable to leading numerical weather prediction systems while being orders of magnitude faster and far less computationally demanding. Once trained, they can generate global forecasts in minutes, enabling new approaches to prediction and attribution.

We combine AIWP forecasts with a pseudo-global-warming (PGW) framework to estimate the influence of anthropogenic climate change (ACC) on recent extreme events. The PGW approach removes the anthropogenic thermodynamic signal, derived from CMIP6 ensemble means, from the initial conditions, enabling counterfactual simulations under preindustrial conditions. Comparing factual and counterfactual forecasts provides a rapid and physically consistent estimate of ACC fingerprints.

We first apply this methodology to recent heatwaves occurring in different climatic zones. These events are well predicted by AIWP models at short lead times, below five days, with skill comparable to hybrid dynamical–AI approaches. Attribution analysis shows that ACC intensified these events, consistent with previous studies using other methods. The magnitude and spatial structure of the ACC signals depend on the synoptic circulation of each event, while sensitivity experiments indicate that ACC-related sea surface temperature anomalies can locally modulate heatwave amplitude.

We then assess extratropical cyclones, focusing on storms Ciarán and Claudia, two high-impact European events with contrasting dynamics. AIWP models skilfully reproduce their large-scale evolution several days in advance, with performance similar to the operational physics-based model. Attribution reveals coherent ACC signals in moisture, precipitation, and, in some cases, sea level pressure and winds. Moisture responses are robust across models and consistent with near-Clausius–Clapeyron scaling, whereas dynamical responses are more event- and model-dependent.

Overall, AIWP models enable fast, event-specific attribution within the forecast window, opening the door to near-real-time assessments of climate change impacts on extreme weather.

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#294 — Oral

Reconstructing Climate And Extremes In Extremadura: Insights From Archival Data

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

Over the past two decades, our research group has made significant progress in reconstructing historical climate variability and atmospheric extreme events in Extremadura (SW Spain) using documentary evidence. We present here a synthesis of these advances, highlighting the recovery and analysis of historical meteorological observations as well as extreme phenomena including floods, thunderstorms, auroras, and other atmospheric events. These reconstructions are primarily based on diverse documentary sources, including municipal archives, historical newspapers, personal diaries, and overlooked scientific observations.
The resulting corpus has enabled the reconstruction of local climate series extending back to the mid-eighteenth century, significantly expanding the temporal coverage of instrumental records in the region. Notable case studies include the catastrophic flood of Badajoz in 1876 and the exceptionally stormy month of June 1925, which provide valuable insights into the dynamics and impacts of extreme atmospheric conditions. In addition, we have developed open-access databases, such as CliPastExtrem, that compile these reconstructed events and observations, facilitating their use by the wider scientific community. Beyond regional analysis, these datasets have proven useful for investigating large-scale atmospheric patterns, particularly their relationship with the North Atlantic Oscillation (NAO). This review underscores the key role of historical documentary sources as a powerful tool for improving our understanding of past climate variability. Such knowledge is essential not only for advancing climate science but also for informing present-day risk assessment and adaptation strategies in the face of ongoing climate change.

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#303 — Oral

Catastrophic Floods In Small Catchments Of Extremadura: Historical Case Studies From Ephemeral Streams

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

Floods represent one of the major challenges that contemporary society must confront in the context of climate change. In Extremadura (SW Spain), research on catastrophic flooding has progressed mainly for the principal river basins (Tagus and Guadiana). However, a substantial gap remains in the scientific literature regarding catastrophic floods that occurred in small catchments, where ephemeral streams can stay dry for much of the year yet produce sudden and highly damaging flood events. The hazardous nature of these intermittent channels was already recognized by past communities, a perception that persists in elements of local popular culture.
In this contribution, we present selected historical cases of catastrophic flooding in small watercourses of Extremadura, focusing in particular on (i) the Tripero stream as it crosses Villafranca de los Barros and (ii) the Gallineras stream as it crosses Valencia de las Torres. To analyze these events, we make extensive use of historical reanalysis datasets produced by the National Oceanic and Atmospheric Administration (NOAA), which allow us to place each flood within its broader meteorological context. By emphasizing how disproportionate impacts can arise from seemingly minor channels, these case studies underline the importance of considering small-catchment floods in regional hazard awareness and risk-oriented discussions.

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#345 — Poster

From Middle-Earth To Milankovitch: Calendars As Tools For Teaching Earth Physics

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

Motivating students in Earth Physics can benefit from interdisciplinary and creative approaches that connect scientific concepts with engaging narratives. This contribution presents two contrasting yet complementary calendars as educational resources to enhance student interest in topics related to Earth Physics.

On one hand, we explore the fictional calendar devised by J.R.R. Tolkien for the world of The Lord of the Rings, particularly focusing on its use by Hobbits and Men. The popularity of fantasy literature among students provides an opportunity to introduce scientific ideas through familiar and attractive contexts. By analysing Tolkien's calendar system and comparing it with the Gregorian calendar, students can develop a deeper understanding of astronomical cycles, the structure of calendars, and the cultural dimensions of time measurement.

On the other hand, we discuss the scientifically rigorous calendar proposed by Milutin Milankovitch in 1923. Known for his astronomical theory of climate change, Milankovitch designed a calendar of remarkable precision and long-term stability, later accepted by the Eastern Orthodox Church. Despite its scientific merits and ease of transition, its adoption has remained limited.

These two examples (one fictional and one scientific) offer complementary pathways to engage students. Together, they illustrate how both imagination and scientific innovation can be used to foster curiosity, deepen conceptual understanding, and motivate learning in Earth Physics.

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#349 — Poster

Ice Monitoring Systems Based On Acoustic Waves. A Comparison Between Plate And Surface Acoustic Waves.

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

Icing detection systems have become a crucial technological field to face the critical challenges experienced by many industries where ice formation can severely degrade performance or compromise safety. Icing impact mitigation requires reliable, robust, and reproducible sensors capable of detecting ice formation while providing rapid detection times, sensitivity, and accuracy to distinguish ice types and liquid water contents. In this field, Acoustic Wave (AW) devices have emerged as promising candidates due to their high sensitivity for monitoring surface loading phenomena [1]. Open issues regarding reliable solutions refer to the selection of the AW mode and device architecture, which are critical in defining performance aspects such as sensitivity and area coverage. In this communication, we present a comparative analysis of the sensing capacities of two radically different acoustic wave modes: Rayleigh Surface Acoustic Waves (R-SAW) and Thickness Shear Mode Plate Waves (TSM-PT)[2, 3]. The device utilized to generate the former type of waves consists of a SAW system based on ZnO which is activated by IDT electrodes in a delay-line configuration. Meanwhile, the TSM device is based on 128Y-X cut $LiNbO_3$ crystal activated with just two extended electrodes. Different icing laboratory tests have been made to assess capabilities such as water-ice discrimination, sensitivity and response to different type of ice accretion. The study is completed with experiments carried out in in close to real conditions in an Ice Wind Tunnel (IWT). To understand the physics underpinning the different responses and performances of the two devices, the results are critically analysed using Finite Element Model (FEM) simulations to get a fundamental view of AW-ice interaction phenomena in each case.

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#352 — Oral

Impacto De La Actividad Solar En La Atmósfera Terrestre: Análisis De Casos Históricos Y Respuesta Del Ozono Atmosférico

GEFAO - Física de la Atmósfera y del Océano

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Abstract Text:

La actividad solar y sus efectos sobre la atmósfera terrestre constituyen un elemento clave para comprender la variabilidad del sistema Sol–Tierra. En esta contribución se presentan resultados recientes basados en reconstrucción histórica, análisis de eventos aurorales y respuesta atmosférica.
En primer lugar, se presenta un estudio de registros aurorales en la prensa española (1923–2017), a partir de 31 noticias del periódico Extremadura. Los eventos se han clasificado en observaciones directas e informes generales, extrayendo información sobre características, localización, temporalidad e impactos, lo que evidencia el valor de las fuentes hemerográficas como proxy de actividad solar.
En segundo lugar, se reconstruye el evento auroral austral del 19 de marzo de 1950 mediante noticias contemporáneas en Australia, identificando observaciones desde múltiples localizaciones y estimando su intensidad geomagnética (Kp ≈ 7+, Dst ≈ −278 nT). El evento, ausente en catálogos modernos, se interpreta como un episodio relevante de space weather.
Finalmente, se presentan resultados en curso sobre el impacto de eventos de protones solares intensos en la atmósfera terrestre, mostrando descensos significativos de los niveles del ozono en toda la columna.
En conjunto, estos trabajos destacan la importancia de los registros históricos y observacionales para caracterizar la actividad solar y su impacto en la atmósfera terrestre.

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#16 — Oral

SEQUOIA: A New Paradigm For Individualised Survival Prediction

GEFM - Simposio de Física Médica

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Abstract Text:

We present “Survival Estimation using QUantitative Oncologic data with Individualized Analysis” (SEQUOIA), a novel artificial intelligence (AI)–based framework for individualized survival prediction that integrates patient-specific clinical variables with pre-treatment computed tomography (CT) imaging. The proposed approach is based on a concatenation of enhanced Long Short-Term Memory (LSTM) neural networks. In contrast to many existing AI models, SEQUOIA predicts the survival curves rather than the event density distribution.

The model training is driven by the minimization of the discrepancy between predicted and empirical patient outcomes while preserving the relative risk ranking between pairs of patients. The model performance was evaluated using an in-house lung cancer dataset with 341 patients. The dataset includes clinical variables such as age, sex, stage, comorbidities, prescribed radiation dose and radiomics. The predictive performance was assessed using the integrated Brier score (iBS), integrated area under the curve (iAUC), and negative log-likelihood (NLL). The 95% confidence intervals obtained for iAUC and iBS were [0.64–0.66] and [0.20–0.21], respectively, which were comparable to those achieved by Random Survival Forests (RSF), with typical values of [0.63–0.66] and [0.19–0.20]. SEQUOIA achieved a substantially lower NLL, with values in the range [2.25–2.32] versus [2.86–3.10] for RSF, indicating more accurate and better calibrated survival predictions. In addition, SEQUOIA outperformed other survival models, including DeepHit and Multi-Task Logistic Regression (MTLR).

We also investigated the contribution of individual patient variables to the survival predictions within the SEQUOIA model. Shapley additive explanations (SHAP) analysis revealed predictive contribution from radiomic variables associated with tumor texture. Cox regression further confirmed a markedly increased risk of death in patients with high tumor heterogeneity. Taken together, these findings suggest that radiomic variables encode clinically relevant phenotypic information about tumors and may provide substantial prognostic value for individualized survival prediction.

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#17 — Poster

A 5 Year Review Of The Automatic Exposure Control System In Conventional Chest Radiography.

GEFM - Simposio de Física Médica

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Abstract Text:

We evaluated the entrance surface dose in chest radiography examinations performed in posterior-anterior (PA) and lateral projections using automatic exposure control settings. We analyzed data from serveral healthcare centers and x-ray machines supervised by the Medical Physics-Radiation Protection Service. Our dataset included approximately 4,200 patients who underwent examinations between 2022 and 2026. For each examination, patient thickness, positioning, X-ray tube output/performance, tube voltage (kV), and delivered tube load (mAs) were recorded.
The evolution of dose distributions in the study population was assessed for each center using the mean, median, and interquartile range (25th–75th percentiles). The recorded doses were compared with reference dose levels reported by international radiological protection organizations, demonstrating safe clinical practice. A substantial reduction in both dose levels and dose dispersion was observed from 2022 onward. Analysis of the center-averaged values showed dose reductions of 30% and 39% for the PA and lateral projections, respectively.
We also found that the delivered dose distribution in the healthcare district under our supervision can be approximated by a log-logistic distribution. The deviation from normality can be explained by the contribution of several stochastic factors affecting the delivered dose, including patient thickness, body composition, positioning, and equipment response. Moreover, dose–thickness plots showed a parabolic dependence of the logarithm of the delivered dose on patient thickness, with this last showed to be normal, thereby accounting for the observed non-normality of the dose distribution. Finally, the dose–thickness relationship was interpreted using a linear beam-hardening model that describes the variation of the X-ray beam attenuation coefficient with the patient thickness.

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#47 — Oral

Magnetic Nanostructures As Heat Mediators In Cancer Therapy

GEFM - Simposio de Física Médica

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Abstract Text:

Magnetic nanostructures are versatile platforms for biomedical applications due to their small size and their ability to be remotely manipulated by external magnetic fields. Beyond their use as contrast agents in MRI, two of their most promising applications in oncology are magnetic hyperthermia and photothermal therapy, both minimally invasive approaches based on localized heat generation to damage tumour cells. In magnetic hyperthermia , nanomagnets dissipate heat under an alternating magnetic field, whereas in photothermal therapy they convert near-infrared light into thermal energy. While the physical mechanisms underlying the performance of magnetic nanoparticles in magnetic hyperthermia have been extensively studied over the past decades, enabling the clinical implementation of this thermal therapy in hospitals as an adjunct to conventional treatments such as chemotherapy and radiotherapy, the mechanisms governing their photothermal response remain insufficiently understood, and most studies are still at the preclinical stage. This work provides an overview of different magnetic nanostructures, ranging from simple co-precipitated nanoparticles to ideal one-dimensional natural magnetic nanostructures such as magnetotactic bacteria, shedding light on the physical principles underlying the thermal response of nanomagnets and aiming to establish design rules to optimize their performance in thermal therapies.

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#51 — Poster

High-Resolution Temporal Mapping Of Retinal Oxygenation

GEFM - Simposio de Física Médica

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Abstract Text:

Retinal oximetry is a critical metric for managing metabolic diseases such as diabetic retinopathy and glaucoma. However, current static reflectivity models are often confounded by retinal pigmentation and a lack of hemodynamic context. This work introduces a high-speed multispectral imaging approach designed to capture retinal hemodynamics by exploiting the cardiac-induced blood pulse.
Using a 16-bit CMOS camera integrated into a customized retinograph [1,2,3], we acquired visible and near-infrared multispectral images at a sampling rate of 25 Hz. The protocol focused on four discrete wavelengths—660 nm, 732 nm, 865 nm, and 955 nm—to capture pulsatile reflectance over a 4-second interval. Raw data underwent radiometric calibration, background noise subtraction, and normalization against a white reference. To enhance image quality, Wiener filtering and moving average filters were applied to mitigate stochastic noise and stripe artifacts before spatial registration. To ensure spatial consistency, we implemented a multi-stage registration workflow combining manual coarse alignment with cross-correlation fine-tuning to suppress ocular micro-movements. To isolate the hemodynamic component, signals were processed using a 4th-order Butterworth band-pass filter (0.8–5 Hz) and a vessel-masking algorithm. This approach allows for the subtraction of static background artifacts, focusing exclusively on the dynamic pulsatile signal.
Preliminary results successfully visualize the retinal blood pulse, enabling the integration of temporal flow data with spectral oxygen sensitivity. By utilizing the dynamic component of the signal, this method mitigates the limitations of static oximetry and accounts for diverse population pigmentation. This framework provides a robust path for detecting early-stage microvascular complications and advancing our understanding of retinal oxygen metabolism.
Acknowledgements: Funded by MCIU /AEI /10.13039/501100011033 / FEDER, UE (PID2023-147541OB-I00) and the European Union (HORIZON–MSCA–2022–DN, GA nº101119924–BE-LIGHT).
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#52 — Oral

Towards A Consistent I-Value For Water: Insights On Phase Effects From Advanced Modelling And Simulations

GEFM - Simposio de Física Médica

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Abstract Text:

Protontherapy precision depends on accurately knowing the stopping power of liquid water. However, a limitation arises due to its elusive experimental determination. Difficulties in measuring volatile liquids have led to a long-standing debate regarding exact value of the mean excitation energy (I) of liquid water [1]. The stopping properties of amorphous ice offer a convenient alternative due to its experimental accessibility. In this work we employ two complementary frameworks to assess proton stopping power across both phases. The MELF-GOS (Mermin Energy Loss Function – Generalized Oscillator Strengths) method [2], based on the perturbative dielectric formalism, serves as an accurate reference for sufficiently high energies, while the novel non-perturbative TDDFT-Penn (time-dependent density functional theory – Penn) approach [3] ensures accuracy for energies even below the stopping maximum. Our results confirm the equivalence between the stopping power of liquid water and amorphous ice per unit mass density across all clinically relevant energies. This synergy allows for a reliable estimation of the I-value. These results were implemented into the Monte Carlo code SEICS (Simulation of Energetic Ions and Clusters through Solids) [4] to simulate proton Bragg curves from 1 to 230 MeV. Comparisons with precise range measurements provide critical insights that help establish a consistent I-value for liquid water, providing robust physical grounds for improving range prediction and treatment planning.
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#65 — Oral

Compton Cameras For Medical Imaging: MACACO Results And AIDER Perspectives.

GEFM - Simposio de Física Médica

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Abstract Text:

The interest in Compton cameras for medical applications continues to increase. In some areas, such as Targeted Radionuclide Therapy (TRT) they can offer advantages over gamma cameras. The IRIS group of IFIC (Valencia) has developed a Compton camera made of LaBr3 crystals coupled to SiPM arrays. MACACO III, with three detector planes, was able to image metastatic lesions in patients. MACACO III+, featuring two planes with four detectors in the second plane, has successfully imaged phantoms with irregular shapes and with hot spots in a warm background, as well as mice injected with I-131. Recent simulation studies carried out with mouse voxelized phantoms in GATE have shown the potential for imaging Ac-225 in mice. Experimental tests with phantoms have been carried out demonstrating the ability of the system to image this radionuclide. Four organs were filled in the mouse (brain, heart, kidneys and bladder) and can be correctly visualized in the images.
Further developments continue in several aspects. On one hand, the system MACACO IV is under development, with four detectors in both the first and the second planes to increase sensitivity and system performance. Other geometries, such as the combination of two Compton cameras placed at 90º, and the combination of PET and Compton systems, have been evaluated through simulations and experimental tests are ongoing. On the other hand, the IRIS group coordinates a European project to improve Compton camera technology. The AIDER project, including four academic partners, two hospitals, one SME and one patient association, will develop a new prototype with dedicated detectors and readout electronics for enhanced detector energy and timing resolution. Within this project, the system will be assembled and tested with phantoms and patients. Simulation system design studies and initial detector testing are ongoing.

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#98 — Oral

Hacia Un Modelo Personalizado De Irradiación Sanguínea En Tratamientos De Radioterapia

GEFM - Simposio de Física Médica

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Abstract Text:

La radiación ionizante es fundamental en oncología; sin embargo, el daño inducido a la sangre circulante durante la radioterapia sigue poco estudiado pese a que incluso dosis bajas pueden afectar a la supervivencia del paciente. Esto se debe a la complejidad del flujo sanguíneo y a su interacción con la irradiación, dificultando la dosimetría sanguínea en radioterapia de protones y fotones. Para abordar este problema, presentamos FLIP-HEDOS, modelo paciente-específico que integra mecánica de fluidos y simulaciones Montecarlo de la radiación.
FLIP-HEDOS combina el método FLIP (FLow and Irradiation Personalized) con HEDOS (HEmatological DOSe). FLIP emplea el contorneo de grandes vasos y campos de velocidad obtenidos mediante resonancia magnética con contraste de fase para reconstruir trayectorias lagrangianas del flujo sanguíneo específicas de cada paciente. HEDOS es un modelo compartimental, poblacional y estocástico, que describe la distribución espaciotemporal de partículas sanguíneas (BPs). El volumen sanguíneo total (5.3L) se discretiza en BPs de 1mm³, cuyo movimiento se modela de forma determinista en FLIP y estocástica en HEDOS. La dinámica sanguínea se acopla con la irradiación mediante la segmentación de planes clínicos y simulaciones Montecarlo que modelan la dosis recibida usando distribuciones dosimétricas 3D y tiempos de irradiación medidos. Se analizaron pacientes con tumores en tórax-abdomen y cabeza-cuello. Este modelo innovador cuantifica la dosis recibida por cada BP y sus (re)visitas a la vasculatura específica del paciente. La proximidad del tumor a grandes vasos incrementa el volumen sanguíneo expuesto a dosis superiores a 0.1Gy, asociadas a daño linfocitario. Asimismo, las revisitas de las BPs aumentan con la duración total del tratamiento.
FLIP-HEDOS estima de forma personalizada la dosis sanguínea en radioterapia, siendo especialmente relevante en tumores próximos a grandes vasos, cuando el volumen vascular es comparable al tumoral o los tiempos de irradiación son prolongados. Este enfoque puede contribuir a mejorar los resultados clínicos.

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#111 — Oral

Impact Of Energy-Loss Fluctuations And Secondary Electron Transport On The Radial Dosimetry Of Electron-Emitting Radioisotopes

GEFM - Simposio de Física Médica

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Abstract Text:

Electron-emitting radioisotopes (Auger or beta emitters) are essential tools in modern cancer therapy [1]. Their clinical efficacy relies on the precise determination of radial dose distributions, which span various spatial scales depending on the nuclear de-excitation mechanism. While beta-emitters deposit energy across micrometer or centimeter scales, Auger-emitting nuclei concentrate damage at the nanometer scale, inducing complex DNA lesions, lethal to cancer cells. These doses are typically assessed via Monte Carlo simulations. However, the level of modeling details —such as tracking only primary electrons with definite energy versus incorporating stochastic energy-loss fluctuations and secondary electron production— can introduce uncertainties in dose estimation.
We have developed detailed models based on the dielectric formalism [2] to accurately calculate inelastic cross sections for swift charged particles in biomaterials, particularly in liquid water [3,4]. By parameterizing energy-loss distributions and secondary electron spectra through analytical approximations, these models are efficiently integrated into simulation codes while maintaining computational speed. This work presents the implementation of our simulation for electron transport in liquid water, highlighting the influence of energy-loss fluctuations and secondary electron transport. The role of different physical interactions on radial dose distributions is analyzed for electron-emitting radioisotopes such as iodine-131 and iodine-125, and results are validated against reference data [5-7].

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#186 — Oral

A Workflow For The Extraction Of Simplified Vascular Graphs From Murine Micro-CT Imaging

GEFM - Simposio de Física Médica

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Abstract Text:

Introduction and Objective
Accurate physical representation of vascular anatomy in murines is essential for modelling hemodynamic transport, contrast-agent dynamics, and preclinical image formation. However, whole-body micro-CT datasets contain complex 3D structures that are difficult to use directly in numerical simulations due to high computational requirements. This study describes a practical workflow to convert contrast-enhanced murine micro-CT data into simplified graph-based models, preserving main anatomical pathways while reducing complexity for downstream flow simulations.
Methodology
Vascular structures from four rodents (two mice and two rats) were opacified via transcardial perfusion with Microfil and imaged by micro-CT with an isotropic voxel size of 118–125 µm. At this spatial resolution, the reconstructed volume mainly captures large and medium-sized perfused vessels, rather than the full capillary bed. Therefore, the workflow focused on extracting the dominant vascular axis extending from the tail region to the cervical vasculature, to generate a computationally tractable representation of the main perfused vascular pathways along this anatomical track.
An initial segmentation of the contrast-filled vascular lumen was performed using ITK-SNAP. The resulting binary mask was refined through manual correction and custom post-processing algorithms to remove isolated noise components, correct discontinuities, and improve the topological consistency of the segmented vascular tree. The curated mask was then processed using VesselVio to extract a mathematical graph representation, where vessel centerlines were encoded as connected nodes and edges with associated local radius estimates.
Results
The workflow transformed million-voxel masks into simplified vascular graphs of a few hundred nodes while accurately capturing tail-to-neck trajectories. By extracting vessel centerlines, branching points, and radius estimates, the models represent scales from sub-millimetric caudal vessels to several millimetres in thoracic pathways. This compact architecture lowers computational overhead, offering a standardized framework for future simulations of flow distribution and contrast-agent propagation versus voxel-based methods.

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#187 — Oral

Spatio-Temporal Encoding For High-Resolution Photoacoustic Tomography With Reduced Hardware Requirements

GEFM - Simposio de Física Médica

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Abstract Text:

Photoacoustic tomography (PAT) is an emerging biomedical imaging modality that combines high optical contrast with deep acoustic penetration, offering strong potential for clinical diagnosis. However, its widespread adoption remains limited by instrumental complexity and the large number of detectors required in conventional system configurations. This contribution addresses these challenges from a physics-driven perspective oriented toward clinical translation.

The present study focuses on the development of spatio-temporal encoding strategies that significantly reduce hardware requirements without compromising image quality. In particular, two approaches are explored: the use of acoustically dispersive coupling media, which introduce controlled scattering to encode spatial information into time-domain signals and enable super-resolution through dynamic absorbers; and reverberant cavities equipped with quadratic residue diffusers, capable of encoding complex angular information and enabling three-dimensional reconstructions with a drastically reduced number of detectors.

These strategies are complemented by tools that enhance their applicability and robustness. First, an image reconstruction method based on a self-calibrated model is introduced, enabling the recovery of spatio-temporal information without prior knowledge of the scattering field. Second, a resolution assessment methodology based on the Rayleigh criterion is employed, providing a more physically meaningful metric than conventional point spread function-based approaches. In addition, biocompatible nanoparticles are integrated as contrast agents, providing strong and stable photoacoustic signals. Together, these elements enable a more rigorous validation of system performance and improved image quality under realistic conditions.

Experimental results obtained in controlled environments and in vivo demonstrate that resolutions comparable to conventional systems can be achieved while maintaining a robust signal-to-noise ratio, even under highly undersampled acquisition schemes. Overall, this work proposes physical solutions that simplify PAT systems, reduce cost, and facilitate their implementation in real clinical settings.

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#194 — Oral

Coded-Mask Prompt Gamma Imaging For Proton Range Verification With Pure Cherenkov Crystal Detectors

GEFM - Simposio de Física Médica

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Abstract Text:

Accurate proton range verification (PRV) in proton therapy (PT) is an unmet clinical need and is essential to exploit the full potential of PT to maximize treatment effectiveness and minimize toxicity. We present a Monte Carlo (GATE 10) study of a Cherenkov-based prompt gamma imaging system combining an array of PbF2 crystal detectors with a MURA coded-aperture collimator for real-time PRV. The detector response was studied through detected Cherenkov photon distributions generated by prompt-gammas with energies ranging from 0.5 MeV to 7.0 MeV in steps of 0.5 MeV. A threshold of 15 detected Cherenkov photons was applied to reject low-energy background, which effectively suppressed 511 keV annihilation gammas and sub-MeV contributions while retaining the prompt gammas of interest. Image reconstruction was performed using the Maximum Likelihood Expectation Maximization algorithm, with the system matrix computed with 4.4 MeV point-like sources. The imaging performance was validated on isotropic gamma point sources in both 1D and 2D coded-mask configurations across a field of view of ∼130 mm. A direct comparison between discrimination based on energy deposition (E > 1 MeV) and discrimination based on the number of detected Cherenkov photons (nckv ≥ 15) showed comparable performance, with position residuals consistent with zero within statistical uncertainties in both cases. For the proton beam measurements, background rejection was performed exclusively via the Cherenkov photon count threshold. Under realistic proton beam conditions, the distal fall-off position was reconstructed with a systematic residual below 1.5 mm and a statistical precision of less than 2 mm for beam intensities above 10^8 protons, corresponding to approximately 10 ms of irradiation at a standard proton current of 2 nA (1.25 × 10^10 protons/s). This work presents the concept and shows the feasibility of using Cherenkov-based coded-aperture imaging for PRV by means of a simulation framework.

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#196 — Oral

How Do Binding Kinetics And Radiopharmaceutical Design Affect In Vitro Dosimetry?

GEFM - Simposio de Física Médica

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Abstract Text:

Alpha-emitting radiopharmaceutical therapy (α-RPT) uses carriers to deliver alpha emitters to cancerous targets, exploiting their high potential to induce unrepairable DNA damage. A key factor in predicting the radioinduced biological response is how fast the radiopharmaceutical binds to its target and how long it is retained, i.e., its binding kinetics. Here, we focus on G-protein-coupled receptors overexpressed in the tumor cell membrane, for which radioligands can be designed as agonist or antagonist. Agonists induce cell signaling and typically internalize into the cytoplasm, whereas antagonists are generally retained at the cell membrane, affecting the radioligand subcellular distribution. Despite this, radioligand development does not include dosimetric evaluation of these effects. We explore this gap studying in silico the dosimetric consequences of binding kinetics and agonist/antagonist design in 212Pb and 225Ac-labeled radiopharmaceuticals in vitro experiments.

In this work, we present the development of a compartmental binding kinetic model including receptor binding, internalization, and radioligand excretion. The model was implemented in TOPAS-RPT, our Monte Carlo radiation transport code for modeling radiopharmaceutical in vitro experiments evolving adherent cells. Simulations used time intervals, in which physical and biological processes were updated and absorbed dose was scored for each cell. We performed a sensitivity study sampling binding affinity, intracellular retention time, and agonist/antagonist profiles.

For both 212Pb and 225Ac, we found a threshold intracellular retention time below which antagonists may deliver up to 2.5-fold higher absorbed dose than agonists. The threshold increases with binding affinity, separating regimes where either agonist or antagonist radioligands are dosimetrically favored.

Our results suggest that, under the conditions studied here, the dosimetric impact of binding kinetics and agonist/antagonist choice should be evaluated during the development and validation of alpha-emitting radiopharmaceuticals. TOPAS-RPT can model complex receptors-ligands binding processes with a time-resolved simulation beyond equilibrium scenarios, linking radioligand subcellular dynamics to cell-by-cell absorbed dose.

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#204 — Oral

Suspended Microchannel Resonators For Multiplexed Physical Characterization Of Cells

GEFM - Simposio de Física Médica

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Abstract Text:

Cells are systems of exceptional interest not only for the wide knowledge they can provide about life and diseases, but also because the rich variety of physical phenomena that happen in them. Mechanics, electricity or molecular dynamics are some examples of different physical approaches under which the cell can be studied. Moreover, changes in one type of physical property can have an influence on other physical properties (e.g. changes in the molecular composition of the cell changes its mechanical, electrical or optical properties). Consequently, measuring physical properties of cells stands as a promising approach for performing label-free discerning between different types of cells as well as expanding our knowledge of different biological processes.
To this purpose, in this work we develop suspended microchannel resonators (SMR): a platform that allows a multiplexed physical characterization of single cells merging in a single device different physical sensing approaches (nanomechanics, microfluidics, optical scattering and dielectrophoresis). These devices consist of a microfluidic channel free-standing for a certain length so it can mechanically oscillate in flexural modes. By means of a laser doppler vibrometer and a piezoelectric actuator, the mechanical resonance frequency of this SMR device can be tracked, obtaining information about cell mass and hydrodynamics by analyzing the resonance frequency shifts individual cells produce as they pass through the free-standing zone. Moreover, we demonstrate that in these devices it can be generated a nonlinear flow, resulting from the interaction between the oscillating beam and the microchannel. We eventually use this flow for trapping the particles under analysis in the most sensitive region of the device. This particle trapping opens the door to a new generation of SMR devices in which the trapping of particles under will allow characterizing how these properties change over the time (a case of special interest for medicine and biophysics).

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#222 — Oral

Radiobiology With Laser-Accelerated Protons At CLPU – A Status Report

GEFM - Simposio de Física Médica

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Abstract Text:

Sources of ionizing radiation based on highly intense pulsed lasers have attracted much attention due to their small size and the concentration of radiation dose in ultra-short bunches. The aim of an ongoing, joint research project of i3M and CLPU is to study radiobiological effects of laser-accelerated protons on cell cultures. In related experiments the instantaneous dose rate has been orders of magnitudes higher than at radiofrequency accelerators. Our goal is to achieve, in addition, a mean dose rate within (or close to) the Flash regime, generally considered to start at 40 Gy/s. The point of reference is a previous pilot experiment at the VEGA-3 laser where a dose of 200-300 mGy per shot and a mean dose rate of 1-3 Gy/min on the cell specimen have been reached [1]. According to simulations with a particle tracking code, the proton flux can be increased by more than an order of magnitude through implementation of permanent cuadrupole magnets acting as beam focussing elements. An alternative setup at VEGA-2 with much shorter flight paths also implies a higher flux which can be additionally leveraged by the 10 Hz shot rate of this laser. The development of new strategies for particle detection and dosimetry is especially interesting in complex experimental environments as those based on laser-plasma particle acceleration. We are studying high energy particle and photon detectors and dosimetry strategies based on cost-effective, commercial CMOS cameras. First tests results will be presented and their implementation into the radiobiology setup will be discussed.

Grants PID2023-148992OB-C21 and PID2023-148992OB-C22 funded by MICIU/AEI/10.13039/501100011033 and cofunded by the European Union, ERDF. Grant PR-084-2022 funded by Consejo de Seguridad Nuclear.

[1] Alicia Reija Vecino, PhD thesis, Universidad de Santiago de Compostela (2026)

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#285 — Oral

Advanced Monte Carlo Simulations For Emission Tomography Imaging

GEFM - Simposio de Física Médica

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Abstract Text:

Monte Carlo simulations are essential tools in nuclear medicine. They are extensively used in the design and characterization of imaging devices, as well as in the optimization of reconstruction algorithms and correction techniques. In the CREATIS laboratory we have a wide experience in developing advanced Monte Carlo simulations for emission tomography systems.
In this contribution, I will present some of our recent and current projects on GATE Monte Carlo simulations of single photon emission imaging in targeted radionuclide therapy (TRT) applications. First, I will focus on the development of Monte Carlo models of innovative systems for TRT. In particular, commercially available 3D ring collimated SPECT systems based on CZT detectors and Compton camera prototypes which are promising candidates for this application due to their non-mechanical collimation will be studied. In addition, I will introduce several approaches designed within GATE to facilitate and speed up the simulations, such as a generic variance reduction technique that has shown accurate results while reducing computation time by up to a factor 200. Finally, I will briefly present some of our efforts towards improving image quality.

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#307 — Oral

Sensitivity Of Proton Microdosimetry In Water To Electron Transport: Evaluation Of The Influence Of PenG4 And Geant4-DNA Models

GEFM - Simposio de Física Médica

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Abstract Text:

Biological effects induced by ionizing radiation show important variations depending on the radiation type. Microdosimetry was developed to study the relationship between these variations and the energy deposition patterns in micrometric volumes, typically through Monte Carlo track structure (MCTS) simulations. However, microdosimetric quantities differ across the MCTS codes, with particle interaction models being the main source of discrepancy. In this study, we analyze the dispersion of frequency- and dose-mean lineal energy distributions f(y) and d(y) of protons in water as well as of their respective mean values, yF and yD. This serves as a primary estimator of the simulation accuracy related to the physics models used for the transport of secondary electrons (Type-I uncertainty), complementary to the statistical uncertainty (Type II).

The Monte Carlo simulations were performed using the Geant4 toolkit (v11.4.0), selecting the main Geant4-DNA physics models (G4EmDNAPhysics_option2, _option4, and_option6), and with the PenG4 code interface to incorporate for secondary electrons the Penelope-2018 physics with the most restrictive transport parameters: $C1$ = $C2$ = 0, $Eabs$ = 50 eV, WCC = WCR = 10 keV. Protons with energies ranging from 1 to 300 MeV were simulated in liquid water to calculate the energy imparted to randomly positioned spherical sites from 0.01 to 10 µm in diameter, yielding f(y) and d(y) spectra.

Preliminary results show that all choices for electron transport converge to agreement with site diameters larger than 0.5 µm. However, deviations between models grow sharply below 0.1 µm, reflecting fundamental differences between the electron transport models at those scales, with Penelope-2018 showing the largest discrepancies in both yF and yD.

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#350 — Oral

Assessment Of A 4H-SiC PIN Diode For Time-Resolved Proton Beam Monitoring

GEFM - Simposio de Física Médica

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Abstract Text:

As proton therapy advances towards high dose rate modalities there is a need for the development of dedicated instrumentation which can both withstand the high levels of radiation and have high temporal resolution which can enable real time beam monitoring. In this context a study of a silicon carbide (SiC) detector is presented in which we evaluate its performance under several irradiation conditions with a clinical proton beam and the feasibility of performing single-proton detection has been assessed experimentally.

A 4H-SiC PIN diode detector manufactured by Onsemi was employed in this study. The device features an active area of 3 × 3 mm² and a thickness of 50 µm. It was operated at a bias voltage of −350 V, ensuring full depletion of the active volume. A dedicated setup was developed for pulsed readout of the detector. The detector performance was evaluated under various clinical beam energies ($E \in [100, 244]$ MeV) and currents using the Varian system at DCPT (Aarhus, Denmark). Pulse shape analysis was carried out to assess device performance in detail.

The detector exhibited sufficient temporal resolution to clearly resolve the cyclotron's bunch structure, observing a train of pulses with a spacing of 13.9 ns (≈72 MHz) across the full 200 ns acquisition window. Each waveform was individually analysed and proton-generated pulses were identified through a selection algorithm based on the shape of the signals. The fast response of the 4H-SiC PIN detector (~1.8 ns), together with its low noise level, enabled clear resolution and analysis of individual proton bunches. However, detector performance was strongly dependent on cyclotron operating conditions: as both beam current and energy decreased, an increasing fraction of bunches went undetected.

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#3 — Oral

From A Material Developed For The Control Of Optical Properties To Innovative Helium Targets Fabrication For Fundamental Studies Of Nuclear Reactions.

GEFN - Simposio de Física Nuclear

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Abstract Text:

In this contribution we present the fabrication and characterization of “solid-gas” nanocomposite films, initially developed for antireflective coatings in solar cell applications. Firstly, it was found that nanoporous silicon films, obtained by magnetron sputtering (MS) deposition in helium plasma, showed the required reduction in refractive index [1]. The IBA (Ion Beam Analysis) and TEM-EELS (Transmission Electron Microscopy) techniques showed, however, that the films contained high amounts of helium trapped inside nano-pores. The formation of He nano-bubbles was demonstrated [2]. This methodology could also be extended to other matrix elements and to the use of the 3He isotope using a low gas consumption procedure [3]. Helium content achieved 3.25E18 at/cm2 in a thickness of 1,4 μm for the Si matrix with Helium release starting at 625 K by heating in vacuum [4]. This behavior allowed to propose these films, initially developed for optical applications, as “helium solid targets” for nuclear reaction studies relevant in astrophysics and nuclear structure. These targets avoid the use of cryogenic or high-pressure cells, making them easier to use, reducing energy straggling effects and simplifying the geometry for calculations. Results will be presented from earlier experiments carried out at LNL [3] to recent experiments at TRIUMF-EMMA facilities [5-6].

[1] V.Godinho et all. “A new bottom-up methodology to produce silicon layers with a closed porosity nanostructure and reduced refractive index”. 10.1088/0957-4484/24/27/275604.
[2] B.Lacroix et all. “On the characteristics of helium filled nano-pores in amorphous silicon thin films”. 10.1016/j.apsusc.2024.161772
[3] A.Fernández et all . “Low gas consumption fabrication of 3He solid targets for nuclear reactions”. 10.1016/j.matdes.2019.108337
[4] A.Fernández et all. “Microstructure and composition evolution of He charged solid-gas nanocomposite films of different matrix elements during thermal annealing in vacuum”. 10.1038/s41598-025-06889-8
[5] M.Williams et all. “First Measurement of a Weak r -Process Reaction on a Radioactive Nucleus”. 10.1103/PhysRevLett.134.112701.
[6] https://triumf.ca/2025/03/17/how-do-neutron-star-mergers-and-exploding-stars-create-the-elements/

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#141 — Oral

High-Precision Nuclear Structure Simulations On NISQ Quantum Devices

GEFN - Simposio de Física Nuclear

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Abstract Text:

Simulating nuclear systems on classical computers becomes exponentially more difficult as the Hilbert space grows with the system size. Quantum computing emerges as a promising alternative to solve this problem, since quantum computers can naturally represent and manipulate these exponentially large state spaces without the classical memory overhead. However, running these simulations on current Noisy Intermediate-Scale Quantum hardware (NISQ) is challenging. Standard mapping methods like the Jordan-Wigner transformation create circuits that are too deep and complex for today's devices to handle. To solve this, we take advantage of the strong pairing correlations in atomic nuclei and apply a hard-core boson mapping (E. Costa et al., "Quasiparticle pairing encoding of atomic nuclei for quantum annealing"). This physics-based approach drastically reduces the circuit depth with a relatively small loss of precision. Thanks to this, we can successfully calculate ground-state properties on available quantum processors.
In this work, we test our approach using the ADAPT-VQE algorithm across two different quantum architectures: superconducting qubits (QMIO-CESGA) and trapped ions (IonQ). By combining quantum error mitigation with symmetry-based corrections, we calculate ground-state energies with an accuracy of 0.2% on the trapped-ion device and 0.4% on the superconducting platform.

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#148 — Oral

Two-Neutrino Double-Beta Decay To Excited States At Next-To-Leading Order

GEFN - Simposio de Física Nuclear

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Abstract Text:

The study of two-neutrino double-beta decay ($2\nu\beta\beta$), an allowed process within the Standard Model in which two neutrons convert into two protons with the emission of two electrons and two antineutrinos, provides a unique window into nuclear structure and plays a crucial role in constraining theoretical descriptions of double-beta decay. In particular, it offers valuable benchmarks for the nuclear matrix elements (NMEs) that also govern neutrinoless double-beta decay ($0\nu\beta\beta$), a hypothetical process beyond the Standard Model of particle physics (BSM) in which no antineutrinos are emitted. The observation of $0\nu\beta\beta$ would have important implications for particle physics, shedding light on open questions such as the origin of neutrino masses and the matter–antimatter asymmetry of the Universe.
In this talk, we present new predictions for $2\nu\beta\beta$ decay half-lives to the first excited 0_2^+ states in nuclei of experimental interest, including ^{76}Ge, ^{82}Se, ^{130}Te, and ^{136}Xe. A major source of theoretical uncertainty in these calculations arises from the NMEs, on which the decay half-lives depend quadratically. We compute the NMEs within the nuclear shell-model framework, including contributions up to next-to-leading order in chiral effective field theory and incorporating important corrections from the lepton energy expansion. Finally, we discuss how uncertainties in the NMEs are connected to key features of nuclear structure, such as nuclear deformation. We show that larger deformation differences between the initial and final states yield to smaller NMEs [1].
[1] Castillo et al. Phys. Lett. B, 875 (2026) 140306

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#154 — Oral

Shape Coexistence And Deformation Fluctuations From Shape Invariants

GEFN - Simposio de Física Nuclear

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Abstract Text:

The complex nature of the nucleon-nucleon interaction allows for spherical, oblate and prolate deformations to appear at similar energies within the same nucleus. This phenomenon, known as shape coexistence, is widespread across the nuclear chart and it provides a crucial role in understanding nuclear structure [1]. In our study we complement shell-model calculations with beyond-mean-field Hartree-Fock-Bogoliubov techniques to shed light on the rich coexistence of differently deformed structures. We infer shape coexistence from multiple observables such as: quadrupole moments, $E2$ transitions, collective wavefunctions, and shape invariants. The combination of all these hints allows us to understand the complexities of shape coexistence and the notion of nuclear shape itself.
Particularly, the shape invariants provide a model-independent framework to quantify the deformation parameters and their fluctuations [2], which are significant in most nuclei. We analyze how nuclear shapes evolve across the band using an extended sum-rule method to compute the shape invariants for $J\neq0$ states, both for even and odd mass nuclei. This method sheds light on long-standing questions, such as whether doubly-magic nuclei are truly spherical, whether truly rigid triaxial nuclei exist, and how axially symmetric prolate and oblate nuclei really are.
For instance, the doubly-magic nucleus ^{40}Ca presents shape coexistence between the spherical ground state, the normal deformed rotational band (3.4 MeV) and the superdeformed rotational band (5.2 MeV) [3]. We analyze the fluctuations of the deformation parameters associated to these states, showing the complexities of the ground state and checking the validity of the perfect rotor approximation for the deformed bands.
[1] P. E. Garrett, M. Zieli\'nska, and E. Cl\'ement, Prog. Part. Nucl. Phys. 124, 103931 (2022).
[2] A. Poves, F. Nowacki, Y. Alhassid, Phys. Rev. C 101, 054307 (2020).
[3] E. Caurier, J. Men\'endez, F. Nowacki, and A. Poves, Phys. Rev. C 75, 054317 (2007).

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#165 — Oral

Study Of Carrier Transport Enhancement In 4H-SiC Radiation Detectors Through Thermal And Optical Excitation

GEFN - Simposio de Física Nuclear

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Abstract Text:

In future nuclear fusion reactors, diagnosing escaping suprathermal ions, such as the 3.5 MeV alpha particles produced in D–T reactions, is essential to optimize plasma performance and ensure reactor integrity. Silicon carbide (SiC) is a promising candidate for fast ion detection due to its wide bandgap, high radiation tolerance, and excellent thermal stability. In this work, we study 4H-SiC p–n junction detectors fabricated at the Institute of Microelectronics of Barcelona (IMB-CNM), featuring a non-metalized surface with a guard ring structure. To support this study, the nuclear microprobe at the Centro Nacional de Aceleradores (CNA) was equipped with a temperature-controlled heating system, enabling in situ irradiation and characterization.

The detectors were irradiated with 3.5 MeV alpha particles at fluences ranging from 10^{11} to 10^{13} ions/cm² at room temperature (RT) and 400 °C. The irradiation process was monitored in real time using Particle-Induced X-ray Emission (PIXE) to ensure precise fluence control. The spectroscopic response of the devices was evaluated through Charge Collection Efficiency (CCE) measurements using Ion Beam Induced Charge (IBIC).

The experimental results indicate that elevated irradiation temperatures promote the dynamic annealing of primary defects, leading to a significant stabilization and reduction of radiation-induced damage. To further mitigate the effects of residual trapping centers, the irradiated devices were subjected to varied illumination regimes. The experimental results demonstrate a significant enhancement in the CCE upon illumination, particularly in regions with higher defect densities, which effectively restores the charge collection performance of the detectors.

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#167 — Oral

Upgrades At CNA HiSPANoS For Continuous And Pulsed (Alpha,N) Measurements Within MANY

GEFN - Simposio de Física Nuclear

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Abstract Text:

Neutrons produced in (α,n) reactions are essential in nuclear astrophysics, dark-matter background studies, and nuclear-security applications, motivating precise and reliable cross-section and yield measurements [1]. Within this context, the Spanish MANY Collaboration (Measurement of Alpha Neutron Yields) is developing new experimental strategies and reference data for reactions of interest. The HiSPANoS neutron source at the Centro Nacional de Aceleradores (CNA) plays a central role in this effort, providing continuous and pulsed neutron beams for activation, neutron spectroscopy, and time-of-flight studies [2,3]. Recent and planned upgrades at HiSPANoS will significantly enhance its capabilities for (α,n) measurements for both continuous and pulsed beams. A new buncher system for compressing pulsed beams has been recently installed to enable nanosecond pulsed alpha beams, aside from proton and deuteron beams. Its performance has been characterized for all three ion species, yielding an improved temporal structure for alpha beams, while aiming to preserve the established performance for protons and deuterons.

In parallel, the program of continuous beam measurements has continued. Following an initial commissioning phase for technique validation, recent experiments on the thick-target yield of the 48Ti(α,n) reaction have been performed with fusion-diagnostics motivation [4], contributing to the development of consistent thick-target yield datasets within MANY.

This contribution will present the preliminary operational results of the upgraded pulsing system, including the full characterization of pulsed beams for H+, D+, and He++, together with the preliminary 48Ti(α,n) thick-target yield by activation. Perspectives given the recent and future upgrades, particularly increased beam intensity by switching the current NEC-ALPHATROSS ion source for the NEC-TORVIS ion source [5,6] and improved neutron-detector capabilities, will also be discussed.

[1] D. Cano-Ott et al., https://arxiv.org/abs/2405.07952
[2] J. Gómez-Camacho et al., https://doi.org/10.1140/epjp/s13360-021-01253-x
[3]M.A. Millán-Callado et al., https://doi.org/10.1016/j.radphyschem.2023.111464
[4] G. Bonheure et al., https://doi.org/10.1016/j.fusengdes.2011.03.007
[5] NEC Alphatross, https://www.pelletron.com/products/rf-charge-exchange-ion-source/
[6] NEC TORVIS, https://www.pelletron.com/products/toroidal-volume-ion-source/

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#179 — Oral

Commissioning And Perspectives Of The New Moderator For Thermal Neutrons At CNA HiSPANoS

GEFN - Simposio de Física Nuclear

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Abstract Text:

The use of thermal neutron radiation is widespread across numerous fields and its use is a core component of many different experiments, including the study of fission and fusion, archeology, astrophysics, medicine or industrial applications. Such experiments are mostly carried out in nuclear reactors, which are the most intense thermal neutron source. This makes measuring in research reactors highly demanded, however many experiments do not require such high neutron fluxes and can be conducted in alternative thermal neutron facilities. In this context, Compact Accelerator Neutron Sources (CANS) produce neutrons via nuclear reactions triggered by energetic ion beams. One such CANS is HiSPANoS, hosted at the Centro Nacional de Aceleradores (CNA) and open to external users. HiSPANoS used to feature epithermal and fast neutrons, and now also a high intensity and reliable thermal field and beam thanks to the newly designed moderator. The versatile and compact system, based on polyethylene and lead, allows for several configurations yielding either high thermal purity or high flux, both for a field inside a cavity or an external beam

Activation measurements have been carried out for commissioning the moderator, with results being compared to the corresponding Geant4 simulations. The result of the commissioning will be presented along with first applications:

Thermal neutron images were obtained with a collimated beam setup at HiSPANoS, allowing evaluation of the beam's intensity and focusing.

Thermal Neutron Activation Analysis was applied to a Roman coin irradiated in the thermal neutron field. By analyzing the decay of radionuclides generated during irradiation, the coin's composition was determined, demonstrating the feasibility of this technique at HiSPANoS.

These results illustrate some of the capabilities of the thermal neutron facility at CNA HiSPANoS, which will be made available to external users as the most intense multipurpose thermal neutron source in Spain.

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#188 — Oral

Advanced Characterization Of Radiation Sensors At High Temperatures Using The CNA Tandem Accelerator

GEFN - Simposio de Física Nuclear

Mauricio Rodríguez Ramos 1, María Del Carmen Jiménez Ramos 1,2, Javier García López 1,3, Adrián García Osuna 1,4, Manuel García Muñoz 3, Giulio Pellegrini 5, Carmen Torres Muñoz 1

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Abstract Text:

High temperature radiation detectors are essential for monitoring extreme environments where conventional devices fail due to thermal limitations. They are critical for applications such as in-core instrumentation in fission reactors, space exploration and next generation fusion reactors. Unlike standard sensors, these detectors maintain electrical stability, low noise, and accurate measurements, enabling reliable operation under intense radiation and harsh thermal conditions where safety and control are crucial. This work utilizes the infrastructure of the Centro Nacional de Aceleradores (CNA) to study devices under extreme radiation and temperature. We present two measurement sets conducted in the TAMARA (Temperature Analysis Measurements and Radiation Applications) chamber. This setup incorporates a thermal heater that can heat the samples up to 500°C, a temperature control system, and a calibrated optical spectrometer. Additionally, the ion beam microprobe has been upgraded with a resistive ceramic oven capable of heating targets up to 1200°C. This enables radiation hardness studies using focused microbeams to induce localized damage at high temperature.
The first example focuses on the characterization of phosphor targets used in nuclear fusion sensors. Their response and radiation hardness under ion irradiation were evaluated using the ion beam induced luminescence technique. Samples were exposed to a 3.5 MeV helium beam at temperatures ranging from room temperature up to 500°C. The results demonstrated significant thermal quenching, together with a beneficial reduction in radiation-induced degradation due to thermal annealing effects.
The second study evaluates SiC detectors developed at the Institute of Microelectronics of Barcelona (IMB-CNM-CSIC). For the detection of alpha particles these sensors showed outstanding spectroscopic response and excellent energy resolution for temperatures up to 450°C. Moreover, the radiation hardness study demonstrated that high temperature operation reduces spectrometric degradation compared with room temperature conditions, thereby extending the device lifetime and ensuring reliable performance in extreme environments.

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#197 — Oral

Development Of A Compact Cryogenic Platform For Multi-Penning-Trap Experiments

GEFN - Simposio de Física Nuclear

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Abstract Text:

In a Penning trap, charged particles are confined by the superposition of a strong magnetic field and a weak electrostatic potential. Under ultra-high vacuum conditions, this configuration provides an ideal environment for high-precision measurements in fundamental physics, allowing for long-term storage and the determination of motional frequencies with extreme accuracy [1]. When the trapped particles possess a spin degree of freedom, the spin state can be detected through spin–axial mode coupling by introducing a magnetic-field bottle [1]. A multi-Penning-trap method, based on this technique, has enabled the BASE Collaboration to perform the most precise measurements of the proton and antiproton g-factors to date [2,3], providing stringent tests of CPT symmetry [4]. In this contribution, we will describe a compact experimental platform at the Universidad de Cádiz that utilizes permanent magnets and a two-stage pulse-tube cryocooler to investigate proton production, non-destructive detection, and adiabatic ion transport within cryogenic multi-Penning-trap stacks for its application to (anti-)proton g-factor experiments. Furthermore, we will introduce a novel monolithic Penning-trap design slated for its first experimental validation on this platform. Finally, we will discuss recent progress toward Quantum Logic Spectroscopy (QLS) for (anti-)proton applications [5], alongside new QLS protocols for molecular ions [6].

[1] K. Blaum et al., Quantum Sci. Technol. 6, 1 (2021).
[2] G. Schneider et al., Science 358, 1081 (2017).
[3] C. Smorra et al., Nature 550, 371 (2017).
[4] V.A. Kostelecký et al., Nucl. Phys. B 359, 545 (1991).
[5] J.M. Cornejo et al., New J. Phys. 23, 073045 (2021).
[6] S. Schiller et al., Molecular Physics (Accepted manuscript).

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#210 — Oral

A Passive Extended Range Bonner Sphere Spectrometer For Neutron Measurements At The ALBA Synchrotron Injection LINAC

GEFN - Simposio de Física Nuclear

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Abstract Text:

Bonner Sphere Spectrometers (BSS) are the most used devices for performing neutron spectrometry for a wide range of neutron energies, from thermal up to about 20 MeV. They are composed by a set of moderating polyethylene spheres of different diameters with a thermal neutron detector at their centre. Extended Range BSSs (ERBSS) are necessary for neutrons with energies above 20 MeV. They include spheres with heavy metal inserts, able to reduce neutron energy through the (n,xn) reaction before they reach the central thermal neutron detector, without overly increasing the sphere diameters. Synchrotron radiation is produced at ALBA from 3 GeV electrons in a storage ring approximately 270 m in circumference. Electrons are initially accelerated to 110 MeV by a LINAC, then transferred to an acceleration ring (“booster”), where they reach 3 GeV, and are finally transferred to the storage ring. A large number of neutrons can be generated from interactions of electrons with beam elements. Given the time structure of the electron beam, the neutron field originated is pulsed, with short high-intensity peaks, and mixed with photons. These makes hard to use active detectors at the centre of the spectrometer spheres because of possible dead time and pile-up issues, together with the difficulty of separating the neutron signal from the photon one. To avoid these drawbacks, a system for using Au activation foils as passive detectors at the centre of the ERBSS spheres was set-up and calibrated.
This work summarizes the neutron spectrometry results from measurements in the ALBA injection LINAC, when electrons are accelerated at 80 MeV and scattered on a YAG screen in the diagnostics line, LIDIA. Results show the adequacy of the methodology. The spectrum and integral radiation quantities will be presented.
Acknowledgements: This work was partially supported by Spanish project NDOSCOR (PID2021-128346NB-C21, cofounded with FEDER).

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#225 — Oral

Direct And Indirect Low-Energy Reaction Studies With Light Nuclei At CNA

GEFN - Simposio de Física Nuclear

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Abstract Text:

The study of nuclear reactions at low energies is essential for the development and validation of theoretical models applied to astrophysical environments[1]. The experimental Basic Nuclear Physics(FNB) beamline, installed at the 3 MV tandem accelerator of the National Accelerators Center(CNA), is currently being adapted to investigate direct and indirect reactions at low energies. A versatile detection system based on large-area segmented single/double-sided silicon strip detectors (S/DSSSDs) has been installed at the FNB-CNA facility. These detectors can be arranged in a telescope configuration to enhance particle identification. Therefore, combining the detector large and segmented area with the telescope configuration, enables accurate particles energy spectroscopy with high angular resolution.
To validate the experimental setup, the direct reaction 6Li+12C was measured at incident energies ranging from 3 to 8 MeV. The excitation functions for the 12C(6Li,4He)14Ng.s. channel, obtained using DSSSD in single and telescope configurations, will be presented. These results demonstrate the particle identification capabilities of the detection system and its potential for studying multiple reaction channels.
A new challenging measurement has been proposed in collaboration with the ASFIN(AstroFisica Nucleare) group from the Laboratori Nazionali del Sud(LNS) of the Istituto Nazionale di Fisica Nucleare(INFN). It consists in the 4He-4He scattering via the indirect reaction 6Li(4He,2H)4He4He, applying the Trojan Horse Method (THM)[2]. This approach enables the investigation of 4He-cluster nuclear interactions without the masking effect of Coulomb repulsion. Preliminary results of alpha particles measured in coincidence will be presented. Thus, this work validates the experimental setup for low-energy reaction measurements and its suitability for both direct and indirect reaction studies at the FNB-CNA.
Finally, this work demonstrates the performance of the CNA-FNB experimental setup for low-energy reaction measurements and evaluates its suitability for both direct and indirect reaction studies.
[1]Goriely, EPJA 59, 16 (2023).
[2]Tumino et al., Annu. Rev. Nucl. Part. Sci. 71, 345(2021)

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#230 — Oral

Probing The Structure Of The Two-Proton Borromean Nucleus 17Ne Through Inclusive Breakup Data

GEFN - Simposio de Física Nuclear

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Abstract Text:

The proton-rich nucleus 17Ne exhibits a Borromean structure, 15O+p+p, since both 16F and diproton systems are unbound. The low-energy spectrum of this nucleus consists of a series of resonances that are not yet well identified. In this work a three-body model is used to describe the structure of 17Ne, with special attention paid to the emergence of resonant states. Subsequently, the four-body Continuum-Discretizd Coupled-Channels (CDCC) is used to study the reaction of 17Ne on a lead target at an energy around the Coulomb barrier. The comparison between the calculated elastic and breakup cross sections and the recent available experimental data (PLB 843 138007), provides an excellent framework for probing the resonant structure of this nucleus.

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#257 — Oral

A Novel Optical Model Protocol For Nuclear Reaction Analyses At Near-Barrier Energies

GEFN - Simposio de Física Nuclear

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Abstract Text:

This work presents an extensive optical model (OM) systematics based on the second version of the São Paulo Potential [1], named the São Paulo Optical Model Protocol (SP-OMP) [2]. The protocol was succesfully applied to different projectiles, such as 4,6He, 6,7Li, 8B, 9,10,11Be, and 12,13C, impinging on a 64Zn target at energies around their respective Coulomb barriers.
The protocol enables to study the sensitivity of the experimental data to the optical potential (OP). The results also allow us to study how the nuclear potential varies as a function of the incident energy and the projectile structure. By analyzing the behavior of the real and imaginary strengths (the dispersion relation) of the OP, the specific structure of each projectile can be closely correlated to the open nuclear reaction channels and the respective reaction dynamics.
We will present new experimental data for the 12,13C + 64Zn systems, along with the corresponding SP-OMP analysis. In addition, we show how the coupled-channels calculations corroborate such analysis [3]. The results allow to investigate how nuclear reaction dynamics are affected by the extra neutron of 13C compared to 12C. Finally, we compare the results obtained for the weakly bound 6,7Li and tightly bound 12,13C projectiles impinging on the 64Zn target.
References:
[1] L. C. Chamon et al. Comput. Phys. Commun. 267, 108061
[2] L. Garrido-Gómez et al. Phys. Rev. C 109, 054608
[3] L. Garrido Gómez et al. Phys. Rev. C 113, 044607

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#276 — Oral

The Nuclear Josephson Effect And γ-Ray Emission

GEFN - Simposio de Física Nuclear

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Abstract Text:

We explore the parallel between the transmission of nucleon pairs in nuclear reactions featuring superfluid components and the conduction of electron pairs across Josephson junctions. This analysis is grounded in both experimental observations and theoretical models of single- and double-neutron transfer probabilities for the 116Sn(60Ni, 61Ni)115Sn and 116Sn(60Ni, 62Ni)114Sn reaction channels. Furthermore, we examine the potential for γ-ray emission as a nuclear counterpart to the microwave radiation characteristic of the Josephson effect. By applying a quantum mechanical framework based on the DWBA, we model the coupling of the electric dipole field generated during the two-neutron transfer sequence , mapping the intrinsic collision dynamics to the frequency and intensity profiles of the resulting photons. Finally, we provide quantitative predictions for the angular distributions, analyzing powers, and spectral strength functions of the radiated γ-rays (1,2,3). We will compare with preliminary results of a experiment carried out at the Laboratorio Nazionale di Legnaro (Italy), using the detectors AGATA and PRISMA for detection of gamma rays in coincidence with the reaction products, performed by the group of L. Corradi (4).
References:
(1) Broglia, RA; Barranco, F; Potel, G and Vigezzi, E, PhysRevC.105.L061602
(2) F. Barranco, E. Vigezzi and G. Potel, IL NUOVO CIMENTO 47 C (2024) 27
(3) P. Magierski, "The Tiniest Superfluid Circuit in Nature", February 25, 2021• Physics (Viewpoint) 14, 27
(4) L. Corradi, "Sub-barrier transfer reactions and the nuclear Josephson effect", EPJ Web of Conferences 324, 00016 (2025)

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#278 — Oral

3D Hybrid Kinetic-MHD Modelling Of The Interaction Between Edge Localised Modes And Energetic Particles In The ASDEX Upgrade Tokamak

GEFN - Simposio de Física Nuclear

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Abstract Text:

The heat loads due to unmitigated Edge Localized Modes (ELMs) pose a serious threat to the first wall of ITER and future nuclear fusion power plants [1]. While extensive efforts are currently focused on the development of ELM control techniques, the non-linear physics underlying the ELM crash remains poorly understood. Experimental observations have revealed fast-ion losses and acceleration during ELM crashes [2, 3], with potential implications for burning plasmas rich in suprathermal particles.
In this work, we discuss hybrid kinetic-MHD simulations of ELMs with the MEGA code [4] for an ASDEX Upgrade plasma. The simulations indicate that, although ELMs are primarily driven by thermal pressure gradients, the resonant interaction between edge fast-ions and the electromagnetic perturbations from the ELMs ultimately determines the resulting spatio-temporal structure of ELMs. In the presence of fast-ions, the modes broaden radially and exhibit high frequencies ($f \sim 200-300$ kHz) during the ELM. This frequency boost originates from the imbalance between MHD and energetic particle forces. The resulting perturbation structure is strongly sheared, and the fast-ion distribution mirrors the bulk plasma pressure perturbation structure, extending into the far scrape-off layer. The simulations qualitatively reproduced key signatures of large type-I ELMs observed in magnetic diagnostics and fast-ion loss detectors, in low collisionality plasmas with high fast-ion content [5]. This research points towards new opportunities to leverage kinetic effects for ELM control and the realization of high-confinement, ELM-free regimes.

[1] A. Loarte, Nat. Phys. 2, 369–370 (2006).
[2] M. Garcia-Munoz et al., Nucl. Fusion 53, 123008 (2013).
[3] J. Galdon-Quiroga el al., Phys. Rev. Lett. 121, 025002 (2018).
[4] Y. Todo et al., Phys. Plasmas 5, 1321 (1998).
[5] J. Dominguez-Palacios et al., Nat. Phys. 21, 43-51 (2025).

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#284 — Oral

Dynamic Neural Quantum States

GEFN - Simposio de Física Nuclear

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Abstract Text:

Neural Quantum States have emerged as a powerful variational ansatz for modeling complex quantum systems. However, extending this framework to time evolution presents notable challenges. In this work, we simulate the time evolution of quantum states subjected to potential shifts and momentum kicks using a real-valued network architecture governed by the Dirac-Frenkel variational principle. The results are validated by benchmarking wavefunction fidelity and certain physical observables. Ultimately, this work demonstrates the viability of achieving accurate time evolution through machine learning, laying the groundwork for simulating the dynamics of more complex, interacting systems.

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#293 — Oral

Study Of Neutron-Rich Beta-Delayed Emitters Relevant For Understanding The Formation Of The R-Process Rare Earth-Peak Around Mass A~160

GEFN - Simposio de Física Nuclear

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Abstract Text:

The Rare-Earth Peak (REP) at A~160 is a distinct feature of the solar r-process abundance pattern. Its sensitivity to physical conditions during the freeze-out phase makes the REP a valuable probe for the late-stage dynamics of the astrophysical environment. Since the r-process path crosses extremely neutron-rich regions that remain experimentally inaccessible, modeling these environments relies heavily on theoretical extrapolations. To refine the predictive power of these models, measurements of half-lives (T1/2) and neutron emission probabilities (P1n) are key to provide constraints. Toward this end, the Beta-delayed neutrons at RIKEN (BRIKEN) collaboration [1] was established to perform high-precision measurements of neutron-rich isotopes.

In this contribution, we focus on the Ba-Nd region (Z=56-60), which is central to the formation of the REP [2,3]. We report the final results from the BRIKEN-REP experiment, providing newly determined T1/2 and P1n values for isotopes ranging from 146Ba to 162Nd. We also present a new set of global nuclear structure calculations and perform a systematic comparison with our experimental data and existing theoretical frameworks. Finally, we discuss the implications of these new constraints on the r-process abundance pattern using nuclear reaction network simulations.

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[2] M. R. Mumpower et al , Phys. Rev. C 85, 045801 (2012).
[3] A. Arcones and G. Martinez Pinedo , Phys. Rev. C 83, 045809 (2011).

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#330 — Oral

PALOMARES: UN “LABORATORIO NATURAL” PARA ESTUDIOS RADIOECOLOGICOS DEL PLUTONIO

GEFN - Simposio de Física Nuclear

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Abstract Text:

En Enero de 1966 y debido a un accidente de un bombardero B-52 de los Estados Unidos mientras se abastecía de combustible en vuelo, dos bombas nucleares experimentaron una explosión convencional al impactar en las cercanías del pueblo de Palomares (Almería), diseminando su contenido radiactivo en varias hectáreas de terreno.
Aunque se realizo una limpieza inmediata, todavía persiste en la zona una contaminación remanente, constituyendo la zona afectada un laboratorio natural para estudiar la forma, distribución, evolución y comportamiento de la contaminación radiactiva presente.
En esta presentación resumimos los estudios realizados por el grupo Física Nuclear Aplicada de la Universidad de Sevilla en el área, con un énfasis especial en remarcar similitudes y diferencias con otros accidentes nucleares que han afectado diversas zonas del planeta.

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#374 — Oral

^{146}Nd(N,γ) Activation At N_TOF NEAR: Bayesian-Optimised HPGe Modelling And First Results Of The SACS

GEFN - Simposio de Física Nuclear

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Abstract Text:

The slow neutron capture process is responsible for about half of the elements heavier than 56Fe, and its yields in AGB stars determine heavy-element isotopic abundances. In presolar stardust SiC grains, the Nd isotopic ratios remain in tension with stellar model predictions, and this discrepancy may be resolved by an approximately 15% increase of the 146Nd(n,γ) cross section at kT = 8 keV [1]. A campaign at n_TOF has therefore been proposed [2, 3], combining for the first time a time-of-flight measurement at n_TOF-EAR2 [4] with an activation measurement at the new NEAR facility [5].
A second uncertainty concerns the 147Nd half-life, a key input for the s-process branching at 147Nd. The reference value of 10.98 d [6] disagrees with a more recent 11.26 d measurement [7], and this affects the extraction of the spectral-averaged cross section .
This contribution will present first results from the 146Nd(n,γ) activation campaign at NEAR [8], where the neutron spectrum is shaped by filters of different thicknesses, allowing the integral cross section to be probed in different energy windows . Preliminary SACS values from NEAR and a new 147Nd half-life determination using HPGe gamma spectrometry in the GEAR decay station will be shown.
As part of this work, the HPGe efficiency at GEAR was experimentally characterised to build a high-accuracy Geant4 model. Since manufacturer-provided geometric parameters are often unreliable [9], we propose a surrogate-based Bayesian optimisation framework to recover accurate detector parameters with far fewer simulations than exhaustive testing of all parameter combinations. First results for the model optimisation and its impact on systematic uncertainties in NEAR activation measurements will be reported.

[1] 10.1016/j.gca.2017.05.027
[2] CERN-INTC-2023-055, INTC-P-671
[3] CERN-INTC-2025-044, INTC-P-671-ADD-1
[4] 10.1016/j.nima.2015.07.027
[5] 10.1140/epja/s10050-025-01674-7
[6] 10.1016/0022-1902(71)80409-8
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[9] 10.1016/j.apradiso.2019.108883

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#375 — Oral

Origen De La Estadística Espectral Intermedia En Caos Cuántico: Grado De Caos Y Niveles Perdidos

GEFN - Simposio de Física Nuclear

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Abstract Text:

El Caos Cuántico carece de una definición sólida en Física Cuántica a día de hoy. La definición más aceptada surgió gracias a la aplicación de la Teoría de Matrices Aleatorias (RMT: Random Matrix Theory) en Física Nuclear y se basa en las propiedades estadísticas del espectro de niveles de energía: las propiedades espectrales en el extremo caótico son las mismas que las de la colectividad GOE de la RMT y las del extremo regular coinciden con la colectividad de Poisson.
La mayoría de sistemas físicos poseen un tipo de dinámica intermedia entre los extremos caótico y regular. Pero cuando un espectro no está completo (hay niveles perdidos), aunque sea caótico, sus propiedades espectrales resultan ser también intermedias entre GOE y Poisson.
Por tanto, si un análisis de estadística espectral de un sistema arroja un resultado intermedio, puede ser muy difícil determinar el origen de este comportamiento (si se trata realmente de dinámica intermedia entre regularidad y caos o se trata solo de niveles perdidos), a no ser que se posea algún tipo de información adicional sobre el sistema a priori.
Existen fórmulas de estadísticos espectrales con 1 parámetro para determinar el grado de caos asumiendo que el espectro está completo o para determinar la fracción de niveles perdidos asumiendo que el espectro es caótico. Pero no existían hasta ahora fórmulas con 2 parámetros para poder abordar ambas situaciones simultáneamente, es decir, poder distinguir cuál es el origen del comportamiento intermedio o poder analizar un sistema que posea un tipo de dinámica intermedia y además una cierta fracción de niveles perdidos.
En este trabajo proponemos una fórmula de ajuste con 2 parámetros (grado de caos y fracción de niveles perdidos) para un estadístico muy utilizado en Caos Cuántico: la distribución de espaciamientos a primeros vecinos (NNSD: Nearest Neighbor Spacing Distribution).

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#168 — Oral

Monte Carlo Study Of LET In Therapeutic Helium Ion Beams: Code Comparison

GEFN y GEFM - Simposio compartido de Física Médica y Física Nuclear

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Abstract Text:

Particle therapy has gained increasing relevance over conventional radiotherapy for certain treatments, and helium ions are emerging as a promising option in this field, with clinical trials recently conducted at the Heidelberg Ion-Beam Therapy Center (Germany). To further develop this modality, accurate characterization of both physical and radiobiological properties of therapeutic helium beams is crucial, and Monte Carlo simulations are a key tool for this purpose.
In this context, linear energy transfer (LET) is a standard quantity for describing radiation quality. Moreover, many radiobiological models for estimating relative biological effectiveness (RBE) rely on LET or related quantities. Consistency in LET calculations across different Monte Carlo codes is therefore essential for reliable radiobiological assessments.
In this work, we compare track-averaged LET (Lt) and dose-averaged LET (Ld) results obtained with widely used Monte Carlo codes in medical physics, including PENHAN, FLUKA and TOPAS, and quantify their variability. Following the approach described in [1], we first consider a simplified scenario with a monoenergetic 160 MeV/u helium pencil beam impinging on a water phantom. Lt and Ld values are computed at different depths, allowing us to characterize the evolution of radiation quality along the beam path. Differences between codes are analyzed, together with the impact of simulation settings such as alpha electronic stopping power models and non-elastic nuclear reaction treatment. We then extend the study to a more realistic configuration and compare simulation results with available experimental data [2] for validation.
This study highlights the importance of accurate physics modelling of alpha electronic stopping power and nuclear reactions in Monte Carlo simulations and the relevance of code consistency in helium ion radiotherapy to ensure reliable results.
[1] D. Puerta et al., Med. Phys. 53, e70378 (2026).
[2] I. D. Muñoz et al., Int. J. Radiat. Oncol. Biol. Phys. 120, 205-215 (2024).

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#176 — Oral

Charge Collection And High-Density Ionization Effects In Ultra-Thin 4H-SiC Diodes For FLASH Radiotherapy Dosimetry

GEFN y GEFM - Simposio compartido de Física Médica y Física Nuclear

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Abstract Text:

Ultra-thin 4H-SiC detectors are promising candidates for real-time dosimetry in FLASH radiotherapy due to their radiation hardness, fast response, and capability to operate at zero bias. In this contribution, we investigate the charge collection properties of ultra-thin 4H-SiC diodes fabricated at IMB-CNM under both low- and high-LET beams, combining experimental measurements with TCAD Sentaurus and SRIM Monte Carlo simulations.
Proton irradiations in the 1-13 MeV energy range were performed using the CNA Cyclotron facility to assess detector linearity under conditions relevant for dosimetry, while high-LET effects were investigated by means of IBIC measurements performed at a the CNA 3 MV Tandem accelerator with alpha particles. The results indicate that ultra-thin 4H-SiC diodes maintain linear response under proton irradiation and exhibit charge collection from nominally undepleted regions under high-LET conditions.
The combined experimental and simulation evidence of these results provides new insight into charge transport in partially depleted 4H-SiC detectors and into the device behavior under FLASH radiotherapy conditions.

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#180 — Oral

Development Of A Fast Electrostatic Chopper For FLASH Proton Radiobiology

GEFN y GEFM - Simposio compartido de Física Médica y Física Nuclear

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Abstract Text:

FLASH proton therapy has attracted considerable interest due to its potential to reduce normal-tissue toxicity while preserving tumor control through the delivery of radiation at ultra-high dose rates (>40 Gy/s). Nevertheless, further experimental studies are required to clarify the underlying radiobiological mechanisms and to establish the optimal irradiation conditions for clinical implementation.
In this context, a fast electrostatic chopper is being developed for the external beamline of the cyclotron at the Centro Nacional de Aceleradores to enable precise manipulation of the proton beam time structure. The system is designed to generate intense proton pulses with durations of the order of microseconds, suitable for radiobiology experiments in the FLASH regime.
The device design has been optimized through electromagnetic simulations performed with CST Studio Suite, allowing the definition of the electrode geometry, estimation of the operating voltages, and evaluation of mechanical tolerances. In parallel, the chopper has been implemented in a complete beamline model using TOPAS simulations to study beam transport conditions, assess the possible incorporation of additional elements such as collimation systems, and optimize the operating parameters of the setup. The installation and preliminary commissioning results are also presented.

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#211 — Oral

Neutron Spectrometry In Proton Therapy At Clinica Universidad De Navarra

GEFN y GEFM - Simposio compartido de Física Médica y Física Nuclear

Carles Domingo 1, Roberto Méndez-Villafañe 2, Evangelina Martínez-Francés 3, Verónica Morán 3, José A. Cuesta-Reina 3, José Manuel Álvarez 4, Josep M. Martí-Climent 5

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Abstract Text:

Projects INTEND and MENPRO are under way for characterizing the stray neutron fields originated during treatment at the Clinica Universidad de Navarra (CUN) proton therapy room. Neutrons are originated from interaction of the primary protons with any material that they could find along their path to the patient's treatment volume, including accelerator elements, beam degraders and compensators, as well as patient's tissues. Irradiations were planned with proton beams of a single energy layer at 70, 150 and 229 MeV, as well as with a realistic clinical treatment, impinging in a solid water phantom. Measurements of neutron ambient dose equivalent H*(10) and personnel dose equivalent Hp(10) are in progress using several types of instruments, including both rem-meter -type and passive detectors at several specified points inside and around the treatment room. Neutron spectrometry was performed in four points inside the room, at different directions with respect to the incoming beam.
This work summarizes the spectrometry results obtained from measurements using two extended-range Bonner sphere spectrometers (ERBSS) based on 3He detectors, one extended-range single-sphere SP2 (Else Nuclear), one single moderator non-extended-range DIAMON-LE (Raylab), and a bubble detector spectrometer (BDS from BTI). Spectra were obtained unfolding measurements using codes and procedures adequate for each type of spectrometer. MC simulated spectra are also compared with the measured ones. DIAMON-LE and BDS results were interpreted considering that these instruments are designed for neutron spectrometry from thermal energies up to 20 MeV.
Results are consistent with which it can be expected for each detector type. All spectrometers, except BDS, identify the thermal peak. Some large discrepancies appear between spectrometers and MC for high-energy neutrons. BDS results show very limited energy resolution, and DIAMON-LE cannot display the high-energy peak.
Acknowledgements: This work has been partially supported by Spanish projects MENPRO (CSN: PR-128-2024) and INTEND (PID2025-168369NB).

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#214 — Oral

Characterization And Biological Validation Of A BNCT Irradiation Field Using PADC Detectors, RCF And Microdosimetric Modelling

GEFN y GEFM - Simposio compartido de Física Médica y Física Nuclear

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Abstract Text:

Boron Neutron Capture Therapy (BNCT) is a binary radiation treatment relying on the selective uptake of B-10 in tumors, requiring a high thermal neutron flux with minimal fast neutron and gamma ray contamination. The reaction between the thermal neutron and the B-10 release an alpha and lithium nucleus, two high-LET particles that deposit their energy inside the cell causing lethal damage. This work characterizes a BNCT-optimized irradiation field at a TRIGA Mark II reactor and compares the effects on various cell samples to standard radiation fields.
The irradiation setup was localized within the graphite thermal column of the TRIGA reactor (Mainz). Gamma contamination was mitigated using lead shielding, while additional graphite bars further thermalized the neutrons. Dosimetric profiling was conducted using radiochromic films paired with specific radiation converters.
Additionally, PADC plates were employed to quantify the alpha particle tracks emitted by the BNCT reaction, as well as proton tracks generated by the elastic scattering of fast neutrons. For biological validation, FaDu tumor cells and isolated lymphocytes were exposed to nominal doses (1–6 Gy) to evaluate clonogenic survival and DNA double-strand breaks (DSB) via the γH2AX foci assay. Experimental data were cross-referenced with Monte Carlo (GATE/Geant4) cellular microdosimetric models.
Dose contributions from primary beam components were assessed across different shielding configurations to optimize the thermal neutron field, and microdosimetric models were applied to estimate biological sample doses. Results demonstrated linear dose-response relationships for lymphocyte DNA damage, while tumor cell survival was reduced compared to photon reference data, due to the relative biological effectiveness of thermal neutrons.
Ultimately, this integrated experimental and computational methodology validates the reactor facility for advanced BNCT research.
Key words:
boron compounds, Boron Neutron Capture Therapy, microdosimetry modelling, MonteCarlo simulations, nuclear reactor, tumor cells

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#289 — Oral

Integration Of A Pixelated Crystal In A Compton Camera For Dose Monitoring In Boron Neutron Capture Therapy

GEFN y GEFM - Simposio compartido de Física Médica y Física Nuclear

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Abstract Text:

Boron Neutron Capture Therapy (BNCT) is an experimental radiotherapy technique in which boron linked to a drug, 10B-BPA, is administered to the patient and selectively accumulates in cancer cells. This therapy relies on the large boron neutron capture cross-section to deliver a targeted dose from neutron irradiation. An unresolved problem in BNCT is the real-time dosimetry. The current method relies on simple extrapolations from previous PET scans and on monitoring of blood boron concentration [1]. While tracking the 478 keV prompt gamma-rays from the neutron capture reaction could provide a direct measurement of the boron dose distribution, the intense radiation fields present during treatment yield overwhelmingly high count rates. These extreme conditions push conventional detection systems beyond their operational limits. The i-TED Compton Camera Array, with its low neutron sensitivity and high efficiency, is an ideal candidate for BNCT dosimetry [2-4]. Nevertheless, its standard monolithic crystal configuration suffers from large count rates and signal pile-up under such intense radiation fields.
To overcome this operational limit, we present the characterization and integration of a pixelated (8x8) CLLBC crystal into the i-TED Compton camera. By confining scintillation light, this segmented design drastically reduces pixel firing rates, allowing the detector to operate at incident rates up to 64 times higher. This contribution details the characterization and integration of this first pixelated crystal into an i-TED module. To evaluate its imaging quality, the prototype was coupled as a scatterer and mounted on a rotary system for experimental measurements and preliminary 3D imaging tests, validating the detector's response.

References
[1] IAEA. Advances in Boron Neutron Capture Therapy. Vienna, 2023.
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#21 — Oral

Spectroscopy-Based Tools For Probing Magnetic Confinement Plasmas In The Stellarator TJ-II

GEFP - Plasma Physics

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Abstract Text:

The goal of magnetic confinement fusion (MCF) research is to establish nuclear fusion as a clean, reliable, secure, and commercially feasible energy source for future generations. Within MCF, stellarators offer intrinsic stability as well as continuous operation potential. One such device is the TJ-II, a heliac-type with major radius of 1.5 m and averaged minor radius ≤0.22 m. Plasmas, which are fully 3-dimensional, are created using up to 500 kW of microwave power provided by 2 gyrotrons operated at 53.2 GHz, and electron densities and temperatures up to 1.7x1019 m-3 and 2 keV, respectively, are achieved. Additional heating of up to 1 MW is injected by 2 tangential neutral beam injectors that accelerate hydrogen atoms to 31 kV, so that electron densities up to 5x1019 m-3 can be attained.
For plasma studies, a broad range of passive and active diagnostics is installed, many of which are spectroscopy-based. For instance, passive spectroscopy diagnostics include filterscopes, e.g., Balmer Halfa at 656.3 nm, vacuum ultraviolet, ultraviolet, visible and infrared spectrometers (16 nm to 1600 nm), broadband bolometers (0.01 to 1100 nm), plus X-ray monitors and arrays (0.5 to 10 keV). In contrast, active systems require external stimulations, e.g., a laser beam is used to obtain density and temperature profiles (Thomson Scattering), a He gas-puff system with fast-frame imaging cameras is used for edge studies, a compact neutral beam is employed to measure ion temperature and velocity profiles plus radial electric (Charge-Exchange Recombination Spectroscopy) or magnetic fields (Motional Stark effect), whilst a supersonic pulsed helium beam is used to measure plasma edge parameters. Spectroscopy techniques are employed also to evaluate transport of impurity tracers injected using TESPEL or laser blow-off methods and to determine ablation during cryogenic pellet injections. Both operational and new techniques, their operational ranges, and representative measurements, will be presented.

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#145 — Poster

Ar/CO2/H2O Plasmas Generated In A Modified Surfatron Device

GEFP - Plasma Physics

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Abstract Text:

A modified surfatron design capable of sustaining non-filamentary argon microwave plasmas (2.45 GHz) at atmospheric pressure with low power consumption was utilized to generate $Ar/CO_2/H_2O$ plasmas under stable operating conditions. The system enabled continuous and reliable plasma operation without the need for external cooling, highlighting its simplicity and energy efficiency. This configuration, previously demonstrated to be highly effective for OH radical production in Ar/H_2O mixtures, is here further investigated regarding its potential application in CO_2 valorization and plasma-assisted conversion processes.
Additionally, the influence of introducing small amounts of water vapor into the gas mixture was systematically examined in order to evaluate its impact on plasma chemistry and reactive species formation. Optical Emission Spectroscopy (OES) was employed to identify and diagnose the excited species generated in the different plasma discharges, providing insight into the underlying reaction pathways and plasma dynamics. Finally, CO_2 conversion into CO was quantitatively evaluated by Gas Chromatography, allowing assessment of the performance and efficiency of the proposed plasma system for CO_2 conversion applications.

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#166 — Poster

Implementation Of The Thomson Scattering System For The SMART Tokamak: Status & Synthetic Modeling

GEFP - Plasma Physics

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Abstract Text:

The SMall Aspect Ratio Tokamak (SMART), recently commissioned at the University of Seville, is the first spherical tokamak designed to explore the synergy between low aspect ratio geometry and negative triangularity (NT). To investigate the confinement regimes and pedestal physics expected in NT scenarios , SMART requires high-fidelity kinetic profile measurements. This work reports on the current implementation status of the Thomson Scattering (TS) diagnostic, developed in collaboration with PPPL, and presents its design validation through a comprehensive synthetic modeling pipeline.
Following the successful generation of the first plasma in November 2024, the SMART project has transitioned into an intensive hardware commissioning phase. We report on the status of the TS system integration, key components have been procured and ready for alignment. The diagnostic is designed to resolve 28 spatial points across the full plasma radius, with dedicated high-resolution coverage for both the High-Field Side (HFS) and Low-Field Side (LFS) pedestals.
To assess the system's capability before the first measurement, a synthetic diagnostic has been developed. The forward model generates realistic scattered spectra using the relativistic Selden-Matoba formalism, convolved with experimentally calibrated polychromator transmission curves. The simulation incorporates a noise model accounting for photon noise, avalanche photodiode (APD) excess noise, electronic noise, and plasma Bremsstrahlung background. An inverse inference module, employing differential evolution for global minimum search refined by least-squares minimization, allows for the reconstruction of electron temperature (Te) and density (ne) profiles.
Sensitivity scans utilizing input profiles from TRANSP simulations for the different operational phases of SMART confirm the design's robustness. The analysis demonstrates that the system can achieve a high spatial resolution, varying from ~ 5.8 mm at the LFS to ~9.2 mm at the HFS, across a dynamic range of 1-1000eV and densities up to 1 × 10^20 m^-3.

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#192 — Poster

Time Evolution Of The Ns-Laser-Generated Plasma On Steel Samples In Controlled Atmospheres

GEFP - Plasma Physics

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Abstract Text:

Laser-Induced Breakdown Spectroscopy (LIBS) has become a widely used analytical technique. Based on the use of a short-duration pulsed laser focused onto a sample surface, producing optical breakdown and generating a high-temperature plasma, LIBS is a powerful and versatile method capable of providing both analytical and physical information in situ and in real time through the spectral emission of laser-induced plasmas.

In general, LIBS analyses are typically performed at relatively short delay times after plasma formation (on the order of 1–2 μs), when the plasma approaches local thermodynamic equilibrium (LTE) conditions and the populations of excited species can often be described by the Boltzmann distribution, while ionization balance approximately follows the Saha equation. Under these conditions, plasma temperature and species concentrations can be estimated more reliably. However, in the analysis of steel samples, which contain a wide variety of alloying elements, plasma emission during the first microseconds includes a large number of ionic lines, atomic lines, and molecular bands. This spectral congestion hinders the detection of certain elements, particularly those with high excitation energies and/or present at very low concentrations. In this work, we propose the use of plasma emission at later times (typically beyond ~10 μs), where spectrally less congested emission can be observed because the remaining signals mainly arise from low-energy atomic transitions, resonance transitions, and molecular species formed during the later stages of plasma evolution.

In addition, this work presents a new portable LIBS arrangement that enables in situ measurements. The design includes a compact and versatile chamber in which measurements can be performed under different gaseous atmospheres and applied to a variety of materials. These techniques are applied to distinguish steels with different chemical compositions.

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#205 — Oral

Physics-Informed Neural Network Modelling Of Perpendicular Energy Diffusion In The Scrape-Off Layer Of Nuclear Fusion Devices.

GEFP - Plasma Physics

Juan Gallego Llorente 1,2, Pavlos Protopapas 3, Andrés Bustos 1, Arturo Alonso 1, María Scherezade Barquero 1, José Antonio Moríñigo 1, Rafael Mayo-García 1

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Abstract Text:

Nuclear fusion is a promising energy source, owing to its abundant fuel and the absence of long-lived radioactive waste. However, commercial fusion remains difficult to achieve. One of the central challenges is protecting the divertor from the intense heat flux exhausted from the plasma. For a given amount of transported power, this heat flux depends on the width of the scrape-off layer (SOL) transport channel, which is set by the balance between perpendicular and parallel transport. Higher perpendicular transport leads to a wider transport channel and therefore a lower peak heat load on the divertor. Determining the perpendicular and parallel heat conductivities, together with their parametric dependencies, is therefore essential for accurately predicting the heat loads the divertor must withstand. We pose this as an inverse problem in which the unknown is not a scalar coefficient but the functional form of the perpendicular conductivity itself, and develop a Physics-Informed Neural Network (PINN) framework to recover its dependence on plasma density and temperature from sparse SOL measurements. The governing energy-transport equation is embedded in the loss function, so the inferred conductivity is jointly constrained by the data and the underlying transport model. The code is written with NeuroDiffEq, a state-of-the-art python library for developing PINN applications. We use the bundle-solution concept to enable the simultaneous analysis of several plasma discharges, and the adaptive weighting of partial losses to improve convergence and prediction accuracy. The results show that the framework can successfully recover the conductivity from noisy data under conditions close to realistic measurements. We also demonstrate that multi-discharge processing extends the temperature and density domain over which the conductivity is determined, improving the generality of the inferred relation. Future work will apply this framework to experimental data from the TJ-II and Wendelstein 7-X stellarators, enabling a multi-machine analysis of SOL diffusivity.

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#207 — Poster

Implementation Of The First NBI System For The SMART Tokamak

GEFP - Plasma Physics

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Abstract Text:

This poster contribution will explore the optimized injection geometry, as part of the design of the beam duct and beam dump of the Neutral Beam Injector for the SMall Aspect Ratio Tokamak (SMART). SMART aims to study the potential of combining negative triangularity (NT) and spherical tokamaks (ST). This synergy promises high-performance plasmas while minimizing instabilities, along with the compactness benefits of ST. SMART was designed to achieve a wide range of geometrical configurations, with a triangularity spanning between $-0.6 < \delta < 0.6$, as well as a plasma current of $I_p > 500$ kA and a toroidal magnetic field of $B_t = 1.0$ T. To enable the desired plasma scenarios, auxiliary heating will be employed, specifically through a Neutral Beam Injector (NBI), to supply the required power.
SMART will gradually increase its capabilities and performance along three different operational phases. During Phase 1 & 2, an NBI will inject neutrals with energy up to $E_{NBI} = 30$ keV and will deliver approximately $P_{NBI} = 0.3$ MW of power, granting access to plasma currents between $100 \text{ kA} < I_p < 500 \text{ kA}$, along with a toroidal magnetic field in the range of $0.1 \text{ T} < B_t < 0.4 \text{ T}$.
A crucial aspect of the NBI is its geometric configuration, which is constrained by the design of the beam duct that connects the injector to the tokamak. The design of this beam duct also accommodates diagnostic access to monitor and characterize the beam. Other important properties worth studying are the shine-through profiles of the neutrals to properly design a beam dump which will protect the first wall. Simulation scenarios produced by the ASCOT5 code suite will guide the design of the beam duct and beam dump. References present in the poster contribution.

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#219 — Oral

Investigation Of Edge Deuterium Density Profiles With MI-CXRS At ASDEX Upgrade

GEFP - Plasma Physics

Julia Perez Gonzalez 1,2,3, Pilar Cano Megías 1,3, Eleonora Viezzer 1, Rachael M. Mcdermott 2, Marco Cavedon 4,2, Diego J. Cruz Zabala 1, Ralph Dux 2, Tabea Gleiter 2, Athina Kappatou 2, Hanna Lindl 2, Kiera A. Mckey 1,3, Alfonso Rodriguez Gonzalez 1, Roxana Takacs 2

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Abstract Text:

The main ion density in the plasma edge plays a key role in determining particle transport, pedestal structure, and confinement properties, making its accurate measurement essential for the validation of predictive models in fusion plasmas. However, deuterium density (nD) profiles have traditionally been inferred from electron, impurity density and effective charge measurements, under the assumption of quasineutrality due to the challenges associated to their direct experimental measurement. In this work, the accurate characterization of the edge deuterium density in inter-ELM H-mode plasmas has been achieved at ASDEX Upgrade using main ion Charge Exchange Recombination Spectroscopy (CXRS) [1,2]. Since nD is not a direct observable in CXRS, it must be inferred from the absolute spectral line intensity using detailed modelling. The applied methodology combines the analysis of experimental main ion CXRS data with forward modelling using the Monte Carlo based forward model FIDASIM4 code[3]. An iterative procedure[4,5] is employed in which synthetic spectra generated by the model are compared with experimental measurements of the main ion CX emission until convergence is achieved, allowing the inference of the nD profile[6]. The results presented in this contribution enable the characterization of the pedestal top and steep gradient region of the nD profile with an average uncertainty below 10%, mainly determined by the experimental CXRS intensity resolution. The experimentally inferred nD profiles are also compared with commonly used theoretical assumptions for edge density reconstruction, providing insight into the validity of standard approximations. Importantly, compared to conventional approaches, the forward modelling methodology provides improved accuracy and lower uncertainty values. Overall, the results obtained in this work represent a meaningful step toward an improved characterization of main ion density in fusion plasmas. Furthermore, the applied methodology has been successfully validated through the analysis of multiple experimental cases, demonstrating their robustness and applicability for pedestal plasma studies.

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#228 — Oral

BRIGHT, A Negative Triangularity, Low Aspect Ratio, HTS-Based Tokamak As A Platform For Fusion Enabling Technology Research

GEFP - Plasma Physics

Fernando Puentes Del Pozo, Diego Jose Cruz Zabala, Manuel Garcia Muñoz, Francisco Jose Aguilera Cabezas, Jorge Campos Garcia, Pilar Cano Megias, Daniil Kabirov, Rafael Marques Gomez, Juan Manuel Ordoñez Jimenez, Alfonso Rodriguez Gonzalez, Lucia Sanchis Sanchez, Eleonora Viezzer

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Abstract Text:

The development of commercially viable fusion power plants (FPP) depends on the maturity of certain enabling technologies, such as high temperature superconductor (HTS) magnets, tritium breeding blankets, and the tritium fuel cycle. Developing these technologies to the extent that they are viable for licensing by regulators requires testing them on FPP relevant conditions [1]. This need motivates the design of the BReedInG High-field Tokamak (BRIGHT), a fusion pilot plant and volumetric neutron source capable of testing these technologies on relevant conditions, as well as enabling the research of the physics of burning plasmas, in order to accelerate the development of compact FPPs.
The design of BRIGHT combines HTS magnets and low aspect ratio to achieve a compact design capable of producing FPP relevant fusion neutron fluences on a fast timeline and with reduced capital costs. However, the combination of these two technologies into a small fusion reactor would lead to prohibitive exhaust heat loads as well as severe space constrains in the design. The introduction of negative triangularity enables this design by increasing the divertor wetted area and the inboard space for neutron shielding and central solenoid and preventing ELMs [2,3]. The design of BRIGHT allows for a high Q inductive scenario, suitable for burning plasma research, as well as a fully non-inductive steady state low Q scenario, suitable for consistently producing neutron fluxes for technology and material testing.
In this work, we present the results of the integrated modeling for the preconceptual design of BRIGHT, including transport simulations, MHD equilibrium, magneto-mechanical design of the magnet system, fast ion physics, Monte Carlo neutron simulations and MHD stability.
[1] G. Federici et al, Nuclear Fusion (2023) 63 125002
[2] A. Mancini et al, Fusion Engineering and Design (2023) 192 113833
[3] D.J. Cruz-Zabala et al, Nuclear Fusion (2024) 64 126071

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#229 — Poster

Status Of The SMall Aspect Ratio Tokamak And Achievements Of The First Experimental Campaign

GEFP - Plasma Physics

Alfonso Rodriguez Gonzalez, Manuel Garcia Munoz, Eleonora Viezzer, Diego Cruz Zabala, Francisco Aguilera Cabezas, Jorge Campos Garcia, Pilar Cano Megias, Joaquin Galdon Quiroga, Javier Gonzalez Martin, Carlos Lopez Jimenez, Juan Manuel Ordoñez Jimenez, David Peña Arevalo, Fernando Puentes Del Pozo, Patrick Campbell Quigley, Juan Ramos Delgado, Jesus Salas Suarez-Barcena, Juan Sanchez Gamino, Pablo Vicente Torres

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Abstract Text:

The SMall Aspect Ratio Tokamak (SMART) is a spherical tokamak (ST) being operated in the University of Seville. SMART is a small to medium size machine that has been designed to operate up to Ip ≤ 1 MA, Bt ≤ 1T, magnetic axis at R=0.45 m and flexible plasma shaping allowing positive and negative triangularity plasmas. Its main objective is investigating the combination of low aspect ratio and negative triangularity as a viable scenario for compact fusion power plants.
The poloidal coil system of SMART allows many different scenarios with aspect ratios 1.46 < A < 3.0, elongations κ < 3.0 and triangularities -0.6 < δ < 0.6. The first operational phase will explore such scenarios with ohmically heated plasmas with currents of Ip ~ 100 kA and Bt = 0.1 T. The next phases of operation will add an NBI heating system of Einj = 30 keV and Pinj ~ 300 kW and an upgrade of the power supply system that will allow higher magnetic field on axis and plasma current (Ip ~ 500 kA and Bt = 0.4 T).
SMART achieved its first plasmas in November 2024 and has operated weekly since then in a commissioning phase without shaping coils. Since then, tokamak confined plasmas have been achieved in limited configuration and several diagnostics have been commissioned with more to come soon.
In this contribution, the actual status and future prospects of SMART will be discussed. An overview of the diagnostics and NBI system will be shown as well as the measurements obtained during the first experimental campaign.

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#234 — Oral

Efecto E Interpretación De Los Parámetros Espaciotemporales De La Re-Excitación De Un Plasma Inducido Por Láser De Femtosegundos Mediante Un Pulso Láser De Nanosegundos

GEFP - Plasma Physics

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Abstract Text:

Los láseres pulsados de femtosegundos son una fuente de excitación poco común en el campo de la Espectroscopía de Plasmas Inducidos por Láser (LIBS, por sus siglas en inglés) en comparación a los usuales láseres de nanosegundos. El régimen de ablación ultrarrápida de los láseres de femtosegundos implica que la energía se deposite en la muestra en una escala temporal por debajo del tiempo de relajación electrón-red, evitando los efectos térmicos de la ablación por láser de nanosegundos. En consecuencia, se reduce el fraccionamiento (ablación no estequiométrica) y se mejora la resolución lateral de la técnica.
Sin embargo, no solo se trata de una instrumentación más compleja y costosa, sino que la aplicación espectroscópica se ve condicionada por la formación de plasmas (fs-LIP) de menor emisividad absoluta y vida más corta. Una de las casusas es que no existe proceso de interacción entre láser y plasma, de gran importancia en las características físicas de los ns-LIP. Para incorporar este efecto, una posible estrategia es focalizar un segundo láser de ns directamente sobre el fs-LIP, llevando el segundo haz de forma paralela a la superficie de la muestra para no inducir más daño sobre ella.
En esta configuración experimental (fs/ns-LIBS ortogonal) es necesario llevar a cabo una optimización tanto temporal como espacial, puesto que el fs-LIP es un plasma dinámico (duración de unos 10 μs) de reducidas dimensiones (menos de 0.5 mm de ancho y, en su mayor extensión, por debajo de 2 mm de alto) y, por tanto, son críticos tanto el momento como la posición relativa en la que se deposita la energía del láser de ns. En este trabajo, se ilustra el diseño del sistema experimental implementado y se discuten los incrementos de señal observados en función de las características espacio-temporales de la re-excitación.

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#238 — Poster

Preliminary Design And Initial Heat Load Assessment Of The BRIGHT Tokamak Divertor Using SOLEDGE3X

GEFP - Plasma Physics

F. Aguilera-Cabezas, D.J. Cruz-Zabala, M. García-Muñoz, J. Campos-García, P. Cano-Mejías, D. Kabirov, R. Marques-Gomez, J.M. Ordoñez-Jimenez, F. Puentes-Del-Pozo, A. Rodriguez-Gonzalez, L. Sanchis-Sanchez, E. Viezzer

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Abstract Text:

The development of commercially viable fusion power plants (FPPs) depends on the maturity ofkey enabling technologies operating under reactor-relevant conditions [1]. To address this need,the conceptual design of BRIGHT (BReedInG High-field Tokamak), a fusion pilot plant and volumetric neutron source, has been proposed. BRIGHT combines high temperature superconductor (HTS) magnets and a low aspect ratio to achieve a compact design capable of producing FPP-relevant neutron fluences on a fast timeline and with reduced capital costs. However, this compactness introduces a critical challenge: the management of exhaust heat loads within severe space constraints. To mitigate this issue, BRIGHT incorporates a negative triangularity configuration, which prevents ELMs and significantly increases the divertor wetted area.
This work presents the study of the thermal loads on the BRIGHT divertor based on its preliminary design. To this end, advanced edge plasma simulations are being performed using the SOLEDGE3X transport code, currently employing a fluid neutral model to characterize the scrape-off layer (SOL) dynamics. The study focuses on a parametric analysis of different fueling scenariosto investigate the plasma response in the different working modes of BRIGHT.
These first simulations aim to identify the heat deposition profiles on the divertor targets and evaluate the effectiveness of the preliminary magnetic configuration. Furthermore, this work sets the stage for future high-fidelity modeling, including the coupling with the Eirene Monte Carlocode for a more kinetic treatment of neutral species. The results of this iterative process will be fundamental to guiding the geometric optimization of the BRIGHT divertor and ensure a robustpower exhaust solution.
[1] G. Federici et al, Nuclear Fusion (2023) 63 12

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#239 — Poster

Diagnostics Overview Of The SMART Spherical Tokamak

GEFP - Plasma Physics

Eleonora Viezzer, Diego Cruz Zabala, Manuel Garcia Muñoz, Alfonso Rodriguez Gonzalez, Fernando Puentes Del Pozo, Pablo Vicente Torres, David Peña, Jesus Salas Suarez-Barcena, Pilar Cano Megias, Joaquin Galdon Quiroga, Et Al

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Abstract Text:

The SMall Aspect Ratio Tokamak (SMART) is a new spherical tokamak (ST) currently being commissioned at the University of Seville (Spain) with the main objective to explore the prospects of negative triangularity (NT) in STs [1,2]. SMART has been designed to accommodate flexible shaping, ranging from positive triangularity (PT) δ=+0.6 to NT δ=-0.6. To characterize the plasmas at SMART, a baseline set of diagnostics has been designed and developed and will be presented in this contribution. The baseline set includes a suite of magnetic measurements (Mirnov coils, flux loops, Rogowski coils and a diamagnetic loop) to reconstruct the magnetic equilibrium of the plasma. It will also be used for plasma control as well as for tracking and identifying plasma fluctuations [3]. A 2-mm microwave interferometer in heterodyne configuration will provide line-integrated fringeless electron density measurements for one radial line of sight. These measurements will be complemented by a Thomson Scattering (TS) diagnostic employing a 2 Joule Nd:YAG laser operating at 1064 nm with 28 spatial channels that will provide local electron density and temperature profiles along the midplane [4]. Radiated power density (Prad) and Soft X-ray measurements with fast filtered Si diodes and visible spectrometers will be used for monitoring impurities in the plasma [5]. The viewing lines-of-sight of the TS diagnostic, Prad measurements and visible spectroscopy are aligned such that the plasma edge is covered on both the low-field side and high-field side for both PT and NT plasma equilibria. A gas-puff based charge exchange recombination spectroscopy diagnostic provides measurements of the impurity ion temperature, density and rotation velocity with a temporal resolution of 2 ms and a spatial resolution down to 3 mm. A combination of a toroidal and poloidal view on the gas puff will enable measurements of the local radial electric field [6].

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#251 — Oral

Solution Cathode Glow Discharge Optical Emission Spectrometry: Fundamental Insights And Methodological Approaches

GEFP - Plasma Physics

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Abstract Text:

Many plasma generation systems have been applied to chemical analysis and, more specifically, to elemental chemical analysis, such as Inductively Coupled Plasmas, Microwave Induced Plasmas or Glow Discharges. During the last decade, extensive research has been carried out using Solution Electrode Glow Discharges (SEGDs) for this application. SEGDs are direct current electrical discharges generated at atmospheric pressure, where one of the electrodes is an electrolytic solution. When coupled with Optical Emission Spectrometry instruments, they are capable of detecting and quantifying the elemental composition of aqueous solution/samples. They gather competitive figures of merit in terms of elemental coverage, sensitivity that allows trace level detection, low consumption and limited instrumental requirements, compared to traditional elemental analysis routine techniques such as ICPs or Atomic Absorption Spectrometry systems.
A key advantage of SEGD systems is the elimination of the nebulization step: the plasma itself is responsible for extracting, atomizing, and exciting dissolved metal ions directly from the solution. Additionally, its excitation capabilities are adequate and the emission spectra are simple, with low ionic contribution. These features favor instrumental simplicity, but also complexity when studying with the underlying analyte solution-to-plasma transfer and its subsequent excitation.
The present communication discusses results from coupling a Solution Cathode Glow Discharge (SCGD) with an AAS setup to characterize analyte presence within the plasma. Comparing these results with plasma excitation temperatures and electron density results, novel insights on the fundamental performance of the source are unveiled. This knowledge is applied to mitigate matrix-related changes in sensitivity to improve analytical accuracy.

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#252 — Oral

Evaluation Of An Artificial Neural Network For Copper Quantification In Optical Emission Spectroscopy Using SCGD-OES

GEFP - Plasma Physics

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Abstract Text:

Solution Cathode Glow Discharge (SCGD) is an atmospheric pressure technique based on the generation of a plasma between a metallic anode and a liquid sample that acts as the cathode. This configuration creates a unique plasma-liquid interface, making it a powerful tool for elemental analysis via Optical Emission Spectroscopy (OES). However, the physical characterization of these plasmas presents significant challenges due to non-linear emission behaviors, matrix effects and spectral interferences arising from the complex excitation processes and the analyte transfer to the plasma in the liquid surface. This study investigates the application of Artificial Neural Networks (ANNs) as an alternative to traditional linear spectroscopic models for the quantification of copper in liquid samples. A dataset of 1525 emission spectra obtained from samples containing up to 40 parts per million of Cu was analyzed comparing three architectures: the traditional univariate calibration curve, a single-layer perceptron and a multi-layer network with a 200-neuron hidden layer.
High-energy resonance lines (324.7 and 327.4 nm) yield superior sensitivity for copper quantification using calibration curves, but are susceptible to self-absorption and interference, whereas higher wavelength transitions (510.6 and 521.8 nm) prioritize linearity over detection limits.
Our results demonstrate that the multi-layer network effectively handles the non-linearities of the SCGD plasma, achieving relative errors below 5%. Furthermore, a weight distribution analysis was conducted to interpret the model's internal logic. This work highlights that ANNs can transcend "black-box" applications, highlighting the spectral regions most critical to the model's predictive power, effectively "re-discovering" the Cu emission manifolds as well as other element contributions. It also suggests a promising path for the application of ANNs in this field, demonstrating that even low-complexity architectures can provide a competitive alternative to traditional calibration curves.

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#264 — Oral

Nuevas Perspectivas De PGD-TOFMS Como Herramienta Versátil Para El Análisis Directo De Compuestos Orgánicos

GEFP - Plasma Physics

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Abstract Text:

La descarga luminiscente (GD) con detección por espectrometría de masas (MS) es una técnica establecida para el análisis directo de sólidos que permite el análisis rápido y sensible de una amplia variedad de muestras (materiales conductores y aislantes). Sus ventajas, entre las que se incluyen la rapidez, el bajo coste de funcionamiento o los bajos efectos de matriz, han motivado el uso creciente de esta técnica como herramienta de control en la industria (p.e. industria del acero, microelectrónica, fotovoltaica, etc.).
El desarrollo de la descarga luminiscente pulsada (PGD) ha permitido reducir los efectos térmicos y las velocidades de arrancado y extender así su uso para el análisis de materiales termosensibles y recubrimientos de espesores de pocos nanómetros [1]. Además, la combinación de la PGD con TOFMS ha resultado en una herramienta capaz de proporcionar información tanto elemental como molecular que está abriendo nuevas vías de aplicación para el análisis de compuestos orgánicos [2, 3].
En este trabajo se analizan nuevas perspectivas dirigidas al avance de PGD-TOFMS como técnica para la determinación de compuestos orgánicos de distinta naturaleza (p.e. polímeros y VOCs) a través del estudio de los procesos de fragmentación e ionización tomando compuestos con características variadas (en cuanto a tipo de compuesto, pesos moleculares, energías de fragmentación e ionización, etc.). En este sentido, ha sido necesario desarrollar cámaras de descarga con diseños mejorados y adaptados a la naturaleza de las muestras (sólidas o gaseosas) así como abordar el tratamiento del gran volumen de datos generados a través del estudio de herramientas automatizadas que permitan extraer toda la información relevante de manera rápida y eficaz.
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#266 — Oral

Impurity Transport Studies In Magnetically-Confined Using Tracer-Encapsulated Solid Pellet (TESPEL)

GEFP - Plasma Physics

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Abstract Text:

Magnetic confinement fusion research aims to establish nuclear fusion as a clean, reliable, and commercially viable energy source. Among the different magnetic confinement concepts, stellarators are considered promising candidates due to their intrinsic stability and capability for steady-state operation. However, impurity accumulation in the plasma core remains a critical issue, since it can lead to enhanced radiation losses and ultimately plasma termination by radiation collapse. Understanding impurity transport processes is therefore essential for the optimization of plasma performance and the development of future fusion reactors.

The Tracer-Encapsulated Solid Pellet (TESPEL) technique has emerged as a powerful diagnostic tool for the investigation of impurity transport in magnetically confined plasmas. TESPEL consists of a small solid pellet containing a predetermined quantity of tracer impurity material encapsulated within a polystyrene shell. When injected into the plasma, the TESPEL, once ablated, deposits a localized and well-characterized impurity source, enabling precise measurements of impurity diffusion, convection, and confinement properties. The controlled deposition profile and timing of the injection make TESPEL particularly suitable for validating transport models and studying impurity dynamics under different plasma conditions.

In this work, the TESPEL technique and its implementation in several stellarator devices are presented. Examples of its application in the TJ-II, Large Helical Device and Wendelstein 7-X are discussed, highlighting the different experimental approaches and diagnostic capabilities developed in each machine. In addition, innovative spectroscopic techniques employed for the analysis of impurity tracer transport are reviewed, demonstrating the relevance of TESPEL experiments for advancing the understanding of impurity behavior in stellarator plasmas.

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#309 — Oral

Control Nanoestructural De Películas Delgadas Nanocolumnares De WOx Mediante Deposición En ángulo Oblicuo Asistida Por Plasma

GEFP - Plasma Physics

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Abstract Text:

Las películas delgadas nanocolumnares presentan características únicas estrechamente vinculadas a su elevada porosidad y gran superficie específica en contacto con el medio externo, lo que las convierte en candidatas idóneas para aplicaciones tan diversas como la microfluídica, la plasmónica, la detección de señales, la biomedicina, la fotovoltaica, las tecnologías aeroespaciales o el almacenamiento de hidrógeno, entre otras. En esta presentación se analiza el crecimiento de películas delgadas nanocolumnares de óxidos de tungsteno (WOx, con $0 \leq x \leq 3$) crecidas mediante pulverización catódica a ángulo oblicuo. Esta técnica de deposición es un buen ejemplo de la aplicación de tecnologías de plasma al desarrollo de nuevos materiales. A pesar de que los distintos óxidos se depositan bajo idénticas condiciones geométricas, se observa que dichas películas exhiben una notable diversidad en cuanto a nanoestructura, porosidad y morfología nanocolumnar en función del contenido de oxígeno. De forma paralela al estudio experimental, el crecimiento de estas capas ha sido abordado mediante simulaciones numéricas, cuyos resultados respaldan el papel determinante de los procesos de movilidad superficial asociados a la incorporación de especies con energía cinética relativamente elevada, y que afectan fuertemente la porosidad y la morfología nanocolumnar. En esta presentación se discutirá el carácter general de dichos procesos durante el crecimiento de estas películas por pulverización catódica, su naturaleza no térmica, así como su relevancia para el control nanoestructural y el desarrollo de aplicaciones basadas en ellas.

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#311 — Oral

CIEMAT-QI4X: A Reactor-Relevant Stellarator Magnetic Configuration As The Basis For Project WISER

GEFP - Plasma Physics

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Abstract Text:

The stellarator offers key advantages over the tokamak as a magnetic fusion reactor concept, including intrinsic steady-state operation capability and immunity to current-driven instabilities and disruptions. However, unlike in tokamaks, good confinement is not guaranteed in a generic stellarator but requires a careful design of the three-dimensional magnetic field, usually known as optimization. Numerical optimization aimed at reducing neoclassical transport has already been experimentally validated in W7-X and HSX. Substantial progress has been achieved in recent years and a second generation of optimized stellarator configurations is now being developed, incorporating additional optimization criteria such as a-particle confinement and turbulent transport [1–3].
Owing to its intrinsic advantages, including a low bootstrap current that supports the implementation of an island divertor, the quasi-isodynamic (QI) type of optimized configuration has been adopted as the basis for several stellarator reactor projects [2, 4, 5]. CIEMAT-QI4 [1] was among the first QI configurations of this new generation, and a whole family of new QI configurationswas afterwards developed at CIEMAT. Building on the optimization strategy and sophisticating the methods employed in [1] to achieve high-quality nested flux surfaces in the confinement region and a robust island structure at the edge compatible with an island divertor, a new configuration, called CIEMAT-QI4X, has been developed [6].
In this work, the CIEMAT-QI4X configuration, which satisfies the physics requirements for a stellarator reactor design and constitutes the basis for Project WISER [7], will be presented.
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#321 — Oral

Influence Of Barrier Architecture And Effective Discharge Volume On Ammonia Decomposition In DBD Reactors

GEFP - Plasma Physics

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Abstract Text:

This work investigates how barrier architecture and effective discharge volume affect NH_3 decomposition in a dielectric barrier discharge (DBD) reactor for hydrogen production. The study focuses on whether increasing plasma volume through reactor scaling leads to sustained gains in ammonia conversion or whether performance eventually reaches a saturation regime.
Experiments were performed in a packed-bed DBD reactor operating at atmospheric pressure and room temperature. Alumina and PZT pellets were used as barrier materials to alter discharge behavior. Different packing arrangements and packing fractions were tested to systematically vary the effective plasma volume and local electric field distribution. Reactor products were analysed by Fourier transform infrared spectroscopy (FTIR) and mass spectrometry, while plasma characteristics were examined using electrical diagnostics and optical emission spectroscopy.
The results demonstrate that barrier architecture strongly influences discharge volume and NH_3 conversion. Increasing the effective plasma volume by modifying the packed-bed configuration initially improves ammonia decomposition. However, this trend is not linear at larger scales. As the packing factor rises and the reactor approaches larger effective discharge volumes, the increase in conversion becomes limited, revealing a clear saturation effect. This indicates that reactor scaling alone does not produce proportional conversion gains. The limitation is likely related to shifts in electric field distribution, changes in electron energy, and the growing importance of reverse reactions in the discharge zone.
Overall, plasma-assisted NH_3 decomposition in DBD reactors depends critically on both barrier design and effective discharge volume. Reactor optimization should therefore emphasize precise control of electric field distribution, packed-bed structure, and suppression of reverse reactions, rather than simply increasing plasma volume. These findings offer broader insight into plasma reactor scaling, using ammonia decomposition as a representative case. The study therefore highlights the importance of balancing reactor geometry and plasma chemistry to maximize hydrogen yield and energy efficiency in scalable systems.

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#332 — Poster

Study On The Role Of Nitrogen In Ammonia Decomposition In A Small Gap DBD Plasma Reactor

GEFP - Plasma Physics

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Abstract Text:

This work investigates the role of nitrogen in ammonia (NH_3) decomposition within a dielectric barrier discharge (DBD) plasma reactor, with particular emphasis on small interelectrode gaps and confined plasma volumes. Building on previous studies demonstrating the beneficial effect of N_2 and the detrimental impact of H_2 on plasma-assisted NH_3 cracking, the present study explores how these mechanisms manifest under reduced gap conditions using a 1 mm alumina dielectric barrier and millimetric discharge distances. Experiments were conducted in an atmospheric-pressure DBD reactor operated at room temperature. The reactor configuration was designed to achieve highly confined plasma regions, where the electric field strength and electron energy distribution are strongly influenced by the small gap geometry. Gas mixtures of NH_3 with controlled additions of N_2 were investigated to assess their effect on conversion and hydrogen production. Plasma diagnostics, including electrical measurements and optical emission spectroscopy, were combined with product analysis via mass spectrometry to evaluate reactor performance and underlying mechanisms.

The results confirm that nitrogen plays a beneficial role in enhancing NH_3 decomposition, even in small-gap configurations. This effect is attributed to the formation of excited and metastable N_2 species, which promote indirect dissociation pathways such as Penning reactions, leading to increased NH_3 conversion. In contrast, conditions favoring hydrogen formation can enhance recombination reactions, limiting net conversion. In the confined geometry of the present reactor, these competing pathways are further influenced by changes in electric field distribution and energy transfer efficiency.

Overall, the study highlights that, in small-gap DBD reactors, the positive influence of nitrogen remains significant but is strongly coupled with reactor geometry and plasma confinement. Therefore, NH_3 decomposition under these conditions requires careful control of gas composition, gap size, and dielectric properties to balance dissociation and recombination processes.

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#336 — Poster

INFLUENCIA DE PROMOTORES EN LA DISOCIACIÓN DE CO_2 MEDIANTE PLASMA CATALÍTICO EN REACTORES DBD PACKED-BED

GEFP - Plasma Physics

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Abstract Text:

La valorización de CO2 mediante plasma no térmico representa una alternativa innovadora para la transformación de emisiones industriales en productos de valor añadido, ofreciendo una tecnología compacta, electrificable y potencialmente integrable en distintos sectores industriales de Andalucía. En este trabajo se estudia la influencia de distintos materiales promotores de plasma-catálisis en la disociación de CO_2 en un reactor de lecho empaquetado DBD usando pellets ferroeléctricos de $BaTiO_3$. Se evaluaron catalizadores tipo 5 wt.% X/SiO2 mesoporosa (X=Fe,Ni,Cu y Au). Se compararon diferentes proporciones X/SiO2:$BaTiO_3$ (0.050 g:1 g y 0.100 g:1 g) así como catalizadores reducidos y sin reducir. El reactor operó con una señal sinusoidal de 9kV y 10kHz, utilizando un flujo de CO_2 de 10 sccm. La composición de gases se analizó mediante espectroscopía FTIR y cromatografía de gases. Los resultados muestran que la composición del catalizador y las propiedades dieléctricas del soporte influyen significativamente en la conversión de CO_2 y la eficiencia energética. El lecho formado por $BaTiO_3$ alcanzó conversiones cercanas al 24 %, mientras que la incorporación de SiO_2 sin fase activa redujo el rendimiento del reactor, evidenciando la influencia del lecho sobre el comportamiento de la descarga. El catalizador 5% wt.Fe/SiO_2 presentó el mejor comportamiento, recuperando conversiones similares a las del lecho ferroeléctrico. Los sistemas basados en Ni y Au mostraron comportamientos intermedios, mientras que 5% wt.Cu/SiO_2 presentó las conversiones más bajas y menor eficiencia energética. El análisis eléctrico muestra diferencias importantes en la intensidad y estabilidad de las microdescargas para cada caso. Asimismo, los catalizadores reducidos mostraron peores resultados que aquellos sin reducir. Estos resultados demuestran que las propiedades eléctricas del lecho y la composición del catalizador influyen directamente en el comportamiento de la descarga y el rendimiento del reactor. El diseño de materiales para plasma-catálisis no debe centrarse únicamente en la química superficial del catalizador.

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#378 — Oral

Merging Plasma Sputtering Deposition And Acoustic Wave Activation For The Deposition Of Materials.

GEFP - Plasma Physics

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Abstract Text:

Plasma-based techniques are a mature technology for thin film deposition and processing. While traditional strategies such as thermal activation, substrate polarization, ion bombardment, or the application of electric and magnetic fields have been used to assist thin-film growth, the activation of plasma thin films by their interaction with acoustic waves (AWs) on piezoelectric plates has remained mainly unexplored. Electro-acoustically activated piezoelectric plates develop a pattern of AWs that in turn generates an oscillating polarization pattern that might interact with the charged species of a plasma. The possibilities of this methodology have been explored by magnetron sputtering deposition on AW activated LiNbO3 piezoelectric substrates. The sputtered materials for this study were dielectric thin films of TiO2 and SiOx, and Ag nanoparticles, and the LiNbO3 plates were activated with a frequency around 3.4 MHz. These experiments revealed that the AW-activation of the substrates produces localized effects in the features of the sputtered materials, reproducing a 2D pattern which replicates the AWs pattern. In the case of TiO2 a SiOx dielectric films, this pattern showed differences in properties such as microstructure, crystallinity, and compositions. In the deposition of Ag, this pattern showed differences in plasmon resonance absorption, particle size, and circularity.
Based on these results, which showcased that a new phenomenology enters into play when AWs interact with plasma, we proposed a model in which the development of a polarization electrical field on the substrate is the responsible for the focusing of Ar+ plasma ions, whose impingement on the substrate produces the observed effects. This model relies on COMSOL and Monte Carlo simulations and makes use of the classical theory of Langmuir on the plasma sheath. From the point of view of plasma-based surface process technologies, this research set the basis for the fabrication of patterned thin-films combining AW and plasma deposition procedures.

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#394 — Poster

Overview Of The Activities On The ITER Fast-Ion Loss Detector

GEFP - Plasma Physics

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Abstract Text:

Latest advancements in the design of the ITER Lost Alpha Monitor diagnostic, also known as Fast-Ion Loss Detector (FILD), are detailed in this contribution. Advanced Hamiltonian full-orbit simulations are performed to estimate the velocity-space of fast-ion fluxes on the diagnostic probe head. Using the ASCOT code, these fluxes are characterized for different spatial spectra of externally applied 3D fields and probe head insertion depths. The probe head is inserted into the scrape-off layer (SOL) at the first-wall level using a reciprocating system featuring an internal moving shaft, double bellows for vacuum integrity, and an electric actuator with a total radial stroke of approximately 50 cm. Detailed structural, electromagnetic, and dynamic analyses of this reciprocating system are presented to validate its mechanical robustness against gravitational and induced electromagnetic forces. Thermomechanical modeling of heat loads on the probe head is used to estimate mechanical stresses and scintillator operating temperature.
The light pattern emitted by the scintillator is computed using the FILDSIM code, which incorporates scintillator efficiency and orbit simulations. A 14 m long optical relay, featuring free-form mirrors and radiation-hardened lenses, collects and transmits the scintillator light into a shielding cabinet in the port cell. This cabinet houses the instrumentation for data acquisition (DAQ), digitizers for Faraday Cups, photomultiplier tubes (PMTs), and charge-coupled device (CCD) cameras. Monte Carlo simulations estimate radiation-induced noise on the scintillator and the effectiveness of DAQ shielding in the interspace. Together, these advancements ensure an acceptable signal-to-noise ratio of the Lost Alpha Monitor throughout the entire ITER operation.
Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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Poster

Finite-β Effects on Energetic-Ion Confinement in W7-X

GEFP - Plasma Physics

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Abstract Text:

Understanding energetic-ion confinement at finite plasma pressure is important for the optimisation of magnetically confined plasmas and reactor extrapolation. The recent availability of finite-β equilibria for Wendelstein 7-X (W7-X) enables a systematic study of the β-dependence of energetic-ion behaviour for realistic
heating scenarios and magnetic configurations.
Energetic-ion modelling is carried out with ASCOT5 using finite-β VMEC equilibria including pressure-driven
plasma response. The standard and high-mirror configurations are considered, together with plasma conditions
corresponding to vacuum (β ≈ 0) and finite pressure (β ≈ 2.5%). For this analysis, the scrape-off-layer magnetic
perturbations associated with the island divertor are included.
Energetic ions generated by neutral beam injection are modelled for hydrogen and helium plasmas. Ionisation
coefficients from the ADAS database are included through the ASCOT5 atomic-reactions module [1], enabling
comparison of species-dependent confinement and loss mechanisms. For β ≈ 0, hydrogen beams produce the
largest wall loads (up to approximately 1 MW m-2), while helium beams yield the lowest losses (down to approximately 0.1 MW m-2); helium target plasmas increase losses relative to hydrogenic plasmas by up to approximately 30%, with losses mainly deposited on carbon plasma-facing components [2]. Helium ions are used
as a proxy for fusion-born α-particles, and comparisons with helium experiments at ASDEX Upgrade [3] using
charge-exchange spectroscopy [4] show good agreement between synthetic and measured signals.
Synthetic signals for the scintillator fast-ion loss detector [5], currently under development for W7-X, are generated with FILDSIM to characterise the phase-space distribution of escaping ions and support future experimental validation. Estimated energetic-ion losses are also used to identify localised wall-load hot spots.

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Poster

Overview of Fast-Ion Physics Studies in Magnetically Confined Fusion Devices from the Plasma Science and Fusion Technology Group

GEFP - Plasma Physics

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Abstract Text:

In future magnetically confined fusion devices, the confinement of fast ions, generated either via auxiliary heating systems such as Neutral Beam Injection (NBI) and Ion Cyclotron Resonance Heating (ICRH) or born in fusion reactions, is critical for optimum plasma performance and machine protection. Fast-ion losses (FILs) can degrade heating efficiency and lead to high, localized heat loads on plasma-facing components that may cause irreversible damage. Therefore, a deep understanding of the transport mechanisms and instabilities responsible for fast-ion redistribution is essential for the success of future power plants. This contribution provides an overview of the recent research activities conducted by the Plasma Science and Fusion Technology (PSFT) group from the University of Seville on fast-ion physics.

In the MAST-U tokamak, the effect of n = 2 externally applied magnetic perturbations (MPs) on fast-ion confinement has been investigated [1]. The experimental measurements reveal a dependence of the fast-ion losses on various parameters such as the MPs differential phase, absolute toroidal phase, the MP intensity and the velocity-space of the fast ions, consistent with the edge resonant transport layer picture [2]. Orbit-following simulations of fast ions in realistic equilibria, including the plasma response to the MPs, reveal the same dependencies but with minima/maxima at phases opposite to those observed experimentally. Additionally, dedicated experiments have been conducted to validate the use of wide-angle infrared thermography diagnostics for the global monitoring of fast-ion losses [3].

In the ASDEX Upgrade tokamak, the studies have focused on leveraging the unique capabilities of this machine, combining an ICRH system and MPs. For the first time, simultaneous measurements of both co- and counter-current fast-ion losses have been possible by means of an innovative double-collimator fast-ion loss detector (FILD) design [4]. The intensity of the co-going losses is found to be about one order of magnitude larger than the counter-going losses, while both show a similar scaling with ICRH power. While the presence of edge localized modes is observed to cause an increase in neutral beam losses, ICRH losses are partially mitigated in both

co- and counter-directions. A particular population corresponding to deeply trapped ions - close to 80° pitch angle - is observed, whose orbits are found to live in the plasma edge and scrape-off layer. This population is observed in both co- and counter-directions and its origin remains unclear.

[1] L. Velarde et al., Nuclear Fusion 65, 112003 (2025).
[2] L. Sanchis-Sanchez et al., Plasma Physics and Controlled Fusion 61, 014038 (2019).
[3] L. Velarde et al., Fusion Engineering and Design 220, 115322 (2025).
[4] A. Reyner-Viñolas et al., Nuclear Fusion 65, 102005 (2025).

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Oral

Overview of the Plasma Science and Fusion Technology Lab

GEFP - Plasma Physics

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Abstract Text:

The Plasma Science and Fusion Technology (PSFT) laboratory at the University of Seville conducts an integrated research program combining plasma physics, advanced diagnostics, and reactor-oriented design to accelerate fusion energy development. This overview highlights activities centered on the SMART tokamak, the BRIGHT pilot plant concept, and research on energetic particles and edge stability.

A central element is the SMART (SMall Aspect Ratio Tokamak), designed to explore compact configurations with negative triangularity. Its physics basis leverages low aspect ratio and optimized plasma shaping to enhance stability, improve confinement, and facilitate power exhaust. SMART serves as a flexible experimental platform to validate these concepts and assess their scalability to reactor conditions.

These results support the development of BRIGHT, a compact, high-field, low-aspect-ratio tokamak conceived as a neutron source and pilot plant. BRIGHT aims to qualify key fusion technologies, including tritium breeding blankets and high-temperature superconducting magnets, under reactor-relevant conditions. Its design exploits negative triangularity to maximize plasma volume, improve power exhaust, and enable operation in both pulsed thermonuclear and steady-state beam-target regimes.

PSFT also focuses on energetic particle physics, crucial for burning plasmas. Research addresses interactions between fast ions and collective modes such as Alfvén eigenmodes, aiming to understand and mitigate energetic particle transport and losses. These studies combine advanced diagnostics with numerical tools for orbit-following and kinetic-MHD stability analysis.

In parallel, PSFT investigates edge plasma physics, including edge localized modes (ELMs), pedestal structure, and boundary turbulence. Experiments are complemented by high-fidelity MHD and hybrid modelling to understand stability limits and transport processes.

Additionally, PSFT contributes to ITER, particularly in fast-ion physics and diagnostics. Overall, the program integrates experiment, theory, and modelling to advance compact fusion reactor concepts.

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#90 — Oral

Anharmonic Lipkin Model: Implementation On A Quantum Device And Quantum Phase Classification.

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

The Lipkin-Meshkov-Glick model (Lipkin model for short) describes a two-level system of N particles interacting with a long-range interaction, which is further generalized by adding an anharmonicity term with an extra control parameter. It is of interest in nuclear physics as a simple non-trivial model with two symmetry configurations that give rise to two distinct quantum phases. In this work, the time-evolution of the anharmonic Lipkin model is implemented and executed in a quantum chip, measuring a dynamical correlation function. This correlation function is then employed to classify the corresponding quantum phase via a supervised machine learning algorithm trained on classical simulations of the simpler Lipkin model.

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#121 — Poster

Rigorous Time-Dependent Hamiltonian Learning Via Weak Measurements

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

A central challenge for scalable quantum computing is reliable validation, characterization, and debugging of quantum processors and analog quantum simulators. These tasks require identifying effective Hamiltonians generated by hardware, including time-dependent deviations from pulse distortions, calibration errors, residual couplings, and crosstalk. Standard black-box techniques probe the system only before and after an operation, missing intermediate dynamics where hardware nonidealities arise. Continuous weak measurements provide a minimally invasive route to reconstruct time-dependent Hamiltonians without interrupting evolution, as demonstrated in small-scale superconducting platforms [1]. However, extending such protocols to many-body quantum devices remains challenging. Recent Hamiltonian-learning advances have shown that static many-body Hamiltonians can be efficiently reconstructed from unitary dynamics and Gibbs states by exploiting the Hamiltonian interaction graph, achieving near-optimal sample complexity [2]. Scalable approaches based on locality and the quantum Zeno effect emphasize the importance of local structure for efficient quantum-device characterization [3]. Here, we generalize continuous weak-measurement Hamiltonian reconstruction to the time-dependent many-body regime. By combining continuous monitoring with graph-theoretic methods, we show that, for sparsely interacting Hamiltonians, the global reconstruction problem reduces to independent local linear inversions. Crucially, the number of required probe states depends only on the maximum interaction degree, not on system size. Using graph coloring, we identify a minimal set of optimal probe states, substantially reducing experimental overhead.
We further derive sample-complexity bounds capturing the trade-off between numerical integration bias and statistical noise in continuous-time estimators. Finally, we validate the framework numerically by reconstructing time-dependent transverse-field Ising dynamics with up to n=8 qubits. Our results provide a scalable route toward time-resolved Hamiltonian learning for benchmarking, error diagnosis, and certification of near-term quantum computing platforms.
[1] K. Siva et al., PRX Quantum 4, 040324 (2023). [2] A. Gu, L. Cincio, and P. J. Coles, Nat. Commun. 15, 312 (2024). [3] G. Franceschetto et al., arXiv:2509.15713 (2025).

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#127 — Oral

Thermodynamic Networks: Harnessing Non-Equilibrium Steady States For Computation

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

In this talk, we will introduce thermodynamic networks, a general framework for autonomous, physics-based computation based on non-equilibrium steady states (NESS). We model these networks as a collection of finite-size reservoirs that exchange conserved quantities--such as energy or charge--while converging to a NESS, which encodes the solution of a computation problem. We identify Negative Differential Conductance (NDC) as the critical physical property governing the computational expressibility of the thermodynamic network: While networks lacking NDC are restricted to computing monotonic functions, the presence of NDC enables universal function approximation. We then adapt two training protocols, implicit differentiation and equilibrium propagation, that take advantage of the natural tendency of the network to equilibrate to achieve the desired input-output behavior. We demonstrate the versatility of our approach through two different physical platforms: quantum dot networks and enzymatic reaction networks. We show that both systems can be engineered to have NDC, enabling them to successfully perform standard benchmarks including sine function approximation and MNIST digit classification. Overall, we will present a rigorous link between physical transport and computational universality, opening a new avenue for the design of physics-based hardware.

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#146 — Oral

Rigorous Quantum State Tomography For Distributed Quantum Computing

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

Distributed quantum computing offers a promising approach to scaling quantum devices by networking multiple quantum processors. We present a quantum state tomography protocol tailored for distributed quantum computers that avoids assuming remote entanglement as a primitive resource [1]. The protocol extends projected least-squares (PLS) tomography based on projective 2-designs to systems composed of multiple quantum processors, using only local operations within each processor and classical communication between nodes. Assuming entanglement within each individual quantum processor is trusted, the protocol can be executed using mutually unbiased bases. We derive rigorous, non-asymptotic trace-norm error bounds for the PLS estimator, with explicit exponential dependence on the number of nodes. In addition, we establish certified error bounds for estimating entanglement negativity from the PLS estimator. Numerical simulations for systems of up to seven qubits distributed across several devices validate the theoretical error bounds.
[1] arXiv:2604.09775 (2026).

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#150 — Oral

Hybrid Reward-Driven Reinforcement Learning For Efficient Quantum Circuit Synthesis

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

We introduce a reinforcement learning (RL) framework for the efficient synthesis of quantum circuits that generate specified target quantum states from a fixed initial state, addressing a central challenge in both the Noisy Intermediate-Scale Quantum (NISQ) era and future fault-tolerant quantum computing. We utilize tabular Q-learning, within a discretized quantum state space, to manage the exponential growth of the space dimension. A hybrid reward mechanism is introduced, combining a static, domain-informed reward that guides the agent toward the target state with customizable dynamic penalties that discourage inefficient circuit structures such as gate congestion and redundant state revisits. This is a circuit-aware reward, in contrast to the current trend of works on this topic, which are primarily fidelity-based. Benchmarking on graph-state preparation tasks for up to seven qubits, we demonstrate that the algorithm consistently discovers minimal-depth circuits with optimized gate counts. Moreover, extending the framework to a universal gate set still yields low depth circuits, highlighting the algorithm's robustness and adaptability. The results confirm that this RL-driven approach efficiently explores the complex quantum state space and synthesizes near-optimal quantum circuits, providing a resource-efficient foundation for quantum circuit optimization.

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#199 — Oral

Leakage Propagation And Passive Removal In Tunable Transmon Architectures

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

Leakage—population outside the computational subspace—is a critical challenge for quantum error correction, as it leads to correlated errors that propagate across a processor. While single-excitation dynamics in tunable coupler architectures are well-understood, the behavior of multi-excitation leakage between idling qubits remains largely unexplored. In this work, we investigate leakage propagation and removal in transmon systems utilizing tunable couplers.
Numerical and analytical results demonstrate that even when a tunable coupler effectively cancels single-excitation hopping, it may still permit leakage propagation between resonant transmons. We characterize the sensitivity of this process to frequency detuning, finding that although typical CZ gate regimes suppress leakage, next-nearest-neighbor tunneling persists in ABAB lattice structures. This tunneling occurs on microsecond timescales, significantly slower than the tens-to-hundreds of nanoseconds observed for direct resonant propagation.
Leveraging the coupler's ability to selectively block single-excitation hopping while allowing leakage transitions, we propose and simulate a Leakage Removal Unit (LRU). By adding dissipation to a dedicated reset transmon and biasing the coupler to its qubit dynamics "off" position, we achieve a passive LRU capable of leakage lifetimes as short as 40 nanoseconds with minimal loss of qubit population. Finally, we evaluate a scalable LRU candidate based on a junction readout scheme. By utilizing junction nonlinearity to facilitate two-excitation hopping while canceling single-excitation transitions through linear capacitance, the intrinsic dissipation of the readout resonator enables efficient leakage removal. Our findings provide a robust framework for mitigating leakage and implementing high-fidelity removal units in scalable superconducting quantum architectures.

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#226 — Oral

Simulating Hardware To Optimize Experiments In A Quantum Hybrid Platform

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

This contribution discusses the application of cavity quantum electrodynamics (cQED) models and open quantum system theory to the characterization and optimization of a hybrid quantum processing platform. This architecture is based on magnetic molecules, which act as multi-level information units (qudits), coupled to superconducting circuits. The platform integrates identical, reproducible units —leveraging precise chemical design— that naturally host additional degrees of freedom beyond binary logic. This expanded computational space is highly advantageous for implementing quantum error correction or reducing circuit complexity, while the superconducting interface facilitates control, readout, and scalability. Using our open-source software suite, we are able to not only reproduce experimental signals from macroscopic samples with high microscopic parameter resolution but also to perform inverse design. By identifying the primary bottlenecks in the experimental implementation, we determine the necessary architectural modifications —from chip design to optimal sample positioning— to approach the coherent operations required for the realization of this hybrid platform as a functional quantum processor.

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#310 — Oral

Implementing The Quantum Fourier Transform On A Molecular Qudit With Full Refocusing And State Tomography

GEITC - Quantum Computing (Theory and Experiment)

Marcos Rubín Osanz 1, Laura Bersani 1, Simone Chicco 1, Giuseppe Allodi 1, Roberto De Renzi 1, Athanasios Mavromagoulos 2, Michael D. Roy 2, Stergios Piligkos 2, Elena Garlatti 1, Stefano Carretta 1

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Abstract Text:

Molecular spin qudits based on lanthanide complexes offer a promising platform for quantum technologies [1], but experimental demonstrations of their capabilities remain scarce. Here, we implement in a 173Yb(trensal) qudit the Quantum Fourier Transform (QFT), a core component of numerous quantum algorithms, storing quantum information in the phases of coherences [2]. QFT provides an ideal benchmark for coherence manipulation and an unprecedented challenge for molecular spin qudits. We address this challenge by embedding a full-refocusing protocol for spin qudits in our algorithm, mitigating inhomogeneous broadening—which otherwise dampens the coherence of the ensemble in a short time $T_2^* < 1$ μs—and enabling a high-fidelity recovery of the state. Complete state tomography demostrates the performance of the algorithm, while simulations provide insight into the physical mechanisms behind inhomogeneous broadening. This result shows the feasibility of quantum logic on molecular spin qudits and highlights their potential for quantum technologies.

Our refocusing strategy can be generalized to any quantum gate and qudit dimension, potentially setting the much longer pure dephasing time $T_2 > T_2^*$ as the maximum time scale for any implementation, at the cost of a longer pulse sequence. In this regard, we have devised a method to find the shortest possible refocused pulse sequence, while in parallel we are exploring how T_2 can be enhanced by both changing magnetic dilution and cooling down to very low temperatures in our new dilution fridge.

[1] A. Chiesa et al., “Molecular nanomagnets: a viable path toward quantum information processing?”, Rep. Prog. Phys. 87, 034501 (2024).

[2] M. Rubín-Osanz et al., “Implementing the Quantum Fourier Transform on a molecular qudit with full refocusing and state tomography”, Nat. Commun. (2026).

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#328 — Oral

Complexity Of Shor’s Algorithm With Qubit Independent Errors

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

This work analyzes the complexity of Shor’s algorithm under qubit independent errors, focusing on the effects of gate and decoherence errors modeled by a normal distribution with parameter σ. The algorithm was implemented in Qiskit with a bespoke noise model that incorporates gate and decoherence errors, and integer factorization was attempted for N equal to 15, 35, 77 and 91 using quantum circuits of 13, 19, 22 and 22 qubits, respectively. Simulations were performed both in the absence of noise and across a grid of fidelity losses at gates and by decoherence. The results show that the number of executions required to achieve successful factorization increases sharply as fidelities decline: for σ = 0.99900 and σ = 0.99950, the required executions were between 3.29 times and 1093.16 times those of the ideal case, depending on the value of N. Larger instances were more sensitive to noise; for N = 77 and N = 91 performance comparable to the noiseless case required σ ≥ 0.99990 and σ ≥ 0.99995. Analysis indicates decoherence errors have a more detrimental impact than gate errors due to the fact that they act collectively on the whole register. The study highlights the necessity of substantial fidelity improvements before Shor-based factorization can outperform classical methods for cryptographically relevant integers.

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#329 — Oral

Effect Of Isotropic Errors On The Complexity Of Grover’s Algorithm

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

Isotropic errors have been shown to be immune to conventional error correction techniques. While general theoretical frameworks have been proposed to model such errors, there have been no studies so far analysing their concrete impact on practical use-cases. Here we explore the effect of isotropic errors on the complexity of Grover’s search algorithm through numerical simulations, with an analysis of the impact on the algorithm’s performance and success probability. The results provide insights into the robustness of Grover’s algorithm against isotropic errors, highlighting potential challenges for implementations on noisy quantum hardware. All results presented here are obtained through numerical simulations using the open-source python library isotropic developed as part of this work. The source code, numerical simulations and documentation for the library are available online at https://www.github.com/lazyoracle/isotropic-error-analysis.
Our simulations demonstrate that isotropic errors impose a significant penalty on Grover’s algorithm, even at relatively modest magnitudes, and makes it clear that choosing the optimal number of iterations of the Grover operator depends on the error magnitude, as larger circuit depths accumulate more erros and negate the amplitude amplification. The need for additional repetitions of the algorithm can, to a certain degree, compensate for error-induced amplitude degradation, but the apparent exponential growth of this number of repetitions negates the quadratic speed-up of Grover’s algorithm.

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#342 — Oral

Quantum Reinforcement Learning In The Presence Of Thermal Dissipation

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

A study of the effect of thermal dissipation on quantum reinforcement learning is performed. For this purpose, a nondissipative quantum reinforcement learning protocol is adapted to the presence of thermal dissipation. Analytical calculations as well as numerical simulation are carried out, obtaining evidence that dissipation does not significantly degrade the performance of the quantum reinforcement learning protocol for sufficiently low temperatures, in some cases being even beneficial. Quantum reinforcement learning under realistic experimental conditions of thermal dissipation opens an avenue for the realization of quantum agent to be able to interact with a changing environment, as well as adapt to it, with many plausible applications inside quantum technologies and machine learning [1, 2]
References:
[1] M. L. Olivera-Atencio, L. Lamata, M. Morillo, and J. Casado-Pascual, Quantum reinforcement learning in the presence of thermal dissipation, Phys. Rev. E 108, 014128 (2023).
[2] M. L. Olivera-Atencio, L. Lamata, and J. Casado- Pascual, Benefits of open quantum systems for quantum machine learning, Adv. Quantum Technol., 2300247 (2023).

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#377 — Oral

Quantum Kernel Methods For High-Energy Neutrino Event Classification

GEITC - Quantum Computing (Theory and Experiment)

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Abstract Text:

The reconstruction and classification of particle-induced events in large-scale neutrino detectors represent a major computational challenge in modern astroparticle physics. In experiments such as IceCube, identifying the morphology of neutrino interactions is essential for distinguishing track-like events, typically associated with muon neutrinos, from cascade-like topologies generated by electromagnetic or hadronic showers. In this work, we investigate the application of quantum machine learning (QML) methods to morphology-based neutrino event classification inspired by IceCube-like detector observables.
The study compares several classical and quantum-enhanced learning strategies, including linear and nonlinear support vector machines (SVMs), quantum kernel support vector machines (QSVMs), projected quantum kernels, reduced-density-matrix (RDM) kernels, and variational quantum classifiers (VQCs). Event representations are constructed from morphology-inspired observables derived from the spatial structure of reconstructed neutrino interactions across multiple energy intervals.
Quantum feature maps are employed to encode detector observables into high-dimensional Hilbert spaces, enabling the exploration of nonclassical feature geometries for event discrimination. The performance of the different approaches is evaluated using consistent preprocessing pipelines and identical train-test configurations in order to assess the role of quantum-enhanced embeddings in particle-physics classification tasks.
The results show that projected quantum kernels and RDM-based approaches achieve competitive and, in some energy regimes, improved separability relative to standard classical kernels. The work also discusses important limitations associated with dataset size, morphology-derived labels, and possible overfitting effects in highly separable feature spaces.
Overall, this study provides an exploratory benchmark of quantum-enhanced learning methods for neutrino-event morphology analysis and contributes to ongoing efforts at the intersection of quantum computing, machine learning, and high-energy astroparticle physics.

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#42 — Oral

Certification Setup For Single Photon Detectors Used In QKD Systems

GEITC - Quantum Information and Quantum Cryptography

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Abstract Text:

Single-photon detectors form a fundamental component of quantum key distribution (QKD) receivers and are responsible for converting incident quantum signals into classical detection events. While QKD protocols such as BB84 offer information-theoretic security in the idealised model, practical implementations are subject to device imperfections that may be exploited by a malicious adversary. In particular, avalanche photodiode (APD) and other single-photon detector technologies can be forced out of the single-photon Geiger mode and into a classical linear response regime by injecting bright light, thereby blinding the detector and allowing an eavesdropper to impose deterministic detection outcomes. This class of detector control or blinding attacks undermines the security assumptions of QKD systems by enabling an eavesdropper to obtain full or partial knowledge of the key without introducing detectable errors in the key generation statistics. In this work, we have designed and implemented a versatile experimental cerification testbench capable of conducting a broad range of detector attack scenarios. In parallel, we have developed custom software enabling full automation of the measurement and attack procedures, facilitating systematic and reproducible vulnerability assessments of devices under test (DUTs). Using this platform, we performed continuous-wave (CW) blinding as well as pulsed blinding experiments on both a gated single-photon detector (SPD) and a free-running passively quenched SPD. Furthermore, we carried out detector control experiments employing 200 ps optical pulses superimposed on the blinding CW light. For the passively quenched SPD, we additionally conducted negative control tests to investigate its response when adding gaps to the blinding illumination.

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#63 — Oral

Device-Independent Quantum Cryptography With Input Leakage

GEITC - Quantum Information and Quantum Cryptography

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Abstract Text:

Device-independence is the gold standard of quantum cryptography. To meet this standard, a central assumption is that no information leakage occurs during protocol execution. We relax this assumption by analyzing CHSH-based randomness certification and key distribution with partial leakage of the inputs, modeled in terms of a noisy channel. Our results quantify the certifiable local randomness and the secret key rate as a function of the magnitude of the input leakage.

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#64 — Oral

Theoretic-Informational Study Of Interelectron Correlations In Non-Heavy Atoms In Position And Momentum Space.

GEITC - Quantum Information and Quantum Cryptography

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Abstract Text:

Interelectron correlations in non-heavy atomic systems are studied by comparing two-body probability densities with single-particle densities. Probability distributions are obtained from the wave functions by using the Hartree-Fock method in position space, and after applying the Fourier transform, in momentum space. The systems under study are neutral atoms and ionized species with atomic numbers ranging from 3 to 54.
This numerical work is conducted using tools from Information Theory. Specifically, well-known uniparametric information-theoretic functionals (Jensen-Tsallis Divergence, Jensen-Rényi Divergence, and Generalized Quantum Similarity Index) allow us to highlight regions of physical interest within the distributions, such as the valence region.
Finally, conclusions are drawn regarding both the appropriateness of these information-based measures and the importance of the shell structure for electronic correlations.

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#120 — Oral

Measuring Temporal Entropies In Experiments

GEITC - Quantum Information and Quantum Cryptography

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Abstract Text:

We propose a novel experimental protocol to measure generalized temporal entropies in many-body quantum systems. Our approach involves using local operators as probes to characterize the out-of-equilibrium dynamics induced by a geometric double quench on a replicated system. Such protocol mimics the path-integral on the corresponding Riemann surface encoding generalized temporal entanglement. We present the results of tensor network simulations of one-dimensional systems which validate the protocol and demonstrate the experimental feasibility of measuring generalized temporal entropies, and we outline the experimental requirements for implementing these quenches using state-of-the-art quantum simulators. Therefore, our results provide a physical interpretation of the meaning of generalized temporal entropies. Furthermore, they reveal that the dynamics induced on two replicas of the Ising model in a transverse field differ qualitatively from the ones of its non-integrable extension, suggesting that generalized temporal entropies can be used as a tool for identifying different dynamical classes in quantum systems.

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#122 — Oral

Analytical Security Analysis For Imperfect Decoy-State QKD

GEITC - Quantum Information and Quantum Cryptography

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Abstract Text:

Practical quantum key distribution (QKD) systems inevitably deviate from idealized theoretical models. Real implementations suffer from a combination of hardware imperfections including state preparation flaws, side-channel leakage, inter-pulse correlations, and detector inefficiencies that are typically addressed in isolation by existing security proofs. This separate treatment leaves a significant gap between theoretical guarantees and real-world setups.
In this work, we present the first unified, fully analytical security proof for decoy-state QKD in the finite-key regime that simultaneously accounts for all the above imperfections. Our framework is built upon three main pillars. First, we generalize the analysis from [Optica Quantum 3 (6), 525-534] originally developed for single-photon protocols to the decoy-state setting, allowing to incorporate state preparation flaws and general side-channel leakage. Second, we extend a recently proposed subprotocol decomposition technique [arXiv:2601.08417] to handle bit and basis correlations in decoy-state protocols; rigorously bounding the phase-error rate even when the i.i.d. assumption is violated, as occurs in high-speed systems. Third, we incorporate receiver imperfections, specifically dark counts and detector efficiency characterized only within finite tolerances, by adapting and strengthening a phase-error-based framework [arXiv:2507.03549] to the decoy-state scenario.
The derived secret key rate holds against general attacks and is valid for finite-size data blocks. Numerical simulations demonstrate that secret key generation remains achievable under the simultaneous presence of all considered imperfections, with a performance penalty that grows with the magnitude of the imperfections. Notably, among other findings, we find that correlations incur a stronger penalty in the decoy-state setting than in single-photon protocols due to the compounded statistical cost of independent phase-error estimation across subprotocols.
We believe that our results represent a meaningful step toward security proofs that faithfully capture the complexity of real QKD hardware as it closes the long-standing problem of incorporating several imperfections at once in a single framework.

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#177 — Oral

Finite-Size Quantum Key Distribution Rates From Rényi Entropies Using Conic Optimization

GEITC - Quantum Information and Quantum Cryptography

Andrés González Lorente

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Abstract Text:

Finite-size general security proofs for quantum key distribution based on Rényi entropies have recently been introduced. These approaches are more flexible and provide tighter bounds on the secret key rate than traditional formulations based on the von Neumann entropy. However, deploying them requires minimizing the conditional Rényi entropy, a difficult optimization problem that has hitherto been tackled using ad-hoc techniques based on the Frank-Wolfe algorithm, which are unstable and can only handle particular cases.
In this work, we introduce a method based on non-symmetric conic optimization for solving this problem. Our technique is fast, reliable, and completely general. We illustrate its performance on several protocols, whose results represent an improvement over the state of the art.

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#184 — Oral

Entanglement-Swapping Measurements For Deterministic Entanglement Distribution

GEITC - Quantum Information and Quantum Cryptography

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Abstract Text:

Entanglement swapping is a fundamental primitive for establishing long-distance entanglement in quantum networks. In standard swapping protocols, the state distributed between distant end users depends on the measurement outcome at the intermediate node. As a result, some outcomes may generate weakly entangled or undesired states, forcing the use of post-selection and reducing the efficiency of entanglement distribution. In this work, we introduce and characterize a deterministic framework for entanglement swapping in which every measurement outcome produces locally unitary equivalent output states for arbitrary pure input links. This property, which we call universal LU-determinism, ensures that all outcomes are equally useful and can be corrected by local unitary operations.
We derive necessary and sufficient structural conditions on the swapping measurements that guarantee universal LU-determinism. In particular, we show that such measurements are built from unbiased operators, and that imposing optimality with respect to the G-concurrence selects maximally entangled measurements generated by complex Hadamard matrices. This connection allows us to classify optimal deterministic entanglement-swapping measurements in a dimension-dependent manner. We find a unique optimal class in dimensions d = 2 and d = 3, infinitely many inequivalent classes in d = 4, and 72 inequivalent classes in d = 5. Distinct classes generate optimal output states that are not only locally inequivalent but also cannot be deterministically converted into one another by LOCC.
We further extend the framework to quantum networks with multiple swapping nodes. For dimensions d = 2 and d = 3, the final end-to-end entangled state is independent of the order in which the intermediate nodes perform their measurements. Our results provide post-selection-free and outcome-independent entanglement-distribution schemes for generic quantum networks, with direct relevance for quantum repeaters and multi-node quantum communication architectures.

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#198 — Oral

The Role Of Entanglement In Energy-Restricted Communication And Randomness Generation

GEITC - Quantum Information and Quantum Cryptography

Carles Roch I Carceller, Armin Tavakoli

Lund University, Lund, Sweden
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Abstract Text:

A promising platform for semi-device-independent quantum information is prepare-and-measure experiments restricted only by a bound on the energy of the communication. Here, we investigate the role of shared entanglement in such scenarios. For classical communication, we derive a general correlation criterion for nonlocal resources and use it to show that entanglement can fail to be a resource in standard tasks. For quantum communication, we consider the basic primitive for energy-constrained communication, namely the probabilistic transmission of a bit, and show that the advantages of entanglement only can be unlocked by non-unitary encoding schemes that purposefully decohere the entangled state. We also find that these advantages can be increased by using entanglement of higher dimension than qubit. We leverage these insights to investigate the impact of entanglement for quantum random number generation, which is a standard application of these systems but whose security so far only has been established against classical side information. In the low-energy regime, our attacks on the protocol indicate that the security remains largely intact, thereby paving the way for strengthened security without more complex setups and with negligible performance reductions.

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#232 — Oral

Quantum State Exclusion For Group-Generated Ensembles Of Pure States

GEITC - Quantum Information and Quantum Cryptography

Arnau Diebra Huertas 1, Santiago Llorens 2, Emili Bagan Capella 1, Gael Sentís 1, Ramon Muñoz Tapia 1

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Abstract Text:

Quantum state exclusion is a fundamental information-theoretic task aimed at determining which states from a known set a quantum system was not prepared in. While traditional state discrimination focuses on identifying the exact state, quantum state exclusion provides a complementary operational framework that is highly relevant to quantum resource theories, state assignments, and foundational debates on the physical reality of quantum systems. In this contribution, we present a complete analytical solution to optimal quantum state exclusion for arbitrary pure state ensembles generated by finite groups. We establish the necessary and sufficient conditions for perfect, zero-error exclusion across the entire parameter space. Crucially, for regions where perfect exclusion is impossible, we introduce and solve two natural extensions of the problem: minimum-error exclusion and unambiguous exclusion. By leveraging group representation theory, semidefinite programming duality, and the Gram matrix formalism, we derive explicit analytical expressions for the optimal protocols, measurements, and corresponding failure probabilities in both scenarios. We demonstrate that the minimum probabilities of error and inconclusive outcomes are strictly governed by the eigenvalues of the ensemble's Gram matrix. Furthermore, we prove that the optimal measurement achieving this minimum can always be taken to be a sharp measurement. Our findings not only unify and generalize previous fragmented results, such as those restricted to circulant sets, but also offer constructive proofs that yield the explicit optimal Positive Operator-Valued Measures. Ultimately, these results provide deep insights into how quantum states encode information under symmetric constraints and non-trivial projective representations.
Note to the Scientific Committee: Please consider that the theoretical findings and proofs detailed in this abstract have already been successfully peer-reviewed and published in Physical Review Research (PRR).

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#233 — Oral

Beyond Weak Coherent Pulses In Decoy-State Quantum Key Distribution: Can Practical Single-Photon Sources Enhance Key Generation?

GEITC - Quantum Information and Quantum Cryptography

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Abstract Text:

High brightness, low-$g^{(2)}$ single-photon sources (SPSs) are an alternative to commonly employed weak coherent pulse (WCP) sources for discrete variable quantum key distribution (QKD) and offering potential key-rate and finite-block scaling advantages. However, the loss tolerance of SPS-based QKD is compromised by photon number splitting (PNS) attacks against non-negligible multiphoton emissions. Decoy state (DS) techniques mitigate against PNS attacks, with WCP-DS QKD over several hundred km in fibre being demonstrated. DS QKD protocols for different source photon number statistics have been proposed, such as for binomial and thermal distributions. Here, we investigate the use of generalised DS techniques assuming we do not have access to the exact photon number statistics of the SPS. Thus, we bound the source distribution using the mean photon number and the second-order correlation function, which provides us with enough partial knowledge to compute our decoy SPS protocols assuming a photon number cut-off. Hence, we provide finite-key security bounds for an SPS-based Efficient BB84 for two decoy protocols with optimised parameters, and derive required SPS characteristics to achieve a key rate enhancement over DS WCPs and match their loss tolerance.

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#381 — Oral

Absolute Dimensionality Of Quantum Ensembles

GEITC - Quantum Information and Quantum Cryptography

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Abstract Text:

The dimension of a quantum state is traditionally seen as the number of superposed distinguishable states in a given basis. In this paper [1] we propose an absolute, i.e., basis-independent, notion of dimensionality for ensembles of quantum states. It is based on whether a quantum ensemble can be simulated with states confined to arbitrary lower-dimensional subspaces and classical post-processing. In order to determine the absolute dimension of quantum ensembles, we develop both analytical witness criteria and a semidefinite programming criterion based on the ensemble's information capacity. Furthermore, we construct explicit simulation models for arbitrary ensembles of pure quantum states subject to white noise, and in natural cases we prove their optimality. Also, efficient numerical methods are provided for simulating generic ensembles. Finally, we discuss the role of absolute dimensionality in high-dimensional quantum information processing.

[1] Phys.Rev.Lett. 133 (2024) 24, 240203

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#24 — Oral

Observation Of String Breaking Dynamics With Rydberg Atoms And Trapped Ions

GEITC y GEOCONL - Quantum Simulation and Ultracold Atoms

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Abstract Text:

In this talk, I will present recent experimental advances in the quantum simulation of lattice gauge theories (LGTs), with a focus on the phenomenon of string breaking. In confining theories, strings of gauge-field excitations bind particle-antiparticle pairs, with an energy that grows linearly with their separation. Beyond a critical distance, this energy cost leads to string breaking via particle-antiparticle pair creation. I will first show how analog quantum simulators based on Rydberg atom arrays can naturally encode a two-dimensional U(1) LGT, enabling the observation of string-breaking dynamics through the creation of particle pairs. I will then discuss how a digital quantum computer based on trapped-ion qudits can simulate an SU(2) LGT on a plaquette ladder, where non-Abelian string breaking is observed through the formation of glueball excitations driven by plaquette interactions. These results highlight the potential of current quantum devices to probe nontrivial phenomena in gauge theories and particle physics.

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#37 — Oral

On The Fragility Of Dissipative Time Crystals

GEITC y GEOCONL - Quantum Simulation and Ultracold Atoms

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Abstract Text:

Time crystals are exotic phases of matter that spontaneously break time-translation symmetry, exhibiting robust periodic dynamics even in the presence of fluctuations, including quantum noise. They can be viewed as temporal counterparts of ordinary spatial crystals, sharing analogous properties but unfolding in time rather than space. Because their existence at thermal equilibrium remains uncertain, attention has shifted toward out-of-equilibrium settings, particularly driven–dissipative platforms. This has led to the concept of dissipative time crystals, in which time-crystalline behavior emerges as a stable asymptotic state of the open-system dynamics.
Within this framework, it has been proposed that dissipative time crystals could be realized in small systems, such as a few harmonic oscillators or a limited number of optical cavity modes. In this work, however, we demonstrate that such small systems are not robust against perturbations such as dephasing or nonlinearities. As a result, they are better understood not as genuine time-crystalline phases of matter, but as mathematical analogues—still valuable as insightful toy models.
Motivated by this observation, we conjecture that extended systems are necessary to achieve true time-crystalline order, as they can exploit many-body mechanisms to protect against local fluctuations. We test this conjecture by introducing local dephasing in spin models widely studied in the context of time crystals, and find that only a small subset exhibit genuine robustness.
Our results highlight the need to adopt robustness against local noise as a defining criterion for dissipative time crystals and support the view that the spontaneous breaking of continuous time-translation symmetry relies on genuinely many-body effects. Consequently, small or structurally simple systems lack the necessary ingredients to sustain true time-crystalline behavior, including several models previously proposed in the literature.

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#45 — Oral

Global Control Of Spin Crystals Via Single-Site Manipulation: Tracking Of Transport

GEITC y GEOCONL - Quantum Simulation and Ultracold Atoms

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Abstract Text:

Spin systems are key platforms for quantum technologies [1], where precise control of their dynamics and a deep understanding of transport phenomena driven by spin-spin interactions are essential. However, achieving full control of a many-body spin chain typically requires addressing multiple sites, posing significant experimental challenges [2].
In this work, we demonstrate global control of a quantum spin chain through single-site manipulation [3]. To do so, we apply quantum optimal control (QOC) to design a driving field that applied to a single spin allows to achieve any given state of the entire system.
Furthermore, we introduce an extended QOC algorithm that advances beyond conventional final-time optimization, facilitating precise control not only at the final time but also at arbitrary intermediate times, using the identical or distinct observables [4]. This methodology allows the tracking of the spin dynamics and transport properties throughout the evolution, not only at the end point.
Our results open the path toward experimentally feasible control of quantum spin networks and provide new tools for probing non-equilibrium transport in interacting quantum systems.
[1] C. P. Koch et al., EPJ Quantum Technol. 9, 19 (2022)
[2] C. Monroe et al., Rev. Mod. Phys., 93, 025001 (2021)
[3] K. Castro, I. R. Solá and J. J. Omiste, J. Math. Phys. 66, 122201 (2025)
[4] J. J. Omiste and I. R. Solá, In preparation (2026)

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#74 — Oral

Enhanced Quantum Heat Engines Using Exchange Symmetry Manipulation

GEITC y GEOCONL - Quantum Simulation and Ultracold Atoms

Joe Dunlop, Álvaro Tejero, Michalis Skotiniotis, Daniel Manzano

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Abstract Text:

The statistical properties of many-particle systems depend intimately on the exchange symmetry of the collective wavefunction. However, individual degrees of freedom (e.g. position, spin) need not have the same symmetry as the total system. By introducing an energy bias towards antisymmetric joint spin, then, the position distribution of fermions (and associated thermal properties) can be made to mimic bosons, and vice versa. We call this construction Hamiltonian Anyons, and the strength of bias can be used to dynamically tune the system between fermionic and bosonic modes.
We here analyse novel fermion-boson phase transitions, with potential applications to thermodynamic cycles, where alternating between fermionic repulsion and bosonic compressibility leads to enhanced performance. We outline avenues for experimental implementation, and present methods for simulating the dynamics of Hamiltonian anyons on current quantum computers.

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#217 — Oral

Does The Stroboscopic Lindbladian Exist? An Analytical Approach

GEITC y GEOCONL - Quantum Simulation and Ultracold Atoms

Antonio De La Misericordia Sojo López, Jesús Casado Pascual

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Abstract Text:

Floquet theory enables the decomposition of periodically driven dynamics into the micromotion within each period and the stroboscopic propagator over one driving cycle. In Lindbladian open quantum systems, the effective stroboscopic generator may fail to retain a Lindbladian structure, despite the full evolution being Markovian. This stroboscopic embedding problem has mainly been investigated numerically, making the analysis particularly sensitive to precision-related artifacts near Markovian--non-Markovian phase boundaries. Here, we introduce a parametrized model that eliminates such ambiguities and provides exact analytical expressions for the conditions under which a stroboscopic Markovian phase exists in parameter space. These results could be relevant to extend Floquet Engineering techniques to open quantum systems.

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#343 — Oral

Measurement Induced Quantum Ratchet

GEITC y GEOCONL - Quantum Simulation and Ultracold Atoms

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Abstract Text:

We study directed transport in a one-dimensional open quantum lattice subject to continuous measurements and time-dependent switching between two lattice configurations. The dynamics combines coherent tunneling, incoherent transitions, and measurement-induced dissipation, while the lattice modulation is implemented through either a periodic protocol or a dichotomous Markov process. We show that an asymmetry in the measurement strengths associated with the two configurations generates a finite ratchet current in the absence of external bias. Both protocols admit an analytical treatment and allow explicit expressions for the long-time transport velocity to be obtained. In the stochastic case, the dynamics can be formulated in terms of linear stochastic equations driven by multiplicative dichotomous noise. The resulting transport properties reveal a nontrivial interplay between coherent dynamics, dissipation, and stochastic switching. We further analyze the connection between the stochastic and periodic protocols and identify the regime in which both approaches lead to the same asymptotic behavior. These results illustrate how continuous quantum measurements and stochastic modulation can be combined to control transport dynamics in open quantum systems.

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#5 — Oral

"Programming" Quantum Simulators Made Of Atoms And Light

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

Alejandro Gonzalez-Tudela

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Abstract Text:

In this talk, I will review some of my recent works [1,2,3] on how to harness the recent experimental advances in programmable AMO simulators based on fermionic ultra-cold atoms, Rydberg atomic arrays or waveguide/cavity QED.
First, I will briefly show how the tunable-range interactions appearing in waveguide or multi-mode cavity QED can be used to construct wavefunction ansätze that approximate the ground state of quantum spin models.
Second, I will discuss several "programmable" protocols [2] for improving ground-state preparation with ultra-cold atoms beyond adiabatic approaches, and apply them to local and extended Fermi-Hubbard models with and without doping.
Finally, I will discuss an algorithm specifically tailored for analog quantum simulators that use data gathered from the device to accurately investigate properties of the ground state of spin and Fermi-Hubbard Hamiltonians [3].
[1] C Tabares, A Muñoz de Las Heras, L Tagliacozzo, D Porras, A. González-Tudela. Physical Review Letters 131 (7), 073602 (2023).
[2] C. Tabares, C. Kokail, P. Zoller, D. González-Cuadra and A. González-Tudela, PRX Quantum 6 (3), 030356 (202
[3] C Tabares, DS Wild, JI Cirac, P Zoller, A González-Tudela, D. González-Cuadra arXiv:2511.04434

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#6 — Oral

Controlling Propagating Photons With Chiral, Multi-Mode Waveguide QED

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

Alejandro Gonzalez-Tudela

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Abstract Text:

Controlling propagating quantum states of light is essential for the development of photonic quantum technologies. In this talk, I will first review how qualitatively new photon-mediated interactions emerge when emitters or resonators couple to chiral, multi-mode waveguides [1]. I will then show how these interactions enable the implementation of controlled photon-photon phase gates using only two-level systems [2,3],. In both cases, I will discuss potential implementations in the microwave using circuit QED setups.
[1] C. Vega, A.M. Heras, D. Porras, A. González-Tudela, Quantum 9, 1861 (2025)
[2] T. Levy-Yeyati, C. Vega, T. Ramos, A. González-Tudela, PRX Quantum 6, 010342 (2025)
[3] T Levy-Yeyati, T Ramos, A González-Tudela, arXiv:2507.05377

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#18 — Oral

Optimal Control For Dipolar Hubbard Rings

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

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Abstract Text:

Precise manipulation of quantum systems underpins progress across quantum technologies, spanning computing, simulation, and metrology applications. A new control framework is introduced for applying optimal control techniques to dipolar systems. The approach employs time-varying control over an external magnetic field's orientation, taking advantage of the directional sensitivity of dipole-dipole interactions via an optimised magnetostirring protocol. The entire dynamical evolution is governed by just two independent control parameters, keeping the scheme experimentally tractable with existing laboratory infrastructure. An examination of symmetry constraints and controllability boundaries is presented, clarifying the roles of inversion symmetry and dipolar-immune eigenstates in setting upper limits on achievable fidelity for particular system geometries. We specialize in preparing entangled current-carrying states in ultracold dipolar atoms arranged on a ring-shaped optical lattice. Numerical results confirm that target entangled current states can be prepared with unit fidelity across a broad class of systems, while configurations subject to symmetry restrictions are shown to saturate their theoretical fidelity bounds. The findings are relevant to atomtronic circuit design and many-body quantum engineering, positioning dipolar optimal control as a powerful methodology for high-fidelity state preparation in dipolar quantum gases.

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#32 — Oral

Quantum Sensing With Optically Active Spin Defects For Magnon-Based Technologies

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

Samuel Mañas-Valero 1,2, Yasmin C Doedes 2, Artem Bondarenko 2, Michael Borst 2, Samer Kurdi 2, Thomas Poirier 3, James H. Edgar 3, Vincent Jacques 4, Yaroslav M. Blanter 2, Toeno Van Der Sar 2

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Abstract Text:

Quantum sensing based on optically active spin defects (also known as color-center magnetometry) exploits electronic spins associated with atomic defects in solid-state materials, such as nitrogen vacancies in diamond and boron vacancies in hexagonal boron nitride, for quantitative nanoscale magnetometry with high sensitivity and spatial resolution.
In this talk, I will introduce spin-wave sensing using color center magnetometry, specifically using color centers in diamond and hexagonal boron nitride to image spin waves at complementary frequencies.[1] Spin waves (also known as magnons) in magnetic films have micrometer-scale wavelengths at gigahertz frequencies and are promising for wave-based information devices with new functionalities.[2] Realizing this promise requires accurate control of both the static magnetization and the spin-wave spectrum in microfabricated magnetic structures. In this context, quantum sensing with spin defects provides an excellent tool.
In particular, we harness the magnetic anisotropy in a permalloy magnetic half-plane to control the magnetic texture and excite spin-waves with highly field-tunable wavelengths. Via color-center magnetometry, we image both the static magnetic field generated by the magnetic texture and the dynamic fields generated by the spin-waves near the film edge. This enables us to determine the magnetic anisotropy, the magnetization curling length, and to correlate these with the spatially varying spin-wavelengths. Rotating the magnetic bias field, we trigger the non-reciprocal nucleation of a domain wall that strongly modulates the spin-wave transport near the film edge.
Our results establish quantum sensing with optically active spin defects in solid-state materials as a versatile tool for advancing spin-wave technologies.
References:
[1] S. Mañas-Valero et al., Nature Communications 17, 379 (2026). DOI: 10.1038/s41467-025-67056-1
[2] S. Mañas-Valero et al., Newton 1, 1, 100018 (2025). DOI: 10.1016/j.newton.2025.100018
Acknowledgements:
We acknowledge support from the Spanish MICIU (RYC2024-048264-I).

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#57 — Oral

Strategies Toward Quantum Optics In The Terahertz Regime

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

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Abstract Text:

Terahertz (THz) radiation has promising applications across a range of fields, including food science, medical diagnostics, biology, high-bandwidth communication, and security. However, the development of quantum technologies in the THz regime remains at a nascent stage compared to their counterparts in the visible and microwave domains. This lag is largely due to the lack of bright and efficient photonic transitions at THz frequencies.
In this talk, I present our theoretical proposals aimed at realizing quantum-optical platforms operating in the THz regime. Our approach leverages the permanent dipole moment of a single polar quantum emitter to induce THz transitions between optically dressed states, alongside the design of hybrid cavity systems. We demonstrate how these concepts can be used to engineer on-demand single-photon sources, as well as to mediate entanglement between quantum emitters via THz photonic modes. These developments point toward novel quantum-optical platforms that offering an strategic compromise between the limitations of the visible spectrum (e.g., nanometric precision and material absorption) and those of the microwave regime (e.g., scalability and the need for millikelvin cooling).

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#89 — Oral

Quantum Sequential Parameter Testing

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

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Abstract Text:

We introduce a new protocol for testing parameters in a statistical models that makes use of sequential strategies in order to furnish estimates with guaranteed precision. Unlike traditional parameter estimation methods that seek to minimize the error using a fixed predetermined number of samples, our protocol seeks to minimize the sample size given predetermined error thresholds. We provide an explicit asymptotic expression for the average number of samples needed to guarantee a given precision. We apply our technique to the case of phase and purity estimation, and derive the protocols that require the minimum sample size in order to furnish estimates with a pre-specified precision. Our protocols make use of only local projective measurements, and do not require any entanglement making them ideal for practical implementations.

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#94 — Oral

Quantum Sensing Through Continuous Monitoring Of Open Many-Body Systems

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

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Abstract Text:

Quantum systems in nonequilibrium conditions, where coherent many-body interactions compete with dissipative effects, can exhibit rich phase diagrams and emergent critical behavior. The quanta emitted by these open quantum systems, typically photons, carry information about intrinsic parameters, enabling their estimation through continuous monitoring. In turn, the collective and quantum effects emerging in these systems can act as metrological resources, enhancing the fundamental sensitivity with which such parameters can be inferred.
However, protocols that fully exploit this enhancement often require intricate measurements on the joint system–environment state. Here, we discuss the conditions under which classical measurement schemes, such as photon counting or homodyne detection, are sufficient to extract the full sensitivity of the system. We illustrate this in detail for a class of open spin–boson models, realizable in trapped-ion or cavity-QED platforms, in which emergent collective phenomena enhance metrological performance. Finally, we examine the impact of detection inefficiency, a key constraint in many setups, on the practical implementation of our findings. We discuss an example for which photon counting is optimal and retains high sensitivity even at very low detection efficiencies, a regime of particular relevance for trapped-ion setups.

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#99 — Oral

Quantum-Enhanced Estimation Of Mode Parameters

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

Manuel - Gessner

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Abstract Text:

Quantum metrology develops techniques that improve the measurement resolution of parameters encoded in quantum states. The quantum states of light are defined not only by the quantum state itself, but also by the shape of the modes that this state occupies. Parameters that determine, for example, a quantum optical mode include the spatial and temporal shape as well as the frequency spectrum. The estimation of these parameters is of high interest for applications in imaging, timing, positioning and precision spectroscopy. In this talk we present a quantum theory for the metrological estimation of mode parameters. We demonstrate that the population of suitably designed modes with nonclassical states enables quantum enhancements for the estimation of arbitrary mode parameters. We discuss applications of our results in the context of superresolution imaging and displacement sensing.

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#103 — Oral

Indene-C60 Monoadduct As A Single-Photon Emitter

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

Beñat Berasategui-Miguéliz 1,2, Raul Lahoz Sanz 3,2, Coral Becerra Gómez 2, Sergi Hernández 1, José María Gómez Cama 1,2,4, Bruno Juliá Díaz 3,2

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Abstract Text:

Single-photon sources (SPSs) are a cornerstone of quantum technologies. In quantum key distribution (QKD), encoding information in individual photons prevents external attacks, while on-demand single-photon emission is essential for linear optical quantum computing [1]. An ideal SPS should be bright, stable, operable atroom-temperature, and low-cost. Current platforms, such as epitaxial and colloidal quantum dots or nitrogen-vacancy centers, do not simultaneously fulfill all these requirements [1,2]. Our group has recently demonstrated that C60 fullerene embedded in polystyrene functions as a room-temperature SPS with on-demand emission and high emission rate [2]. We hypothesize that a photoinduced ternary functionalization process, in which C60 reacts with polystyrene and oxygen, breaks the molecular symmetry and enables previously forbidden HOMO-LUMO transitions [2,3]. However, this process is nondeterministic, making it difficult to control or characterize the emitting species. Here, we study indene-C60 monoadduct (ICMA), a C60 derivative in which an indene group is covalently bonded to fullerene. Under 515 nm excitation, we observe a spectral evolution analogous to that of C60: an initial emission band near 725 nm progressively degrades while a new band near 610 nm emerges, suggesting that further photoinduced modifications shape the emitting species. Most importantly, we demonstrate single-photon emission from individual ICMA molecules via fiber-based Hanbury Brown-Twiss interferometry. We measure $g^{(2)}(0) < 0.5$ for photons near 620 nm at room temperature, unambiguous evidence of nonclassical light emission. These results establish ICMA as a novel room-temperature SPS and pave the way for understanding the role of molecular symmetry in fullerene-based quantum emitters.
[1] M. B. Gaither-Ganim et al., "Organic molecule single-photon sources", Oxford Open Materials Science 3 (2023).
[2] R. Lahoz-Sanz et al., "C60 fullerene as an on-demand single-photon source at room temperature", Nano Letters 25 (2025).
[3] C. Zhang et al., "Photoluminescence study of C60 doped polystyrene", Applied Physics Letters 68 (1996).

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#130 — Oral

Aproximación Semiclásica Al Antiarracimamiento Fotoeléctrico

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

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Abstract Text:

El antiarracimamiento (antibunching), es una característica de la radiación electromagnética que se considera explicable únicamente dentro del marco de la teoría cuántica de la radiación. Consiste en que el grado de coherencia de segundo orden, g(2)(t), en lugar de verificar g(2)(0) > g(2)(t), tal y como predice la teoría semiclásica (materia cuantizada en interacción con radiación clásica), puede verificar g(2)(0) < g(2)(t), como ocurre, e.g., con estados de Fock.
En nuestro trabajo, exploramos la posibilidad de explicar semiclásicamente el antiarracimamiento. Para ello, generalizamos la descripción semiclásica estándar de la fotodetección múltiple imponiendo conservación de la energía. Es decir, incorporamos el hecho de que, tras cada fotodetección, la intensidad de la luz ha de disminuir porque una cantidad de energía hf ha sido extraída del campo para generar un fotoelectrón. Asumimos que esta energía desaparece del haz instantáneamente en el instante mismo de la fotodetección.
Con esta prescripción, llevamos a cabo simulaciones numéricas en las que la probabilidad de detección depende de la intensidad del haz de luz en el instante de la detección (un resultado semiclásico), de forma que cuando hay una detección, la intensidad del pulso de luz detectado disminuye uniformemente tras perder la energía hf (también manejamos otros modelos de la dinámica de pérdida de energía). Nuestros resultados, demuestran que es posible obtener antiarracimamiento cuando la señal luminosa consiste en una secuencia suficientemente regular de pulsos. Si se introducen fluctuaciones en la secuencia de pulsos, se pasa de antiarracimamiento a arracimamiento al ir aumentando, gradualmente, las fluctuaciones. Parece, pues, que es posible obtener antiarracimamiento con nuestra sencilla teoría semiclásica; sin embargo, no parece posible obtener el importante resultado g(2)(0) = g(2)(t) = 1 propio de la radiación coherente.

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#149 — Oral

Photon-Counting RGB Cathodoluminescence Imaging In Scanning Electron Microscopy: Prototype Description And First Results

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

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Abstract Text:

Cathodoluminescence (CL) imaging in the scanning electron microscope (SEM) is widely used for the spatial and temporal characterization of light-emitting materials such as semiconductors, phosphors, and quantum emitters. However, conventional consumer-grade RGB CL detectors operating in analogue integration mode suffer from systematic artefacts when the luminescence decay time exceeds the pixel dwell time. Under these conditions, residual emission from one pixel is integrated into subsequent pixels, producing a directional intensity tail known as streaking. This effect is particularly severe in materials with millisecond-scale decay times, and compromises both spatial resolution and quantitative spectral analysis. In this work, we present a photon-counting RGB CL detector for CL-SEM based on silicon photomultiplier (SiPM) sensors and compare its performance directly with that of a conventional analogue RGB detector. Measurements were performed on a well-characterized multi-phosphor test sample derived from a vintage cathode-ray tube display, containing red, green, and blue phosphor particles with markedly different decay times. The red phosphor Y2O2S:Eu3+, exhibits millisecond decay, whereas the green and blue phosphors decay on microsecond timescales, providing an ideal benchmark for artefact characterization. In addition, we analyse representative real-material samples to demonstrate the applicability of the method under practical CL imaging conditions.
Our results demonstrate that analogue detection produces pronounced streaking from red-emitting particles in the fast-scan direction, while photon-counting detection effectively suppresses this artefact when dwell time exceeds a critical threshold relative to decay time. Quantitative analysis further reveals that analogue detection artificially broadens chromaticity distributions and increases inter-channel correlations because of spectral contamination from trailing emission. In contrast, photon-counting measurements recover near-Poisson photon statistics and more accurate spectral separation.
Finally, we evaluate detector sensitivity under photon-limited conditions and investigate several denoising strategies, including Gaussian and unsupervised deep-learning approaches.

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#172 — Oral

Benchmarking Quantum Extreme Learning Based On Gaussian Boson Sampling

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

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Abstract Text:

The rising cost of training large machine-learning models motivates the development of hardware-efficient learning approaches. Quantum reservoir models offer a hardware-efficient learning paradigm for noisy intermediate-scale quantum devices by exploiting untrained quantum dynamics as a fixed feature map and restricting optimization to a simple classical readout layer. We propose a quantum extreme learning machine implemented using Gaussian boson sampling and an encoding strategy that achieves high classification accuracy while reducing optical resource requirements. Classical inputs are jointly encoded in the squeezing parameters and in the interferometer unitary, enabling sampling-based, highly nonlinear feature maps while leveraging large-scale GBS output statistics, which are conjectured to be classically intractable. We systematically compare multiple families of quantum features accessible in the same setup and find that photon-number sampling probabilities provide the best performance, consistent with their higher effective feature dimensionality. Finally, we benchmark against classical nonlinear baselines and analyze robustness under noisy scenarios, showing competitive performance with fewer trainable parameters and indicating practical promise for near-term photonic implementations.

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#185 — Oral

Topological Phases Of Interacting Driven-Dissipative Lattices

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

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Abstract Text:

Topology in quantum physics leads to phenomena that are robust against disorder and experimental imperfections. A paradigmatic example is the Majorana qubit, where quantum information is encoded in topologically protected Majorana zero modes.
In this talk, I will present a topological framework for quantum driven-dissipative systems. This framework relies on an extension of topological insulator theory. Our theory predicts the existence of topological phases in which a quantum driven-dissipative system behaves as a directional amplifier. This directional amplification mechanism is topologically protected from disorder and fabrication errors by a mechanism similar to that of Majorana modes in electronic systems.
Our topological theory applies to Gaussian or non-interacting systems. However, I will show that topological phases can arise from fluctuations in non-linear or interacting systems. In particular, I will focus on the driven-dissipative Bose-Hubbard model [1].
Our work can have applications, for example, in the design of efficient microwave amplifiers for superconducting quantum computers, as quantum-limited directional amplification remains a challenge in this field. Topological dissipative phases can also be used for quantum sensing, for example, with trapped ion force sensors [2].
[1] L. Rassaert, T. Ramos, T. Roscilde, D. Porras, Phys. Rev. Lett. 135, 203603 (2025)
[2] M. Clavero, T. Ramos, D. Porras, Phys. Rev. Res. 7, 043218 (2025)

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#325 — Oral

Tailoring Quantum Radiation With Giant Atoms For Quantum Metrology

GEITC y GEOCONL - Quantum Technologies with Photons and Atoms and Quantum Metrology

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Abstract Text:

Giant atoms—quantum emitters coupled to a continuum at multiple, spatially separated points—offer a powerful platform for nonlocal light–matter interactions. We study the radiation emitted by coherently driven giant atoms in a Markovian waveguide environment, focusing on how the spectral and statistical properties of the transmitted field can be tailored by tuning intrinsic parameters such as coupling-point positions, accumulated phase, and network topology. We also explore the metrological potential of this radiation, assessing quantum sensing strategies based on photon-counting and homodyne detection to infer system parameters. Our results illustrate how the nonlocal nature of giant atoms enables tunable radiation and enhanced sensitivity, opening new directions for engineered quantum optics and precision measurements.

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#61 — Oral

Women In Physics In Spain: Gender Inequalities, Academic Trajectories, And Structural Barriers In The University System

GEM - Mujeres en Física

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Abstract Text:

This study examines gender inequalities in physics within the Spanish university system through a multidimensional approach that integrates structural, institutional, and cultural dimensions. Drawing on secondary data from official sources—such as the Sistema Integrado de Información Universitaria (SIIU), Científicas en Cifras, and the Real Sociedad Española de Física—the analysis explores women's participation across key stages of the academic trajectory: undergraduate studies, doctoral training, research careers, scientific recognition, and involvement in institutional tasks.
The results reveal a persistent pattern of underrepresentation. At the undergraduate level, women's participation has remained below 30% for more than four decades, despite women constituting the majority in higher education overall. At the doctoral level, increased participation has not translated into meaningful progress toward gender balance, as existing proportions are largely reproduced over time. In academic careers, women account for approximately 22% of teaching and research staff and remain significantly underrepresented in senior positions, reflecting strong vertical segregation. At the same time, horizontal segregation across subfields highlights the influence of differentiated disciplinary cultures.
The analysis of research performance indicators does not show lower success rates for women in evaluation processes or competitive funding schemes. Instead, gender disparities are primarily associated with lower participation levels and structural constraints. Additionally, the findings point to an unequal distribution of academic labour, with women more heavily involved in management and evaluation tasks—typically less valued—which may negatively affect their research productivity and career progression.
Overall, the study demonstrates that gender inequality in physics is a structural, persistent, and cumulative phenomenon, and underscores the need to move toward systemic transformations that address institutional practices, cultural norms, and the organisation of academic work.organisation of academic work.

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#62 — Oral

Beyond Neutrality In Physics: Integrating Gender Perspectives In Mechanics Education

GEM - Mujeres en Física

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Abstract Text:

This paper presents a teaching innovation in physics education, specifically within a Mechanics course in Mechanical Engineering, aimed at integrating a gender perspective into the development of scientific and analytical competencies. While physics and mechanics are often perceived as neutral and objective disciplines, recent approaches highlight the importance of incorporating social and gender dimensions to enhance both the quality and relevance of scientific knowledge.
The proposed activity is embedded in a guided research assignment in which students analyze case studies from the Gendered Innovations project, focusing on how sex and gender analysis can influence problem definition, experimental design, data interpretation, and technological applications in physics-related contexts. Through this approach, students engage with real examples where overlooking gender variables has led to incomplete or biased results, and where their inclusion has generated more accurate and innovative outcomes.
The methodology combines independent or collaborative work with structured supervision, requiring students to critically examine the objectives of selected projects, assess the role of gender in physical modeling and engineering design, and reflect on methodological choices. This process supports the development of core competencies in mechanics, including data analysis, critical evaluation, and the synthesis of complex concepts, while also fostering awareness of the broader social implications of physics.
Aligned with current research frameworks such as Horizon Europe, which emphasize the integration of gender analysis in scientific excellence, this experience demonstrates that incorporating a gender perspective in physics education is not only a matter of equity but also a driver of more robust and context-sensitive scientific practices. The results suggest that such pedagogical strategies can enrich the teaching of mechanics by connecting abstract physical principles with real-world complexity and diversity.

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#67 — Oral

Las Científicas: El Imaginario Social Y La Realidad

GEM - Mujeres en Física

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Abstract Text:

El legado cultural y social heredado conlleva sesgos de género que se han convertido en estructuras de conocimiento no contrastado que minoriza a las mujeres. La diferencia entre usos de los lóbulos cerebrales o la preconcepción de la diferencia con desempeño masculino son ejemplos claros. Pero la anulación de la mujer en la ciencia ha llevado a parcialidades que sí han afectado incluso a la supervivencia, como por ejemplo el estudio sesgado a lo largo de los años de los infartos o el efecto de los medicamentos. Estos sesgos han estado relacionados con la dificultad del acceso de la mujer a la investigación científica, ya que el veto sufrido ha impedido la contribución femenina a la ciencia y en particular a la física. Poco a poco estos sesgos se van venciendo, pero todavía pervive un imaginario social de la mujer científica que viene fomentado, entre otras fuentes, por la imagen que se proyecta de las científicas en los medios de comunicación y en la educación. En particular, en las películas y series tanto infantiles como para adultos, con contenido científico aparecen pocas mujeres relacionadas con la ciencia. Además, la imagen que se proyecta está asociada a la vinculación de las mujeres con las carreras de ámbito sanitario y si no es así, la imagen proyectada está profundamente estereotipada.
Pero la realidad es que a lo largo de la historia ha habido numerosas mujeres que han participado y contribuido al desarrollo científico y que por distintos motivos han sido borradas de las bibliografías y no aparecen en la enseñanza de las ciencias.
Esta comunicación está basada en el libro “Las científicas: del imaginario social a la realidad” (Solbes, Petit i Traver, 2025) que pretende contribuir a la mejora en el conocimiento social de la ciencia, en particular, la física, en femenino

Volver al índice

#70 — Oral

¿Es La Física Realmente Neutral? Cultura, Estereotipos Y Desigualdad En La Disciplina

GEM - Mujeres en Física

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Abstract Text:

La desigualdad de género en física suele abordarse a partir de indicadores cuantitativos: cuántas mujeres estudian física, cuántas acceden a la carrera académica o cuántas alcanzan posiciones de liderazgo. Sin embargo, limitar el análisis a los números deja fuera una cuestión central: qué cultura disciplinar produce y reproduce esa desigualdad. Esta contribución se centra en esa dimensión, desplazando el foco desde la representación hacia la construcción cultural de la física.
Aunque la física se presenta habitualmente como una disciplina objetiva, neutral y ajena a condicionantes sociales, diversos estudios muestran que su cultura está cargada de significados, normas implícitas e imaginarios que no son neutros. La asociación de la física con la brillantez innata, la competitividad extrema, el individualismo o determinadas formas de masculinidad condiciona quién puede reconocerse como parte legítima de la disciplina y quién es reconocido por los demás como "físico" o "física". En este marco, la cuestión no es solo cuántas mujeres hay en física, sino qué coste tiene para muchas de ellas encajar en una cultura que sigue definiendo la excelencia desde parámetros estrechos.
La ponencia analizará también cómo esta dimensión cultural ayuda a interpretar paradojas internacionales presentes en la literatura y en los datos comparados: países con mayores niveles de igualdad no presentan necesariamente una mayor presencia femenina en determinadas áreas STEM, mientras otros contextos muestran una participación relativamente alta de mujeres en física por motivos que no pueden entenderse solo en términos de libertad o igualdad. Estas diferencias obligan a pensar la física no solo como conocimiento, sino como práctica social situada.
En definitiva, incorporar la perspectiva de género en física exige interrogar su cultura, sus estereotipos y sus mecanismos de pertenencia. No se trata de sumar mujeres a una estructura dada, sino de comprender qué rasgos de la propia disciplina siguen actuando como barrera.

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#286 — Oral

¿Es Posible Reducir La Brecha De Género En Los Estudios De Física? Conclusiones Tras 4 Años De Actividades De Divulgación Científica De Las Estudiantes De La Facultat De Física En Sus Centros De Secundaria

GEM - Mujeres en Física

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Abstract Text:

La baja presencia de mujeres en los estudios de Física continúa siendo un reto para las facultades y sociedades científicas. En este contexto, la Comissió d'Igualtat de la Facultat de Física de la Universitat de València impulsa desde 2023 la actividad Tornem als instituts, una iniciativa vinculada al Día Internacional de la Mujer y la Niña en la Ciencia. La actividad consiste en que estudiantes de la Facultat preparan e imparten charlas y talleres divulgativos de Física en sus antiguos centros de secundaria, dirigidos principalmente a alumnado de ESO y Bachillerato.
El proyecto persigue un doble objetivo. Por una parte, ofrecer al alumnado de secundaria referentes cercanos, especialmente mujeres jóvenes que estudian Física, capaces de desmontar estereotipos sobre quién puede dedicarse a esta disciplina. Por otra, empoderar a las propias estudiantes universitarias, proporcionándoles formación básica en perspectiva de género, acompañamiento por parte de mentoras y una experiencia activa de comunicación científica.
Tras cuatro ediciones, Tornem als instituts ha movilizado a más de un centenar de estudiantes de grado y máster, ha llegado a un número similar de centros de secundaria y ha implicado a más de tres mil asistentes. En esta comunicación presentaremos la estructura de la actividad, su evolución desde 2023 y un primer análisis de las encuestas recogidas entre el alumnado de secundaria participante y las estudiantes ponentes. Estas encuestas permiten explorar aspectos como el interés por los estudios científicos y técnicos, la percepción de la Física como disciplina, la identificación con las personas que estudian ciencia y el posible impacto de escuchar experiencias de mujeres físicas. Los resultados preliminares servirán para valorar el alcance de la iniciativa y orientar futuras acciones de igualdad más eficaces y evaluables.

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#313 — Oral

Grandes Científicas En Física Aplicada: Un Proyecto De Divulgación Y Reconocimiento Histórico En La Universidad De Granada

GEM - Mujeres en Física

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Abstract Text:

La brecha de género histórica en las disciplinas STEM ha invisibilizado el legado de investigadoras fundamentales. Con el objetivo de revertir esta narrativa y fomentar la igualdad en el ámbito académico, la Embajada del Grupo Especializado de Mujeres en Física de la RSEF (GEMF) en la Universidad de Granada (UGR) presenta la exposición permanente “Grandes científicas en Física Aplicada”, inaugurada con motivo del Día de la Mujer y la Niña en la Ciencia 2026.
La muestra, ubicada en el Departamento de Física Aplicada de la UGR, analiza la vida y obra de físicas eminentes cuyas aportaciones transformaron la ciencia contemporánea. A través de un recorrido biobibliográfico e iconográfico, se destaca su trabajo como pioneras en campos tan diversos como la física de superficies, meteorología y biofísica.
Más allá de sus hitos técnicos, la comunicación contextualiza las barreras sociales y académicas que estas científicas sortearon, subrayando su perseverancia y rigor.
El propósito de este proyecto es triple: reconocer el legado de estas investigadoras, servir de referente para futuras generaciones y generar un espacio de reflexión colectiva sobre la importancia de la equidad de género en la ciencia actual.
Este proyecto ha sido cofinanciado por el Vicerrectorado de Extensión Universitaria, Patrimonio y Relaciones Institucionales, el Departamento de Física Aplicada y la Facultad de Ciencias de la Universidad de Granada.

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#318 — Oral

Programa Autorreferentes: Mujer Y Ciencia. Una Experiencia De Divulgación Con Perspectiva De Género En Centros Educativos De Sevilla.

GEM - Mujeres en Física

María Laura Olivera Atencio

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Abstract Text:

El Programa Autorreferentes: Mujer y Ciencia es un proyecto de divulgación científica con perspectiva de género orientado a visibilizar las contribuciones de las mujeres al desarrollo de la ciencia y a despertar el interés por las disciplinas STEAM entre el alumnado, especialmente entre las niñas. A través de referentes de mujeres científicas en distintas áreas del conocimiento, el programa busca promover la reflexión sobre la igualdad de género en la ciencia, inspirar nuevas vocaciones STEAM y contribuir a una participación más diversa e inclusiva en el ámbito científico.
En esta charla presentaremos la experiencia desarrollada en el marco del programa y compartiremos los principales aprendizajes extraídos, las dificultades encontradas y algunas ideas surgidas durante el proceso. A partir de esta experiencia, esperamos aportar elementos que puedan resultar útiles e inspirar nuevas iniciativas y colaboraciones entre la comunidad científica y el entorno educativo para generar referentes y favorecer el desarrollo de vocaciones STEAM desde una perspectiva más inclusiva

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#368 — Oral

Geometry Of Silence: Women Computers And Engravers In 19th-Century Cartography

GEM - Mujeres en Física

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Abstract Text:

This research recovers and reclaims the far-reaching scientific and technical work of women within major publishing firms and cartographic institutions during the turn of the century (19th and 20th). Traditionally obscured by the dynamics of anonymity inherent to mass industrial production, this study demonstrates that these workers did not operate as mere mechanical labour. On the contrary, this group was composed of highly qualified professionals who applied advanced principles of experimental physics, metrology, and precision optics, proving to be crucial figures in safeguarding the accuracy of the geographical record. To evidence this impact, the analysis examines the critical role of these female scientists in state organizations such as the Instituto Geográfico y Estadístico (Geographical and Statistical Institute) of Spain, as well as in prestigious European publishing houses, most notably Justus Perthes in Germany, Louis Delagrave in France, and Luis Vives in Spain. Their indispensable activity is articulated here through three fundamental axes. Firstly, human computing, which was responsible for the complex processing of geodetic data and the resolution of triangulation algorithms. Secondly, micro-precision engraving which required transferring astronomical and topographical data onto copper matrices with micrometric tolerances. Lastly, chromatic coding, in which colour was employed as a rigorous physical variable to represent altimetric gradients.
In conclusion, this work not only rescues turn-of-the-century female cartography worker from oblivion, but also positions female operational intelligence as the determining factor in the reliability of the century-old map. By demonstrating their conceptual mastery of physics, metrology, and optics, this research definitively elevates their historical status, from mere assembly-line operators to true specialists in applied image sciences, whose methodological rigor guaranteed the precision of the cartography of the era.

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#19 — Oral

Orbital Angular Momentum Conservation Versus Scaling Laws In High-Order Harmonic Generation Driven By Spatiotemporal Structured Light

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

There is a growing interest in nonlinear photon upconversion processes driven by diverse forms of structured light. In harmonic and high-order harmonic generation with Laguerre-Gauss beams, linear scaling the driver topological charge with the harmonic order is equivalent to driver orbital angular momentum (OAM) per photon scaling, and constitutes a proof of OAM conservation. However, with generic driving fields other that Laguerre-Gauss beams, or spatiotemporal optical vortices, topological charge and OAM per photon may scale or not in a process in which the OAM is nevertheless conserved. In this talk we unveil the physical magnitude that scales with generality when the OAM, either longitudinal or transverse, or its intrinsic part, is conserved [1]. This new rule allows for the wealth of phenomena observed in high-order harmonic generation that are unintelligible from the rigid Laguerre-Gauss rule, for example, high-order harmonics with non-scaling topological charge, enabling the generation of isolated attosecond spatiotemporal vortices [2].

[1] Miguel A. Porras, Marcos G. Barriopedro, and Rodrigo Martín-Hernández, Scaling law from orbital angular momentum conservation in harmonic and high-order harmonic generation driven by spatiotemporal light fields, arXiv preprint arXiv:2603.08263 (2025).

[2] Rodrigo Martin-Hernandez, Luis Plaja, Carlos Hernandez-Garcia, and Miguel A. Porras, Isolated attosecond spatiotemporal optical vortices: Interplay between the topological charge and orbital angular momentum scaling in high harmonic generation, Phys. Rev. Lett. 135, 223801 (2025).

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#38 — Poster

Vortex Bullets In Guiding And Anti-Guiding Potentials

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Spatiotemporal stationary states of self-focusing nonlinear systems with a linear potential are studied. The case where the medium exhibits anomalous dispersion is considered, and the stability of states with different vorticity is analyzed. Regarding the external potential, different functional forms, such as the Gaussian or the zero-order Bessel function, are analyzed and families of solutions are constructed for both the guiding and anti-guiding cases. An analysis of these families of solutions reveals that in the guiding case, whenever the potential amplitude is above a certain threshold, a region of stability exists for low propagation constants. In this region, the norm or energy of the stationary state sweeps the interval between zero (linear limit) and a maximum, exhibiting a positive slope in accordance with the necessary (though not sufficient) condition imposed by the Vakhitov-Kolokolov criterion. To support the stability of these solutions, simulations are presented, including both free propagation and elastic collisions in the time direction, that maintain the integrity of the stationary states. Furthermore, the different instability patterns are also analyzed, with modulational instability generally being dominant in the case of guiding potentials, while azimuthal instability is dominant in the case of anti-guiding potentials.

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#40 — Oral

Artificial Intelligence For Multi-Symmetry Topological High-Harmonic Spectroscopy

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Structured light has become a key tool in the last few years to probe the nonlinear light-matter interactions of solid materials, which unlike gases, show anisotropic responses giving rise to rich phenomena. Recently, a new characterization technique named topological high-harmonic spectroscopy was developed to retrieve information of the nonlinear susceptibility of two-dimensional (2D) materials from far-field harmonic intensity patterns. In particular, it was proposed that when the process of high harmonic generation (HHG) is driven by vector fields in solids, the anisotropic response imprints a unique intensity profile that encodes information from the nonlinear ultrafast light-matter interaction.
In this work, we include artificial intelligence as a way to retrieve the nonlinear anisotropic response (i.e. the nonlinear susceptibility) of the solid system from the generated harmonic signal. We have trained and validated a convolutional neural network to reliably identify the nonlinear susceptibility from the intensity distribution of the circularly polarized components of the harmonic far-field. This approach enables the characterization of the nonlinear interaction as well as a fast and straightforward description of the target symmetries through the related topological structure of the far-field. We show that the neural network is able to successfully predict the coefficients in accordance with full quantum microscopic HHG simulations in materials with different symmetries, such as graphene, graphite, or hBN. Furthermore, we compare our results with macroscopic vector beam driven HHG simulations, demonstrating the consistency of the results and the applicability limits of the technique. We propose AI-based topological harmonic spectroscopy as a fast characterization tool of 2D materials in experimental setups, particularly appealing for complex quantum materials as polycrystals or heterostructures.

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#43 — Oral

Time-Gated Optical-Parametric-Amplification Of Mid-Infrared Free-Induction Decay Signals

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Infrared (IR) spectroscopy is a powerful tool for studying electronic transitions in semiconductors [1] and vibrational transitions in molecules [2]. Recent advances in high-intensity coherent IR laser sources and electro-optical sampling (EOS) techniques have enabled unprecedented sensitivity in detecting a wide range of absorption lines and resolving complex dynamics in the time-domain, particularly free-induction decay (FID) signals [3]. A significant challenge in IR spectroscopy is detecting IR-FID signals in low-concentration environments, crucial for applications such as clinical diagnostics where biomarkers are present in very low levels [4]. To address this, we developed a novel technique using synchronized time-gated optical-parametric-amplification (OPA) to enhance the detection of these signals, thereby improving signal-to-noise ratio (SNR) and dynamic range (DR) significantly.
Our experimental setup involves a Cr:ZnS laser system producing a broad spectrum in the near-infrared (NIR) range with sub-10 fs pulses. The laser beam is split into two parts: one for EOS as a gate and the other for NIR amplification. The NIR light is split again in two: one for generating mid-infrared (MIR) radiation through a ZnGeP2 crystal and the other is used as a pump for the OPA. With this tool, we have achieved a 2-fold increase of the SNR and 2-orders of magnitude enhancement of the DR. Testing this technique with isopropyl alcohol as sample material, we achieved an observable window increase of over 600%, allowing for more precise molecular fingerprints. This advancement holds significant implications for fields such as clinical diagnostics and fundamental physical chemistry, offering enhanced sensitivity and insight into molecular dynamics.
References
[1] J. Toudert, et al. Opt. Mater. Express 7, 2299 (2017).
[2] M. A. Czarnecki, et. al. Chem. Rev. 115, 9707 (2015).
[3] M. T. Peschel, et. al. Nat. Comm. 2022 13:1 13, 5897 (2022).
[4] P. E. Geyer, et. al. Mol. Syst. Biol. 13, (2017).

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#44 — Oral

Towards Attosecond Pulse Generation In Graphene Via Macroscopic High-Harmonic Generation

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Attosecond light pulses enable direct access to electronic dynamics in atoms, molecules, and solids on their natural timescales, providing a unique tool to probe light-matter interaction processes. In gases, high-order harmonic generation (HHG) is established as a robust tabletop route to generate attosecond pulses thanks to the intrinsic phase locking arising from well-defined quantum path contributions. While solid-state HHG has already been demonstrated as an efficient mechanism to drive high-order harmonics, the generation of solid-state attosecond pulses remains elusive due to the complex microscopic dynamics, and the difficulty of achieving regular spectral phase relationships of the intraband and interband contributions to HHG. Recent theoretical advances suggest that macroscopic propagation and phase-matching effects may play a crucial role in selecting dominant components and achieving temporal phase coherence. In this work, we theoretically investigate HHG in single layer graphene including macroscopic aspects, exploring how phase-matching effects can be exploited to enhance phase locking and enable the synthesis of attosecond pulses. Performing out of focus HHG in single layer graphene we demonstrate that specific frequency components with different wavefront curvatures can be selected at the far field, leading to a more regular phase relationship and a cleaner attosecond time emission from the filtered high harmonics. Our results provide new insight into the mechanisms governing coherent harmonic emission in solids and outline a viable route towards attosecond pulse generation in condensed matter systems.

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#126 — Poster

Achromatic Fourier Optics With Geometric-Phase Lenses Under Supercontinuum Illumination

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Fourier optical processors based on diffractive elements are inherently chromatic: under broadband illumination, different wavelengths form Fourier-transform patterns at different axial positions and with different transverse scales. This effect limits the direct use of compact diffractive Fourier systems over the visible spectrum, especially when working with spectrally broad laser sources such as supercontinuum illumination.

We present an achromatic optical Fourier-transform system based on geometric-phase diffractive lenses. Using the ABCD ray-matrix formalism, the system is designed to compensate both chromatic effects of broadband Fourier optics: the wavelength-dependent transverse scaling of the Fourier transform and the longitudinal shift of the Fourier plane. The proposed architecture is a symmetric triplet formed by two diffractive lenses of opposite sign and one non-dispersive achromatic lens. In the experimental realization, the diffractive elements are geometric-phase flat lenses, whose focal power is controlled by circular polarization and propagation direction. This property also enables a compact folded configuration, in which a single geometric-phase lens combined with a mirror reproduces the triplet behaviour.

The system is tested under supercontinuum laser illumination using diffractive objects and computer-generated holograms. Compared with a single geometric-phase lens, the achromatic configuration strongly reduces the chromatic separation of diffraction orders and improves the overlap between the RGB components of the Fourier patterns.

Supercontinuum illumination directly connects this work with nonlinear optics, since the source is produced by nonlinear spectral broadening. The results show that achromatic diffractive Fourier systems can preserve spatial information across the visible band by compensating axial and transverse chromatic dispersion. This is relevant to ultrashort-pulse processing, structured spatio-temporal fields, and scalable extensions toward high-harmonic generation, mid-infrared photonics and terahertz waves.

Reference: I. Moreno, S. Ríos-Alvarez, P. García-Martínez, D. Marco and M. M. Sánchez-López, Journal of Physics: Photonics 7, 045032 (2025), doi:10.1088/2515-7647/ae0bd5

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#136 — Oral

Experimental Observation Of Discrete Time Crystals And Domain-Wall Dynamics In Active Mode-Locked Laser Cavities

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Active mode-locking is a well-established technique for generating ultrashort laser pulses with a wide range of applications. The concept of time crystals (TCs), first proposed by Wilczek in 2012, describes the spontaneous breaking of time-translation symmetry and offers a novel framework for understanding periodically driven systems.
In this work, we present both experimental and theoretical evidence for the emergence of discrete time crystals in a laser ring cavity. The experimental setup consists of a Mach–Zehnder modulator, a semiconductor optical amplifier, a band-pass filter, and an optical coupler. By tuning the modulation frequency and/or the amplifier pumping current, discrete TC states emerge, characterized by the disappearance of every second pulse in the cavity. Two equivalent TC configurations are observed, corresponding to even or odd slot occupation.
Moreover, when the system is driven at an odd harmonic of the cavity resonance, transitions between these two TC states naturally occur. These transitions manifest as defects propagating along the cavity and can be interpreted as domain walls, which necessarily appear in pairs. The dynamics of these domain walls lead to a slow coarsening process, occurring over remarkably long time scales (on the order of several minutes).
To further investigate this coarsening dynamics, we introduce an additional modulation of the effective potential, creating an energy imbalance between the two TC states and favoring one over the other. This enables the formation of spatial regions dominated by a single TC state, separated by stationary boundaries. By carefully controlling the modulation signal, both the relative size of these regions and the persistence time of each TC state within the cavity can be tuned. All experimental observations are in excellent agreement with theoretical simulations based on a time-delayed model.

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#157 — Poster

Polarization Gating Techniques Towards The Characterization Of Structured Attosecond Pulses.

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

High-harmonic generation (HHG) is a highly nonlinear and non-perturbative process that enables the production of coherent extreme ultraviolet (EUV) and soft X-ray radiation. Its remarkable coherence allows translating properties of an infrared femtosecond intense driving field to the high-order harmonics, making HHG a key tool in attosecond science. The temporal and spectral structure of attosecond pulses has become crucial for applications such as ultrafast spectroscopy and metrology. Recently, it has been shown that structured attosecond pulses, with tailored spatially-resolved amplitude, phase and polarization properties, can be generated. However, their application is limited due to the lack of all-optical spatially-resolved diagnostic tools that enable their complete characterization.
In this work, we theoretically explore all-optical diagnostic tools to characterize attosecond pulses with tailored polarization properties using counter-rotating circularly polarized driving pulses. Our theoretical simulations demonstrate that the interference between two identical counter-rotating driving pulses, enables the retrieval of the spectro-temporal properties of the EUV radiation generated by the corresponding linearly-polarized driver pulse.
We thus provide a proposal to experimentally retrieve the time-frequency structure of attosecond pulses. The resulting spectrograms provide for a direct visualization of the temporal emission of individual harmonics, a crucial step for the full experimental characterization of structured attosecond pulses.

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#160 — Oral

Spontaneous Optical Skyrmion Generation By Frequency Doubling In Underdense Plasmas

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Optical skyrmions have been widely explored in recent years. Among them, Stokes skyrmions require sophisticated wave engineering or photonic devices for their generation. We show that Stokes skyrmions can emerge spontaneously in second-order harmonic generation in underdense plasmas driven by optical vortices [1], due to the spin orbit couplings of the free electrons and the driving field. The nonlinear response produces a structured frequency-doubled field whose polarization texture maps the Poincaré sphere.

Furthermore, we investigate the effect of plasma inhomogeneities, showing that electron density gradients deform the skyrmionic polarization texture. Since the specific deformation of the polarization texture is highly sensitive to these gradients, this phenomenon offers a novel route for the topological diagnosis of plasma density, providing an optical signature of the plasma profile.

[1] Marcos G. barriopedro, et al, Spontaneous optical skyrmion generation by frequency doubling in underdense plasmas, arXiv:2605.03145 (2026)

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#163 — Oral

Compact High-Order Harmonic Attosecond Pulse Sources Driven By Hollow Gaussian Beams

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

High-order harmonic generation (HHG) is one of the most robust and widely used techniques for generating extreme ultraviolet (EUV) radiation with attosecond pulse durations. HHG is a highly coherent process in both the spatial and temporal domains, enabling precise control of the emitted high-frequency radiation through manipulation of the infrared femtosecond driving field. In applications such as EUV imaging and attosecond spectroscopy, precise control over the harmonic divergence and spot size is essential for optimizing the intensity delivered to the target. Conventional driving fields with Gaussian spatial profiles typically produce harmonics whose divergence increases with harmonic order due to the intensity- and harmonic-order-dependent intrinsic dipole phase associated with the HHG process. Furthermore, the dipole phase limits the efficient refocusing of attosecond pulses by introducing chromatic-aberration-like distortions into the generated radiation.
Several structured driving fields have been proposed to mitigate the effects of the dipole phase, including necklace and flat-top beam profiles. Although flat-top drivers have been shown to reduce the influence of the dipole phase and improve harmonic focusability, scaling the driving energy often requires long beamlines and extended interaction targets. Here, we present an alternative approach based on driving HHG with hollow Gaussian beams (HGBs). We experimentally and theoretically demonstrate that HGB driving fields generate high-order harmonics in which the contribution of the dipole phase becomes negligible. Theoretical modeling further shows that HGB-driven harmonics can be refocused into a single spot with minimal chromatic aberrations and high peak intensities. These results make HGB-driven HHG a promising route toward compact, high-intensity attosecond light sources and applications.

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#190 — Oral

Adaptive Robotic Laser System For Coating Removal From Aeronautical Components Of Arbitrary Geometry

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

The removal of coatings from aeronautical components is a key operation in maintenance, repair, and overhaul processes. Conventional cleaning techniques based on chemical agents or abrasive methods may generate hazardous waste, increase processing times, and damage sensitive substrates. Pulsed laser ablation has emerged as a precise and environmentally friendly alternative for the selective removal of surface layers.
This work presents the development of a robotic laser system for the controlled removal of coatings from components with arbitrary geometries. The system integrates three main subsystems: (i) a robotic positioning unit based on a six-degree-of-freedom industrial manipulator; (ii) an Yb-doped fibre laser coupled with a galvanometric scanning head for laser beam trajectory control; and (iii) an optical inspection module incorporating laser line scanners and a 3D camera for surface digitisation and process monitoring. Surface scanning enables the acquisition of geometric information from the component, which is subsequently used to generate adaptive processing trajectories through custom-developed algorithms. Experimental tests were performed on three-dimensional samples of aluminium alloys and carbon-fibre-reinforced polymer composites commonly used in the aeronautical industry and coated with protective paint layers. The results demonstrate that the proposed system effectively removes coatings from curved surfaces with high uniformity while enabling controlled surface texturing in aluminium-based materials. These preliminary results confirm the feasibility of combining robotic manipulation, laser processing, and optical sensing for the automated treatment of non-planar aeronautical components. The proposed approach represents a promising step towards flexible and automated laser-based solutions for surface preparation and maintenance operations in the aeronautical sector.
Acknowledgments: This work was supported by project PID2021-123948OB-100 funded by MCIN/AEI/ 10.13039/501100011033 and by FEDER “A way of making Europe” from the European Union

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#221 — Oral

Ultrafast Thermodynamic Characterization Of The Photoinduced Metal-Insulator Transition In Vanadium Dioxide.

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Photoinduced phase transitions in quantum materials can access material states that are inaccessible via thermal pathways. Photoexcitation activates specific degrees of freedom, leading to emergent non-thermal transient states which persist until the material reaches equilibrium at a later time. The photoinduced metal-insulator transition in vanadium dioxide (VO_2) is one of the most widely studied and controversial transitions, but the underlying physical mechanism, whether it is driven primarily by lattice structural changes or by strong electronic interactions, is still a matter of debate. This is in large part due to the short duration of the transient states that follow photoexcitation, which mean directly probing the internal degrees of freedom remains challenging.
Here described a method that allows us to identify the degrees of freedom relevant to the phase change without the need for ultrafast probing of the different degrees of freedom out of equilibrium. We perform ultrafast measurements of the optical critical fluence required to induce the phase transition at different temperatures, and compare them with the heat capacity predicted by different thermodynamic models. By just a few picosecond delay we stabilizing the photoinduced phase requires thermally populating the high-frequency optical phonon modes [1]. By examining the critical fluence at even shorter time delays we shed light on whether VO2 first passes through an even shorter lived electronic-only phase transitions, as proposed in some works [2]. The method presented here has the potential to provide key information for analyzing the dynamics of the degrees of freedom involved in photoinduced phase transitions in a wide range of quantum materials.
[1] Thermodynamics of the ultrafast phase transition of vanadium dioxide, S. Bagchi et al, arXiv:2603.04600 (2026)
[2] Decoupled few-femtosecond phase transitions in vanadium dioxide. C. Brahms et al, Nat. Commun. 16, 3714 (2025)

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#245 — Oral

Selective Up- And Down-Conversion Of Weak Optical Signals By Raman Molecular Modulation In Hydrogen-Filled Hollow-Core Fibres

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

We report the selective frequency up- and down-conversion of low-intensity visible signals through molecular modulation in a hydrogen-filled hollow-core fibre. Raman coherence waves generated by synchronised pump pulses are used to mediate the efficient spectral transduction, enabling operation below the Raman threshold for the weak signals. Specifically, as proof of concept, 585 nm signals are converted to 773 nm in the near infrared and to 471 nm in the blue spectral region. The phase-matching conditions are controlled through the effective dispersion of the system, which can be engineered by an adequate choice of fibre geometry and gas pressure. This provides excellent selectivity over the up- and down-conversion processes. The experiments, performed with a kagome-style hollow-core fibre pumped at 515 nm with nanosecond pulses, reveal strong depletion of the mixing signal indicating efficient Raman-mediated energy transfer. In addition, we analyse how the transduction process affects the statistical distribution of the intensity fluctuations of the mixing and converted signals. Owing to its broad tunability, large achievable frequency shifts, and compatibility with weak optical signals, this approach offers a flexible platform for quantum transduction. The demonstrated visible-to-near-infrared interfacing may support the integration of quantum-dot emitters, NV-centre technologies, and atomic quantum memories, contributing to the development of hybrid quantum communication and information-processing architectures.

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#248 — Oral

Engineering Classical And Quantum Properties In An Ultrafast Bright Squeezed-Vacuum Source

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Quantum optics is commonly associated with low photon number states. In contrast, many disciplines such as nonlinear optics, spectroscopy, or metrology often require intense pulses with high photon fluxes, making the direct exploitation of quantum optical properties to achieve an advantage particularly challenging. Bright squeezed vacuum, i.e. a macroscopic quantum light state exhibiting fluctuations below the vacuum level in one of the field quadratures, provides a route to bridge this gap. Although its average electric field remains zero, as it corresponds to a vacuum state, the electric field fluctuations enable individual ultrabright transients containing up to 10 billion photons per pulse while preserving squeezing and nonclassical photon number statistics. The interaction of these macroscopic quantum states with matter, particularly on ultrafast timescales, is of considerable interest, as nonlinear optical processes may enable the transfer or imprinting of their quantum properties into spectral regions that are otherwise difficult to access.

In this work, we report ongoing development of an ultrafast bright squeezed vacuum source in the near-infrared spectral domain, with pulse durations of hundreds of femtoseconds. Its operating principle is based on parametric down-conversion of visible pump pulses, and it exhibits controllable quantum statistics and spatio-spectral emission through phase matching under different experimental conditions. The combination of ultrashort pulse duration, high brightness, and tunable properties establishes this source as a versatile platform for quantum-enhanced experiments in fields such as spectroscopy, microscopy and metrology.

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#255 — Oral

Polarization-Stable Frequency Conversion Via Stimulated Raman Scattering In Birefringent Hollow-Core Fibers

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Hollow-core fibers (HCFs) are outstanding platforms for guiding intense light, offering high damage thresholds and low attenuation across broad transmission windows. When filled with gases, their reconfigurable optical properties enable key nonlinear phenomena such as pulse compression, dispersive wave emission, and stimulated Raman scattering (SRS). However, in conventional HCFs, polarization preservation rapidly deteriorates due to microbending and other perturbations, limiting their applicability. To overcome this challenge, a new class of birefringent hollow-core fibers based on anti-resonant reflection has recently emerged. These structures combine strong birefringence with broadband, low-loss guidance, opening new possibilities in gas-based nonlinear photonics. They enable precise control and stable preservation of modal polarization during frequency conversion, yielding large and stable polarization extinction ratios (PER), a crucial metric in applications such as quantum communication.
In this work, we employ a nitrogen-filled birefringent HCF to drive a vibrational SRS transition and generate highly polarized Stokes light. The strong birefringence of the fiber decouples the two principal polarization axes, allowing the pump components along each axis to independently shift to the Stokes frequency. Specifically, the axis carrying sufficient pump power reaches the SRS threshold and produces strong Stokes emission, while residual power along the orthogonal axis remains below threshold, suppressing unwanted down-conversion. This approach enables gas-based light sources that are spectrally agile, power-scalable, and polarization-stable.

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#388 — Oral

Surface Light Localization In Topological Multilayers: Linear And Nonlinear Applications

GEOCONL y GELUR - Óptica Cuántica y Óptica No Lineal

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Abstract Text:

Surface states in periodic structures play a key role in physics and photonics by enabling light confinement at interfaces, with applications in optical sensing, lasing, and nonlinear optics. Topological photonics has recently emerged as a powerful approach to realize edge states that are robust against defects and disorder. In one-dimensional (1D) systems, the Su–Schrieffer–Heeger (SSH) model describes a periodic chain with alternating weak and strong couplings, where a protected edge state arises at the interface between different topological phases. Although widely predicted in multilayer 1D photonic crystals, experimental demonstrations remain limited.
Here, we experimentally implement the SSH model in a 1D photonic crystal. We design and fabricate two structures with identical periodicity but different edge terminations. Structure A corresponds to a non-trivial phase, while Structure B represents a trivial phase, both consisting of alternating SiO_2 and Ta_2O_5 layers. Numerical calculations using the Transfer Matrix Method show that, at 800 nm under TE polarization, only Structure A supports a strongly localized surface state with a field enhancement of 300, while Structure B does not show such state.
We experimentally probe the surface modes using a Kretschmann configuration, where total internal reflection generates an evanescent field that excites the multilayer. When incident light is incident on the structure, a dip in reflectance is observed if there is coupling to the surface mode. Our measurements show a clear resonance near 800 nm only for Structure A, while Structure B exhibits nearly total reflection. The surface nature of the mode is confirmed by depositing a thin absorbing dye layer, which enhances the resonance without altering it. Finally, the strong field localization is exploited to enhance fluorescence and second-harmonic generation from materials deposited on the surface.

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