Summer Doctoral Day Program – 25st June 2025
Morning Session

Date and time: 8:50. Wednesday 25th June.
Venue: Facultad de Matemáticas. Sala de Grados. 2ª Planta

08:50-09:00 - Welcome
Antonio Prados Montaño, Academic Program Coordinator, Universidad de Sevilla

09:00-10:00 Opening Talk. Dr. Javier García de Abajo
Presenting: Francisco Medina, Dept. Electrónica y Electromagnetismo

10:00-14.40. – Students talks

Quantum nanophotonics with free electrons

Javier García de Abajo
ICREA Prof. ICFO-Institut de Ciencies Fotoniques. Castelldefels (Barcelona)

Abstract:

Ultrafast electron microscopy has emerged as a research frontier at the intersection between electron microscopy and ultrafast optics, aiming to investigate material excitations with an unprecedented combination of spatiotemporal resolution. However, free electrons are powerful quantum probes with unique characteristics that can enhance quantum nanophotonics and enable previously unattainable quantum protocols. We will discuss the fundamental principles ruling the interactions between free electrons, light, and photonic nanostructures, with an emphasis on exploring quantum aspects that include electron decoherence caused by coupling to radiative modes and the generation and manipulation of quantum states of light. In particular, radiative decoherence could be potentially useful to sense the presence of distant objects and measure the vacuum temperature, while the study of quantum correlations between electrons and waveguided polaritons enables the generation of single and entangled photons heralded by the detection of electrons that have experienced specific amounts of energy losses and angular deflections. We will discuss the exploitation of these phenonema to perform quantum sensing and metrology with unprecedented resolution.

Javier García de Abajo short CV:

Javier García de Abajo obtained his PhD in condensed matter theory from the University of the Basque Country (Spain) in 1993. After spending three years in Berkeley National Lab., he became a staff scientist at CSIC (Spain) and was promoted to Research Professor in 2008. He is currently an ICREA Research Professor and leader of the Nanophotonics Theory Group at ICFO. His interests include electron microscopy, light-matter interactions, ultrafast phenomena, and nanophotonics. He has co-authored about 500 papers (including 6 papers in Science and 4 papers in Nature) that have accumulated 66,000+ citations and an h index of 124 (Google Scholar, June 2025). He is then one of the most cited scientists in the field of nanophotonics. He is a Fellow of both the American Physical Society and the Optical Society of America.

García de Abajo is an expert in the science of light, free electrons, and their interaction with atoms, molecules, and material nanostructures. He has predicted and explained new phenomena that include collective electron excitations –plasmons– in atomic-scale systems (e.g., molecules and nanographenes); ultrafast electron-beam interactions with localized optical fields; strong molecule–plasmon coupling; ultrafast radiative heat transfer; quantum friction; and others. Many of his predictions have been corroborated experimentally. He maintains an intense research agenda covering a wide range of topics in collaboration with a network of groups in the fields of electron microscope spectroscopies, ultrafast phenomena, and nanophotonics.

Morning session

Venue: Facultad de Matemáticas. Sala de Grados. 2ª Planta

8:50 – 9:00	Welcome Opening talk
9:00 – 10:00	Javier García de Abajo
	STUDENTS PRESENTATION
10:00 – 10:20	González González, Beatriz
10:20 – 10:40	López Rodríguez, Álvaro
10:40 – 11:00	Saucedo Cuberes, Demetrio
11:00 – 11:20	Misas Arcos, Mario
11:20 – 11:40	Rodríguez Galán, Andrés
11:40 – 12:10	COFFEE BREAK
12:10 – 12:30	Casado Galán, Alejandro
12:30 – 12:50	Fernández Peramo, Pablo
12:50 – 13:10	Méndez Romero, Roberto J
13:10 – 13:30	Mayo León, Manuel
13:30 – 13:50	Rodríguez Fernández, Eusebio J
13:50 – 14:10	Téllez Calle, Daniel
14:10 – 14:40	*FLASH TALKS*

Abstracts Students' presentations

LONG TALKS

10:00 – 10:20 **González González, Beatriz**

Accuracy of Machine Learning algorithms for HPGe detector efficiency determination

The accurate determination of full-energy peak efficiency (FEPE) in High-Purity Germanium (HPGe) detectors is critical for gamma-ray spectrometry, especially when source-detector geometries vary. In this study, we investigate the application of six supervised machine learning (ML) algorithms—Polynomial Regression, Random Forest, XGBoost, LightGBM, Sparse Gaussian Process, and Multi-Layer Perceptron—for predicting FEPE of a Low Energy HPGe (LEGe) detector across a broad energy range (40–1600 keV) and diverse source types (point and volumetric). Datasets used for training, validation and testing the ML models were generated using Monte Carlo simulations (GESPECOR). Model performance was evaluated using cross-validation and standard error metrics (R^2, RMSE, MRE). Among the tested models, Polynomial Regression and LightGBM demonstrated superior predictive accuracy and interpretability, achieving R^2 values above 0.9999. SHAP values were used for explainability, demonstrating that the models successfully capture the key physical mechanisms influencing FEPE. These results position ML models as reliable and generalizable alternative to conventional FEPE calibration methods.

10:20 – 10:40 **López Rodríguez, Álvaro**

Analysis of POC Fluxes, Expeff and Teff around the PAP-Site Observatory: an update from the APERO project

The ocean is a major active sink of atmospheric CO_2, largely through the Biological Carbon Pump (BCP), which transfers carbon from the surface to the deep ocean. The BCP starts in the euphotic zone, where phytoplankton photosynthesis fixes Particulate Organic Carbon (POC). POC export can be quantified using sediment traps (ST), which directly collect sinking particles, or through the natural radioactive disequilibrium between 210Po and 210Pb, as sinking organic matter preferentially adsorb 210Po over 210Pb. These methods are complementary, and their combined use improves POC flux estimates. APERO cruises, carried out at the PAP-Site observatory during the during the decline of a spring bloom in June and July 2023 aimed to study the BCP using high-resolution water and particle profiles (0–1000 m) at five stations. For the first time, POC fluxes were derived simultaneously from both 210Po-210Pb disequilibrium and high-depth-resolution sediment traps. We also compiled POC flux data from 1989–2023 at the PAP-Site to assess two key BCP metrics: Export Efficiency (Expeff), the fraction of Primary Production (PP) exported as POC at the base of the euphotic zone (EZB), and Transfer Efficiency (Teff), fraction of POC flux below the EZB reaching a set depth in the Twilight Zone (TZ).

10:40 – 11:00 **Saucedo Cuberes, Demetrio**

Preliminary studies of the radiosensitizing effect of gold nanoparticles for hadron therapy.

Medical physics applies physics to disease diagnosis and treatment, playing a key role in cancer radiotherapy. Proton therapy is a cutting-edge technique that uses proton interactions with matter to deliver highly localized energy via the Bragg peak, minimizing damage to healthy tissue. This study explores enhancing proton therapy with gold nanoparticles (Au-NPs), which offer advantages like biocompatibility, tumor targeting, low toxicity, and strong radiation interaction due to their high atomic number.

11:00 – 11:20 **Misas Arcos, Mario**

Black hole stability: a numerical analysis

The stability of black holes under perturbations is a cornerstone problem in general relativity. Intuitively, we expect that when a black hole is perturbed by, for instance, an infalling particle, it will eventually return to its original state after the emission of gravitational waves. However, proving this statement is often not straightforward: due to the formal complexity of the equations involved, a numerical approach becomes most suitable. Specifically, we shall explore how the Finite Element Method can be applied to solving several PDEs related to the topic, such as the Regge-Wheeler or Zerilli equations (which describe the stability of a Schwarzschild black hole) and the better-known Teukolsky equation (which describes that of a Kerr black hole), in hopes of eventually shedding light on a yet unanswered question: are Kerr-Newman black holes stable?

11:20 – 11:40 **Rodríguez Galán, Andrés**

Travelling-Wave electrophoresis of microparticles

Separation of microparticles using electrophoresis has been researched in the past years due to its variety of applications in fields as medicine. We study the motion of particles in a microfluidic channel influenced by a one-sided, periodic electrode array with a periodic potential applied. This array results in a Travelling Wave type electric field that causes particles to drift in the horizontal direction in different ways depending on its mobility and channel parameters. We provide a general description of the different motions which can be achieved in this channel, obtained via numerical simulation of the dynamic equations. In particular, some characteristic behaviour of chaotic motion arise, resulting in a rich variety of trajectories in different parts of the channel.

Coffee break

12:10 – 12:30 **Casado Galán, Alejandro**

FPGA Implementation and Test of the TERORO-PUF

The TERORO PUF is a Physical Unclonavle Function (PUF) based on Transient Effect Ring Oscillator (TERO) and Ring Oscillator (RO). The main goal of a PUF is to extract entropy from a physical source and transform it into readable information, like a bit string. This information should be unique for each different device, acting as a kind of fingerprint. PUFs are very useful in cryptography applications, since their output can be used as an input for a cryptographic function or even as a key itself for some encryption algorithm. The use of ROs and TEROs in making PUFs is widely studied, but in my previous work I presented a way of combining both functionalities in the same structure called TERORO (TERO+RO). In this work I present the FPGA implementation and test of the TERORO PUF to see its viability in hardware.

12:30 – 12:50 **Fernández Peramo, Pablo**

A Photovoltaic Asynchronous Time-Based Image Sensor

This presentation introduces a novel Photovoltaic Asynchronous Time-Based Image Sensor that integrates two complementary sensing modalities—event-based detection of temporal contrast and time-coding of absolute brightness—within a shared-diode pixel architecture. The sensor leverages a photovoltaic photoreceptor to simultaneously support both operation modes without requiring additional pixel circuitry, enabling significant reductions in area and power consumption. Event-based sensing captures dynamic changes in illuminance with high temporal resolution, making it ideal for motion detection and energy-efficient processing. Concurrently, time-coding of brightness encodes static light intensity as pulse timing, providing absolute luminance information without the need for analog-to-digital conversion. By enabling both modes to operate concurrently on the same photodiode, the sensor architecture achieves efficient fusion of dynamic and static visual data in a compact footprint. This dual-mode capability is especially suited for resource-constrained applications such as mobile robotics, surveillance, and wearable vision systems. The shared-diode configuration also simplifies the design, enhances fill factor, and reduces parasitic capacitance, further improving sensitivity and responsiveness. Overall, this sensor design demonstrates a compelling balance of performance, simplicity, and energy efficiency, advancing the state of the art in time-based vision sensing

12:50 – 13:10 **Méndez Romero, Roberto J**

Active Balun for high-frequency and low-voltage applications

Radio Frequency (RF) and Microwave (MW) signal detection systems are critical in diverse applications beyond conventional communication systems, including neuromorphic computing and radio astronomy. These applications often involve the reception of weak signals characterized by low signal-to-noise ratios (SNR), requiring the conversion of conventional single-ended receiver input signals into differential ones to improve signal integrity. This is commonly achieved using a balun integrated at the front end of the receiver chain. Although active balun solutions exist for low-frequency applications, the design and implementation of active baluns capable of operating efficiently in the RF and MW frequency ranges remain a significant challenge. This presentation introduces a novel active balun topology specifically designed for high-frequency operation under low-voltage supply conditions. The good match between the results of the post-layout simulations and the computed values highlights the effectiveness of the circuit for advanced high-frequency detection applications.

13:10 – 13:30 **Mayo León, Manuel**

Self-diffusion in confined systems

In this work a system of hard spheres confined between two parallel plates is considered. The distance between the walls, h, is on the order of diameter of particles, the collisions between particles are elastic and the walls are reflecting. A kinetic description of this system is developed by establishing a Boltzmann--like equation that takes into account the effects of the confinement of the distribution function. This equation is valid in the dilute limit. It is shown that the equation verifies an H-theorem implying a monotonic approach to equilibrium. Starting with Boltzmann-Lorentz kinetic equation, the projection operator method is employed to derive the Green--Kubo relation for the self-diffusion coefficient in the directions parallel to the confining walls, that depends on the dimensionless height. The agreement between the theoretical predictions and Molecular Dynamics simulations results is very good.

13:30 – 13:50 **Rodríguez Fernández, Eusebio J**

Quantum Spin Dynamics in Curved Circuits

Interferometry is a powerful technique which has been successfully used to extract valuable information about the state characteristics of spin carriers in a system. In this work, we study different devices built on flat 2DEG that use interferometry as their operating principle. This allows us to determine and characterize, on each case, the spin phases, geometry, topology, or general characteristics of the spin carrier's state. This is achieved by using spin transport (conductance) as a function of the coupling fields (Zeeman, spin-orbit). The results show how the geometry of the circuits can determine the behavior of the spin dynamics of the systems. By studying cases with inhomogeneities in curvature (polygonal interferometers) and comparing them with homogeneous geometry (ring interferometers), we observe how non-Abelian behavior at the vertices drasticallyalters the spin dynamics.

13:50 – 14:10 **Téllez Calle, Daniel**

Oscillating solutions to the Boltzmann equation and their decay mechanisms

It is well-known that thermodynamic systems, when left to evolve freely, should reach an equilibrium state independent of their initial conditions. One of the great successes of kinetic theory, and particularly of the Boltzmann equation, is its ability to predict this fact through the so-called H-theorem. However, when the system is confined by an isotropic harmonic potential, the theorem does not hold true, and eternal oscillating solutions exist that never decay to an equilibrium state. In this talk, we will briefly contextualize the Boltzmann equation for hard spheres, which is considered the simplest and most intuitive case, and then study these oscillatory solutions. Finally, we will see how these solutions don't exist when the harmonic potential is not isotropic or when the density is finite (i.e., beyond the Boltzmann limit). We will also discuss how we can simulate these systems computationally in an exact way.

FLASH TALKS

14:10 – 14:15 **Hidalgo Zamora, Fco. Javier**

Frequency Selective Surfaces: Applications and a example

In this talk some applications for Frequency Selective Surfaces will be introduced. Finally photos of a fabricated prototype will be shown

14:15 – 14:20 **Rodríguez Sánchez, Juan Manuel**

Design Challenges in Deep Submicron CMOS for High-Speed Data Converters

As CMOS technology continues to scale into deeply submicron nodes, the design of high-speed analog and mixed-signal circuits faces increasing challenges. This talk explores the impact of such scaling on the implementation of high-performance analog-to-digital converters (ADCs), with a particular focus on SAR-pipelined architectures used in multi-gigabit communication systems. Deep submicron processes offer advantages in speed and integration density, but introduce significant difficulties related to reduced intrinsic gain, increased device mismatch, lower supply voltages, and degraded analog performance. These issues complicate the design of critical building blocks such as comparators, reference buffers, and capacitor arrays, which are fundamental in achieving high resolution and sampling rates. Moreover, timing constraints and clock distribution become more stringent at high speeds, especially in applications involving time-interleaved ADCs for direct RF sampling. The talk highlights how these technology-induced constraints influence system-level architectural choices and require careful trade-offs between speed, power, linearity, and area. Understanding and addressing these challenges is essential for developing efficient data converters that meet the stringent demands of standards like 100 Gb/s Ethernet.

14:20 – 14:25 **Lamouaraa Sedlackova, Yassine**

Auto-Exposure Image Sensor with Improved Power Efficiency and Fill Factor Using Macro Block Design

We present a new design for an auto-exposure image sensors that improves both power consumption and FF (fill factor) without affecting the overall image quality. By removing the opamp from each individual pixel and instead grouping pixels into larger "macro blocks," we increase the light-sensitive area and reduce power consumption. This simplified architecture allows the sensor to automatically adjust to lighting conditions while being more energy-efficient and better suited for compact, high-performance imaging systems.

14:25 – 14:30 **Palomeque Mangut, Sergio**

Event-Based Spiking Image Sensors

Active-pixel sensors (APS) dominate most commercial imaging applications. In them, pixels output a measure of the photogenerated charge during a period by sampling the voltage in the integration capacitance at the end of that period. A radically different approach is the pulse frequency modulated (PFM) pixel, which encode the photocurrent in time by sensing the integration node with a comparator until a threshold is reached. In this talk, I will briefly compare the two approaches and give insights about how PFM pixels is a method of non-uniform, weighted average sampling

14:30 – 14:35 **Karmakar, Apurba**

Performance Analysis of RISC-V Processors

RISC-V is an open standard instruction set architecture (ISA), evolving a new era of processor design. RISC-V is capturing enormous attention from the chip industry and researcher community due to its open nature and flexibility, resulting in a swift growth of the RISC-V user community. Moreover, the European commission is pushing its use looking forward the European sovereignty and avoiding dependence from others proprietary processors like ARM or IBM. So that, RISC-V core is being used as the fundamental building block for many electronic systems like embedded systems and IoT applications. Therefore, performance analysis of RISC-V processors in terms of timing and compactness has become indispensable. As part of my PhD, the real-time performances of some popular open-source RISC-V cores based on standalone platforms as well as their resource occupation on different programmable logic devices (FPGAs) have been compared. Additionally, as a novelty performance evaluation and given the importance of the security in the embedded systems, the RISC-V cores have been analyzed by extracting the leakage while running Crypto algorithms on them in a novel side channel analysis setup.

14:35 – 14:40 **Garrido Gómez, Lucas**

Reactions with 12,13C around the Coulomb barrier

During the last years, an analysis protocol has been developed in order to stablish a common framework for describing reactions involving tightly and weakly bound nuclei. This work presents new data for the 12,13C+120Sn and 12,13C+64Zn reactions, including elastic scattering, inelastic scattering and nucleon transfer. Optical Model calculations are performed and compared to the experimental angular distributions. The results are consistent with previous systematic studies and contribute to an unified description of nuclear reactions at energies around the Coulomb barrier.

Attendees (not presenting)

- Gabriel Auñon Fernandez
- Jesus Bartolome Sarsa
- Yanjin Lyu
- Miguel Galocha Oliva
- Mateo Ruiz Martin
- Javad Gorji
- Daniel Jimenez Flores
- Rafael Martin Arenas
- Amir Khan
- Francisco Javier Riquel Castilla
- Victoria Lerida Toro
- Dario Sanchez Jimenez
- Antonio De La Misericordi Sojo Lopez
- Alejandro Vegas Diaz
- Antonio Ordoñez Aguilera
- Joaquín Ceballos Cáceres
- Joseba Martínez Arrizabalaga
- Carlos López Jiménez