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Book of Abstract

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14:00 - 14:30	**REGISTRATION (GAIAS)**
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19:00 - 19:30	**Welcome Cocktail (GAIAS)**
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Monday 22

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09:30 - 10:00	Belov *"Hybrid nanophotonics for sensing, thermometry and generation of white light at the nanoscale"*
10:00 - 10:30	Grinblat *"Sub-30 fs All-Optical Switching Based on Dielectric Photonics"*
10:30 - 11:00	**Coffee Break**
11:00 - 11:30	Mansuripur *"Self-field, Radiated Energy, and Radiated Linear Momentum of an Accelerated Point Charge"*
11:30 - 12:00	Käll *"Optical trapping of resonant all-dielectric nanoparticles"*
12:00 - 12:30	Molina-Terriza *"Scattering of Quantum and Classical helicity states of light off nanostructures"*
12:30 - 13:00	Merlin *"Synchrotron Radiation from an Accelerating Light Pulse"*
13:00 - 13:30	
13:30 - 14:00	**LUNCH**
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15:30 - 16:00	Infusino *"Optical vortices generation in Nematic Liquid Crystal and Differential Method applied to Hyperbolic Metamaterials"*
16:00 - 16:30	Cwilich *"Signal and Information Spreading, Dynamic Connectivity and Segregation"*
16:30 - 17:00	**Coffee Break**
17:00 - 17:30	Lopez *"Order and porosity to increase optical materials' versatility"*
17:30 - 18:00	Volke-Sepúlveda *"Wave Vortices at Different Scales: Learning from Analogies between Optics and Acoustics"*
18:00 - 18:30	García-Martín *"Magnetic-field controlled radiative heat transfer"*
18:30 - 19:00	Lanzillotti-Kimura *"Taming Sound at the Nanoscale"*
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Active semiconductor nanoantennas

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Research on dielectric and semiconductor nanoantennas represents the new branch of nanophotonics opening way to multiple applications in photonics, optoelectronics and biology. It has been actively developing over the past several years and numerous functionalities of the nanoantennas, including near-field energy concentration, emission enhancement, flat optical components for full light wavefront control etc., have been demonstrated [1]. However, so far most of the investigated functionalities are related to passive devices, which can control the incoming light but cannot emit light by themselves. It this talk, I will present recent results of our group on nanoantennas made of active semiconductor materials, which can emit light and control the light emission directivity through their resonant properties. Moreover we have shown that by properly engineering the nanoantenna resonances it is possible to create high-quality factor nanoantenna cavities. This lead to the first demonstrations of directional dielectric nanoantenna lasers in 2D nanoantenna arrays [2], 1D nanoantenna chains and even single nanoantennas supporting bound states in the continuum.

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Hybrid nanophotonics for sensing, thermometry and generation of white light at the nanoscale

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The integration of plasmonic and all-dielectric nanosystems opens up tremendous prospects for nanophotonics. Here we demonstrate two examples of implementation of such hybrid nanosystems for biology, chemicstry and nanooptics. (i) We prove that silicon nanoparticle coupled with a thin gold film can serve as a multifunctional hybrid nanocavity operating up to 1200 K. Resonant interaction of light with such nanocavity enables molecular sensing, heat-induced molecular events (protein unfolding), and their real-time tracing with a nanoscale thermometry through the monitoring enhanced Raman scattering both from the nanoparticle and analyzed molecules [1, 2]. (ii) Moreover, we suggest a simple, yet highly efficient, nanoscale white-light source based on a hybrid silicon-gold nanoparticle with ultrabroadband (1.3–3.4 eV) spectral characteristics [3]. We incorporate this novel source into a scanning-probe microscope and observe broadband spectrum of photoluminescence that allows fast mapping of local optical response of advanced nanophotonic structures.

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Sub-30 fs all-optical switching based on dielectric photonics

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The realisation of compact and efficient all-optical information processing devices at the nanometre scale has attracted great attention within the nanophotonics community in recent years, as they are expected to overcome the intrinsic speed and heat dissipation limitations of conventional electronics. In particular, nonlinear optical effects are predicted to give rise to the fastest performances, as they can produce response times in the femtosecond range [1].

Benefiting from large intrinsic nonlinearities and high field confinement abilities, nanostructured high refractive index dielectrics are crucial for efficient ultrafast nonlinear processes at subwavelength volumes [2]. In this work, we implement a novel pump-probe method using ~7 fs pulses to investigate the ultrafast dynamics of single Si nanodisks fabricated through e-beam lithography, covered with a thin 30-nm thick layer of Au to enhance sample reflectivity and thermal dissipation. We demonstrate that the nanoantenna can generate positive and negative sub-20 fs reflectivity modulations of ~0.3% at resonance, in the visible to near-infrared spectral range [3]. Recent measurements on GaP showing the possibility to enhance this response will also be discussed. The results suggest that the nonlinear optical Kerr effect and two-photon absorption are the responsible mechanisms for the observed all-optical switching phenomena.

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Self-field, radiated energy, and radiated linear momentum of an accelerated point charge

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Working within the framework of the classical theory of electrodynamics [1-3], we derive an exact mathematical solution to the problem of self-force (or radiation reaction) of an accelerated point-charge traveling in free space. In addition to deriving relativistic expressions for self electromagnetic fields ($\boldsymbol{E}_{\text{self}}$ and $\boldsymbol{B}_{\text{self}}$), we obtain exact formulas for the rates of radiated energy and linear momentum without the need to renormalize the particle's mass—or to discard undesirable infinities [4,5]. The relativistic expression of self-force known as the Abraham-Lorentz Dirac equation [6-8] is derived in two different ways [5]. Certain properties of the self-force are examined, and an approximate formula for the self-force, first proposed by Landau and Lifshitz [9], is discussed in some detail.

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Optical trapping of resonant all-dielectric nanoparticles

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Optical resonances in nanoparticles enhance light-matter interactions and can therefore be utilized to amplify optical forces. Most studies to date have considered metal nanoparticles that support localized surface plasmon resonances [1,2], but high-index dielectric nanoparticles can support geometrical resonances, or Mie modes, that can be just as pronounced. These resonances can results in unusual optical interference effects, such as cancellation of scattering in certain directions (Kerker conditions) and high local field-enhancement (e.g. in the "anapole state" [3]) of both fundamental and applied interest. In this presentation, we will describe how to fabricate [4] and optically manipulate colloidal Si nanoparticles of various shapes, how their resonances might affect optical forces acting on them [5], and how photothermal heating associated with laser tweezing can be quantified.

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Scattering of Quantum and Classical helicity states of light off nanostructures

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The helicity of light is a property of electromagnetic fields, much as the linear or the angular momenta, which has not been fully exploited to describe the scattering of light from particles. Some interesting properties of the helicity of light, which makes it useful for some applications is that it is the generator of dual transformations. Therefore, it is conserved in a dual symmetric system, i.e. a system that does not distinguish between electric and magnetic fields. Examples of such systems are those where the relative permittivity and permeability are the same ($\epsilon = \mu$), or those which can be approximately described just with an electric and magnetic dipolar moment and they are of the same magnitude and direction. Another interesting property of the helicity of electromagnetic fields is that in the paraxial approximation it corresponds with the usual circular polarization of electromagnetic fields and that it is conserved in ideal microscope objectives, so it allows us to describe the polarization of both focused and paraxial fields with the same quantity.

In this presentation I will present how can we use the helicity of light to describe classical scattering off nanostructures and will mention some applications to distinguishing biomolecules. As the helicity of light can be used to label electromagnetic modes, it is equally useful in the quantum regime. I will show some interesting properties of multiphoton states that can be constructed with helicity eigenmodes with special emphasis on their symmetry features.

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Synchrotron radiation from an accelerating light pulse

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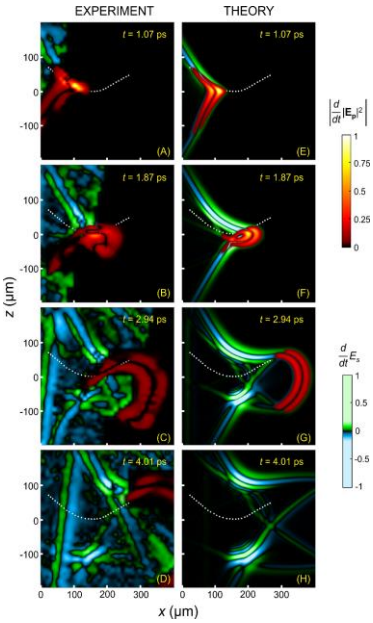
We report the observation of synchrotron radiation resulting from a subpicosecond light pulse that moves in a circular path [1]. A metasurface, consisting of an array of plasmonic nanoantennas, was used to guide an infrared pulse along a 100-μm-radius arc inside a $LiTaO_3$ crystal. The metasurface generates a self-accelerating wave, which belongs to a novel class of non-diffracting solutions to Maxwell's equations. Through two-wave mixing, the accelerating light pulse mixes with itself to generate a nonlinear polarization with THz components. As for a charge traversing a circular trajectory in vacuum, the moving nonlinear polarization emits THz synchrotron radiation over a scale of 100 μm, which is the smallest to date. The accompanying figure shows a comparison between contour plots of experimental results (A)-(D) and theoretical simulations (E)-(G). The experimental signals are proportional to the time-derivatives of the pump intensity and the THz field. The dashed-white curve is the circular light beam trajectory.



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Leveraging the crystal anisotropy for infrared nano-optics

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The current state-of-the-art in materials used for IR optical components offers significant material limitations. This is exacerbated by the long free-space wavelengths in this spectral region. Through the use of polaritons, one can surpass the diffraction limit and thus these limitations can be circumvented. However, the predominant types of polaritons employed, the surface plasmon (SPP) and surface phonon polaritons (SPhP) are typically realized within epitaxial semiconductors and dielectrics in the IR, restricting the design space due to lattice match requirements. In contrast, two-dimensional materials offer a broad suite of alternative semiconductor, conductor and dielectric species with atomic-scale thickness control and "Lego-like" stacking enabling arbitrary heterostructure and superlattice designs. Further, the natural crystal anisotropy resulting from the strong covalent in-plane and weak van der Waals out-of-plane bonds gives rise to extreme birefringence and in many cases hyperbolicity, offering new pathways for on-chip photonics and compact optical components.

In 2014, it was demonstrated that hexagonal boron nitride (hBN) was a natural hyperbolic material,[1,2] serving as the basis for applications such as hyperlensing.[3,4] More recently, it was demonstrated that MoO_3 offers strong out-of-plane and *in-plane* hyperbolicity.[5]This provides the potential basis for deeply sub-diffractional waveplates, polarizers and polarized thermal emitters.[6]

This talk will address the potential for leveraging such large crystal anisotropy for realizing reconfigurable planar metasurfaces,[7] flat and compact IR components and actively tunable and modulated IR optics.

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Optical vortices generation in nematic liquid crystal and differential method applied to hyperbolic metamaterials

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Part A: Optical vortices are light beams characterized by a helicoidal wavefront. They carry quantized orbital angular momentum (OAM): this property make them suitable for many applications [1]: they have been extensively used in quantum optics, since OAM can be used to encode quantum information; they have been employed in imaging techniques because of their specific intensity profile; they have been also used in optical trapping experiments as a tool for transferring angular momentum to trapped particles. By searching literature, it is possible to find many techniques that allow to generate them. Here we discuss a method for optical vortices generation whose main advantage is its accessibility, since it is inexpensive and does not require any specific fabrication facility. The technique consists in propagating light trough the edge dislocations that spontaneously form in periodical structures of nematic liquid crystals. These periodical structures, known as Williams domains, can be easily obtained by applying a low amplitude electric field to a nematic liquid crystal cell [2].

Part B: Hyperbolic metameterials (HMMs) are artificial optical materials, characterized by a hyperbolic dispersion [3]. We studied the propagation of electro-magnetic waves through HMMs made of alternating layers of dielectric and metal. By using grating coupled HMMs we could observe both Surface Plasmon Polaritons and Volume Plasmon Polaritons.

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Signal and information spreading, dynamic connectivity and segregation

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There is a strong connection between diffusion or information spreading dynamic processes and the underlying structure, periodic or disordered, on which that process takes place.

In this talk we want to discuss some examples of traditional optimization of information spreading phenomena in a disordered system[1], and present a tool, the information matrix, with which these processes can be described in an arbitrary network or periodic structure. We will compare the spreading efficiency of different algorithms, and we will show that many of the traditional concepts of network structure (like cliques or "n-connectivity" of graphs) can be successfully adapted to discuss these processes and their dynamical evolution.

The same framework of information spreading can be extended to consider processes in which active agents influence each other's information. This leads to a multi-dimensional generalization of the traditional voter models or invasion processes[2,3], which have been solved exactly. In this context one can discuss the emergence of consensus or formation of sub-communities (segregation of species) in random or periodic structures.

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Order and porosity to increase optical materials' versatility

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Some sort of order is always behind pattern formation, which is key to understanding, modelling and prediction in many areas of science and technology. This is the basis of solid-state physics and its light counterpart, photonic crystals. Disruption of order can fundamentally alter their optical properties to such degree that they give rise to new kinds of materials. Porosity on the other hand enables materials to be mixed with guest materials into composites changing their physical properties.

Order (or its lack) and its repercussions can be turned into tools capable to measure the alterations produced when porosity is employed to create new types of materials.

Opals and related particulate materials, through templating methods, are apt for the synthesis of composites that enjoy the advantages both of the amounts of order and porosity.

The difficulty of imparting and controlling order in self-assembled materials depends on the shape of the assembling particles, spheres being the easiest. Polyhedra required special care and their colloidal assembly is still subject of intense research [1].

If order is granted the optical properties, permit studying for instance the incorporation the guest materials (such as water) in the host (such as silica or carbon [2] microporous spheres) and its dynamics or turn the system into sensors for humidity of dew point [3].

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Wave vortices at different scales: learning from analogies between optics and acoustics

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A wave vortex is a phase singularity, around which the phase of the wave field changes by an integer multiple *m* of 2π-cycles [1]. The integer *m* is known as the topological charge of the vortex. A relevant dynamical property of wave vortices is that they carry orbital angular momentum [2]. In optics, there is a myriad of applications of vortices in different areas, such as optical communications and quantum information, particle trapping, and microscopy, to name but a few [3]. Interestingly, vortices can be generated with many kinds of waves: acoustic fields, electron beams, X-rays, Bose-Einstein condensates, etc.

Here we present some recent advances on the generation of acoustical vortices and structured fields [3]. By analyzing their similitudes and differences with respect to optical systems, we discuss some applications in particle manipulation and angular momentum transfer.

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Magnetic-field controlled radiative heat transfer

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The combination of magneto-optically active and resonant materials (e.g. plasmonic modes), makes it feasible to control optical properties using magnetic fields in connection to the excitation of resonances [1] (magnetoplasmonics). It has been shown that these nanostructures can be employed to modulate the propagation wavevector of SPPs [2], which allows the development of label free sensors with enhanced capabilities [3] or to enhance the magneto-optical response in isolated entities as well as films, in connection with a strong localization of the electromagnetic field [4,5].

Here we will show that they also play a crucial role in the active control thermal emission and the radiative heat transfer between objects in the near and far field regime [6-8].

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Taming sound at the nanoscale

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Nanophononics is essential for the engineering of thermal transport in nanostructured electronic devices, it greatly facilitates the manipulation of mechanical resonators in the quantum regime, and it could unveil a new route in quantum communications using phonons as carriers of information. Acoustic phonons also constitute a versatile platform for the study of fundamental wave dynamics, including Bloch oscillations, Wannier-Stark ladders, and other localization phenomena.

In this work, we present two strategies to confine phonons at the nanoscale. On one hand we present topological acoustic states confined in the interface between two superlattices presenting inverted symmetries. We experimentally evidenced these topological modes through Raman spectroscopy and pump-probe coherent phonon generation experiments. These structures enable a new tool in the study of the more complex topology-driven phonon dynamics such as phonon nonlinearities and optomechanical systems with simultaneous confinement of light and sound. On the other hand, we report on the Anderson colocalization of light and sound in disordered GaAs/AlAs superlattices and the enhancement of the interactions between these two fields. The colocalization effect shown here unlocks the access to unexplored localization phenomena and the engineering of light-matter interactions mediated by Anderson-localized states.

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First Electronic Posters Session

- Abujetas *“Bound States in the Continuum: Coupling Through Symmetry Breaks”*
- Campos *“Analysis of hyperbolic metamaterial and design of biosensors using the differential method”*
- Samaniego *“Adjustment, validation and testing of a tool for optical micromanipulation”*

Bound States in the Continuum: Coupling Through Symmetry Breaks

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Bound states in the continuum (BICs) are ubiquitous in many areas of physics, and have attracted especial interest for their ability to confine waves not allowed to couple to the continuous of radiation channels. Periodic structures provide a suitable platform to engineer and manipulate them in photonics, controlling their frequency and phase. The main mechanics that lead to BICs are: (i) the symmetry mismatch between the radiation state and the external channels; (ii) the destructive interference between different modes. The understanding of their origin is crucial to know how to modify the parameters of the system in order to control the coupling to the initial BIC state, leading to tailoring narrow resonances, huge amplifications of the near field and large Q-factor.

In this work, we study the fundamental mechanics that lead to BICs in dielectric metasurfaces as the base to control their coupling from the far field. Also, we analyze the symmetry that originate them and through several examples, different ways to break these symmetries are proposed.

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Analysis of hyperbolic metamaterial and design of biosensors using the differential method

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When light interacts with an object two different phenomena can occur: diffraction and absorption of photons. Light keeps information of the object with which it interacts. This information can be “read” through parameters like the intensity, polarization, phase, etc. So, the study of light diffracted by a structure is important since different properties of the structure can be known. Among many methods to analyze diffracted light, there is a subset called “spectral methods”. The work that we realized is centered around one particular spectral method, the differential method [1].

We develop a computational algorithm in C++ to analyze the diffracted field of a structure of any material and geometry through the differential method. With this code, we study hyperbolic metamaterials (HMM), which are materials that present dielectric properties in one direction and metallic properties in an orthogonal direction. This kind of behavior, at optical frequencies, is not present in nature. The HMM that we consider is a stack of metal-dielectric bilayers and each layer of material has subwavelength dimensions. With our code, we find the presence of surface plasmon polaritons (SPPs) and we study the behavior of this plasmons when changing the materials and numbers of the bilayers.

Moreover, with our code we verified the excitation of volume plasmon polaritons (VPPs) that appear in a planar HMM using a grating-coupling technique [2].

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Adjustment, validation and testing of a tool for optical micromanipulation

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The optical micromanipulation of nano and microparticles is of great current interest. To improve our ability to venture into this area, we have reviewed and assembled the parts of an optical clamp to achieve the entrapment and manipulation of micro and nanoparticles in our laboratory. The experimental arrangement combines a beam expansion system ~4X, a focusing system based on a microscope lens with NA 1.25, combined with an observation system. The system focuses the laser beam (628nm) in a very small area to achieve the greatest possible effect on the trapped particles. In the assembly and calibration of the tool has been considered basic principles of lasers, lens, refraction and reflection of light. Changing several times, the assembly system has sought to obtain the main features that the arrangement must present for proper operation such as: alignment of the red laser, collimation of the laser beam, use of the main maximum diffraction (order 0), and better focus of the particles. As sample, we were used polystyrene microparticles (2.6μm) and CdS nanoparticles (~30 nm) prepared in a water-in-oil micro emulsion were used. These systems allow us to study the limit cases: $R \gg \lambda$ and $R \ll \lambda$, where R is the radius of the particles under study and λ the wavelength of the laser used. The polystyrene dielectric particles have a refractive index of n=1.57 and those of CdS of approximately n=2.39.The samples of micro and nanoparticles were prepared at different concentrations, to decrease spherical aberrations. The results obtained are satisfactory and promising in the area of manipulation and analysis of individual particles. In this presentation, the main challenges and the results obtained will be discussed. The study of the results obtained will allow us to compare with results of other research works in this area.

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Tuesday 23

09:00 - 09:30	Nordlander *“Hot Carrier Generation, Relaxation, and Applications”*
09:30 - 10:00	Cortés *“Single-particle plasmonic photocatalysis”*
10:00 - 10:30	Oh *“Resonant Nanogap Devices for Sensing and Spectroscopy”*
10:30 - 11:00	**Coffee Break**
11:00 - 11:30	Halas *“Nanomaterials and Light for Sustainability and Societal Impact”*
11:30 - 12:00	Feldmann *“Halide Perovskite Nanocrystals: From Platelets to Supercrystals”*
12:00 - 12:30	Ritsch *“Sub-radiance and excitation dynamics in radiation coupled nano-arrays of quantum emitters ”*
12:30 - 13:00	Pensa *“Spectral screening of the energy of hot holes over a particle plasmon resonance”*/ Jacucci *“Bio-inspired highly scattering materials ”*
13:00 - 13:30	
13:30 - 14:00	
14:00 - 14:30	**LUNCH**
14:30 - 15:00	
15:00 - 15:30	Giessen *“Local dynamics of switching plasmonic systems on the nanometer scale”*
15:30 - 16:00	De Liberato *“Non-linear and non-perturbative intersubband polaritons”*
16:00 - 16:30	Kéna-Cohen *“Superfluidity of light and other nonlinear effects in the strong light-matter coupling regime”*
16:30 - 17:00	**Coffee Break**
17:00 - 17:30	Hillenbrand *“Phonon Polariton Nanophotonics based on 2D Materials”*
17:30 - 18:00	Sánchez-Gil *“Bound States in the Continuum in resonant electric and/or magnetic dipole metasurfaces ”*
18:00 - 18:30	Scheffold *“Transition from Light Diffusion to Localization in Hyperuniform Photonic Bandgap Materials ”*
18:30 - 19:00	Marqués *“Novel Phenomena in Optical Manipulation due to Magnetic-Field-Induced Resonant States”*
19:00 - 19:30	**SOCIAL DINNER 2**
19:30 - 20:00	
20:00 - 20:30	
20:30 - 21:00	Electronic Posters
21:00 - 21:30	
21:30 - 22:00	

Hot carrier generation, relaxation, and applications

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Plasmons can serve as efficient generators of hot electrons and holes that can be exploited in light harvesting applications.[1] The physical mechanism for plasmon-induced hot carrier generation is plasmon decay. Plasmons can decay either radiatively or non-radiatively with a branching ratio that can be controlled by tuning the radiance of the plasmon mode. Non-radiative plasmon decay is a quantum mechanical process in which one plasmon quantum is transferred to the conduction electrons of the nanostructure by creating an electron-hole pair, i.e., excitation of an electron below the Fermi level of the metal into a state above the Fermi level but below the vacuum level. I will discuss the time-dependent relaxation of plasmon-induced hot carriers including electron-electron scattering, fluorescence, and electron-phonon coupling.[2,3] I will also discuss recent applications of plasmon-induced hot carrier generation such as photocatalysis, and how photocatalytic efficiencies can be enhanced and quantified by placing catalytic reactors in the nearfield of a plasmonic antenna in Antenna/Reactor geometries.[4]

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Single-particle plasmonic photocatalysis

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Unravelling the interaction between molecules and plasmonic interfaces set the basis for plasmonic chemistry. Enhanced electric fields, energetic (hot) electron-hole pairs and abrupt thermal gradients, build up a complex scenario for molecules sitting next to a metal nanoparticle illuminated at visible wavelengths. However, at the same time, this combination offers all the necessary ingredients to manipulate photochemical reactions and ultimately revolutionize the electromagnetic-into-chemical energy conversion processes [1]. In this context, single molecule and/or single nanoparticle approaches, even being methodologically challenging, should reduce the complexity of the problem allowing to explore, rationalize and optimize energy transfer pathways in these systems [2].

Here, I will show a range of examples where the energy confinement achieved by plasmonic nanoparticles has been further employed to in-situ monitor, guide or induce charge-transfer processes at the single molecule and/or at the single nanoparticle level [3-8]. Using light to study, enhance and drive chemical reactions, beyond the traditional photochemistry or photocatalysis fields, is now possible thanks to plasmonic chemistry.

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Resonant nanogap devices for sensing and spectroscopy

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Nanometer-scale gaps in metals are one of key building blocks for plasmonics and nano-optics. I will present (1) new approaches to manufacture sub-10-nm gaps with uniformity and high throughput; (2) resonant annular nanogap devices for optical trapping of single protein molecule; and (3) graphene plasmon resonators for ultrasensitive infrared spectroscopy. In our scheme, the width of nanogap structure is precisely defined by the thickness of oxide films grown by atomic layer deposition (ALD). By scaling the gap size toward single-nanometer regime, we can perform low-power trapping of nanoparticles and biomolecules, followed by surface-enhanced spectroscopic detection. With a ring-shaped coaxial nanoaperture, we can generate strong optical resonances that can be tuned from visible to mid-infrared frequencies. We show applications of resonant coaxial nanoapertures for single-molecule optical trapping and nanogap-based graphene acoustic plasmon resonators for mid-infrared spectroscopy.

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Nanomaterials and light for sustainability and societal impact

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Metallic nanoparticles, used since antiquity to impart intense, vibrant color into materials, then brought to scientific attention in the 19th century as "Faraday's colloid", have more recently become a central tool in the nanoscale manipulation of light. While the scientific foundation of this field has been built on noble and coinage metals (most typically gold or silver), more recently we have begun to question whether the same, or similar properties can also be realized in more sustainable materials. Aluminum, the most abundant metal on our planet, can support high-quality plasmonic properties spanning the UV-to-IR region of the spectrum,[1] and is showing its usefulness in the detection and identification of molecules ranging from DNA to environmental contaminants in our "exposome". [2] We previously introduced photothermal effects for biomedical therapeutics; [3] this approach is being utilized in human trials for the precise and highly localized ablation of cancerous regions of the prostate, eliminating the deleterious side effects characteristic of conventional prostate cancer therapies. Photothermal effects can also be harvested for sustainability applications, which we have most recently demonstrated in an off-grid solar thermal desalination system that transforms membrane distillation into a scalable water purification process. [4]

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Halide perovskite nanocrystals: from platelets to supercrystals

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The optical properties of metal halide perovskite nano-platelets with controllable thickness down to one monolayer will be discussed. Pronounced quantum confinement effects, large excitonic binding energies and comparably high radiative recombination rates have been found, all depending on the number of monolayers present in the respective nano-platelets. Ultrafast optical experiments provide further insight into characteristic charge carrier and spin relaxation scenarios in colloidal perovskite nanocrystals. Finally, the assembly of halide perovskite nanocrystals into ordered supercrystals leads to remarkable changes of their linear and nonlinear optical properties.

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Sub-radiance and excitation dynamics in radiation coupled nano-arrays of quantum emitters

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Regular arrays as polygons of sub-wavelength spaced dipole-coupled quantum emitters exhibits a single superradiant and many extraordinarily sub-radiant collective modes with a spatial confined electric field pattern forming nanoscale high Q optical resonators. Tailoring geometry and distance between several identical configurations allows to increase the ratio of coherent excitation transfer versus free space emission by several orders of magnitude. Any initially localized excitation is spread along the structure before it can decay. For special symmetric arrangement of multiple rings inspired by the geometry of biological light harvesting complexes we find a very rich dynamical behavior within the dark state manifolds. Coupling quantum emitters arrays to optical cavities or fiber guided field modes strongly modifies of free space radiation properties via an enhanced or suppressed Purcell effect. Surprisingly, dark excitonic states exhibit vastly enhanced effective cooperativities as compared to super-radiant modes.

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Spectral screening of the energy of hot holes over a particle plasmon resonance

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Plasmonic hot carriers have been recently identified as key elements for photocatalysis at visible wavelengths. The possibility to transfer energy between metal plasmonic nanoparticles and nearby molecules depends not only on carrier generation and collection efficiencies but also on their energy at the metal-molecule interface. [1]

Here, electrochemistry and single-particle dark-field microscopy and spectroscopy are combined to study the role of a photoexcited Au nanoparticle (AuNP) in the electro-oxidation of aniline to polyaniline. Electrochemistry provides a way to control the energy of the electrons in the metal nanoparticle and at the same time allows to compute the overpotential needed for the electrochemical reaction to proceed. Wavelength-dependence studies show that the overall energy requirements of the electrochemical reaction can be reduced up to ~35% when exciting the AuNP at it plasmon resonance. To understand the mechanism behind this photocatalytic effect, a single particle nanothermometry technique based on anti-Stokes photoluminescence emission is implemented. It is shown that even if the total absorbed energy at each excitation wavelength is the same, the reactivity of the hot-holes follow the plasmon resonance profile. These results shed light on the role of the absorption processes in plasmonic photocatalysts and the maximum energy of the reactive hot holes at the surface of a 80 nm AuNP.[2]

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Bio-inspired highly scattering materials

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Whiteness arises when light interacts with disordered media, where different wavelengths are scattered with comparable intensity. Such appearance is the result of light undergoing multiple scattering events before exiting the object, i.e. when the object is optically thick. The optical thickness of a material is determined by the ratio between its physical thickness and the transport mean free path, namely the distance that light travels before losing information about its starting propagation direction. Commonly, the transport mean free path in low-refractive index white materials is about tens of micrometres long. Therefore, opacity is achieved for relatively large thicknesses (in the millimetres range) to allow a high enough number of scattering events. Nature provides an invaluable source of inspiration for the study and the manufacturing of thin opaque white materials. The Cyphochilus white beetle achieves a high total reflectance ($\simeq$ 75% over the whole visible range) with a few micron thick, lightweight, anisotropic network of chitin fibres ($n_c \simeq 1.55$).

Herein, after quantifying the scattering efficiency of the chitin network via a coherent backscattering setup, we show an experimental approach to produce bio-inspired, sustainable white materials. In particular, we demonstrate that tuning the morphology of a network of polymer fibres strongly affects its optical properties: from transparent, to bright white materials. Notably, our bio-inspired materials achieve high scattering efficiency whilst being only a few micrometres thick (up to 75 % reflectance while only 4 μm thick). Our study illustrates the potential of using biopolymers as building blocks to produce next-generation sustainable and biocompatible highly scattering materials. In addition, we show that it is possible to manipulate the light transport regime, moving from standard to anomalous diffusion, when a long-tailed distribution of the fibres size is introduced.

Local dynamics of switching plasmonic systems on the nanometer scale

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Magnesium is a plasmonic material for the UV and visible spectral range that can be switched from a metallic state to a dielectric state and back using hydrogen and oxygen. Its switching can be quite fast and the contrast is excellent. In fact, the local surface plasmon resonance can be completely switched on and off [1].

In order to make magnesium a suitable material for active plasmonic devices such as switchable plasmonic displays, spatial light modulators, and active holographic metasurfaces, it is of utmost importance to understand the hydrogenation processes and its dynamics on a nanometer scale. Particularly, the in- and outdiffusion as well as the propagation of hydrogen into the magnesium layers and across grain boundaries can influence the switching properties substantially.

Here, we investigate the dynamics of switchable plasmonic nanostructures from Magnesium in-situ during the hydrogenation and dehydrogenation processes using scattering SNOM, as well as single-particle dark- and bright-field microscopy [2]. We find that individual crystallites can be hydrogenized extremely fast, whereas grain boundaries can hamper the propagation of hydrogen and even prevent the full switching. Tuning our novel broadband infrared laser source to magnesium hydride phonons in the mid-IR spectral range [3], we have a powerful tool to monitor the hydrogenation dynamics selectively (discriminating from magnesium oxide or hydroxide) and with high selectivity and spectral contrast.

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Non-linear and non-perturbative intersubband polaritons

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Intersubband polaritons are hybrid light-matter quasiparticles due to the strong coupling between the photonic field of a dielectric or metallic microcavity and the electronic transition between quasi-parallel conduction subbands in doped quantum wells [1]. In this talk I will describe some recent advancement in the study and exploitation of those quasiparticles.

In the first part I will present recent results pertaining the realization of a mid-infrared intersubband polariton laser. Polariton lasers, exploiting stimulated polariton-polariton scattering instead than stimulated emission from electronically inverted transitions, have been achieved at shorter wavelengths but never in the mid-infrared regime. I will show how phonon-mediated scattering between intersubband polaritons can lead to lasing [2] and discuss recent experimental advances in this direction [3].

In the second part I will instead demonstrate how the non-perturbative coupling of intersubbband transitions to the photonic field of the microcavity can lead to novel bound excitonic resonances. In those cavity-induced excitons the electron and hole are not kept together by the longitudinal Coulomb interaction (which in intersubband systems is repulsive) but by the exchange of virtual cavity photons [4]. Beyond its direct technological interest, this result demonstrates how the light-matter coupling can be used to qualitatively change the system's spectral and electronic features.

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Superfluidity of light and other nonlinear effects in the strong light-matter coupling regime

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Over the past decade, strongly-coupled microcavities based on epitaxially-grown group III-V semiconductors have been a playground for nonlinear optics. Fascinating effects such as optical bistability, parametric amplification and polariton superfluidity have been demonstrated. In these systems, the strong nonlinearity is inherited from the resonant $\chi^{(3)}$ nonlinearity of the Wannier-Mott exciton and enhanced by the large cavity electric field. These systems are, however, limited to low-temperatures due to the small exciton binding energy. Over the past few years, organic Frenkel exciton and Wannier-Mott excitons in layered transition metal dichalcogenides (TMDs) have emerged as potential candidates for room-temperature polariton nonlinearities due to their strong exciton binding energy. These materials are particularly interesting given that weak interlayer bonding allows for excellent optoelectronic properties when deposited on arbitrary substrates.

We will describe recent experiments that show how under resonant excitation, polaritons in organic microcavities can show a transition from normal to superfluid flow. In this regime, they can flow across defects in the absence of scattering. Although the polariton-polariton interaction strength in organics is much lower than in III-V microcavities, the large polariton densities achievable lead to similar effects to those in III-V materials. We will also describe some of the first experiments on resonant excitonic non-linearities in monolayers of TMDs and demonstrate stuctures where TMD-polaritons can flow for hundreds of micrometers on a sample surface.

Phonon polariton nanophotonics based on 2d materials

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Phonon polaritons in 2D materials exhibit ultra-short wavelengths, long lifetimes and strong field confinement, which allows for manipulating infrared light at the nanometer scale. Here, we discuss real-space nanoimaging studies of infrared phonon polaritons in boron nitride and molybdenum trioxide nanostructures and metasurfaces, revealing intriguing aspects such as polariton propagation with anomalous wavefronts or with ultra-long lifetimes of several 10 picoseconds.

Bound States in the Continuum in resonant electric and/or magnetic dipole metasurfaces

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Bound states in the continuum (BICs) have attracted much interest lately in photonics for their (theoretically) infinite Q factor. These states are leaky modes that in a certain limit of some parameter space cannot couple to any radiation channel [1]. In order to trap light in such nearly-zero-linewidth electromagnetic modes, a common approach is to exploit metasurfaces: outgoing specular channels can be suppressed by tuning the parameters of the system in various manners, leading to symmetry-protected BICs.

Here we will show that simple metasurface configurations may support robust, symmetry-protected BICs. On the basis of a generalized coupled electric/magnetic dipole theory for infinite arrays [2], a variety of scenarios is investigated where single/double meta-atoms can be simply described by a combination of various electric (ED) and/or magnetic dipoles (MD). First, a dipole-dimer array is shown to yield a BIC at normal incidence as the dipole detuning parameter vanishes; this has been experimentally verified through Au-rod dimer metasurface in the THz domain [3]. A similar phenomenology is theoretically predicted for a Si cylinder/disk metasurface supporting overlapping MD/ED resonances [2]. Second, an array of single perpendicular MDs exhibits a so-called Brewster BIC at normal incidence, which evolves into a quasi-BIC at oblique incidence with a rich phenomenology as the (non-degenerate) MD is tilted. We will show that a high-refractive-index disk metasurface in the GHz domain in turn provides clear experimental evidence of such Brewster quasi-BICs [4].

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Transition from Light Diffusion to Localization in Hyperuniform Photonic Bandgap Materials

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We report on the fabrication and characterization of disordered hyperuniform photonic materials in two and three dimensions [1-3]. We first discuss the fabrication of polymer templates of network structures using direct laser writing (DLW) lithography [1]. Next we demonstrate how these mesoscopic polymer networks can be converted into silicon materials ($n \simeq 3.6$) by infiltration and double-inversion [2]. The resulting hyperuniform photonic materials display a pronounced pseudo gap in the optical transmittance in the shortwave infrared, $\lambda \sim 2\mu$m. To obtain a deeper understanding of the physical parameters dictating the properties of disordered photonic materials we investigate band gaps, and we report Anderson localization in hyperuniform structures using numerical simulations of the density of states and optical transport [3-5]. Our results show that, depending on the frequency of incident radiation, a disordered, but highly correlated, dielectric material can transition from photon diffusion to Anderson localization and to a bandgap. In two dimensions we can also identify a regime, near the gap, dominated by tunnelling between weakly coupled states [4].

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Novel phenomena in optical manipulation due to magnetic-field-induced resonant states

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We study the effect of optical forces [1] and torques on a spherical isotropic magneto-optical (MO) nanoparticle [2]. The force on the direction of the applied external magnetic field has two contributions: A first conservative component coming from the "Zeeman" coupling between the light spin density and the external magnetic field through the imaginary part of the MO polarizability, and a second component coming from the direct transfer of the helicity of the electromagnetic field to the particle through the real part of the MO polarizability. The torque also has two contributions: The usual one coming from the spin of the light field and another one depending only on the modulus of the electromagnetic field.

We explicitly show examples where these new contributions lead to: (i) An optical torque on an isotropic, spherical particle using a linearly polarized plane wave, (ii) the formation of a conservative optical lattice with non-interfering incoming fields and (iii) radiation pressure using electromagnetic fields with zero average value of the Poynting vector.

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Second Electronic Posters Session

- Andrén *“Surface Interactions of Gold Nanoparticles Optically Trapped Against an Interface”*
- Olmos-Trigo *“Spin-orbit interactions of light from a single measurement of the DoCP in the dipolar regime”*
- Sanz Fernández *“Enhanced spin-orbit optical mirages from dual nanospheres”*

Surface interactions of gold nanoparticles optically trapped against an interface

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Gold nanoparticles confined in circularly polarized optical tweezers can function as highly efficient rotary nanomotors [1], demonstrating potential as a probe of photothermal interactions [2] as well as for molecular binding and unbinding events [3]. This nanomotor system is based on two-dimensional trapping of metallic nanoparticles where the scattering force in the laser's propagation direction is counteracted by Coulomb repulsion from a similarly charged glass surface.

It is well known that the behavior of a nanoparticle is strongly influenced by the presence of a surface, as it affects its Brownian motion, and its optical and thermal properties. For our nanomotor system, as well as others related to optical printing lithography, thermophoretic effects, or plasmonic tweezers, knowing the absolute separation distance as well as interaction between the nanoparticle and the surface is of utter importance.

In this work, total internal reflection microscopy is utilized to study gold nanoparticles in two-dimensional optical tweezers. Optical experiments are performed to deduce the absolute separation distance between the two entities, and time-resolved measurements provide us with a handle to obtain information about the positional probability distribution for the nanoparticle. This is supplemented by an *in-silica* equivalent of the experiment that combines electromagnetic calculations with Brownian motion simulations.

Using this approach, we determine the separation distance to be 90 nm, a distance that can be reduced down to 30 nm by increased radiation pressure or ionic charge screening. Moreover, the translational friction in the trapping region is found to increase up to 60%, whereas the rotational friction is practically unaffected.

These findings deepen the understanding of the properties of nanoparticles in proximity to surfaces, which could be harnessed for a range of potential applications on this size scale.

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Spin-orbit interactions of light from a single measurement of the DoCP in the dipolar regime

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Light spin-orbit angular momentum (AM) coupling phenomena are receiving an increasing interest in the analysis of scattering processes from sub-wavelength objects [1]. They are of particular relevance in far-field optical imaging [2], where this coupling leads to significant shifts between the measured and actual position of particles [3], known as optical mirages for spherical scatterers [4]. Here we show that for small isotropic particles with electric and magnetic dipolar response, the angular scattering pattern of the spin-orbit coupling and optical mirage is fully determined by the (measurable) degree of circular polarization (DoCP) at a right-angle scattering [5]. We explicitly show that the maximum AM exchange, the zeros of the DoCP and the maximum optical mirage do not appear at the same scattering angle. Our results open the possibility to infer optical properties by a single measurement of the polarization in the far-field limit.

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Enhanced spin-orbit optical mirages from dual nanosphere

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Spin-orbit interaction of light can lead to the so-called optical mirages, i.e., a perceived displacement in the position of a particle due to the spiraling structure of the scattered light. In electric dipoles, the maximum displacement is subwavelength and does not depend on the optical properties of the scatterer [1, 2]. Here we will show that the optical mirage in high refractive index dielectric nanoparticles depends strongly on the ratio between electric and magnetic dipolar responses. When the dual symmetry is satisfied (at the first Kerker condition) [3, 4], there is a considerable enhancement (far above the wavelength) of the spin-orbit optical mirage which can be related to the emergence of an optical vortex in the backscattering direction.

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Wednesday 24: TOUR DAY

Thursday 25

09:00 - 09:30	Leosson *“Optics and Innovation”*
09:30 - 10:00	Volpe, Giovanni *“Deep Learning Applications in Photonics and Active Matter”*
10:00 - 10:30	Volpe, Giorgio *“Reconstructing Microscopic Force Fields with FORMA”*
10:30 - 11:00	**Coffee Break**
11:00 - 11:30	Ritsch-Marte *“Optical Forces Across the Scales”*
11:30 - 12:00	Ramos *“Nanomechanical Plasmon Spectroscopy: optomechanics as a new plasmonic transducer”*
12:00 - 12:30	Maragò *“Optical Forces for Materials and Metamaterials”*
12:30 - 13:00	Zemánek *“Underdamped dynamics of optically levitated objects”*
13:00 - 13:30	
13:30 - 14:00	
14:00 - 14:30	**LUNCH**
14:30 - 15:00	
15:00 - 15:30	Pinheiro *“Light Localization in Aperiodic Vogel Spirals”*
15:30 - 16:00	Garcia-Etxarri *“Topological photonics: mistaken paradigms and new opportunities”* / Aubry *“Experimentel evidence for band gap formation and Anderson localization regimes for microwaves in hyperuniform 2D materials”*
16:00 - 16:30	Kutrovskaya *“Free Standing Monoatomic Carbon Chains”*/ 15 min free
16:30 - 17:00	**Coffee Break**
17:00 - 17:30	Vignolini *“Colour engineering: from nature to applications”*
17:30 - 18:00	Rubinsztein-Dunlop *“From cold atoms to living cells with sculpted light”*
18:00 - 18:30	Garcia-Parajo *“Nanophotonic approaches for super-resolution imaging and single molecule dynamics in living cells”*
18:30 - 19:00	Barberi *“Unclonable fingerprints for anti-counterfeiting devices”*
19:00 - 19:30	**SOCIAL DINNER 2**
19:30 - 20:00	
20:00 - 20:30	
20:30 - 21:00	Electronic Posters
21:00 - 21:30	
21:30 - 22:00	

Optics and Innovation

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The talk will provide a personal perspective of transferring research (mainly in optics and photonics) to patents and business start-ups during the past two decades. This includes work in the areas of plasmonics [1], biophotonics [2], electrophoresis [3], polarimetry [4], (photo)catalysis [5] and, most recently, laser-induced breakdown spectroscopy [6].

One of the main lessons to be drawn from these experiences is the importance of "knowing the customer," in other words making sure that a particular technology development satisfies an actual demand. Whereas researchers can often provide wonderful and scientifically interesting solutions to non-existing problems, it is also important from an economic, political and moral standpoint that fundamental research, to a certain degree, addresses current technological problems, both large and small.

Ideally, such developments should also benefit the greater good in terms of their environmental and/or social impact. In an age of pronounced anti-science sentiments where scientists are often blamed for negative impacts of technology, researchers must emphasize that problems created by science must also be solved by science.

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Deep learning applications in photonics and active matter

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After a brief overview of artificial intelligence, machine learning and deep learning, I will present a series of recent works in which we have employed deep learning for applications in photonics and active matter. In particular, I will explain how we employed deep learning to enhance digital video microscopy [1], to estimate the properties of anomalous diffusion, and to improve the calculation of optical forces. Finally, I will provide an outlook for the application of deep learning in photonics and active matter.

References

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Reconstructing Microscopic Force Fields with FORMA

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The accurate measurement of microscopic force fields is crucial in many branches of science and technology, from biophotonics and mechanobiology to microscopy and optomechanics. These forces are often probed by analysing their influence on the motion of Brownian particles. We have proposed a new powerful algorithm for microscopic force reconstruction via maximum-likelihood-estimator analysis (FORMA) to retrieve the force field acting on a Brownian particle from the analysis of its displacements [1]. FORMA estimates accurately the conservative and non-conservative components of the force field with important advantages over established techniques: it is parameter-free, it requires ten-fold less data and it executes orders-of-magnitude faster. By demonstrating FORMA performance using optical tweezers, we show how, outperforming other available techniques, FORMA can identify and characterise stable and unstable equilibrium points in generic force fields. We believe that, thanks to its high performance, FORMA can help accelerate the development of microscopic and nanoscopic force transducers for physics, biology and engineering.

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Optical forces across the scales

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Optical tweezers enable precise and controllable manipulations of objects over a large range of sizes, from atoms to entire living organisms. Some recent advances, some controversies, and some remaining challenges of optical micro-manipulation in various scenarios from astrophysics to biophotonics will be discussed.

Specifically, it will be demonstrated how the shortcomings of holographically controlled optical forces can be compensated by other force generating fields, such as acoustic forces, which scale differently with particle size [1].

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Nanomechanical plasmon spectroscopy: optomechanics as a new plasmonic transducer

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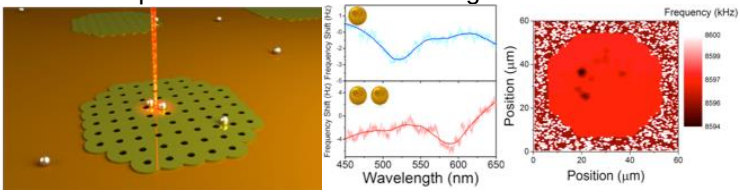
Last decade has witnessed the advent of nanomechanical devices as a new platform for sensing applications in many diverse fields like physical, biological or chemical applications. Optical methods are usually employed due to their versatility and the non-physically limited bandwidth. However, as the lateral size of the resonators approaches the illuminating wavelength, interplay between the mechanical object and the light, or optical back-action, arises, resulting in a new branch known as optomechanics. In this work, we present a thorough optomechanical characterization of suspended silicon nitride membranes[1]. Despite the low-quality optical factor, plasmomechanical systems[2] represent an attractive alternative when compared with other optical cavities when the size of the mechanical system is below the wavelength, which, on the other hand, it is needed to achieve high frequency regime. Researchers have dealt with the diffraction limit by engineering optical resonators operating in telecom wavelength or by using the scattered electromagnetic field to apply the feedback force on the mechanical resonator[3]. Here, we demonstrate the optomechanical coupling that emerges in the low finesse plasmonic cavity formed by a spherical gold nanoparticle of 100nm in diameter onto a free-standing silicon nitride membrane. We discover that a key effect to explain the unexpected optomechanical coupling in these systems is the excitation of the plasmon resonance which is related with an enhancement in the extinction cross section of the nanoparticle at selected wavelength.



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Optical forces for materials and metamaterials

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Mechanical effects of light are a consequence of conservation laws in light scattering. Optical tweezers [1,2], tools based on strongly focused light, enables optical trapping and manipulation of a wide range of microscopic and nanoscopic materials, as well as their characterization [3]. When used as force transducer, they are capable of femtonewton force sensing in photonic force and torque microscopy [4,5]. For non-spherical particles or at intermediate (meso)scale regimes, shape, aggregation, and composition can have dramatic consequences for optically trapped particle dynamics [6,7]. Here, after an introduction to optical forces at the mesoscale, we give an overview of results on optical trapping, optical binding, and characterization of 1D (silicon and zinc oxide nanowires) and 2D materials with a focus on scaling laws. Furthermore, we theoretically investigate optical forces in proximity of surfaces and epsilon-near-zero metasurfaces yielding attraction or repulsion depending on the surface properties and particle size.

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Underdamped dynamics of optically levitated objects

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Recent progress in optical control of mechanical systems opens new ways to investigate a wide variety of mechanical effects in thermodynamics and statistical physics, stochastic dynamics and quantum mechanics. In near future, the most interesting in these fields are nonlinear stochastic effects which autonomously transform environmental noise to useful mechanical effects. A nonlinearity of potential brings mechanical systems out of thermal equilibrium with their environment, changing their statistics far away from thermal statistics of the environment. Such mechanical processes can be therefore principally used as a primary source of coherent mechanical displacement and mechanical oscillations. They might allow to do autonomously mechanical work at micrometer and nanometer distances. Thinking forward, about a long term vision, such nonlinear processes might be extremely interesting in the underdamped regime that has been already reached for some cases.

We provide experimental demonstrations of underdamped dynamics of optically levitated objects, analyze their motion and system parameters. Working in vacuum with a circularly polarized Gaussian optical trap, transverse spin momentum drives the underdamped motion of a probe particle far beyond thermodynamic equilibrium. Constrained by optical gradient forces, we first observe spin-driven Brownian motion and, subsequently, the formation of thermally excited orbits. Ultimately, centripetal forces overcome the trap, causing the expulsion of the particle. Our results complement and corroborate recent measurements of spin momentum in evanescent waves, and extend them to a new geometry. In doing so, we exhibit fundamental, generic features of the mechanical interaction of circularly polarized light beams with matter. Our work shows how observations of the underdamped motion of probe particles can illuminate our understanding of the nature and morphology of momentum flows in arbitrarily structured light fields as well as providing a test bed for elementary non-equilibrium statistical mechanics.

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Light Localization in Aperiodic Vogel Spirals

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By using the dyadic Green's matrix spectral method, we demonstrate that aperiodic deterministic Vogel spirals made of electric dipoles support light localization in three dimensions, an effect that does not occur in traditional uniform random media. We discover a light localization transition in Vogel spiral arrays embedded in three-dimensional space by evaluating the Thouless conductance, the level spacing statistics, and by performing a finite-size scaling [1]. This light localization transition is different from the Anderson transition because Vogel spirals are deterministic structures. Moreover, this transition occurs when the vector character of light is fully taken into account, in contrast to what is expected for uniform random media of point-like scatterers [2]. We show that light localization in Vogel spirals is a collective phenomenon that involves the contribution of multiple length scales. Vogel spirals are suitable photonic platforms to localize light thanks to their distinctive structural correlation properties that enable collective electromagnetic excitations with strong light-matter coupling. Our results unveil the importance of aperiodic correlations for the engineering of photonic media with strongly enhanced light-matter coupling compared to the traditional periodic and homogeneous random media.

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Topological photonics: mistaken paradigms and new opportunities

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Topological states of matter were first discovered in the field of solid-state physics but recent contributions are proving their existence in diverse fields of science. To mention a few, topological surface states have been recently identified in the fields of optics [1], acoustics [2] and in excitonic and polaritonic materials [3].

Most of these cross-disciplinary designs have been directly inherited from concepts previously discovered in electronic materials. Nevertheless, these different physical mechanisms, should lead to distinct effects with interesting properties of their own. Unfortunately those assets will remain hindered if the research on topological effects in these fields continues to be exclusively based on analogies with solid-state systems.

A recent article unveiled a new method, named Topological Quantum Chemistry (TQC) [4], which allows predicting the emergence of topological phases on matter based exclusively on Elementary Band Representations, a mathematical tool very well known in the field of crystallography. Applying TQC to electronic, photonic, excitonic and acoustic systems could unveil the emergence of novel and distinct topological states pivoted by the unique characteristics of the distinct physical excitations in each system.

In this work, we applied TQC to Photonic crystals; surprisingly, we discovered that certain paradigms in the design of Photonic Topological insulators are not strictly truthful. Moreover, the versatility of the method allowed us to design novel topological photonic systems with unprecedented physical properties.

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Experimental evidence for Band Gap Formation and Anderson localization regimes for microwaves in hyperuniform 2D materials

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Recently, it has been shown that disordered dielectrics can show a photonic band gap in the presence of structural correlations [1], but 30 years after John's seminal proposal on the interplay between the photonic pseudo band gap in disordered photonic crystals and Anderson localization [2], a controlled experimental study of the transport properties in between ordered and disordered states is still lacking.

In this talk, I present new experimental and numerical results obtained for a 2D system composed of high index dielectric cylinders in air [3] placed according to stealthy hyperuniform point patterns [1].

Measurements are performed in the microwave range (1 to 10 GHz).

In addition to the (local) density of states and the Thouless conductance, we can access experimentally the field amplitude which allows us to unambiguously visualize single eigenmodes in finite size open systems for all the transport regimes such as stealthy-transparent, diffusion, Anderson-localization and the band gap [4], as a function of the degree of stealthiness χ. Our observations are supported by the analysis of the spreading of the wave in the time domain.

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Free standing monoatomic carbon chains

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Being monoatomic chains of carbon atoms, carbynes represent ultimate one-dimensional crystals. Unfortunately, free standing carbon chains are instable in vacuum, and fluctuations almost necessarily lead to their deformation and folding. The synthesis of free-standing carbon chains remains one of the Holy Graals of nano-physics and nano-chemistry [1,2]. Here we report on the experimental realization of long straight free-standing carbon chains stabilized by metallic nanoparticles. We synthesize linear carbon chains (carbynes) in a colloidal solution, then deposit them on a surface and study free standing carbyne films with the transmission electron microscopy (TEM). TEM images of the carbon threads with golden nanoparticles attached to their ends demonstrate straight monoatomic carbon chains with full lengths of over 100 nm and linear parts of about 12 nm length (52 atoms), in average. Parallel linear chains of carbon atoms form a quasi one-dimensional crystal structure with a lattice constant of 0.256 nm as confirmed by the diffraction measurements. This method paves the way to fabrication of an ultimate one-dimensional crystal: a monoatomic carbon wire. Further experiments are under way in order to reveal excitonic features in the optical spectra of carbynes.

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Colour engineering: from nature to applications

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The most brilliant colours in nature are obtained by structuring transparent materials on the scale of the wavelength of visible light. By controlling/designing the dimensions of such nanostructures, it is possible to achieve extremely intense colourations over the entire visible spectrum without using pigments or colorants. Colour obtained through structure, namely structural colour, is widespread in the animal and plant kingdom [1]. Such natural photonic nanostructures are generally synthesised in ambient conditions using a limited range of biopolymers. Given these limitations, an amazing range of optical structures exists: from very ordered photonic structures [2], to partially disordered [3], to completely random ones [4]. In this seminar, I will introduce some striking example of natural photonic structures [2-4] and review our recent advances to fabricate bio-mimetic photonic structures using the same material as nature. Biomimetic with cellulose-based architectures enables us to fabricate novel photonic structures using low cost materials in ambient conditions [6-7]. Importantly, it also allows us to understand the biological processes at work during the growth of these structures in plants.

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From cold atoms to living cells with sculpted light

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The ability to sculpt light fields using spatial light modulators (SLM) or Digital Micromirror Devices (DMD) has given us tools of choice for the production of configurable and flexible confining potentials at the nano and micron-scale. We categorize the techniques used to create sculpted light to those based on time averaged methods and those utilizing spatial light modulators in either Fourier plane or direct imaging plane. A rapid angular modulation of Gaussian beam with a two-axis acousto-optic modulator, AOM, can be used as highly configurable time-averaged traps. This type of modulation has found applications in holographic tweezers and ringtraps for ultra-cold atoms. SLMs can be used as a way of producing extremely versatile structured light. SLMs in Fourier plane which control the phase and /or amplitude of an input Gaussian beam, with the pattern representing the spatial Fourier transform of the desired amplitude pattern. The optical system then focuses this sculpted light pattern to the plane containing the system of interests, performing a Fourier transform and recovering the desired pattern. Yet another way for production of dynamical, fast and flexible structured light fields is using digital micro mirror devices (DMD), which is based on direct imaging of amplitude patterns. DMD can configure the amplitude of an input beam either in the Fourier plane or in a direct imaging configuration. Sculptured light produced using these methods promises high flexibility and an opportunity for trapping and driving systems ranging from studies of quantum thermodynamics using ultra cold atoms to trapping and manipulating nano and micron-size objects or even using these objects inside a biological cell.

Nanophotonic approaches for super-resolution imaging and single molecule dynamics in living cells

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The quest for optical imaging of biological processes at the nanoscale has driven in recent years a swift development of a large number of nanoscopy techniques based on far-field optics. In parallel, within the nanophotonics community, photonic antennas have emerged as excellent alternative candidates to break the diffraction limit of light by enhancing electromagnetic fields into regions of space much smaller than the wavelength of light. In this contribution I will describe our efforts towards the fabrication of different nanoantenna probe configurations[1,2] as well as in-plane 2D antenna arrays for applications in nano-imaging and spectroscopy of living cells with unprecedented resolution and sensitivity[3-7]. By taking advantage of the superior optical performance of our in-plane 2D-antennas arrays together with their extreme planarity we have enquired on the nanoscale dynamics of multicomponent lipid bilayers and living cell membranes[5-7]. Our results reveal the coexistence of cholesterol-enriched fluctuating nanoscopic domains on mimetic and living cell membranes, in the microsecond scale and with characteristic sizes below 10nm[5-7]. These nanoscale assemblies might represent lipid raft precursors that in the absence of proteins and/or other molecular stabilizing factors, are poised to be highly transient.

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Unclonable fingerprints for anti-counterfeiting devices

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Nowadays, there is an increasing need for novel technical solutions for the authentication, identification and traceability of goods. Physical Unclonable Functions (PUFs) are the basis for highly secure anti-counterfeiting systems [1]. A PUF key is a physical manifestation of a cryptographic key, it is randomly generated and impossible to counterfeit.
Soft materials and, among them, liquid crystals are suitable candidates for the creation of PUFs since they are excellent optical materials capable to self-assemble in complex photonic structures and self-repair [2]. Here, we report on the possibility to obtain microscopic randomly generated fingerprints applying an electric field to dye doped cholesteric liquid crystal droplets encapsulated in a fluid matrix. Figure 1 shows a cholesteric microdroplet with fingerprints on the left and its binarized picture on the right.

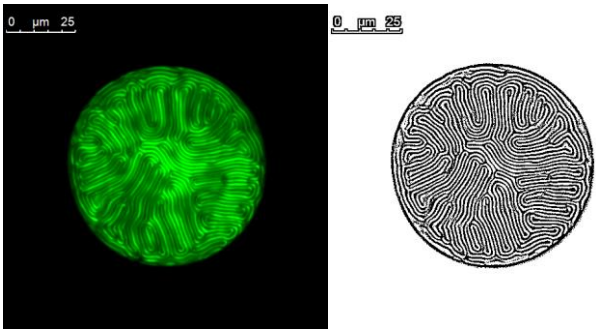

Figure 1. Dye doped cholesteric liquid crystals microdroplet, encapsulated in a fluid matrix, exhibiting fingerprint-like texture (left) and its binarized picture (right)

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Third Electronic Posters Session

- Bustamante *“Nonlinear dynamical interaction between a spherical metal nanoparticle and the surrounding gain media ”*
- Caicedo *“Intensity Steady State and Harmonic Field of a Gain-Assisted Silver Nanoshell ”*

Nonlinear dynamical interaction between a spherical metal nanoparticle and the surrounding gain media

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We study the plasmonic response of a spherical metal nanoparticle immersed in a dielectric medium with gain elements using a nonlinear generalization of the Mie theory for light scattering and the optical Bloch formalism. A classical electrodynamic approach allows us to make an attempt to solve a time-dependent electromagnetic field scattering problem by a sphere to find the electric fields near its surface. Then, by means of a free electron model and the interaction of the fields with the gain elements described by the Bloch equations, we try to get the time evolution of the polarization inside and outside the sphere to study the nonlinear amplification regime in the optical response of this system and the appearance of modes of higher order to the dipolar plasmonic mode of the linear regime.

Intensity steady state and harmonic field of a gain-assisted silver nanoshell

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In this work, we discuss the emission (SPASER) regimes of a nanostructure constituted by a metallic spherical shell whose core is filled by an active gain material.

We present a time-dynamical set of equations for the plasmonic field around such a particle and use it to discuss the stability of the widely accepted SPASER solution. We also show the existence of additional regimes of amplification and stimulated emission which are, to our knowledge, passed unnoticed until now.

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Friday 26

09:00 - 09:30	Ciracì *“Microscopic physics of large plasmonic systems: a quantum hydrodynamic approach”*
09:30 - 10:00	Aradian *“Loss compensation and emission of spherical plasmonic nanolasers”*
10:00 - 10:30	Veltri *“Is the emission regime in gain enhanced silver nano-shells an actual SPASER?”*
10:30 - 11:00	**Coffee Break**
11:00 - 11:30	Aizpurua *“Ultrafast Photocurrents Induced by Single-Cycle Optical Pulses in Nanoscale Gaps”*
11:30 - 12:00	Törmä *“Bose-Einstein condensation and K-point lasing in plasmonic lattices”*
12:00 - 12:30	Sivan *“Lightning-fast solution of scattering problems in nanophotonics: an effortless modal approach ”* / Schertel *“Quantitative Description of Disordered Photonic Media: from Resonant Transport to Structural Colors”*
12:30 - 13:00	Kavokin *“Pseudo-drag of a polariton superfluid”*
13:00 - 13:30	
13:30 - 14:00	
14:00 - 14:30	**LUNCH**
14:30 - 15:00	
15:00 - 15:30	Maier *“Hot-electron and ultrafast phenomena in nanostructured materials”*
15:30 - 16:00	van Hulst *“Looking at Single Photon Emitters on nm and fs Scale”*
16:00 - 16:30	Staude *“Light-emitting, nonlinear, and tunable dielectric metasurfaces ”*
16:30 - 17:00	**Coffee Break**
17:00 - 17:30	Méndez *“Magnetic mirror design based on magnetic dipole and electric quadrupole resonances”*
17:30 - 18:00	Bragas *“Optical reading of nanoresonators mechanically-excited by surface acoustic waves”*
18:00 - 18:30	Abbarchi *“Solid-state dewetting of Si(Ge)-based complex nano-architectures and their applications in photonics”*
18:30 - 19:00	Sáenz *“Asymmetry and Spin-Orbit interactions in light scattering by high refractive index particles”*
19:00 - 19:30	**Farewell Cocktail (GAIAS)**

Microscopic physics of large plasmonic systems: a quantum hydrodynamic approach

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Metals support surface plasmons at optical wavelengths and have the ability to localize light to sub-wavelength regions. Nano-gap plasmonic systems – in which two or more metallic nanoparticles are separated only few nanometers from each other by an insulating spacer – have been predicted to produce enormous field enhancements (as much as thousands of times that of the incident radiation) [1]. For the narrowest (<1 nm) gaps, light can be so tightly confined that the nonlocality associated with the dielectric response of the metal and quantum effects can have a strong impact on the scattering properties of the system, placing strict bounds on the ultimate field enhancement [2].

A reliable way to theoretically describe and numerically model optical properties of plasmonic nanostructures with different length scales requires methods beyond classical electromagnetism. In this context, it becomes very important to develop simulation techniques to take into account quantum microscopic features at the scale of billions of atoms. A promising solution is given by the hydrodynamic theory, which takes into account the nonlocal behavior of the electron response by including the electron pressure and it can be generalized so that it can describe electron spill-out and tunneling effects, including nonlocal broadening near metal surfaces [3-5]. This method allows to explore light-matter interactions in extreme scenarios in which microscopic features can strongly affect the macroscopic optical response.

In this talk, I will present the quantum hydrodynamic theory for plasmonics and will discuss some applications including, photon emission, strong-coupling and nonlinear optics.

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Loss compensation and emission of spherical plasmonic nanolasers

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Metamaterials, and more generally nanophotonics, based on plasmonic nanostructures, suffer from significant Ohmic losses. One way to circumvent this issue is to couple plasmonic structures with active material to mitigate losses. In cases where the amount of optical gain provided exceeds losses, one may observe extremely intense near and/or far fields, with sharp spectral features. These phenomena have been dubbed “spasing” and “nano-lasing”, as they are in several ways akin to macroscopic lasers [1].

I will present work carried out in the Metamaterials Group in Bordeaux, France over recent years, where we have endeavoured to model spasing and nano-lasing in various geometries involving single plasmonic nanoparticles, with the help of theoretical approaches of increasing complexity [2, 3, 4].

This work has allowed us to study optical properties such as lasing threshold, the initial stages of the lasing instability, emission width, and long-term dynamics.

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Is the emission regime in gain enhanced silver nano-shells an actual SPASER?

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The Gain enhanced Nano-shell, a metal nano-particle constituted by a gain rich dielectric core covered by a metal shell, is one of the most promising design for the realization of the Surface Plasmon Amplification by Stimulated Emission of Radiation or SPASER: the plasmonic equivalent of the LASER.

In this work, we present a time-dynamical set of equations for the plasmonic field around such a particle and we use it to discuss the widely accepted SPASER steady state solution. We also show the existence of an additional "broadband" stimulated emission regime, which could question the single line propriety necessary for the SPASER to be the actual plasmonic equivalent of a LASER.

Ultrafast photocurrents induced by single-cycle optical pulses in nanoscale gaps

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A nanoscale gap between two metallic nanoparticles is an ideal platform to exploit the interplay between electron currents and photonic excitations. The capability of the metallic gap to enhance the amplitude of the induced plasmonic field produces a variety of non-linear effects [1] which can be exploited in different applications of optoelectronics, such as optical rectification, light emission driven by DC currents, or high-harmonic generation, among others. Furthermore, in ultranarrow gaps, tunneling of electrons at optical frequencies has been found to screen the plasmonic bonding gap resonance, and activate a new distribution of optical modes characterized by optical charge transfer [2].

Here we address the complex dynamics of photoelectrons driven by single-cycle optical pulses in nanoscale gaps. By solving Schrödinger equation within the framework of Time-Dependent Density Functional Theory (TDDFT), the complex dynamics of the electrons photoemitted across the gap can be monitored, identifying ultrafast electron bursts where electron quiver occurs when the amplitude of the induced field at the plasmonic gap is reversed within the optical cycle. The properties of the amplitude and carrier-envelope phase (CEP) of the incident pulse, together with the gap length determine the complex electron dynamics [3].

Experimental measurements of the current autocorrelations for pairs of such pulses with controlled relative delay between them, confirms the ultrafast dynamics of the photoelectrons in the gap and its complexity.

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Bose-Einstein condensation and K-point lasing in plasmonic lattices

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Bose-Einstein condensation has been realized for various particles or quasi-particles, such as atoms, molecules, photons, magnons and semiconductor exciton polaritons. We have recently experimentally realized a new type of condensate: a BEC of hybrids of surface plasmons and light in a nanoparticle array [1]. The condensate forms at room temperature and shows ultrafast dynamics. We utilized a special measurement technique, based on formation of the condensate under propagation of the plasmonic excitations, to monitor the sub-picosecond thermalization dynamics of the system. This new platform is ideal for studies of differences and connections between BEC and lasing [2,3]. While usually lasing in nanoparticle arrays occurs at the centre of the Brillouin zone, we have now demonstrated lasing also at the K-point [4]. The lasing mode can be identified with the help of group theory. Clear lasing is observed despite a narrow band gap at the K-point, which is promising considering future studies of topological photonics. Nanoparticle arrays are well suited for studies of topological phenomena due to the easy tunability of the array geometry and the system symmetries.

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Lightning-fast solution of scattering problems in nanophotonics: an effortless modal approach

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Modal expansion techniques have long been used as an efficient way to calculate radiation of sources in closed cavities. With one set of cavity modes, calculated once and for all, the solution for any arbitrary configuration of sources can be generated almost instantaneously, providing clear physical insight into the spatial variation of Greens function and thus the local density of states. Nanophotonics research has recently generated an explosion of interest in generalizing modal expansion methods to *open* systems, for example using quasinormal mode / resonant state expansion [1]. Yet one major practical obstacle remains: numerical generation of resonator modes is slow and unreliable, often requiring considerable skill and hand guiding.

Here, we present a practical numerical method for generating suitable modes, possessing the trifecta of traits: speed, accuracy, and reliability. Our method is capable of handling arbitrarily-shaped lossy resonators in open systems. It extends existing methods that expand modes of the target structure using modes of a simpler analytically solvable geometry as a basis [1]. This process is guaranteed to succeed due to completeness, but is ordinarily inefficient because optical structures are usually piecewise uniform, so the resulting field discontinuities cripple convergence rates. Our key innovation is use of a new minimal set of basis modes that are inherently discontinuous, yet remarkably simple. We choose to implement our method for the Generalized Normal Mode Expansion (GENOME) [2] which unlike its alternatives [1], is valid for any source configuration, including the important case of sources exterior to the scatterer. We achieve rapid exponential convergence, with 4 accurate digits after only 16 basis modes, far more than is necessary. This also means lightning-speed simulation results, faster by 2-3 orders of magnitude compared to mode generation using COMSOL. Finally, our method is extremely reliable, as it culminates in a small dense linear eigensystem. No modes go missing, nor are there spurious modes that need to be manually discarded, which is critical to the success of modal expansion methods.

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Quantitative Description of Disordered Photonic Media: from Resonant Transport to Structural Colors

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Ordered assemblies structured at the scale of the wavelength, such as photonic crystals, are a class of well understood optical materials. In contrast, their disorder counterpart, photonic glasses (PG) [1] have been less explored, despite their most interesting isotropic properties. As an example, isotropic structural colors based on resonances in the reflectance has been experimentally realized and first attempts to explain their optical appearance by Mie scattering and spatial short-range correlations showed qualitative agreement [2]. In a recent publication, we provided a first model that quantitatively describes light transport in densely packed PGs made of polystyrene (PS) spheres [3]. The main contributions to the calculated scattering strength are resonant Mie scattering of the spherical scatterers, spatial short-range correlations and the choice of an appropriate effective index. Here a coated sphere effective refractive index approach was used.

In a new study, the appropriateness of the model is tested for the description of light transport in high index materials, namely tunable PGs made of titanium dioxide [4]. To demonstrate the presented model's strength we further use it to predict isotropic structural colors. We prepare optical thin films of PGs from PS spheres. The samples show isotropic structural colors from blue, green to red. The model explains the observed resonant features remarkably well and is able to predict all structural colors in these materials. To conclude, the earlier introduced scattering model [3] serves as an accurate description of resonant transport in photonic glasses and can be used to make predictions about the reachable space of isotropic structural colors by PGs.

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Pseudo-drag of a polariton superfluid

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The common wisdom tells us that the drag effect is incompatible with superfluidity. A superfluid is characterized by zero viscosity, hence it cannot be dragged. The question we would like discuss here is: does it apply to polariton superfluids as well? The theoretical work by Berman, Kezerashvili and Lozovik offers a negative answer to this question [1]. The authors of Ref. [1] propose the disappearance of drag as a smoking gun for the superfluid transition in an exciton-polariton liquid. This conclusion is challenged by the recent experimental work [2], where the propagation of a polariton superfluid in the presence of an electric current is studied. The superfluid created in a high-Q planar microcavity by a non-resonant optical pumping is propagating due to the gradient of the cavity width and due to the repulsion of polaritons from a spatially localized excitonic reservoir. An in-plane electric current is induced in this system by the application of an external voltage. Surprisingly, the speed of the superfluid appears to be sensitive to the value and the direction of the electric current. Namely, if the electric current flows in the same direction with the superfluid, the propagation speed of the superfluid increases. If the electric current is flowing in the opposite direction, the superfluid propagation is decelerated. The inverse effect is observed as well: the current voltage characteristic of this microcavity device becomes strongly asymmetric in the presence of the propagating superfluid.

In this communication, we shall give our vision on the possible origin of the drag effect in a system containing a polariton superfluid and a Fermi gas of free electrons in the presence of an electric field. We propose two possible reasons of this effect. The first mechanism is the drag of the superfluid fraction by the normal fraction of the polariton gas due to the virtual particle exchange between these two fractions. This effect is known in liquid He, and it can be described within the fluctuation theory by introducing an analogue of the Ginzburg-Levanyuk number that describes the fluctuation correction to the mean-field theory. The normal component of the polariton gas that constitutes the reservoir is dragged by propagating electrons in a conventional way, as described in [1]. For polaritons, the effective Ginzburg-Levanyuk number is governed by the ratio of the polariton-exciton interaction constant to the energy splitting between the condensate and the reservoir. The second mechanism is the drag of the superfluid fraction by the normal

fraction due to the real transitions of excitons from the reservoir to the condensate and the radiative decay of the exciton-polaritons in the condensate. If the mean momentum-per-particle in the normal fraction is different from the momentum-per-particle in the superfluid fraction, the incoming flow of reservoir particles accelerates the condensate. The normal fraction is dragged by an electric current as we discussed above. This effect is governed by the polariton decay rate, and it vanishes in the limit of the infinite polariton life-time. We describe both effects with use of three coupled differential equations: the generalized Gross-Pitaevskii equation for the polariton superfluid where two drag terms are introduced and the coupled classical drag-diffusion equations for the exciton reservoir and free electrons. We analyze the comparative contribution of two drag mechanisms described above.

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Hot-electron and ultrafast phenomena in nanostructured materials

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The combination of nanoscale metallic or dielectric resonators with ultrathin materials provides new opportunities for optoelectronic devices. Here we present recent studies of our group on relevant physical processes occurring in the constituent materials:

Firstly, we show that the photoresponse in two-dimensional materials such as graphene can be amplified via an electronic temperature gradient [1]. Using a combination of plasmon-resonant and non-resonant contacts, we demonstrate an additional contribution to the photocurrent, apart from the well-studied photovoltaic effect. Secondly, we focus on the optical properties of thin, air-stable perovskite layers. Here we demonstrate harmonic generation with record efficiencies for a particular film thickness, due to the interplay of re-absorption and phase-matching. Lastly, we study the response of metal-clad dielectric nanoresonators to ultrashort light pulses with a FWHM of around 20 fs. The optical Kerr effects allows for ultrafast modulations in reflectivity and transmission for nanoresonators excited at their fundamental anapole mode.

Our studies point the way towards employing these phenomena in new generations of optoelectronic devices.

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Looking at single photon emitters on nm and fs scale

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Tracing of individual molecules both in space and in time, provides super-resolution images of intra- and inter-molecular dynamic processes, all beyond the ensemble [1,2]. A host of important dynamic processes occurs on fs-ps timescale, such as electronic relaxation/dephasing, energy & charge transfer, vibrational relaxation, photo-dissociation-ionization, photo-isomerization. Yet capturing fast dynamics is fundamentally limited by the ns lifetime of the detected fluorescence.

Here first, we challenge ultrafast transient absorption of a single molecule and have set out to probe the non-linear ultrafast response of the single molecule using a broadband laser in an effective 3-pulse scheme with fluorescence detection. 2D electronic spectroscopy is getting into reach [3]. Alternatively, stimulated emission has the advantage of coherence and unity quantum efficiency, compared to fluorescence. Moreover depleting the excited state rapidly reduces photodissociation. Thus, we have set out to directly detect the stimulated emission from individual molecules at ambient conditions, to disentangle ultrafast fs-ps dynamics in the excited state, by both stimulated emission detection and depletion [4].

Next, we enhance the sensitivity, resolution and rates using the local optical near-fields of plasmonic nano-antennas. We apply both deterministic scanning probe [5,6] and stochastic localisation [7] mapping of the nanoscale plasmon-molecule interaction, to optimize the coupling strength and ultrafast interaction. We show antenna coupling up to 100 GHz, strong enhancement of photosynthetic complexes (LH2) [8], detection of first single FMO complexes at room temperature and local maps of defect emitters in hexagonal boron nitride with 20 nm spatial response.

Finally, time permitting, I might address interferometric mapping of single emitters, where the detection of both amplitude and phase allows single shot full 3D localisation and computational focussing.

I will conclude with an outlook of the challenges ahead and the perspectives of addressing coupled networks in real nano-space and on femtosecond timescale.

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Light-emitting, nonlinear, and tunable dielectric metasurfaces

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Metasurfaces composed of designed all-dielectric Mie-resonant nanoparticles offer unique opportunities for controlling the properties of light fields [1]. Such metasurfaces can e.g. impose a spatially variant phase shift onto an incident light field, thereby providing control over its wave front with high transmittance efficiency. However, most semiconductor metasurfaces realized so far were passive and linear, and their optical response was permanently encoded into the structure during fabrication. Recently, a growing amount of research is concentrated on the integration of emitters and optical nonlinearities into these metasurfaces, and on obtaining dynamic control of their optical response.

This talk will provide an overview of our recent advances in light-emitting, nonlinear, and tunable Mie-resonant all-dielectric metasurfaces. In particular, we have studied spontaneous emission from semiconductor metasurfaces integrated with various types of emitters, including semiconductor quantum dots [2], monolayers of transition metal dichalcogenides, and trivalent lanthanide ions exhibiting magnetic-dipole dominated electronic transitions [3]. We have also investigated harmonic generation and nonlinear mixing processes [4] in metasurfaces composed of III-V semiconductors. Our results show that the directional, spectral and polarization properties of both the spontaneously emitted and the nonlinear generated light can be tailored by the metasurface design. Furthermore, by integrating silicon metasurfaces into a nematic-liquid-crystal cell, we have demonstrated tuning of their linear-optical transmittance and reflectance spectra at near-infrared frequencies, and we have achieved dynamic control of the emission from a silicon metasurface coupled to a fluorescent substrate [5]. Recently, by use of a photoalignment material layer on top of the metasurface, we could also obtain pronounced liquid-crystal tuning of the metasurface response in the visible spectral range, and we demonstrated an exemplary metasurface display device based on this approach.

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Magnetic mirror design based on magnetic dipole and electric quadrupole resonances

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A magnetic mirror is a highly reflective optical device that produce no phase changes between the incident and reflected fields. This is in contrast with the mirrors made with good conductors, for which the reflected field tends to be out of phase with the incident one. In this work, we consider the design of magnetic mirrors in the near infrared region of the spectrum. The device consists of a subwavelength layer of two-dimensional dielectric particles, and the design is based on the properties of the individual particles which, in the spectral region considered, have magnetic dipole, electric dipole and electric quadrupole resonances.

The central idea is to search for conditions in which the light backscattered by a particle has a zero phase lag with respect to the incident field. Employing physical arguments, we conclude that this can occur when the electric dipolar contribution vanishes. Optimizing the form of the cross section, we find a case in which the vanishing of the dipolar contribution coincides with an in-phase condition for the magnetic dipole and the electric quadrupole contributions. The resulting scattering pattern of the particle resembles that of an electric dipole, with the difference that the forward and backscattered lobes have the same phase. Based on these results, we describe a procedure to design metasurfaces that behave as magnetic mirrors at prescribes wavelengths.

Optical reading of nanoresonators mechanically-excited by surface acoustic waves

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Surface acoustic waves (SAW), which are known since nineteenth century Rayleigh works [1], exist over a wide range of frequencies, from the ultra-low frequency seismic waves to the surface phononic waves in materials. Pushing SAW wavelength to the nanometer scale enables to envision a broad range of applications in the field of nanomaterial and interfaces characterization as well as in signal processing, since the elastic wave penetration is just a fraction of its wavelength.

In this talk, we report that vibrational modes in the GHz regime sustained by single optically-excited plasmonic nanoantennas can significantly couple to nm-SAWs on the underlying quartz substrate and thereby probed in the acoustic far field by a second nanoantenna which is mechanically-excited and optically read. Distance-dependent detection times reveal that the emitted SAW show the characteristic propagation velocities and amplitude decay akin to Rayleigh waves in semi-infinite elastic substrates, as investigated experimentally by pump-probe techniques and with FEM calculations.

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Solid-state dewetting of Si(Ge)-based complex nano-architectures and their applications in photonics

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Dewetting is a ubiquitous phenomenon in nature: many different thin films of organic and inorganic substances share this shape instability driven by surface tension and mass transport. This spontaneous phenomenon leads a thin film to break and drip in isolated islands. Here, I will address two distinct cases of solid-state dewetting: 1) templated dewetting of silicon and 2) spontaneous dewetting of silicon-germanium.

Templated solid-state dewetting can be used to frame complex nanoarchitectures, nanowires (up to 0.75 mm long) and connected circuits of monocrystalline silicon on insulator with unprecedented precision and reproducibility over large scales [1]. Phase-field simulations quantitatively benchmark the experimental results revealing the dominant role of surface diffusion as a driving force for dewetting and the role of faceting in stabilizing the nanostructures. I will discuss the use of these ordered structures as dielectric Mie resonators for visible and NIR light manipulation [2,3].

Spontaneous dewetting of thick SiGe layers leads to the onset of spinodal-like structures as accounted for by the features of Minkowski-functionals and evolution of Betti numbers [4]. The formation of these disordered structures is interpreted in the framework of the Cahn-Hilliard-Cook theory of phase separation in analogy with spinodal dewetting of polymers and liquid-metals. I will discuss the possibility to exploit this bottom-up, self-assembly method to form hyper-uniform, dielectric metasurfaces at visible and near-infrared frequencies [5] over ultra-large scales.

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Asymmetry and Spin-Orbit interactions in light scattering by high refractive index particles

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Light spin-orbit angular momentum (AM) coupling phenomena are receiving an increasing interest in the analysis of scattering processes from sub-wavelength objects [1]. Spin-orbit interaction (SOI) of light can lead to optical mirages, i.e. a perceived displacement in the position of a particle due to the spiraling structure of the scattered light [2]. Here we will discuss the relevance of SOI phenomena in light scattering from subwavelength high refractive index (HRI) dielectric nanoparticles [3,4]

The optical properties of Silicon nanoparticles and other HRI materials are dominated by their dipolar electric and magnetic responses [5,6,7]. While for electric dipoles, the SOI induced optical mirage lead to subwavelength maximum displacements, we will see that the optical mirage depends strongly on the ratio between electric and magnetic dipolar responses. At the so-called first Kerker condition, there is a considerable enhancement (far above the wavelength) of the SOI mirage related to the emergence of an optical vortex in the backscattering direction [3].

The remarkable angular dependence of these optical mirages and those of the intensity, degree of circular polarization (DoCP) and spin and orbital angular momentum of scattered photons are all linked, and fully determined, by the dimensionless "asymmetry parameter" *g*, being independent of the specific optical properties of the scatterer. Interestingly, for g not equal 0, the maxima of the optical mirage and angular momentum exchange take place at different scattering angles. We further we show that the *g* parameter is exactly half of the DoCP at a right-angle scattering, which opens the possibility to infer the whole angular properties of the scattered fields by a single far-field polarization measurement.

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Thank you for coming!