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ONLINE INTERNATIONAL CONFERENCE

June 10, 2021

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FOREWORD

On behalf of the Organising Committee we take great pleasure in welcoming you for the 1st edition of the "SPPM2021" Online Conference (Spintronics, Photonics, Phononics & Magneto-Optics): June 10, 2021.

The SPPM2021 Online conference will present the most recent advances in fundamental research and related applications in Photonics, Phononics, Spintronics or Magneto-Optics. This online event aim is to bring together top researchers and future leaders encouraging interactions between students, young speakers, and senior figures in the field.

The topics will cover the experimental and theoretical aspects of light interaction with nanoscale objects and nanostructured materials. SPPM2021 will also explore different cutting edge research topics where phonons play a central role such as quantum photonics, nanoscale thermal transport, topological phononics, nanophononics and optomechanics.

We are indebted to IFIMAC/UAM (Spain) for their help and financial support. We also would like to thank all the speakers and participants that join us this year.

Hope to see you in-person in Bilbao (Spain) for the 3PM2021 International Conference organised within Imaginenano2021 (www.imaginenano.com/2021/PPM2021.php).

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ABSTRACTS - INDEX

Speakers/Orals/FlashPosters & ePosters list:

Alphabetical order

KEYNOTE

Nanocrystalline silicon, a material for future applications

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Nanocrystalline silicon is an interesting candidate for electromechanical and optomechanical systems due to the mechanical, thermal and optical properties and isotropy of the material. The properties have been probed by various characterisation tools, including thermoreflectance, optomechanical cavities, electromechanical systems and picoacoustics. Interestingly, nanobeams made of nanocrystalline silicon show higher Q-values and dynamical bandwidths than single crystalline silicon and provide a highly flexible technology platform. In this presentation, we will describe the specific properties of nanocrystalline silicon and the prospects in NEMS and NOEMS applications.

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Plasmon-exciton coupling: electromagnetic field quantization and emitter description beyond the two-level, point-dipole approximation

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Plasmonic nanostructures enable light-matter interaction strengths well beyond those provided by semiconductor devices. This makes it possible the emergence of polaritonic phenomena at the nanoscale and at a few, or even single, molecule levels. In this seminar, I will explore classical and quantum optical effects behind this strong plasmon-exciton coupling, with particular focus on two different topics. First, I will treat the quantization of the electromagnetic fields in both purely metallic [1] and hybrid metallo-dielectric [2] cavities. Second, I will discuss different configurations in which the strong confinement of plasmonic fields unveils features of quantum emitters not accounted for in a two-level-system and point-dipole approximation. Namely, I will explore the far-field signatures of light-forbidden molecular transitions [3] and the impact of the vibrational degrees of freedom in the plasmonic Purcell effect [4].

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Quantum interactions between free electrons and optical excitations

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The control over the longitudinal and transverse properties of electron beams has recently experienced a tremendous boost because of the combination of new advances in electron microscope instrumentation, particularly in combination with ultrafast light pulses and the ability to synthesize femtosecond electron wave packets. In this presentation, we overview key concepts describing the associated interactions between free electrons, light, and photonic nanostructures, making emphasis on quantum aspects and exploring several remaining challenges and emerging opportunities. We further discuss potential applications in noninvasive spectroscopy and microscopy, the possibility of sampling the nonlinear optical response at the nanoscale, the manipulation of the density matrices associated with free electrons and optical sample modes, optical modulation of electron beams, and improved schemes for electron-driven light emission over a wide range of photon energies.

This work has been supported in part by the European Research Council (Advanced Grant 789104-eNANO), the European Commission (Horizon 2020 Grants FET-Proactive 101017720-EBEAM and FET-Open 964591-SMART-electron), the Spanish MINECO (MAT2017-88492-R and Severo Ochoa CEX2019-000910-S), the Catalan CERCA Program, and Fundaciós Cellex and Mir-Puig.

Wave scattering in chiral parity-time symmetric metamaterials

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Abstract

Chiral electromagnetic metamaterials, i.e. structures with building units lacking any mirror-symmetry plane, are a class of metamaterials associated with unique electromagnetic wave polarization effects and polarization control capabilities. Despite the fact that such metamaterials are inherently mirror asymmetric, we have recently shown that they can exhibit full parity-time (PT) symmetry [1], a symmetry associated with peculiar wave propagation and scattering characteristics (e.g. asymmetric reflection, loss-induced transparency, unidirectional invisibility, etc.). We will show in this talk that combining chirality and PT-symmetry in a single metamaterial structure one can achieve unique propagation and scattering characteristics [2-3]. These characteristics include multiple exceptional points, asymmetric circular dichroism, asymmetric optical activity (see Fig. 1), and others. All these novel effects can be highly and easily controlled in a scattering system by adjusting the impinging wave direction and polarization, giving thus to chiral PT-symmetric systems a great potential in a large variety of applications related with dynamic electromagnetic wave polarization control**.**

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FIGURES

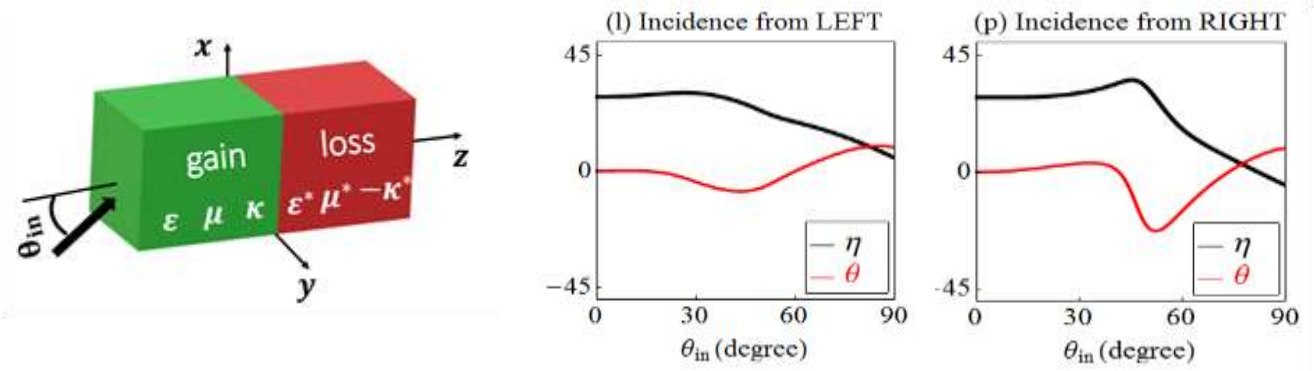

Figure 1: *Left:* The model system discussed in the present study: A simple chiral PT-symmetric bilayer (infinite along the *x* and *y* directions) of constant material parameters, permittivity (ε), permeability (μ) and chirality (κ). (the * in the parameters denotes the complex conjugate). *Right:* Optical activity (θ) and transmitted wave ellipticity (η) as a function of incidence angle for a monochromatic wave incident from the left and from the right side of the bilayer shown in the left panel.

Removing SERS Memory Effects in Plasmonic Superlattices

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The development of continuous monitoring systems requires in situ sensors that are capable of screening multiple chemical species and providing real-time information. Such in situ measurements, in which the sample is analyzed at the point of interest, are hindered by underlying problems derived from the recording of successive measurements within complex environments. In this context, surface-enhanced Raman scattering (SERS) spectroscopy appears as a non-invasive technology with the ability of identifying low concentrations of chemical species, as well as resolving dynamic processes under different conditions. To this aim, the technique requires the use of a plasmonic substrate, typically made of nanostructured metals such as gold or silver, to enhance the Raman signal of adsorbed molecules (the analyte). However, a common source of uncertainty in real-time SERS measurements originates from the irreversible adsorption of (analyte) molecules onto the plasmonic substrate, which may interfere in subsequent measurements. This so-called "SERS memory effect" leads to measurements that do not accurately reflect varying conditions of the sample over time. We introduce herein the design of plasmonic substrates involving a non-permeable poly(lactic co-glycolic acid) (PLGA) thin layer on top of the plasmonic nanostructure, toward controlling the adsorption of molecules at different times. The polymeric layer can be locally degraded by irradiation with the same laser used for SERS measurements (albeit at a higher fluence), thereby creating a micrometer-size window on the plasmonic substrate available to molecules present in solution at a selected measurement time. Using SERS substrates coated with such thermolabile polymer layers, we demonstrate the possibility of performing over 10,000 consecutive measurements per substrate, as well as accurate continuous monitoring of analytes in microfluidic channels and biological systems.

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FIGURES

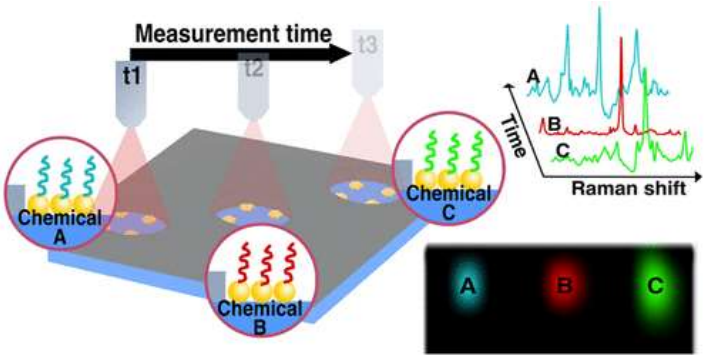

Figure 1: Schematic view of the use of an PLGA-covered plasmonic substrate for sequential SERS measurements, upon localized PLGA removal by photothermal heating.

Dielectric nanophotonics for reconfigurable planar optics and biosensing

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In this talk, we present our recent advances in the development of novel nanophotonic platforms for both imaging and biosensing. We first focus on our recent efforts towards reconfigurable metasurfaces. Our approach relies on dynamically engineering the refractive index in the close vicinity of a silicon metalens by means of a resistor embedded in a thermo-optical polymer. We demonstrate precise and continuous tuneability of the focal length, and achieve focal length variations larger than the Rayleigh length for voltages as low as 10V. The system time-response is of the order of 100ms, with the potential to be reduced with further integration [1]. Beyond focus adjustment, our technology, when combined with a genetic algorithm optimization, can be applied to generate almost any wavefront, with key applications, especially to adaptive optics [2].
In the second part of the talk, we discuss the use of dielectric nanoresonators in the context of biosensing and lab-on-a-chip technology. In our approach, Si nanocylinders on quartz are integrated into a state-of-the-art PDMS microfluidic environment. We first demonstrate that periodic arrays of Si nanocylinders can be used for the specific detection of cancer markers in human serum with sensitivity levels comparable to the one obtained with gold nanoantennas [3]. We also study the respective contribution of electric and magnetic resonances to the sensing performance [4]. Finally, we explore the use of dielectric nanoresonators for chiral molecular sensing, demonstrating, for the first time, enantio-selective differentiation with improved performance over plasmonics [5].

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Studying heat transport in 2D materials using ultrafast light

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Understanding heat transport is relevant for applications such as thermal management and thermoelectrics. Our group has been studying transport of heat carried by both electrons and phonons in systems based on 2D materials using newly developed techniques exploiting ultrafast light pulses. We will present two recent results.

The first topic is diffusion of heat carried by the electron system in graphene, which we have studied using a novel spatiotemporal thermoelectric microscopy technique with femtosecond temporal and sub-100 nm spatial control [1]. With this technique we follow electronic heat flow in space and time at room temperature, and observe electronic heat flow consistent with charge flow in the “normal” diffusive regime. In the hydrodynamic time window before momentum relaxation occurs, and under so-called “Dirac-fluid” conditions, we observe much more significant heat spreading. Importantly, we show that heat spreading is so efficient that the thermal conductivity of the electron system can be larger than the already record-high thermal conductivity of the phonon system of graphene. This result is relevant for thermal management applications where heat needs to be extracted as fast as possible from sub-micron-sized local hot spots.

The second topic we will discuss is a novel technique we have developed to study in-plane heat diffusion in thin films [2]. Most optical techniques for studying thermal transport suffer from relatively complex models that require several known material parameters in order to extract thermal transport properties and the need for relatively strong heating. In contrast, our technique – based on spatiotemporal pump-probe microscopy – does not require any material input parameters and yields the material’s diffusivity from a direct comparison with a simple Fourier diffusion model, under relatively weak heating conditions. We demonstrate the power of this technique by extracting the diffusivity of suspended films of $MoSe_2$ and WSe_2, prototypical transition metal dichalcogenide materials. We expect that this technique will be a valuable tool for studying heat transport in thin films.

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Optomechanical Frequency Conversion: Fundamentals and Applications in Photonics and Phononics

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In optomechanical systems, radiation pressure couples optical and mechanical degrees of freedom. This interaction has been exploited for extremely sensitive displacement measurements and control over the quantum states of macroscopic objects. Suitable laser drives induce a coherent transfer of optical to mechanical states and vice versa. This simple mechanism leads to a powerful array of applications for quantum and classical information processing. As the photon-phonon conversion spans a wide frequency difference, it allows the realization of coherent interfaces between optical and microwave fields mediated via a mechanical mode, and more generally transduction between various degrees of freedom that couple to nanomechanical resonators. Moreover, since the conversion can break time-reversal symmetry, it allows nonreciprocal functionality such as photonic and phononic isolation and circulation, polarization conversion, unidirectional amplifiers, high-frequency phonon lasing, and the emergence of topological phases of light and sound. I will review the state of the art in the field and our latest advances in these directions.

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INVITED

Bound in the continuum modes and multimodal physics in indirectly-patterned hyperbolic media

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The general premise of nanophotonics involves shrinking light to the subwavelength nanometric scale, thereby compressing and enhancing light-matter interactions. Innovations in nanocavity design approach new regimes of light-matter-interactions[1]. However, shrinking light typically comes at a cost – absorption losses, which plague all existing nanocavity designs. Fig. 1a visually summarizes the state of the art in nanocavity research, showing that cavity performance progressively worsens beneath the 100 nm scale (i.e. for $V < 10^{-4}\ \lambda_0^3$, with λ_0 the vacuum wavelength). A possible route to strong nanoscale confinement lies with hyperbolic Phonon polaritons (PhPs), which can exhibit very high momenta modes. Indeed cavities with $Q > 200$ and of sizes of ~300 nm have been demonstrated in hexagonal Boron Nitride (hBN) [2]. However, further size reduction is inhibited by nanoscale damage intrinsic to the conventional cavity design.
Here, we use ideas from bound in continuum (BIC) physics [3] to make nanocavities that combine high-quality factors with ultra-small modal volumes, reaching the previously unattainable $Q > 100$ in a cavity size <100nm and with mode volume confinement above 10^9. Unlike conventional cavities our nanocavities are indirectly patterned and consequently, the cavity modes have a plethora of modes the cavity can couple to. Accordingly, cavity is performance is limited by leakage to impedance mismatched modes outside of the cavity. But to our surprise, we find the cavities perform significantly better then expected from impedance mismatch considerations. We attribute this quality factor enhancement to a novel model of multimodal reflection. We investigate this multimodal reflection mechanism in both theory and experiment (using scattering-type near-field microscopy) and show it's conceptual relation to a new (hyperbolic) type of BICs.

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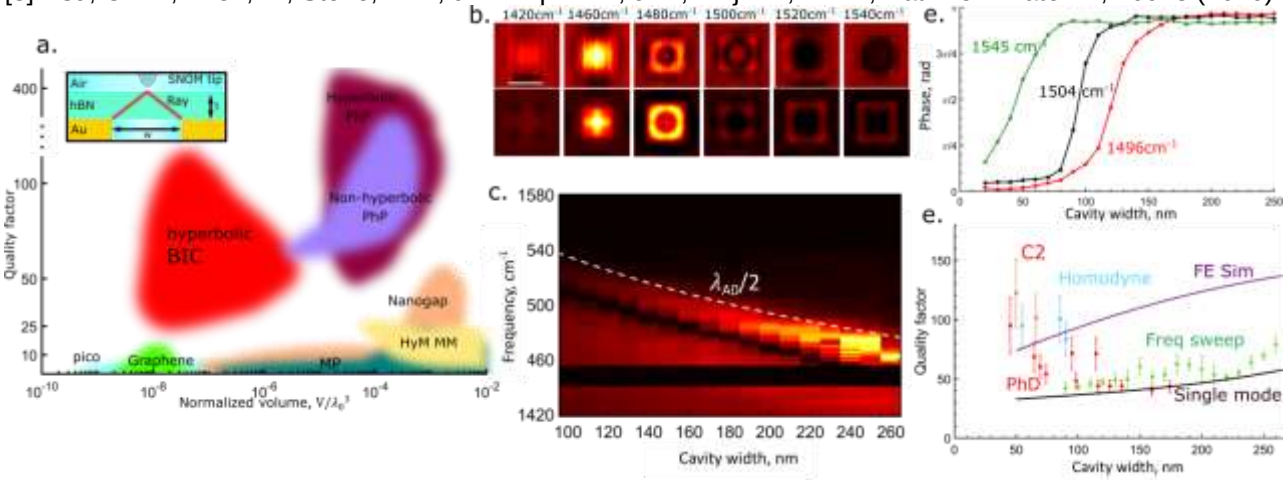

Figure 1: a. Survey of nanocavity quality factors and volumes. Different colors correspond to reported values of different cavity types (HyM MM stands for hyperbolic metamaterial, MP stands for metallic particle) and the red blob represents the values in this work. Inset shows system schematics **b.** Measured nearfield signal at different excitation wavelengths, showing the passage through a resonance in a 200nm wide cavity **c.** Spectrum of cavity response as a function of the cavity width. The narrowness of the spectral response is indicative of high quality factors. The weakening of the signal below 100nm size is due to sample drift and detailed measurements show that the quality of the cavity does not diminish. The white line represents the half wavelength of the zero order PhP mode, where the cavity mode is expected. **d.** Measured SNOM phase as a function of cavity showing a π phase-jump across the resonance. **e.** Quality factor vs. cavity. Solid black line shows the theoretical upper-bound limit that can be attained by neglecting higher order modes and the purple line is a finite element simulation that includes the ray-like propagation and reflection. The measured values have been extracted by three different type of measurements (see SI): frequency sweeps (green), pseudoheterodyne scans (red for cavity set C1 and orange for cavity set C2) and homodyne amplitude scans (light blue). Different extraction methods are in general agreement and in all cases exceed the single mode theory. Theory and simulations are for a 25nm h11BN flake, similar to cavity set C1.

Nonlinear dynamics in novel plasmonic and spintronic systems

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Nonlinear optical processes are vital for fields including telecommunications, signal processing, data storage, spectroscopy, sensing, imaging and computing. However, practicable optical nonlinearities are difficult to achieve due to fundamental physical limitations. Indeed, nonlinear optical interactions are possible mostly when high-power laser light and certain natural or artificial optical materials are combined together. This challenge shapes the current efforts in the field of nonlinear photonics aimed at achieving strong optical nonlinearities on demand using low-power light and nanostructures [1]. However, despite the recent progress in this area, even the strongest nonlinear optical effects observed to date are much weaker than ordinary nonlinear effects observed in many other common physical systems [1]. For example, in many acoustic systems nonlinear effects are so strong that special technical measures need to be taken to eliminate them. Therefore, it has been suggested that the robustness of acoustic nonlinear effects could be transposed to the optical domain and used in photonic devices [1]. The first part of this talk focuses on potential implementations of this idea.

It is well-known that liquid drops, gas bubbles and vibrations, which are ubiquitous in both everyday life and technology, exhibit intriguing nonlinear dynamics phenomena [2, 3]. For example, using a low-pressure ultrasound wave propagating through a liquid with gas bubbles one can readily generate up to 20 higher-order harmonics of the fundamental ultrasound frequency. This is a remarkable results when compared with the ability of nonlinear-optical systems to reliably generate just several harmonics of the fundamental frequency of the incident high-power laser light. Exploring this topic further, we demonstrated that liquid nanodroplets of gallium and its metal alloys exhibit both conventional plasmonic effects in the UV spectral range and nonlinear vibrations. We observed that nonlinear deformations of the surface of the droplets change their plasmonic properties in a very fascinating way [1]. We also theoretically demonstrated that cavitation (violent collapse) of a gas bubble near a liquid metal surface can result in strong emission of UV light through the effect called sonoluminescence, and that so-generated light can, in turn, excite surface plasmon resonances at the interface between the liquid metal and the liquid hosting the bubble [4].

The second part of the talk focuses on nonlinear dynamics in spin-torque nano-oscillators (STNOs) equipped with a delayed feedback circuit. Such STNOs can be used to remember and recognise patterns and therefore are promising candidates for physical reservoir computing (RC) systems [5-7]. Whereas RC has already been demonstrated in delayed-feedback STNOs [5], those systems employ vortex-type STNOs but the feedback signal is obtained by passing the envelope of the signal generated by the oscillator through a diode. Here, we suggest that non-vortex STNOs—those that rely on the ferromagnetic resonance (FMR) effect to generate microwave oscillations [8, 9]—can be used in RC systems. We also demonstrate the possibility of creating a feedback circuit using the delayed signal generated by the oscillator without passing it through a diode.

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High performance infrared magnetoplasmonics with transparent conductive oxide nanostructures

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Magnetoplasmonics, the combination of magnetic fields and light polarization to actively and remotely modulate the plasmonic response of nanostructures triggered significant improvements in optical nanodevices for telecommunications and refractometric sensing. Two main factors guide the design of high performance magnetoplasmonic platforms: a strong modulation of the plasmonic response and a sharp plasmon resonance. Within this framework, noble metal nanocrystals [1], nickel ferromagnetic nanodisks [2] or hybrid bimetallic nanostructures [3] have been proposed. While noble metals offer relatively sharp resonances, their weak magnetic response limits applicability. On the other hand, hybrid or ferromagnetic magnetoplasmonic nanostructures offer strong field response, at the cost of severely broadened resonances.
To overcome these issues, we propose a paradigm shift in material choice, shifting the attention to a novel class of plasmonic materials: transparent conductive oxides. Here we show that colloidal dispersions of tin-doped indium oxide (ITO) nanoparticles, with a sharp plasmon resonance in the near infrared, afford a 20-fold enhanced magnetic modulation with respect to Au, as detected by magneto-optical spectroscopies. We ascribe the enhanced magneto-optical response to the reduced free electron effective mass (m^*) of free carriers in ITO with respect to most metals, which in turn boosts the magnetic modulation. The latter is given in first approximation by the cyclotron frequency ω_C, which is inversely proportional to m^* and directly proportional to the applied field [1,4]. A further enhancement of the magneto-optical response was achieved in F- and In-co-doped cadmium oxide (FICO) nanoparticles, which display a 2-fold reduced plasmonic line width with respect to ITO and comparable effective mass [5,6].
Finally, using FICO NCs in a proof of concept magnetoplasmonic refractometric sensing experiment we obtained a superior refractive index sensitivity with respect to the most promising magnetoplasmonic systems reported in the literature [1-3] and performance competitive with the current state of the art of plasmonic refractometric sensing employing extinction spectroscopy [7], with the advantage of not requiring complicate curve fitting.

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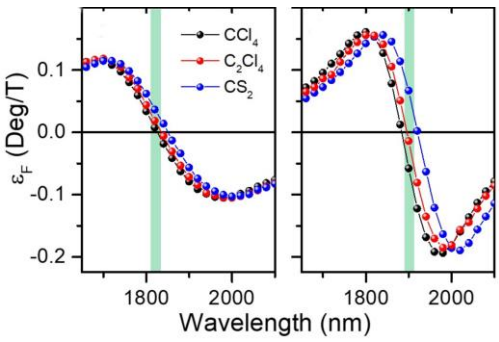

Figure 1: Proof of concept of a magnetoplasmonic refractometric sensing experiment. Change in magneto-optical ellipticity of ITO (left) and FICO (right) nanoparticles in media with different refractive indexes.

Spin on 2D Topological Quantum Material Devices

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An outstanding feature of topological quantum materials is their unique spin topology in the electronic band structures with novel charge-to-spin conversion effects. Here, the we integrated graphene with a topological insulator (TI) in van der Waals heterostructures[1] to engineer proximity-induced spin-charge conversion phenomena. In these heterostructures, we experimentally demonstrate a gate-tunable spin-galvanic effect at room temperature, allowing for efficient conversion of a non-equilibrium spin polarization into a transverse charge current.[2] Furthermore, in the Weyl semimetal candidate WTe_2, we observed both conventional[3] and unconventional[4] charge-to-spin conversion effects at room temperature (Fig. 1). Such an unconventional charge-spin conversion can be possible in WTe_2 due to a reduced crystal symmetry combined with its large spin Berry curvature, spin-orbit interaction with a novel spin-texture of the Fermi states. These findings provide an efficient route for realizing all-electrical and gate-tunable spin-orbit phenomenon in topological materials and their heterostructures.

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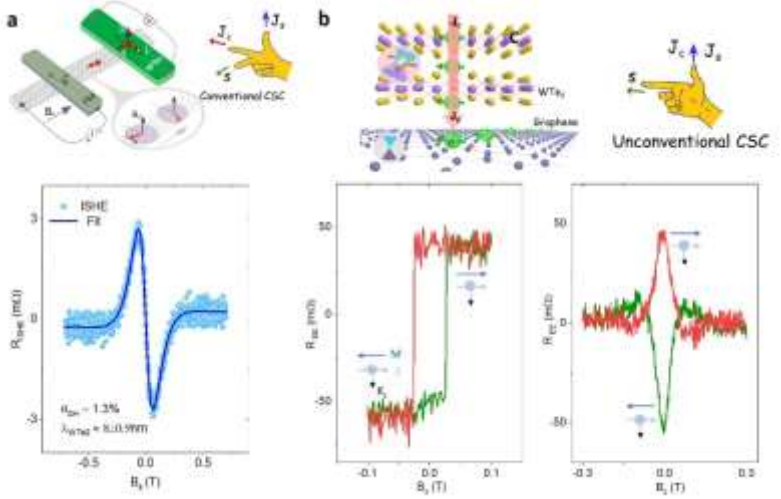

Fig. 1. Charge-to-spin conversion in WTe_2. **a.** Device geometry and Hanle measurement of conventional charge-to-spin conversion in WTe_2 (Ref. 1). **b**. Measurement of unconventional charge-to-spin conversion in WTe_2. The measurement of spin-valve and Hanle signals both in parallel and anti-parallel configurations at room temperature show the unconventional nature of charge-to-spin conversion.

Optical switching on silicon photonics with phase change materials

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The interest in the development of silicon-based photonic integrated circuits (PICs) for a large range of applications is nowadays unquestionable. Silicon PICs benefit from a CMOS compatible fabrication and high index contrast that allows manufacturing at a large scale, low cost, and high density of integration. To enhance and develop new functionalities, the integration of materials, featuring outstanding optical properties, with silicon photonic structures has become an active research field. In this context, phase change materials, such as vanadium dioxide (VO_2) [1] or germanium-antimony-tellurides [2], have been established as effective approaches for optical switching with ultra-compact footprints, broadband operation, low-power consumption and fast speeds. The main benefits and limitations of both technologies will be reviewed in this work. Furthermore, our recent results on all-optical switching employing an ultra-compact VO_2/Si photonic waveguide with switching speeds of around 300 ns will be presented [3].

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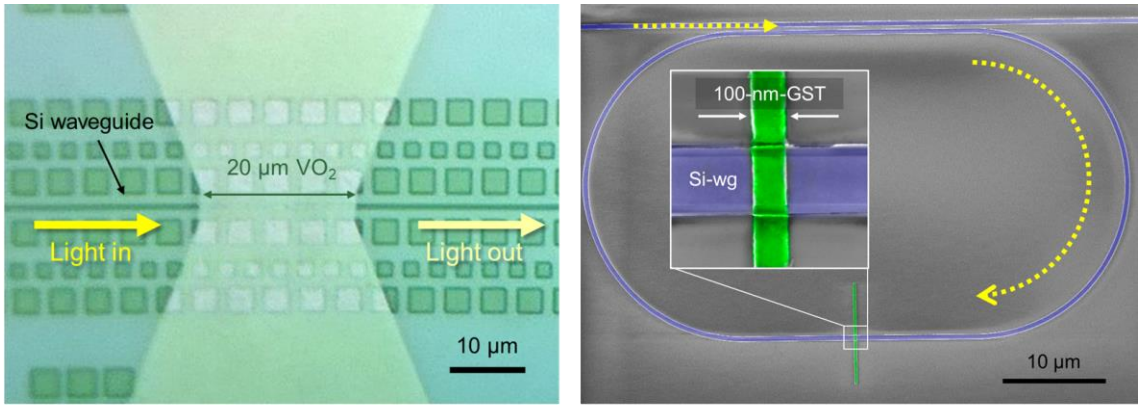

Figure 1: (a) Optical microscope image of VO_2/Si waveguides. (b) False-colored scanning electron microscope (SEM) of a GST/Si waveguide in a ring resonator.

ACKNOWLEDGEMENTS
Financial support from Ministerio de Ciencia e Innovación (PID2019-111460GB-I00, ICTS-2017-28-UPV-9F, TEC2017-90556-REDI, FPU17/04224) and Generalitat Valenciana (PROMETEO/2019/123, IDIFEDER/2018/033) are acknowledged.

Plasmonic antenna hybrids for active control of the optical response

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Hybrid platforms merging metallic nanoantennas and materials with specific functionalities, such as phase-change or spintronic properties, offer excellent technological opportunities for active plasmonics, as they provide large changes in their optical response, which can be activated by external stimuli. In the first part of the talk I will present our recent study of fast, nanoscale optical switching of an IMT phase-transition material, such as VO_2, driven by a single Au nanoantenna in its proximity [1]. The VO_2-single antenna hybrid is the first step to understand more complex building blocks formed by antenna arrays grown on VO_2 films [2], and allows for selecting the nanoscale active volume through a resonant pumping arrangement. This system is of paramount technological interest, as it represents the smallest possible switching unit. In the second part I will focus on the magnetic modulation of the optical response of spintronic metasurfaces composed of microantenna arrays (rods or slits), fabricated out of giant magnetoresistance $Ni_{81}Fe_{19}$/Au multilayers [3]. In this case the plasmonic response of the antenna combined with the magneto-refractive effect (MRE) of the multilayer allows for low magnetic-field control of the modulation of the optical response in mid-infrared [3]. Moreover, our study suggests that these GMR plasmonic metasurfaces are excellent candidates to improve the molecule detection capabilities of traditional Surface-Enhanced Infrared Absorption (SEIRA) Spectroscopy platforms and develop a novel type of infrared sensing technique based on spintronic antennas. [4,5].

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ORALS

Maximal Coupling of Light into 2D Polaritons

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Polaritons in 2D materials have been extensively studied over the past decade due to their fundamental interest and as a platform for applications in telecommunications and sensing. The wavelength of these polaritons is generally small compared to that of a free-space photon of the same frequency, making them very attractive to manipulate light at deep-subwavelength distances. However, it simultaneously introduces a challenge in the coupling between propagation light and plasmonic modes, since the momentum mismatch between the two makes the in/out-coupling of this process intrinsically weak [1]. In this work [2], we demonstrate that a small scatterer placed at a suitable distance from a planar surface can produce complete coupling of a focused light beam to surface polaritons (Fig. 1a). We present rigorous closed-form analytical prescriptions for the modulation of the incident light beam that maximizes this coupling, depending on the characteristics of both scatterer and surface. We subsequently use the derived expressions to provide a rigorous theoretical analysis of extremal focused light coupling to plasmons in silver films and graphene, as well as coupling to phonon polaritons in hexagonal boron nitride films and waveguide modes in silica waveguides. We corroborate these analytical results by performing rigorous numerical simulations for realistic setups, which exhibit a very strong enhancement of light absorption into surface plasmons under the prescribed optimal conditions (Fig. 1b,c). Our results open a practical route to circumvent the long-standing photon-polariton wavelength mismatch problem in nanophotonics.

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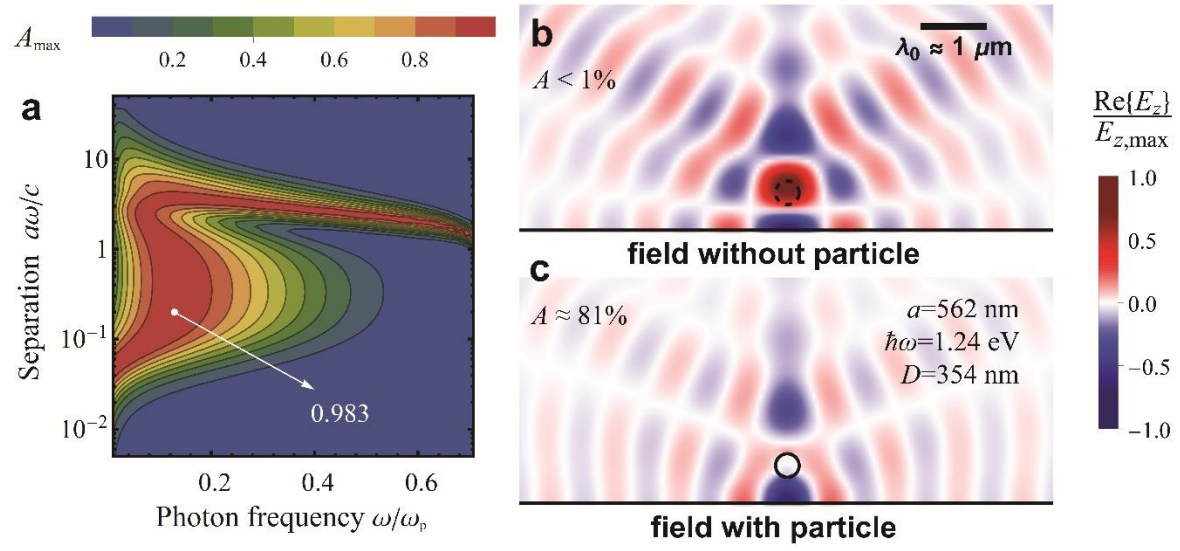

Figure 1: (a) Dependence of the maximum coupling fraction $A_{\max}$ on light frequency ω and particle-surface separation a for a point dipole placed above a semi-infinite Drude metal film with plasma frequency ω_p and damping $\omega_p/100$. Copuling approaches 100% for a wide range of these two parameters. (b,c) Numerical simulations of the near-field under optimal illumination in the (a) absence and (b) presence of a Si spherical scatterer with diameter D (represented by open and solid circles, respectively) at a distance a from the surface of a Ag semi-infinite film. The presence of the Si sphere enhances absorption into silver plasmons to ~80%.

Photoprotecting uracil by coupling with lossy nanocavities

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Abstract

Photodamage in nucleobases is associated to the excitation of the molecule to the S_2 state, typically occurring when the molecule is irradiated by UV light [1]. More practically, the probability to incur photodamage is associated to the long permanence of the nuclear wavepacket on the electronic state S_2 [2]. Strong coupling between molecules and plasmonic nanocavities has emerged in the last few years [3] as a compelling strategy to modify and possibly control photochemical reactions, but is limited by the intrinsically short (few fs) lifetimes of plasmonic nanocavities. In this work, we explore how to make virtue out of necessity by making use of the cavity losses. We perform full quantum dynamics simulations on pre-computed potential energy surfaces to describe the molecular relaxation, accounting for cavity losses by means of a non-Hermitian Hamiltonian. Remarkably, we identify that the optimal photoprotection is achieved when the coupling between molecule and nanoparticle is comparable to the cavity losses, just at the border between the weak and strong coupling regimes.

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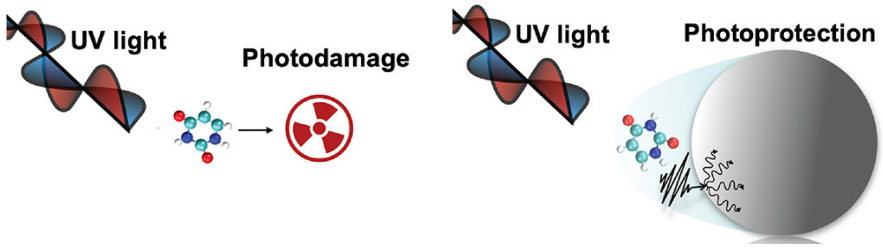

Figure 1: Uracil under action of UV-light may incur in photodamaging reactions, potentially resulting in dangerous mutations. We couple the uracil molecule to a silver nanosphere to open up an efficient relaxation channel, finally achieving a photoprotective effect.

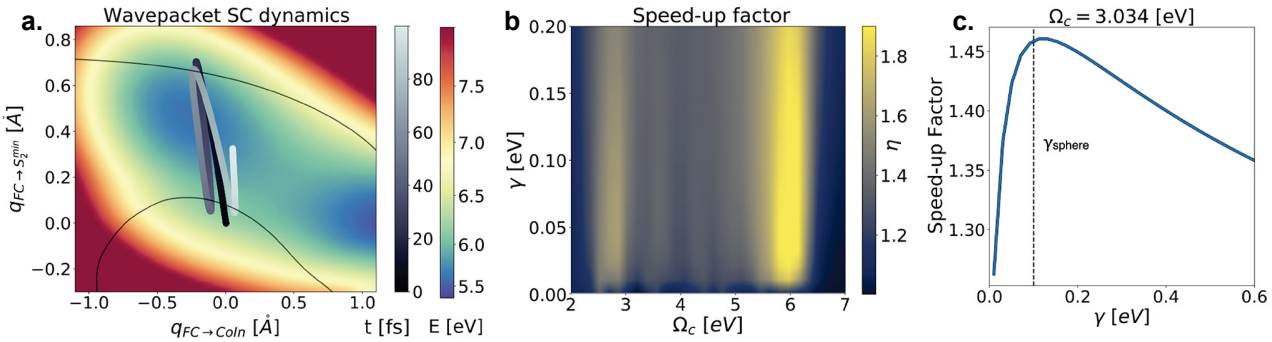

Figure 2: By investigating the nuclear wavepacket dynamics on the uracil potential energy surfaces, we are able to find suitable conditions to stir the wavepacket away from dangerous reaction pathways (Panel **a.**). Quantifying the photo protection effect, we find that the optimal photoprotection (Panels **b.** and **c.**) is achieved at the crossover between the weak and strong coupling regimes.

Spin-Steered Magnonics

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Current information technologies based on electronics are near a saturation point, as transistor miniaturization becomes increasingly challenging. Satisfying the demand for faster and more powerful computing requires to develop new technological platforms to replace electronics in the next few decades. Spin waves, namely magnetization waves propagating in magnetic materials, are major candidates for future information carrying and processing [1]. Their useful properties, such as nonlinearity, tuneable spectra, and the absence of Joule heating, has already enabled a first generation of fast and low-power-consumption spin wave (magnonic) devices [2]. Although way ahead of most competing technologies, these devices are far from performing at the level of current electronics. The main obstacle is the lack of an efficient and flexible way to tailor spin wave propagation.

We propose a novel way to control the propagation of spin waves, namely to couple them to a large ensemble of solid-state paramagnetic spins such as NV centres. The collective back-action of this ensemble, enabled by magnetic dipole interaction, depends on the internal state of the spins, which can be externally tuned. This enables controlling spin wave propagation, in analogy with the dispersion engineering of optical light using atomic ensembles (e.g. slow light).

In our work [3], we develop a quantum theory describing the effective spin wave dynamics in the presence of a spin ensemble, and apply it to a thin magnetic film, a usual experimental configuration [4]. We predict strong modifications of the spin wave propagation properties induced by the spin ensemble, including enhancement and full suppression of their propagation length. These modifications are fully tunable through an externally applied field, and can be turned on and off by optically pumping the spin ensemble. We show that our proposal is experimentally feasible in current experimental platforms. The flexibility of this platform, evidenced by our results, can be enhanced in multiple ways with state of the art techniques. This could enable a new generation of fast, flexible, reconfigurable, and easy to fabricate *spin-steered magnonic devices*.

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Temperature triggered dynamic self-assembly of gold nanoparticles and -rods: The role of hysteresis

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The development of dynamic self-assembly systems is still a young research area.(1) An in-depth investigation of the assembly and disassembly processes is of great importance to gain insights into the intermediate assembly states. Here we show the detailed picture of temperature-driven reversible clustering of gold nanoparticles (gold nanospheres(2) and gold nanorods) functionalized with bis(p-sulfonatophenyl)phenylphosphine (BSPP). In-situ UV-VIS spectroscopy revealed the emergence of hysteresis during the cyclic temperature changes (Fig. 1). By varying nanoparticles diameter and their surface charge as well as the rate of applied stimulus we were able to describe qualitatively the contribution of thermodynamic and kinetic hysteresis in the whole process.
A particularly intriguing case is the reversible clustering of gold nanorods, that exhibits an asymmetric hysteretic response. Upon the clustering, gold nanorods adapt to transient mutual configurations, such as tip-to-tip or side-to-side, enriching the hysteretic response (Fig 1b). In addition, the large absorption cross-section of gold nanorods in the infrared spectral range allowed us for taking advantage of their efficient light to heat conversion. By using infrared light, instead of an external heating source, we were able to control locally the change of temperature which in turn altered the colloidal stability of the nanorods, revealing again hysteretic and oscillatory behaviour.
We foresee that the presented experimental framework offers an exciting playground to study the nature of meta-stable assemblies, and enables possible applications in spatiotemporal catalysis, thermo-mechanical nanotransducers, smart windows, among others.

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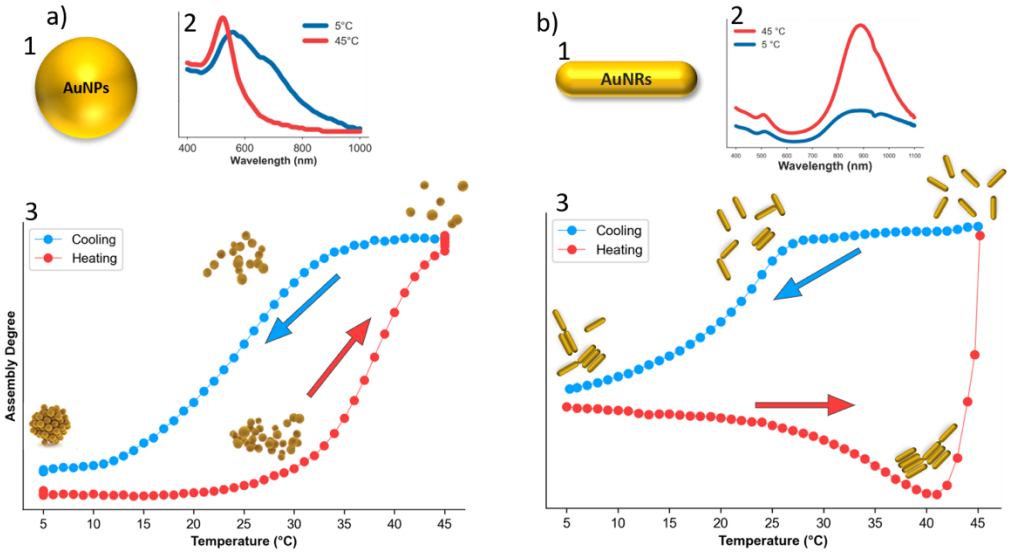

Figure 1 Temperature-induced reversible clustering of gold nanoparticles with hysteretic behavior. Upper panel demonstrates the change of optical properties for gold nanospheres (a) and nanorods (b). Lower panel shows the change of the aggregation degree over wide temperature range (5 - 45 °C). The nanoparticles can remain either in dispersed or aggregated states at the same temperature depending whether the sample is heated or cooled.

Vibrational resonance amplification in a thermo-optic photonic crystal optomechanical cavity

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Abstract

Bistable resonators can be used to amplify weak signals via the phenomena of stochastic or vibrational resonance (VR). While the first, most famous, occurs when noise is added to the bistability, the second rather involve an additional high-frequency signal [1]. Here we demonstrate VR amplification in a thermo-optic bistable resonator [2] made of a suspended photonic-crystal molecule (fig1). Interestingly the system can be characterized by focusing on a mechanical mode of the membrane, frequency is strongly thermally coupled to the intracavity load. The realization of such operations is of first interest in the context of computational photonics.

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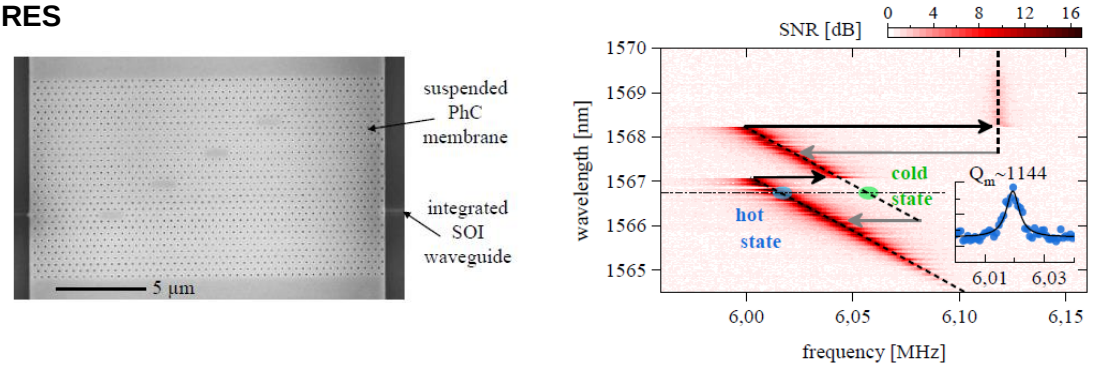

Figure 1: Left: SEM micrograph of the suspended photonic crystal membrane. Right: Noise spectrum centered at the fundamental mechanical resonance, plotted as a function of the laser wavelength. The thermo-optic bistability in imprinted in the mechanical frequency via a strong thermo-elastic coupling.

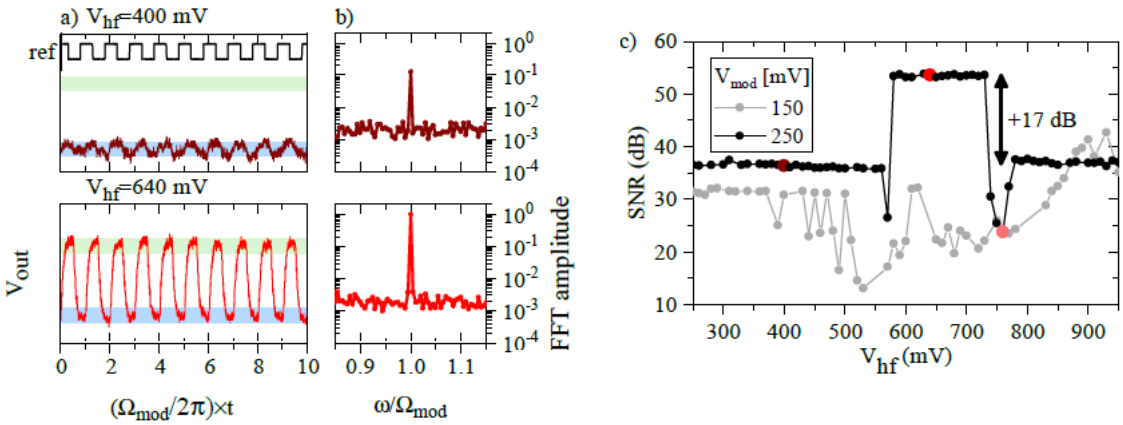

Figure 2: Temporal (a) and spectral (b) responses of the bistable system under modulation with a weak signal (Ω_{mod}) for increasing amplitude of the added high frequency signal (V_{hf}) of a high frequency signal. Amplification (bottom) occurs when the switching in the bistability is enabled. (c): SNR of the weak signal as a function of the HF signal amplitude, A range of amplification is observed (the black curve). Too weak signals (gray curve) do not experience amplification.

Magneto-optical binding in the near field

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Abstract

In this work we show analytically and numerically the formation of a near-field stable optical binding between two identical plasmonic particles, induced by an incident plane wave.
The equilibrium binding distance is controlled by the angle between the polarization plane of the incoming field and the dimer axis, for which we have calculated an explicit formula. We have found that the condition to achieve stable binding depends on the particle's dielectric function and happens near the frequency of the dipole plasmonic resonance.
The binding stiffness of this stable attaching interaction is four orders of magnitude larger than the usual far-field optical binding and is formed orthogonally to the propagation direction of the incident beam (transverse binding).
The binding distance can be further manipulated considering the magneto-optical effect [1] and an equation relating the desired equilibrium distance with the required external magnetic field is obtained. Finally, the effect induced by the proposed binding method is tested using molecular dynamics simulations (see Figure 1).
Our study paves the way to achieve complete control of near-field binding forces between plasmonic nanoparticles.

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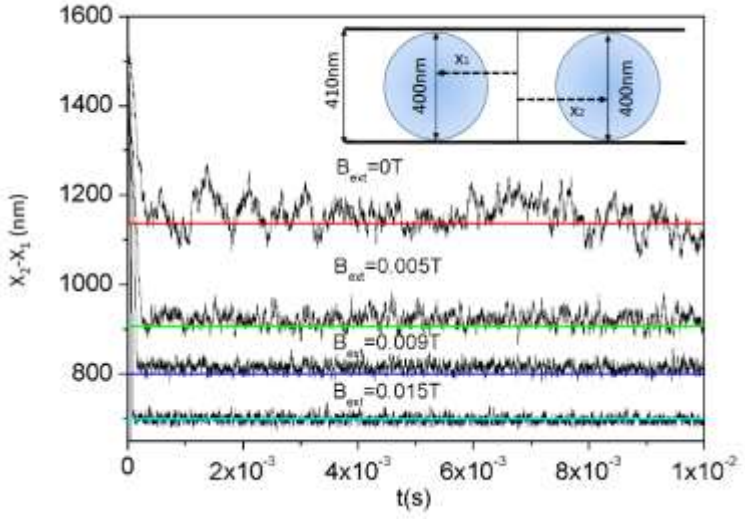

Figure 1: X-Y Langevin molecular dynamics simulation of a 200 nm InSb nanoparticle inside a micro-channel with a diameter of $0.41 \mu m$ illuminated by a plane wave with wavelength $\lambda=47.97 \mu$m, polarization angle $\theta=\arctan(\sqrt{2})$ and intensity $25 \mu W/nm^{2}$. Temperature is set to 293K. The simulation shows the particles separation versus time for different values of the external magnetic field. Straight lines correspond to the following expected equilibrium distances, $ R=1136$ nm (red), 906 nm (green) 800 nm(blue) 698 nm (cyan), obtained from the analytic expression Eq.\ref{Bext}. Inset shows an sketch of the particles configuration.

Engineering long-lived vibrational states for an organic molecule

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Single organic molecules are promising contestants for realizing quantum optical networks in solid-state platforms due to their outstanding coherent properties [1]. Such a high degree of coherence is a result of strong zero-phonon lines that are Fourier-limited linewidths. However, their associated timescales are limited to nanoseconds, which implies a significant challenge for practical implementations of quantum networks with such molecular platforms.

In this theoretical work, we propose exploiting the optomechanical character of single molecules in the solid-state to build a new molecular system with quantum coherences up to millisecond timescales [2]. For such purpose we tailor the host matrix of a single organic molecule to the nanoscale and position it on a structured phononic environment that suppress its phononic decay [3] (see illustrations in Fig. 1). We show that the resulting long-lived vibrational states in these systems facilitate reaching strong optomechanical regimes at single photon level, which can be witnessed from strong anti-stokes scattering in the molecular emission spectrum. We exploit such long optomechanical coherence time of the molecule to store and retrieve optical information with proper pulse excitation up to milliseconds (see Fig. 1, right). The proposed system shows the prospects of organic molecules for reaching unexplored optomechanical regimes and realizing long-lived quantum memories.

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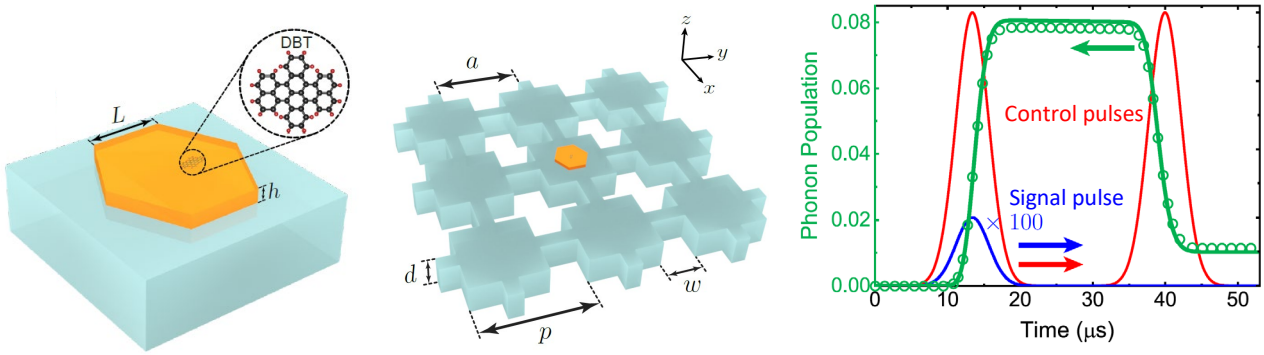

Figure 1: Left: Illustration of an anthracene nanocrystal doped with a single dibenzoterrylene molecule on a substrate. Middle: Hybrid cavity formed by the nanocrystal-molecule system on top of a phononic crystal structure with suppressed phonon density of states [3]. Right: Coherent optical generation of ms-lived phonons by stimulated Raman scattering in the proposed molecular system.

Nonlinear plasmonic response of crystalline few-atom-thick silver films

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Abstract : Atomically thin crystalline metallic films are attracting attention as suitable platform material for plasmonics owing to their ability to confine light down to few-nanometer scales with tolerable optical losses, well below those of amorphous metal films [1,2] (see Fig1a). Recently, substantial advances have been made to synthetize films with thickness down to a few atomic planes and demonstrate that they support surface plasmons (SP, collective oscillations of conductions electrons at metal-dielectric interfaces) with high quality factor [3]. These modes exhibit thickness-dependent dispersion relations, as illustrated in Fig1b by means of the loss function for silver films with a (111) crystallographic orientation. Such plasmons confine light, thus boosting the magnitude of linear fields by several orders of magnitudes, making them ideal to explore nonlinear phenomena, which in addition are combined with intrinsic features arising from the band structure of thinner films as demonstrated by comparing panels c and d, where we represent the density of states of a thick film consisting of $N = 100$ and $N = 5$ atomic planes, respectively. In our work, we employ a quantum mechanical (QM) method based on a one-dimensional potential [4] that capture the salient electronic-structure features of the Ag (111) surface to compute the optical response within the random-phase approximation (RPA). We extend this method to calculate the nonlinear response of the metallic films, and as shown in Fig1e for second harmonic generation, we define a figure of merit that facilitates the comparison of the nonlinear plasmonic yield as a function of film thickness. We find that thinner films give rise to larger nonlinear response. We also explore third order processes like third harmonic generation and Kerr effect, showing a similar increase with decreasing film thickness.

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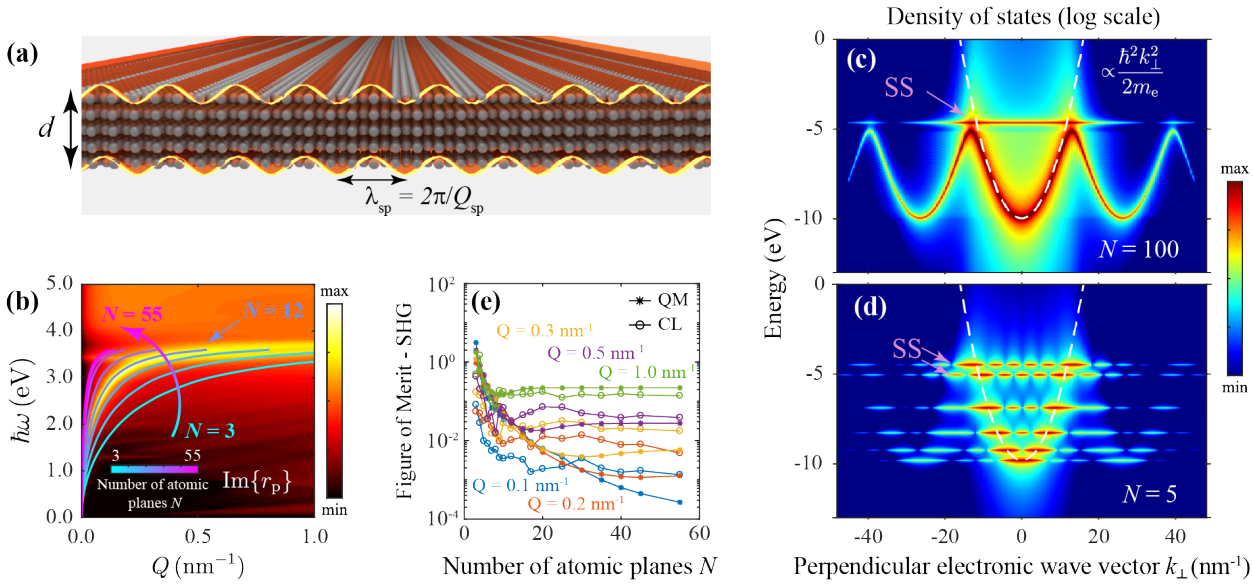

Figure 1: (a) Illustration of surface plasmons (SP) in a few-atom-thick silver (111) film. (b) SP dispersion relation calculated via the loss function (imaginary part of the reflection coefficient) in momentum and energy space. Dispersion curves of SPs for various thicknesses are superimposed on the dispersion map and indicated by the coloured code in the legend. (c,d) Electronic density of states obtained by Fourier-transforming the out-of-plane electronic wave functions for $N = 100$ and $N = 5$ Ag(111) atomic layers, respectively. (e) Figure of merit quantifying the nonlinear plasmonic yield using quantum-mechanical (circles) or classical (stars) models for selected values of the in-plane parallel wave vector Q.

ePOSTERS

Engineering of Photonic Structures in Nanoporous Anodic Alumina

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Nanoporous anodic alumina (NAA) is a promising material formed by the electrochemical anodization of aluminum, a cost effective and fully scalable process compatible with conventional micro and nanofabrication approaches that allows the precise control over the geometry and distribution of the pores [1-2].Therefore, to engineer the nanoporous structure of NAA provides novel means of modulating its refractive index in a multidimensional fashion to fabricate advanced materials with unique optical properties to guide, reflect, transmit, emit incident light. the optical properties of NAA rely intrinsically upon its nanoporous architecture [3]. Furthermore, the pore geometry can be varied by different methods to obtain different functionalities such as funnels and structures with remarkable optical properties such as Distributed Bragg Reflectors, Rugate filters, etc. [4] Photonic structures (PS) can be obtained by NAA pore engineering. NAA-PSs are obtained by applying a sinusoidal anodization current. The application of this modulation results in a one-dimensional photonic crystal with a periodic variation of the refractive index along the pore direction and a photonic stop band.[5-6]. In this work, we present different anodization approaches to obtain photonic structures fabricated with NAA (PS-NAA) with well-resolved photonic stop bands. Figure 1a shows the sinusoidal anodization approach for the formation of photonic structures. Figure1b shows the reflection spectrum of the photonic structure fabricated by sinusoidal anodization. Figure 1c an 1d shows the top view and the cross-section of the photonic structure.

Acknowledgments

This work was supported by the Spanish Ministerio de Ciencia, Innovación y Universidades (MICINN/FEDER) RTI2018-094040-B-I00, by the Agency for Management of University and Research Grants (AGAUR) ref 2017-SGR-1527

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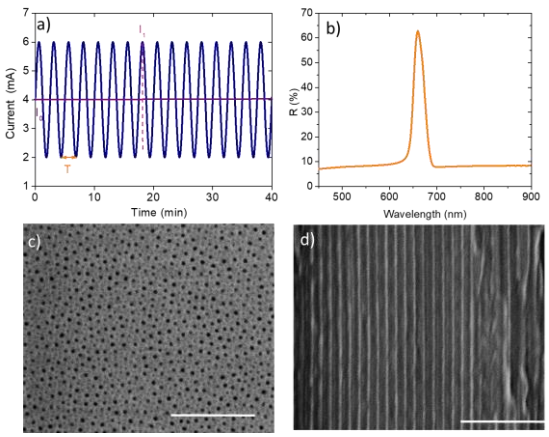

Figure 1: Photonic Structure fabricated with sinusoidal anodization profile. (a) anodization profile. (b) reflection spectrum of Photonic structure. (c) top view of NAA-PSs. (d) cross-section of NAA-PS.

Silicon nanodisks for Surface Enhance Raman Scattering

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All-dielectric resonant nanophotonics based on dipolar and multipolar Mie-type resonances have recently emerged as a new research field for the design of nanoscale metadevices. [1] New types of Surface Enhance Raman Scattering (SERS) non-plasmonic substrates are of particular interest for the study of light-matter interactions of novel nanomaterials such as transition metal dichalcogenides (TMDs) thanks to their ability to produce localized hot spots with lower absorption and thermal effects than in their plasmonic counterparts. [2-3] Here, we present a theoretical and experimental study of different designs of SERS substrates based on silicon-disk nano resonators. Their efficiency and operation are tested by the integration with TMDs and self-assembled monolayers (SAMs) of molecules chemically compatible with the Silicon nanostructures. First, the Raman scattering signal enhancement is studied by depositing by spin coating, mono and few layers of chemically exfoliated MoS_2 onto two types of dielectric nanopatterned surfaces: 1- Silicon single nanodisks and 2- Silicon dimers with different gaps. We observe Raman enhancement factors comparable to those reported for dry exfoliated monolayer TMDs coupled to dielectric nano-antennas (Figure 1). [4] Further effects are observed in the Raman polarization dependence and in the scattering signal enhancement of the same type of Silicon nanostructures now functionalized with aminopropyltriethoxysilane (APTES) .

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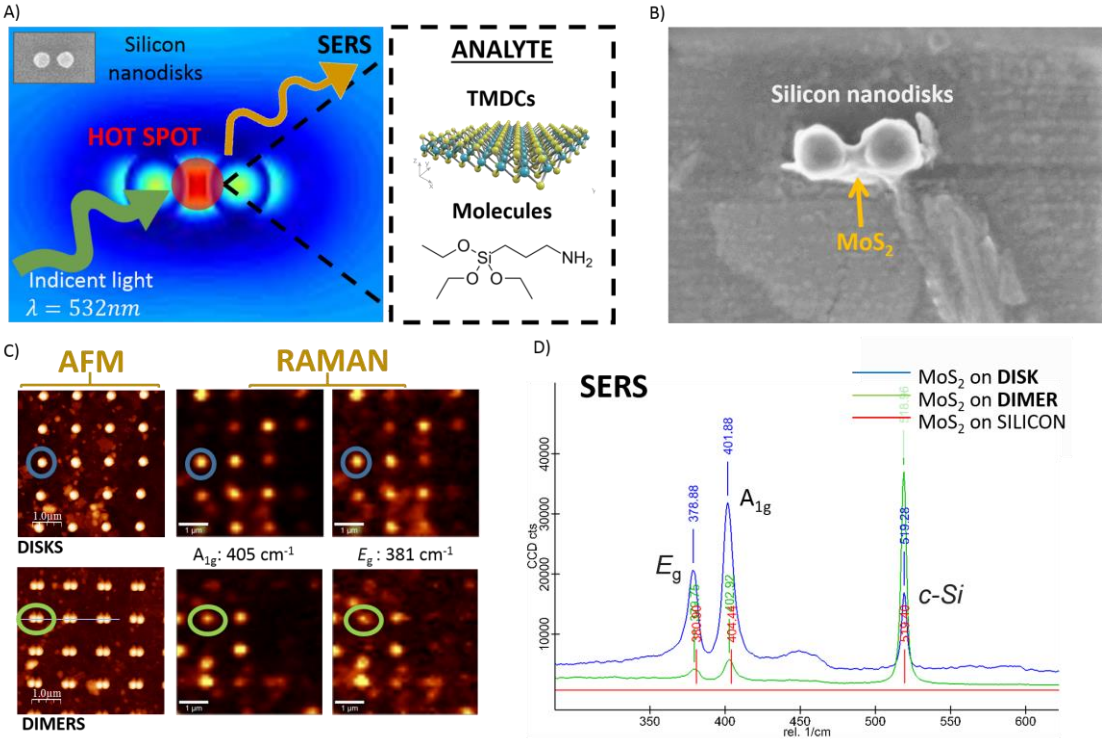

Figure 1: A) Scheme of SERS process superposed on a CST simulation of the Electric field of a Si dimer. B) SEM image of spin-coated MoS_2 onto a Si dimer, C) Same area of AFM and Raman scattering images (5x5 μm^2) of spin-coated MoS_2 onto Si disks (top) and dimers (down), D) Raman scattering spectra of a 4L-MoS_2 flake taken onto a disk and a dimer (marked in blue and green respectively in C)) and onto planar Silicon.

Magneto-optical Stern-Gerlach forces and non-reciprocal torques on small particles

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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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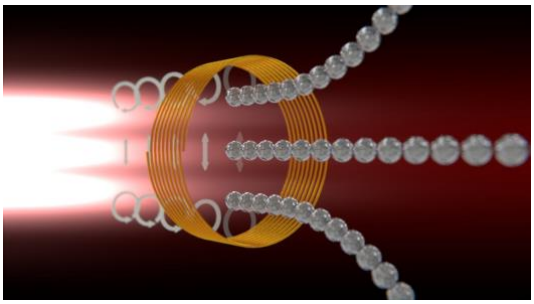

Figure 1: Optical Stern-Gerlach experiment: photons are deflected from a magneto-optical active particle up or down based on their spin angular momentum

High-performance optical switches based on GST/Si waveguides

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Phase change materials (PCMs), such as germanium-antimony-tellurides [1] or vanadium dioxide [2], are promising materials to combine with silicon (Si) photonics devices. In this field, $Ge_2Sb_2Te_5$ or GST stands out due to the large and non-volatile variation of its refractive index when switching between an amorphous and crystalline state [3]. This singular attribute permits the development of ultra-compact and high-performance optical switches based on hybrid GST/Si waveguides. In this work, an optical switch based on a ring resonator structure has been designed and optimized to achieve a high extinction ratio and low insertion losses. The device has also been fabricated and experimentally demonstrated. Figure 1(a) shows an optical microscope image of the fabricated optical switch based on a silicon ring resonator structure with an ultra-short GST/Si waveguide as the active element. The GST/Si waveguide has a length of only 500 nm. The optimal GST thickness has been analyzed and experimentally tested to avoid coupling of undesired higher-order modes. The experimental transmission response of the switch is shown in Fig. 1(b). An extinction ratio above 24 dB and almost negligible insertion losses are achieved at the resonance wavelength when the GST is switched between the amorphous and crystalline states.

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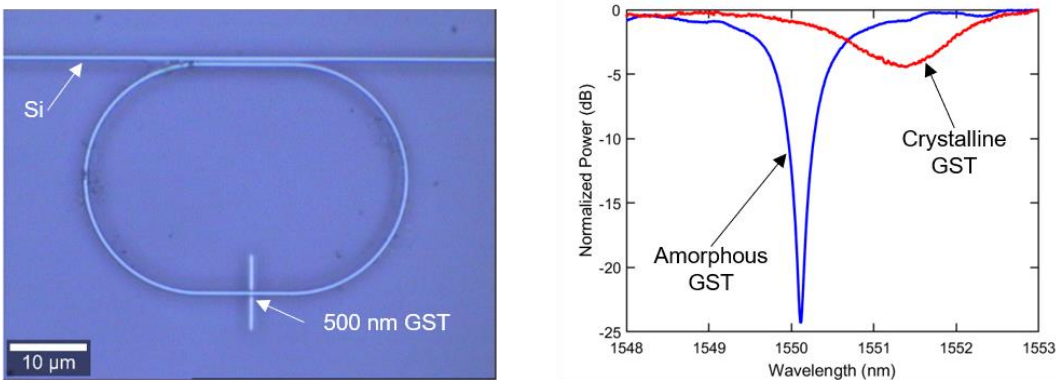

(a) (b)

Figure 1: (a) Optical microscope image of a fabricated silicon ring resonator with a 500-nm-long GST/Si waveguide. (b) Experimental transmission response when switching between the amorphous and crystalline states of the GST.

ACKNOWLEDGEMENTS
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FLASHPOSTER

First-principles study of plasmon-molecule coupling in metallic cluster dimers

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Metallic clusters behave as nanoscale plasmonic resonators, and can serve to build up optical cavities where light is amplified and localized into nanoscale volumes. When an emitter, such as a molecule, is placed in a cavity formed by a cluster dimer, the optical response of the whole system depends greatly on the atomistic shape and relative orientation of both the clusters and the molecule [1, 2]. Atomistic ab-initio methods allow for an accurate description of the coupling between clusters and molecules, capturing the physics of the plasmonic response [3]. We present preliminary results of the atomistic optical spectra of porphyrin molecules coupled to silver nanodimers, using the ab-initio SIESTA [4] software to obtain the ground-state of the system, and the linear-response TDDFT code PyNAO [5] to compute the optical excitations. The results show the emergence of a Fano spectral line in absorption spectroscopy near the plasmonic resonance, a characteristic feature of the weak light-matter coupling regime. The strength of the coupling varies drastically with the gap geometry, as well as with the orientation of the molecule. Moreover, our simulations also reveal the existence of a Charge Transfer Plasmon at lower frequencies.

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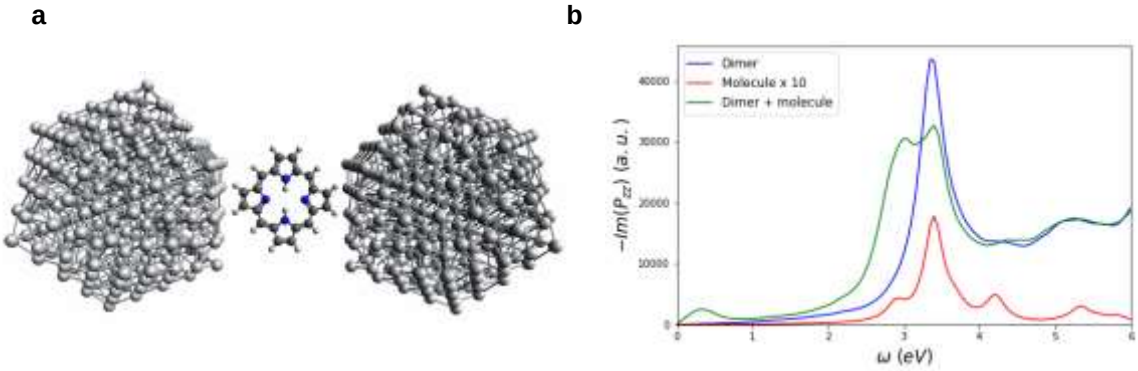

Figure 1: a) Atomistic structure of the studied system, composed of two Ag309 clusters with a 2,3-Dihydroporphyrin molecule placed in the gap between them. **b)** Imaginary part of the optical polarizability along the dimer axis direction for the bare silver dimer (blue), the bare single molecule (red), and the coupled dimer and molecule system (green).

Radiationless anapole states in on-chip photonics

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Interference between different radiative modes supported by high-index dielectric particles can eventually lead to scattering cancellation in the far-field, resulting in anapole resonances [1]. Such non-radiative resonance is accompanied by a strong field concentration inside the nanoparticle, which has been used to boost light-matter interaction and to enhance nonlinear effects such as harmonic generation or Raman scattering [2]. So far, all experiments showing anapole resonances, in silicon nanodisks, have been achieved by external normal illumination. In this work, we report on the reduction of scattering produced by silicon nanodisks resulting from anapole resonances when excited on-chip using silicon waveguides at telecom wavelengths fo use in photonic integrates circuits. We observe a strong reduction of the top out-of-chip scattering from the silicon disks when the conditions for appearance of the anapole resonance are met. To get further insight into the disk behavior, we performed phase- and polarization-resolved SNOM measurements [3] on the waveguide-disk system at different wavelengths. At wavelength around the expected anapole resonance, we observed the formation of three lobes in the transversal electric field component, a feature not observed at larger wavelengths, and a clear fingerprint of the anapole condition. Our work can pave the way towards integration of silicon disks in complex photonic integrated circuitry for applications such as sensing or nonlinear photonics.

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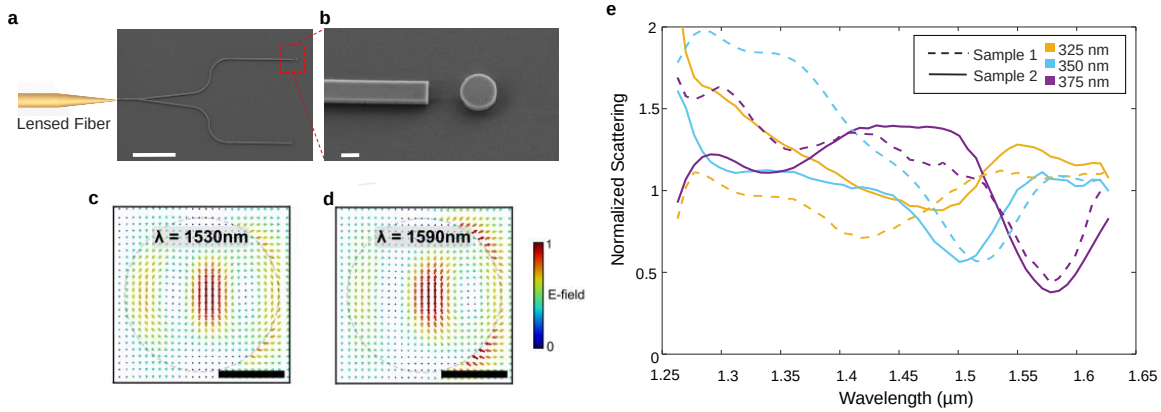

Figure 1: Far-field top-scattering measurements. **a**, SEM picture of one of the fabricated circuits. Scale bar: 10 mm. **b**, SEM image showing in detail the disk and the waveguide termination. Scale bar: 400 nm. **c**, Electric field lines at the anapole and **d** maximum energy wavelengths under waveguide illumination for a r=350nm disk. **e**, Experimental results of the normalized top-scattering recorded for disks with different radii (nominal values shown in the figure) in two different samples.

Unveiling atomic-scale features in plasmonic nanoparticles using light and electron beams

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Plasmonic nanoparticles (NPs) are known to produce localization and enhancement of electromagnetic fields, providing nanometer- scale effective mode volumes. Atomistic quantum calculations based on Time-Dependent Density Functional Theory (TDDFT) reveal the effect of subnanometric localization of optical fields due to the presence of atomic-scale features at the surface of metallic NPs and interparticle gaps [1]. Using classical electrodynamics (Boundary Element Method, BEM), we explain this effect as a non-resonant lightning rod effect at the atomic scale that produces an extra enhancement over that of the plasmonic background [2]. We have further studied this effect for plasmons excited with fast electrons and calculated the electron energy loss spectra (EELS) of electron beams passing nearby and through the same atomistic structures [3]. The results reveal great influence of the atomic-scale features on the localized surface plasmons (LSPs), and the failure of the classical description to address the confined bulk plasmons (CBPs) observed in the TDDFT calculations (Fig. 1). The latter are similar to CBPs observed within the spherical hydrodynamic model [4]. These findings bear out the importance of a proper consideration of the atomic-scale shape of nanoparticles in EEL spectroscopy.

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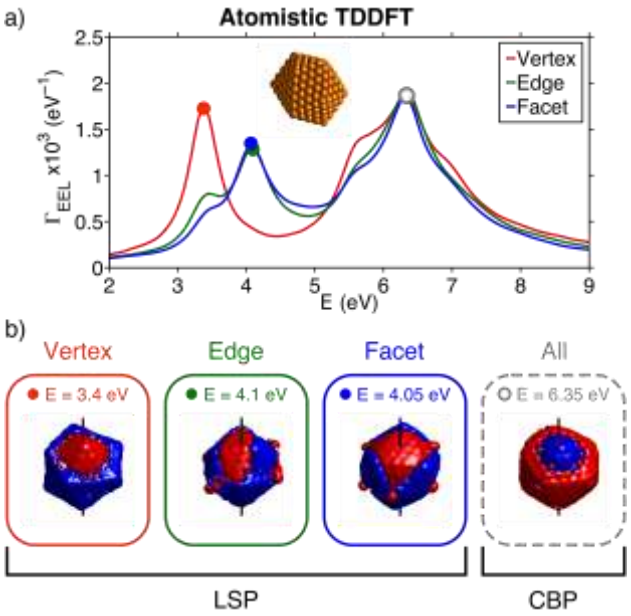

Figure 2: a) Electron energy loss spectra for the Na icosahedral cluster calculated using TDDFT for electron trajectories penetrating the NP through different atomic-scale features. b) Charge density isosurfaces corresponding to the main excited plasmon modes for each trajectory.

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