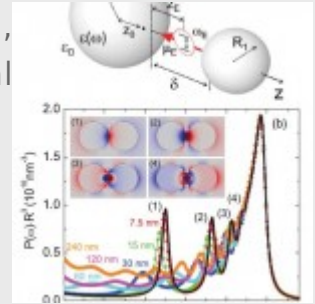


## Transformation Optics Approach to Plasmon-Exciton Strong Coupling in Nanocavities

Article: published in [Physical Review Letters](#) by F. J. García-Vidal, and A. I. Fernández-Domínguez, Department of Theoretical Condensed Matter Physics and IFIMAC researchers.

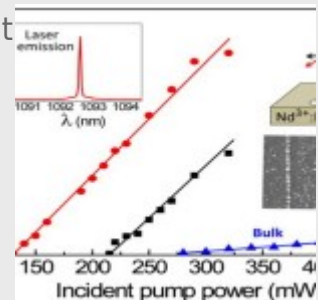


**W**e investigate the conditions yielding plasmon-exciton strong coupling at the single emitter level in the gap between two metal nanoparticles. Inspired by transformation optics ideas, a quasianalytical approach is developed that makes possible a thorough exploration of this hybrid system incorporating the full richness of its plasmonic spectrum. This allows us to reveal that by placing the emitter away from the cavity center, its coupling to multipolar dark modes of both even and odd parity increases remarkably. This way, reversible dynamics in the population of the quantum emitter takes place in feasible implementations of this archetypal nanocavity. [\[Full article\]](#)

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## Solid-state Lasers Go Nano

Article: published in [Nano Letters](#) by Jorge Bravo-Abad, Department of Theoretical Condensed Matter Physics and IFIMAC researcher.



**S**ince the first experimental demonstration of the ruby laser in 1960, the development of solid-state lasers has led to an enormous variety of systems capable of generating laser action with characteristics relevant for applications in research, industry, medicine, or optical communications. Their versatile performance includes the possibility of operating in continuous-wave or ultrashort pulsed regimes, as well as single line or tunable sources, being accessible in very different configurations

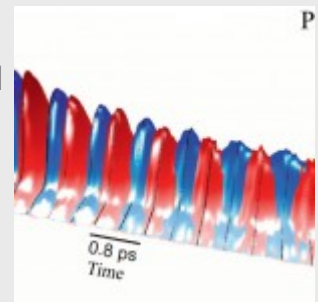
comprising from large devices delivering high power to fibers or compact microchip lasers for integrated optics. In the last years, laser action at the subwavelength regime has been observed by combining organic dye molecules or semiconductors with plasmonic nanostructures. However, nanoscale laser operation from solid-state lasers still remained a challenge.

A recent work published in *Nano Letters* by a collaboration between IFIMAC researcher Jorge Bravo-Abad and the research groups led by Luisa Bausá (UAM) and Javier Aizpurua (Center for Materials Physics, CSIC-UPV/EHU, and Donostia International Physics Center) has overcome this key challenge. In this work, the authors have demonstrated room temperature laser action with subwavelength confinement in a Nd<sup>3+</sup>-based solid-state laser by means of the localized surface plasmon resonances supported by chains of metallic nanoparticles. The researchers have shown a 50% reduction of the pump power at threshold and a remarkable 15-fold improvement of the slope efficiency with respect to the bulk laser operation. These results can be extended to a large diversity of solid-state lasers and open new prospects for the miniaturization of this class of light sources. [\[Full article\]](#)

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### Polarization Shaping of Poincaré Beams by Polariton Oscillations

Article: published in [Light: Science & Applications](#) by David Colas, E. del Valle, and F. P. Laussy Department of Theoretical Condensed Matter Physics and IFIMAC researchers.



**T**he polarization of light is a powerful degree of freedom for advanced optical applications. Its control is therefore important for many important technologies. So far, the main approaches have been i) to let the polarization vary spatially, with so-called “full Poincaré” beams when all the states of polarization are provided, and ii) to let the polarization vary temporally, with light “visiting” different parts of the Poincaré sphere through a so-called polarization shaping. These types of beams have been used notably in spectroscopy, targeting molecules sensible to only some type of polarization, or in laser micro-processing, sub wavelength localization, etc.

Here, we propose theoretically and demonstrate experimentally a new mechanism that brings together these two types of polarization control, namely, we realize full-Poincaré beams in time, with a device that emits pulse taking all the states of polarization in

each pulse within a range of 10 picoseconds.

The principle is based on the interaction between light and matter present in semiconductor microcavities and exhibiting so-called Rabi oscillations, of which we have recently demonstrated an accurate control [[Phys. Rev. Lett.](#), **113**:226401, 2014.].

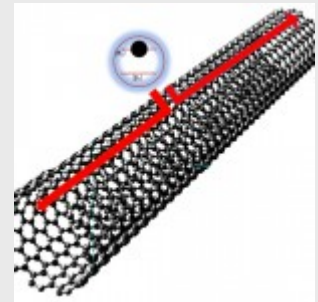
Both classical (normal mode coupling) and quantum regimes can be obtained. This principle can be extended to other platforms and with different timescales thanks to the universality of the Rabi oscillations phenomenon.

This new type of light [<http://www.ifimac.uam.es/two-new-kinds-of-light>] should be of a general interest for a large scope of domains that rely on polarized light. [[Full article](#)]

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## Ultraefficient Coupling of a Quantum Emitter to the Tunable Guided Plasmons of a Carbon Nanotube

Article: published in [Physical Review Letters](#) by Francisco J. García-Vidal, Department of Theoretical Condensed Matter Physics and IFIMAC researcher.



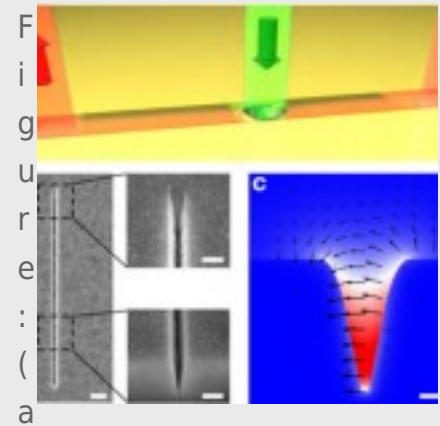
**T**he quest for schemes leading to efficient coupling between quantum emitters and the electromagnetic field is very actively pursued nowadays, for its potential applications to quantum information and to induce effective interactions between two-level systems (mediated by the electromagnetic field) and effective photon-photon interactions (mediated by the quantum emitters).

In this context, IFIMAC researcher Francisco J. Garcia-Vidal, in collaboration with Luis Martin-Moreno (ICMA) and Javier Garcia de Abajo (ICFO) have shown that the tunable plasmons of a highly doped single-wall carbon nanotube are a very promising platform for efficient coupling between quantum emitters and the confined plasmon field. Plasmons in these quasi-one-dimensional carbon structures exhibit very deep subwavelength confinement that pushes the coupling efficiency close to 100% over a very broad spectral range. This phenomenon takes place for distances and tube diameters comprising the nanometer and micrometer scales. As opposite to other metallic systems and also to graphene, carbon nanotubes present the crucial advantage of not requiring a spacer to avoid quenching (i.e., irreversible dissipation leading to heating of the metal) of quantum emitters at small separations. This finding not only holds great potential for waveguide Quantum Electrodynamics, in which an

efficient interaction between emitters and electromagnetic modes is pivotal, but it also provides a way of realizing quantum strong coupling between several emitters mediated by carbon nanotube plasmons, which can be controlled through the large electro-optical tunability of these excitations. [\[Full article\]](#)

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## Coupling of Artificial Atoms to V-groove Plasmonic Waveguides



(a) Schematic of the considered configuration. A single nanodiamond hosting a single nitrogen vacancy (NV) center is placed inside a V-groove channel waveguide. On excitation with a laser, the NV center couples, in the ideal case, all of its emission into the VG-supported CPP mode. The channeled emission out-couples from the VG via the tapered nanomirrors at the VG extremities. (b) Scanning electron microscopy (SEM) image of a 10- $\mu\text{m}$ -long V-shaped groove (315-nm-width and 510-nm-depth) fabricated by milling a thick gold film with a FIB. The scale bar is 1  $\mu\text{m}$ . (c) Total electric field profile of the

VG-supported CPP mode for a wavelength of 650 nm.

Article: published in [Nature Communications](#) by Carlos González Ballesterero, [Esteban Moreno](#) and [Prof. Francisco J. García Vidal](#), Department of Theoretical Condensed Matter Physics and IFIMAC researchers.

Department of Theoretical Condensed Matter Physics and [IFIMAC - Condensed Matter Physics Center researchers](#) report on deterministic coupling of single quantum emitters with channel plasmons

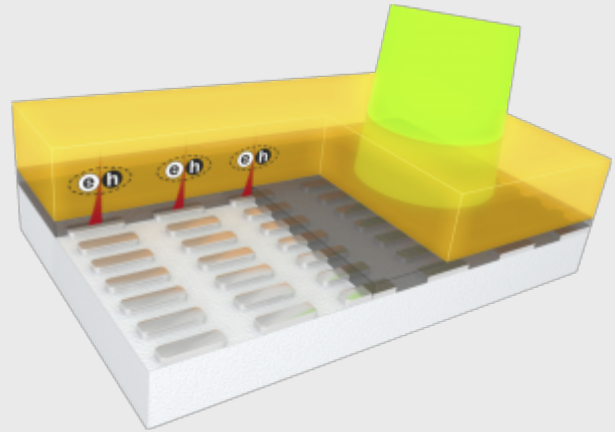
One of the main challenges in developing future nanoscale quantum photonic circuits is to manage combining on a single chip a single photon source, waveguides, modulators and detectors. An important milestone towards this ultimate goal is the deterministic coupling of a single quantum emitter to an integrated waveguide. In this context, IFIMAC researchers Carlos González Ballesterero and Esteban Moreno lead by Prof. Francisco J. García Vidal, in collaboration with scientists from ICFO in Barcelona (Romain Quidant's group), Denmark (Sergey Bozhevolnyi's group) and United Kingdom (Yuri Alaverdyan), have been able to demonstrate coupling of the emission of a single quantum emitter to channel plasmons polaritons (CPPs) in a V-shaped plasmonic architecture. The study "Coupling of individual quantum emitters to channel plasmons", has been published recently in the journal Nature Communications.

In this work, the researchers first used theoretical simulations to study the behaviour of the coupling between a quantum emitter and the V-groove plasmonic channel. Once an optimal theoretical configuration was identified, they used state-of-the-art techniques to assemble the experiment using a single Nitrogen Vacancy (NV) centre, a single quantum emitter present in diamond, coupled to the CPPs supported by a V-groove (VG) channel. The observations obtained from the experiment revealed efficient coupling of the NV centre emission to the propagating modes of the VG, in accordance with the theoretical predictions postulated by the team. This demonstrates that their approach can enable realistic and functional plasmonic circuitry and therefore, paves the way towards the development of efficient and long distance transfer of energy in integrated solid-state quantum systems. [\[Full article\]](#)

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[Thermalization and Cooling of Plasmon-exciton-polaritons: Towards Quantum Condensation](#)

Date: Wednesday, 11st December 2013.



Time: 12:00h

Place: Departamento de Física de la Materia Condensada, Facultad Ciencias, Módulo 3 ,  
Aula de Seminarios (5ª Planta)

Johannes Feist (Departamento de Física Teórica de la Materia Condensada Universidad  
Autónoma de Madrid).

ABSTRACT:

**C**ondensation, where a single quantum state is macroscopically populated, lies at the heart of superfluidity, superconductivity, and Bose-Einstein condensation. A long-standing goal is to find systems that show condensation at higher temperatures than the well-known case of ultracold atomic gases, even at or above room temperature. Bosonic quasi-particles in solids are excellent candidates due to their low effective masses, and condensation has been observed for semiconductor exciton-polaritons, magnons and cavity photons.

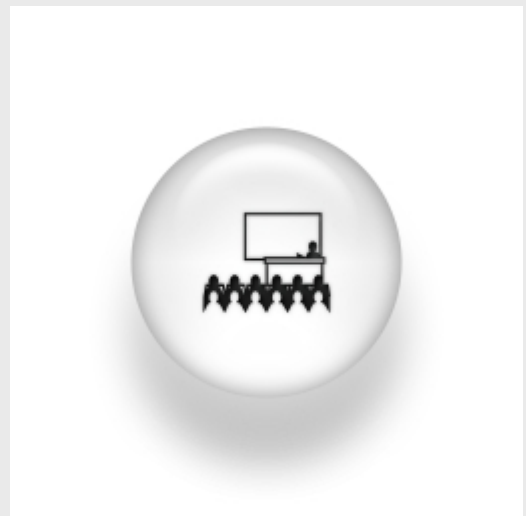
I will present and discuss experimental signatures of thermalization and cooling, a precursor for condensation, of plasmon-exciton-polaritons (PEPs) at room temperature. The system consists of an array of metallic nanorods covered by an organic dye layer. PEPs are formed by strong coupling between organic molecule excitons and surface lattice resonances (hybrid photonic-plasmonic states). The effective PEP mass is seven orders of magnitude below the electron mass and two orders of magnitude below exciton-polaritons in semiconductor microcavities. PEPs can be easily pumped and observed due to their photonic component. By increasing the PEP density through optical pumping, we observe signatures of thermalization and cooling, despite the nonequilibrium character of this driven and dissipative system. For increased pumping, we observe saturation of the strong coupling and emission in a new weakly coupled band, which again shows thermalization and cooling.

[More information on IFIMAC Website](#)

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## Spoof Plasmons: Dominos, Endoscopes and Invisibility Cloaks

Wednesday, 17 November 2010, 12:00-13.00



*Prof. Francisco J. García Vidal*

Departamento de Física Teórica de la Materia Condensada, UAM

### ABSTRACT:

In this talk we will review two different routes for controlling the flow of surface plasmons (SPs) at metal surfaces. First, we will show how the concept of spoof SPs [1] (introduction of a periodic modulation on a metal surface at a length scale much smaller than the wavelength) can be used to tailor the propagation characteristics of SPs in the optical and telecom regimes [2] and even to create new types of SPs as, for example, domino plasmons [3]. Second, we will demonstrate how Transformation Optics can be applied to the propagation of SPs [4], yielding to recipes for the refractive index map that can lead to several SP-functionalities and to cloaking devices for SPs. In addition, we will show how the idea of spoof SPs can be extended to develop holey-structured metamaterials able to perform very deep subwavelength imaging [5].

[1] Mimicking surface plasmons with structured surfaces, J.B. Pendry, L. Martin-Moreno and F.J. Garcia-Vidal, *Science* 305, 847 (2004).

[2] Geometrically induced modification of surface plasmons in the optical and telecom regimes, M.L. Nesterov, D. Martin-Cano, A.I. Fernandez-Dominguez, E. Moreno, L. Martin-Moreno and F.J. Garcia-Vidal, *Opt. Lett.* 35, 423 (2010).

[3] Domino plasmons for subwavelength terahertz circuitry, D. Martin-Cano, M.L. Nesterov, A.I. Fernandez-Dominguez, F.J. Garcia-Vidal, L. Martin-Moreno and E. Moreno, *Opt. Express* 18, 754 (2010).

[4] Transformation Optics for Plasmonics, P.A. Huidobro, M.L. Nesterov, L. Martin-Moreno and F.J. Garcia-Vidal, *Nano Letters* 10, 1985 (2010).

[5] A holey-structured metamaterial for deep acoustic deep subwavelength imaging, J. Zhu, J. Christensen, J. Jung, L. Martin-Moreno, X. Yin, L. Fok, X. Zhang and F.J. Garcia-Vidal, *Nature Physics* (AOP, November 7th 2010)

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