

C'Nano 2018

THE NANOSCIENCE MEETING

Toulon December, 11, 12 and 13
Palais des Congrès Neptune



In partnership with:



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Biography

Emmanuel Lhuillier is ESPCI engineer who hold a master in condensed matter physic. As a PhD candidate he studied transport properties of superlattices used as infrared detector under the mentorship of Emmanuel Rosencher at the French Aerospace Lab Onera. Then he moved as a Postdoc fellow in the Guyot-Sionnest group at the University of Chicago where he studied photoconductive properties of HgTe nanocrystals. In 2012, he moved back to ESPCI for a second Postdoc position in Dubetret group and investigated the optoelectronic properties of colloidal quantum wells. Since 2015, he is a CNRS researcher at the Institute for Nanoscience of Paris (INSP) at Sorbonne University. His work focuses on the optoelectronic properties of confined nanomaterial. In 2017, he defended the “*Habilitation à Diriger des Recherches*” French Diploma providing him accreditation to supervise research. The same year, he obtained a ERC starting grant.

INFRARED OPTOELECTRONICS USING COLLOIDAL NANOCRYSTALS

In this talk I will review recent progress relative to the use of colloidal nanocrystal as a low-cost strategy for the design of infrared sensor. In the first part, I will discuss progresses relative to inter-band transition in narrow band gap material such as HgTe. Over the past 10 years, huge progresses have been obtained for the design of finely tunable absorption in the mid infrared. Now HgTe is certainly the most tunable colloidal material with absorption from the visible to the THz range.

Beyond the chemical challenge, the integration of this colloidal infrared material into photoconductive and photodiode devices have been far more complicated. Nevertheless, I will show how it is possible to obtain high performance devices which compete with the ones based on epitaxially grown semiconductors.

In the second part, I will discuss how intra-band transition in doped nanocrystal is an alternative path to obtain mid infrared transition. I will mention about the origin and tunability of this doping, this include measurement down to the single particle level.

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Keywords: nanocrystal, infrared, intraband transistions

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CV/ biography (10 lines max.)

Philippe Lalanne est Directeur de Recherche au CNRS. C'est un expert en nanophotonique. Dans le groupe de Pierre Chavel à l'Institut d'Optique à Orsay, il a débuté avec des travaux sur le traitement optique de l'information, réseaux de neurones optiques et rétines artificielles. En 1996, il a passé une année sabbatique dans le groupe de Mike Morris à l'Institute of Optics à Rochester, où il a commencé des travaux dans le domaine de l'optique diffractive et de la théorie électromagnétique de la diffraction. A Palaiseau, il a ensuite travaillé sur les microcavités à cristaux photoniques et sur la transmission optique extraordinaire. Il est actuellement en poste à l'Institut d'Optique d'Aquitaine, où il anime l'axe Matter and light waves in artificial media, avec des études portant sur les micro-et nanorésonateurs optiques. Il est fellow de l'IOP, la SPIE et l'OSA et a reçu le prix Fabry-de-Gramont de la SFO et la médaille de bronze du CNRS.

Diffraction de la lumière par les nanorésonateurs

Abstract

Because they enhance and localize fields, nanoresonators are key elements for controlling light in modern optics. This control is ultimately limited by our capability to combine several nanoresonances, enable energy transfers between them, and understand how every individual mode precisely interfere to create new resonant states that overlap in space and energy. Starting from the actual leaky nature or resonator modes, we will review the basics: their definition, how we may compute them, normalize them, how much we excite them by some driving fields. Then we will move to physics: mode volume, weak and strong coupling, cavity perturbation theory, Fano lineshapes.

See Laser Photonics Rev. 2018, **12**, 1700113 <https://onlinelibrary.wiley.com/doi/full/10.1002/lpor.201700113> for details.

Keywords: electromagnetic resonance, quasinormal modes, cavity perturbation theory, Purcell effect, modal theory

11, 12 & 13 septembre

Session Nano-optics, nanophonics and plasmonics

Keywords: Electromagnetism, nanophotonics, Quasi-normal mode analysis, Mie resonators

Modal analysis of Light-scattering by Mie resonators

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Nanostructures resonantly interacting with light and can be viewed as open cavities for light. Such cavities are characterized by significant leakage of electromagnetic energy into the environment. In addition to the scattering losses, open cavities can also lose energy via absorption losses into material degrees of freedom. The optical properties of lossy nanostructures can be described by means of discrete eigen-modes, also called Quasi-Normal Modes (QNM) or resonant-states, and the losses lead to complex values for the QNM eigenfrequencies, which necessarily results in divergences of the QNM fields in the far-field region^[1].

We will present in this talk our recent advances for solving this longstanding problem while focusing on the resonant interaction between light and subwavelength particles with a large refractive index featuring Mie resonances^[2]. To address this problem, we first derive the pole expansion of the S-matrix coefficient of high refractive index scatterers^[3,4,5]. In particular, we show that in addition to the resonant contribution, a non-resonant term must be taken into account to ensure the convergence of the modal expansion. In a second step, this modal expansion in the frequency domain is used to derive the expansion of the scattered field in the temporal domain by inverse Fourier transform. The theorem of residue and the causality principle allow us to derive an expansion of the scattered field that does not diverge far from the scatterer^[5]. This divergence-free expression of the field shows that in the time domain, the scattered field also possesses resonant and non-resonant contributions.

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11, 12 & 13 septembre

Session: Nano-optics, nanophonics and plasmonics

Keywords: integrated quantum photonics, semiconductor nonlinear waveguides, quantum frequency correlations, boson/fermion statistics

Controlling frequency correlations and biphoton statistics in a semiconductor photonic chip

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Abstract

Nonclassical states of light are key components in quantum information science; in this domain, the maturity of semiconductor technology offers high potential in terms of ultra-compact devices including the generation, manipulation and detection of photonic quantum bits. The technological maturity and optoelectronic capabilities of III-V materials make them an ideal platform to develop integrated quantum light sources. In particular, employing a transverse pump geometry enables a high control on the frequency correlations of the emitted states, hardly achievable in a collinear geometry.

In this work, we demonstrate that tailoring the spatial profile of the pump beam in intensity and phase enables the control of the frequency correlations and the symmetry properties of the spectral wavefunction emitted by an AlGaAs waveguide, without post-manipulation. Using a spatial light modulator, we add a phase shift between the two halves of the pump beam, leading to a progressive splitting of the joint spectrum of the emitted photon pairs into two distinct lobes as the amplitude of the phase shift increases. These results enable the study of new effects linked to the parity control of the biphoton wavefunction, where the coincidence probabilities in HOM experiments feature a clear change from a bunching behavior, typical of bosonic statistics, to an anti-bunching behavior, typical of fermionic statistics. These findings open interesting perspectives for the utilization of our platform to perform quantum simulation of fermionic and bosonic statistics by simple frequency correlation engineering of photon pairs.

11, 12 & 13 décembre

Session: Nano-optics, nanophonics and plasmonics

Keywords: nonlinear optics; nanophotonics; plasmonics; spatial soliton; Kerr effect; chalcogenide

Experimental proof and modelling of plasmon-soliton coupling and propagation in a nonlinear plasmonic structure

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While plasmonics has seen numerous striking experimental results during the last decade, there is only very few dealing with nonlinear integrated plasmonics. This last research topic addresses photonic devices in which waveguide aspects are predominant and nonlinear effects emerges from bulk term. Our current work belongs to this difficult but promising topic. We have obtained the first experimental proof of the coupling between a plasmon and a spatial soliton. This demonstration have been realized in a layered planar structure where the nonlinear layer is made of a specific chalcogenide glass ensuring both a high nonlinear coefficient, a low two-photon absorption, and a relatively high power damage threshold. In its plasmonic part, the chalcogenide layer is separated from the 32 nm thick gold layer by a 10 nm thick silica layer whom the thickness was optimized by modal numerical simulations in order to ensure a high effective nonlinearity of the plasmonic structure.

Our experimental results reveal a strong reinforcement of the self-focusing of the incident beam only when it passes through the plasmonic part of the structure. This effect occurs when TM polarized waves are launched while no reinforcement is observed when TE polarized waves are considered. This is one of the signatures of the plasmon-soliton coupling.

Power dependency of the recorded spatial profiles has also been studied together with the impact of the localization of the plasmonic structure relatively to the input facet of the light beam.

In order to get a better understanding of these phenomena, we have build a spatial nonlinear propagation model taking into account two spatial dimensions and the different field profiles along the full structure (with/without the gold layer). We get a good agreement between the experimental data and the numerical results.

11, 12 & 13 décembre

Session : Nanophonics and plasmonics

Keywords: magnetoelectric coupling; plasmonic colors; circular polarization; metasurfaces

Circularly polarized images concealed in pseudochiral metasurfaces

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Many anticounterfeiting technologies use visual effects that are concealed to the unwary observer. In that respect, the possibility offered by plasmonics to design covert images in a particular polarization state of light is particularly interesting. Here we show how pseudochiral plasmonic resonators hosting magnetoelectric resonances can be used to tailor spatially the sign and the magnitude of circular dichroism.

We will explain how the optical response of pseudochiral plasmonic resonators can be related to the radiation patterns of point-like electric and magnetic dipoles. Through the shape and position engineering of the resonators, we will define a palette of 10 levels of contrasts observable only in circular dichroism. We will then illustrate the possibility to design covert images encoded in a pseudochiral metasurface with a reproduction of La Joconde revealed only in circular dichroism.

Reference : T. Sang Hyuk Yoo, J. Berthelot, G. Guida, D. Demaille, E. Garcia-Caurel, N. Bonod, B. Gallas, ACS Photonics (2018) DOI: 10.1021/acsp Photonics.8b00730

11, 12 & 13 décembre

Nano-optics, nanophonics and plasmonics

Keywords: semiconductor nanowire, optical antenna, telecom band, monolithic integration

InAs/InP quantum dot-nanowire single photon sources in the telecom band grown monolithically on silicon substrates

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Non-classical light sources such as single photon sources emitting at optical fiber communication wavelengths are highly interesting for quantum communication applications. In particular, InAs/InP Quantum Dot-Nanowires (QD-NWs) grown on silicon is a promising system which requires the efficient coupling of the QD emission with the fundamental guided mode and the shaping of the NW tip to optimize the collection efficiency.

Here we report our recent efforts to obtain low density vertical wurtzite InAs/InP QD-NWs with controlled NW morphology to reach efficient single photon emission in the telecom wavelength range. The QD-NWs were grown on silicon (111) substrates by Vapor-Liquid-Solid (VLS) assisted solid-source Molecular Beam Epitaxy using In-Au droplets as a catalyst in-situ deposited at 500°C. First, low QD-NW density $<0.1 \text{ NW}/\mu\text{m}^2$ was obtained by using catalyst droplets with a low In/Au ratio. Then, the growth conditions of the InAs/InP QD-NWs have been investigated to optimize the coupling of the single InAs QD with the fundamental guided mode of the NW. By modifying the shell growth temperature, an upper taper geometry has been achieved with a tapering angle of 2° . Such a small taper angle should transmit into free space almost 100% of the guided light propagating upwards.

Results obtained on single QD-NWs by micro-photoluminescence at low temperature revealed single QD linewidths which are limited by the resolution of the spectrometer. Moreover, the radiation pattern of a single InAs/InP QD-NW is Gaussian with an emission angle $\theta \approx 27^\circ$. Finally, the characteristic of a single photon source was verified with $g^{(2)}(0) < 0.5$.

11, 12 & 13 septembre

Session: nanophotonics

Keywords: 'spin-photon interface, cavity QED, quantum dot'

Deterministic assembly of an electrically-tuned spin-photon interface based on a semiconductor quantum dot

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N.D. Lanzilloti-Kimura¹, N. Somaschi¹, O. Krebs¹, P. Senellart¹ and L. Lanco^{1,2}**

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The development of quantum networks requires efficient interfaces between stationary and flying qubits. A promising approach is to use micropillars (fig. 1.a) to deterministically couple a single photon with a single charge trapped in a semiconductor quantum dot (QD) whose spin acts as a memory qubit. Such devices offer the possibility to produce high-rate spin-photon entanglement. We have previously demonstrated high quality single-photon sources [1] by deterministically coupling a QD to an electrically contacted micropillar cavity, albeit without prior identification of the QD charge state [2].

Here we propose to deterministically couple a micropillar cavity with a QD transition identified beforehand. We design a layer structure to allow optical trapping of a single hole and we use in-plane magnetic field spectroscopy to identify the QD optical transitions. The devices are fabricated using the in-situ lithography (fig. 1.b) to define a cavity centered on a single quantum dot with 50 nanometer accuracy [2]. The identification of the QD charge state during the in-situ lithography step allows to tune the micropillar parameters so that the cavity is resonant with the targeted trion transition.

The device is characterized through resonant excitation, combined with weak non-resonant pumping. We demonstrate an occupation probability of the hole state of 85-90% and excellent single-photon source properties.

With such a device, we aim at significantly increasing the Faraday rotation induced by a single spin [3], to get closer to an ideal spin-photon interface.

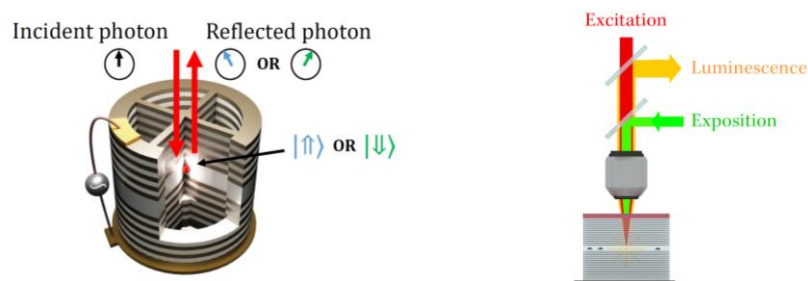


Figure 1 : (a) Micropillar structure and Faraday rotation principle. (b) In-situ lithography technique.

References

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11, 12 & 13 décembre

Session Nanophotonics

Keywords: near-field, plasmonics, spectroscopy, nanoantenna, thermal radiation

Thermal radiation of individual and coupled nanoantennas

Claire Li^{1,2}, Valentina Krachmalnicoff¹, Patrick Bouchon², Julien Jaeck², Nathalie Bardou³, Riad Haïdar² and Yannick De Wilde¹

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The ability of nanoantennas to shape light both spatially and spectrally at the nanoscale renders them essential for a wide range of applications such as sensing, energy harvesting or the design of novel optical sources in the infrared. Nanoantennas are commonly characterized by ensemble measurements on extended arrays containing hundreds of thousands of nanoantennas, leading to collective modes and diffraction affecting the overall optical response. Here, we investigate the intrinsic properties of a single nanoantenna and the effects of inter-antenna coupling in the near field and the far field using thermal radiation.

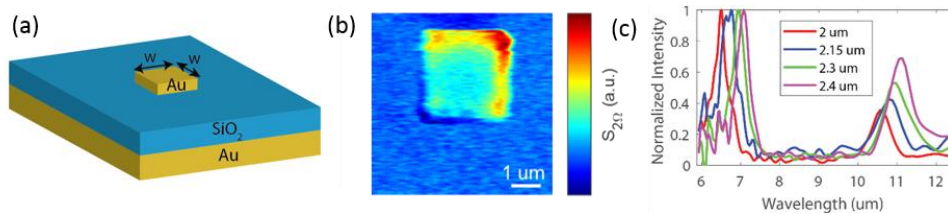


Figure 1. (a) Schematic of a single square MIM nanoantenna (b) Near-field distribution (c) Experimental spectra of single MIM nanoantennas of various widths

We study single and dimer metal/insulator/metal (MIM) nanoantennas (Fig. 1a) which constitute plasmonic resonators whose dimensions are deeply sub-wavelength [1]. Thermal radiation scanning tunneling microscopy [2] is used to perform super-resolved imaging of thermally excited fields and to reveal hot spots at the nanoantenna surface (Fig. 1b). In order to measure the spectral response of isolated nanostructures while getting rid of the overwhelming background thermal radiation spectrum, we have developed a novel detection method based on spatial modulation [3] of the heated sample. Spectra for different nanoantenna widths obtained with this technique (Fig. 1c) highlight the size-dependent resonances supported by the resonators in the mid-infrared. These results provide insight on the resonant behavior of nanoantennas at the nanoscale and open new opportunities for the design of near-field and far-field patterns.

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Congrès 2018, Toulon

11, 12 & 13 septembre

Session (Nano-optics, nanophonics and plasmonics)

Keywords: quantum dots, nonlinear optics, vibroelectronic coupling

Semiconductor quantum dots reveal dipolar coupling from exciton to ligand vibration through unconventional nonlinear optics

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Within colloidal quantum dots (QDs) research, the influence of the molecular surroundings on the optoelectronic properties of CdTe_{0.25}S_{0.75} semiconductor nanocrystals is intensively studied [1]. In particular, exciton recombination processes are noteworthy for depending on the nature of surface coordination and therefore nanocrystal/ligand bonding. In this context, our work consists in probing this QD/molecule coupling from the converse point of view: we examine the influence of the optoelectronic properties of QDs on their ligands. More specifically, we evidence a correlation between the electronic structure of QDs and the vibrational structure of molecules. Thanks to Two-Color Sum-Frequency Generation nonlinear optical spectroscopy, combining visible and infrared laser beams on ligand-conjugated QDs, we demonstrate that the vibrational response of ligands is maximum when QDs are pumped into their excitonic states. Given the different hypotheses commonly put forward, such a correlation is expected to derive from a direct overlap between the electronic wavefunctions, a charge transfer or an energy transfer. The theoretical modeling that we developed to describe this coupling concludes here in favor of an energy transfer-based process, rather than a charge transfer. Our formal calculations showed that a classical dipolar interaction can account for the results, considering that the polarizability of the molecules is subordinate to the local electric field induced by the excitons [2]. Besides, the generality and the simplicity of this approach, only based on dielectrics, make it useful and applicable to other systems within the framework of nanophysics and nonlinear optics.

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