Session (Nano-optics, nanophonics and plasmonics)
Keywords: Ideal absorption, Unitary limit, Quasi-normal modes, Resonant States

Designing Ideal absorbing and scattering nano-structures

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Abstract : Conservation laws impose absolute bounds on the strengths of the resonant interactions of light with sub-wavelength particles like those employed in nano-photonics applications.[1,2] When these limits are attained in the context of light absorption, one commonly refers to 'ideal' or 'perfect' absorption, while when they are attained in light scattering, one often speaks of reaching the 'unitary limit'. Recent progress in nano-photonics has led to a better understanding of all of these limit behaviors and how to design particles and interactions that can reach them. Such studies have also allowed a better understanding of the so-called anapole phenomenon where the scattered field is null.[3] We pass all of these phenomenon in review and explain how this improved understanding has profited from recent advances in the theory of resonant state expansions[3,4] (also known as Quasi-normal mode expansions). We will also discuss how these theories allow a better description of resonant limit phenomena in broad band and temporal regimes.

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Phys. Rev. A, 88 (2013) 011803(R).

Session: Nano-optics, nanophonics and plasmonics
Keywords: integrated quantum optics, entangled photons, semiconductor nonlinear waveguides

Generation and manipulation of hyper-entangled frequency combs in an AlGaAs chip

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Abstract

The generation, manipulation and detection of non-classical states of light on a miniaturized chip is fundamental for quantum information technologies. Entangled states in more than one degree of freedom, known as hyperentangled states, give access to large Hilbert spaces, allowing for high-capacity quantum communications and more robust quantum computation protocols. Among the different material platforms explored in these last years to generate on-chip quantum states, AlGaAs attracts a particular interest due to its compliance with electrical injection and electro-optic effect.
In this work, we demonstrate an AlGaAs waveguide presenting a high rate of hyper-entangled photon pairs generation (2.37MHz) in the telecom range and room temperature with a signal-to-noise ratio up to $5x10^4$.
Our source emits two-photon states which are hyper-entangled in polarization and frequency spanning several tens of nanometers in comb-like spectra. The two-photon joint spectral intensity presents a strong frequency anti-correlation and oscillates with peaks spaced of around 20 GHz due to the waveguide facets reflectivity. Hong-Ou-Mandel interferometric measurement shows a central dip having a visibility of 88%, and a width corresponding to a two-photon bandwidth of around 80nm. Finally, we demonstrate a novel use of the frequency-comb entangled state by manipulating the symmetry of its spatial state. By finely tuning the CW pumping frequency in an unbalanced Hong-Ou-Mandel interferometer scheme, the spatial wavefunction is transformed from bosonic to fermionic. These results demonstrate the ability of our chip to generate and manipulate hyper-entangled high-dimensional entangled states and open the way to its utilisation in a large variety of quantum information protocols.

Nanophonics and Plasmonics
LED, Phosphor, Nanocubes, Surface Plasmonic, Photoluminescence.

Surface Plasmonic effect of Ag Nanocubes on YAG:Ce3+ Photoluminescence

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Ce-doped $Y_3Al_5O_{12}$ (YAG:Ce) phosphor has been extensively studied since it constitutes the main luminescent material used in currently commercialized white Light Emitting Diodes based on blue LED [1]. Even if these devices provide an intense light, they can be further improved by increasing the light extraction efficiency of the fluorescent layer. The enhancement of the forward emission from YAG:Ce layers appears as one of the foreseen strategies [2]. In our work, metallic nanoparticles supporting surface plasmon (SP) have been used as optical nanoantennas in order to modify the emission rate and directionality of YAG:Ce coatings. The plasmonic nanoparticles were expected to modify the local density of optical states in addition to allowing the guided modes in the phosphor layer to be converted into propagating light. Colloidal Ag nanocubes were homogenously deposited onto thin sol-gel derived YAG:Ce coatings. Emission spectra were recorded and compared over areas with and without the nanoparticles on top (figure 1). The influence of surface coverage concentration and the nanocubes size have been studied using Photoluminescence (PL) Mapping.

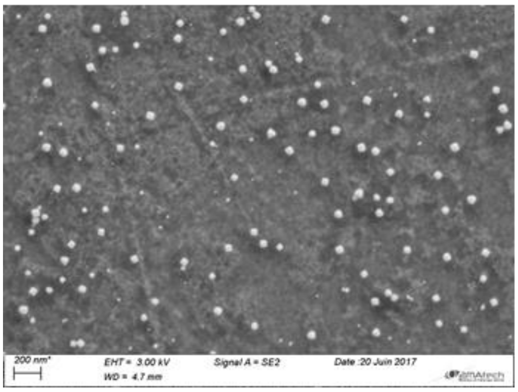

Figure 1. SEM image of Ag nanocubes homogeneously deposited over thin YAG:Ce phosphor film.

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Remerciements

Ces travaux ont été réalisés dans le cadre du CPER DEFI MMASYF. Les auteurs remercient donc l'Union Européenne dans le cadre du Fonds Européen de Développement Régional et la Région Auvergne Rhône-Alpes qui cofinancent ce projet.

Second harmonic generation from AlGaAs metasurfaces

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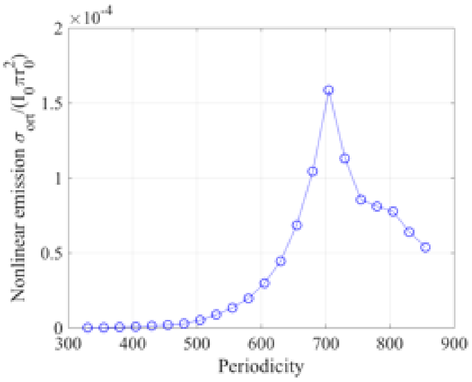
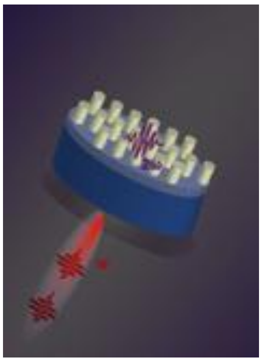
Dielectric metasurfaces lend themselves to intracavity mode shaping in external-cavity semiconductor lasers thanks to their ability of creating distributions of high-contrast membranes on the same epitaxial growth [1]. In this context, an intriguing option is represented by using the metasurface to generate harmonic frequencies inside the laser cavity. While $\chi^{(3)}$ effects were reported in silicon-on-insulator nanoantennas [2], the AlGaAs-on-insulator platform has recently enabled the demonstration of second harmonic generation (SHG) in $\chi^{(2)}$ nanoantennas [3]. Their excitation at normal incidence results in efficient SHG driven by Mie-type magnetic dipole resonance at the pump frequency in the near infrared and a polarisation behaviour dominated by a high-order multipole resonance at the second harmonic (SH) [4].

Here we focus on SHG from MOCVD-grown monolithic metasurfaces of $Al_{0.18}Ga_{0.82}As$-on-AlOx nanoantennas, where AlOx is obtained from selective wet oxidation of µm-thick aluminium-rich AlGaAs layer. As a prototype example, we report the case of a set of coupled nanocylinders with height h = 400 nm, radius r = 122 nm and 300 to 900 nm periodicity, which we excite with a pump beam at λ = 1064 nm linearly polarized along the [100] AlGaAs axis. The related SHG efficiency is low for periodicities smaller than the array diffraction limit, where SH modes stay confined in the metasurface plane. Conversely, for greater periodicities the SH modes are coupled into the zero-diffraction order. In this case, the SH fields generated from neighbouring nanoantennas constructively interfere, with a strong enhancement with respect to the case of the SHG from an isolated nanoantenna. This result paves the way to dielectric intracavity metasurfaces for SHG with an arbitrary wavefront.



a)



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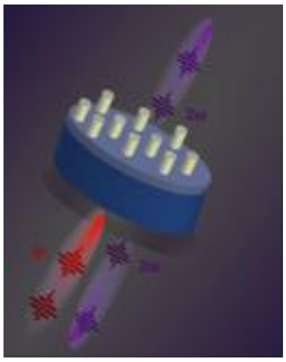

c)

Figure. a) Calculated SHG efficiency vs periodicity. b) Schematic of SH waveguided modes for a periodicity of 300 nm. c) SH modes emitted at the zero order for a periodicity of 700 nm.

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Congrès 2018, Toulon
11, 12 & 13 septembre
Session : Nano-optics, nanophonics and plasmonics
Keywords: Nanowire; Quantum dot; Photonic wire; Single photon; Nano-optics

CdSe/ZnSe nanowires-quantum dots and enhanced photon extraction with a bottom-up dielectric photonic shell

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Semiconductor nanowires (NWs) offer the possibility to grow high quality quantum dot (QD) heterostructures, and in particular CdSe QDs inserted in ZnSe NWs have demonstrated the ability to emit single photons up to room temperature. Moreover, the NW geometry offers the possibility to form photonic wires in order to guide and extract efficiently the photon from the QD. In this contribution, we present our work on the growth and optical studies of vertically oriented CdSe/ZnSe NW-QDs by molecular beam epitaxy, with a ZnMgSe passivating shell to increase the (otherwise weak) QD luminescence. The NWs diameter is typically 10 nm and single QDs shows clearly exciton, biexciton and charged exciton transitions. We show that, using Atomic Layer Deposition (ALD), a thick conformal dielectric coating of Al_2O_3 on the NW-QDs can be obtained (fig. 1), forming a bottom-up photonic wire with the CdSe QD deterministically positioned on its axis.
Optical studies of single NW-QDs show that a 4-fold increase of the collected photoluminescence intensity can be obtained with an oxide shell of 110 nm thick. This improvement is due to an increase of the QD emission rate, as shown by decay time measurements, and a redirection of the emitted light as shown by numerical simulations [1]. We will discuss the importance of the optical dipole orientation and how it can be controlled through the QD aspect ratio.

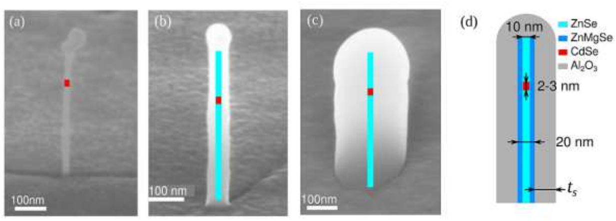

Fig. 1 : Nanowire quantum dot in a photonic wire

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Congrès 2018, Toulon

11, 12 & 13 septembre

Session: Nano-optics, nanophonics and plasmonics

Keywords: Topological photonics, graphene-based structures, photonic nanotube, Dirac point

Analogies between the properties of graphene/carbon nanotube transition and its photonic equivalent

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The study of the photonic analog of atomic crystals has been paving the way to new perspectives in the light engineering. In particular, graphene-like structures have drawn interest as, like their electronic counterparts, they exhibit remarkable properties such as the presence of a Dirac point in their band diagram. Beyond the linear dispersion around this point, it has been proved that by opening a gap around this peculiar point, topological edges states could be obtained even without the need of any external fields ([1], [2]).

Stress-engineering based fabrication recently opened the path to produce rolled-up structures based on planar photonic crystals [3]. These new opportunities allow us to pursue the above mentioned analogy and to fabricate and characterize the analog of carbon nanotubes in the class of photonic crystals. It is well known that, depending on their chirality, the carbon nanotubes may (or not) present a band-gap so that a natural question we address here concerns the existence of a folding induced band-gap in the case of photonic micro-tubes.

Toward the answer to this question, 3D FDTD simulations have been performed so as to design a graphene-like photonic structure with a Dirac point centered at 1.55 µm. In addition, a tight-binding approach was used to predict which chirality of the photonic micro-tubes would generate a band gap. Finally, we also report here fabrication of the first photonic nanotubes with honeycomb pattern (Figure 1). Optical characterization using photoluminescence measurements of fabricated structures is still in progress. Our goal is to experimentally construct band diagrams of the structures and validate theoretical expectations.

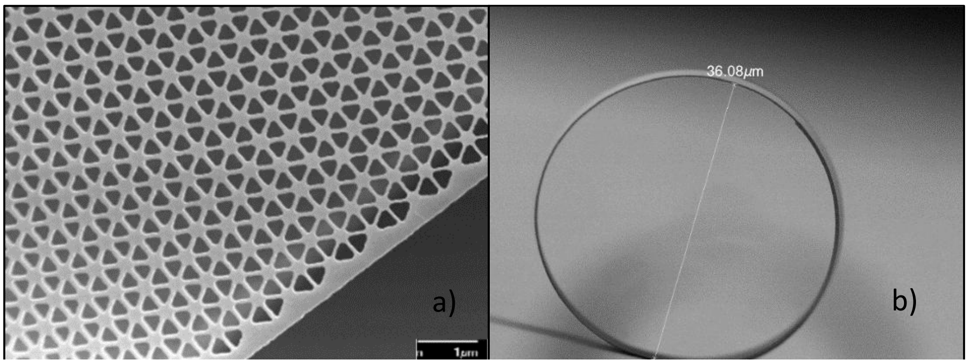

Figure 1: MEB pictures of (a) honeycomb lattice of triangular air holes in InP membrane and (b) the photonic nanotube obtained after rolling the previous membrane up.

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Congrès 2018, Toulon

11, 12 & 13 septembre

Session: Nano-optics, nanophonics and plasmonics

Keywords: Plasmonics, levitation, spectroscopy

Optical spectroscopy of "flying" plasmonic particles

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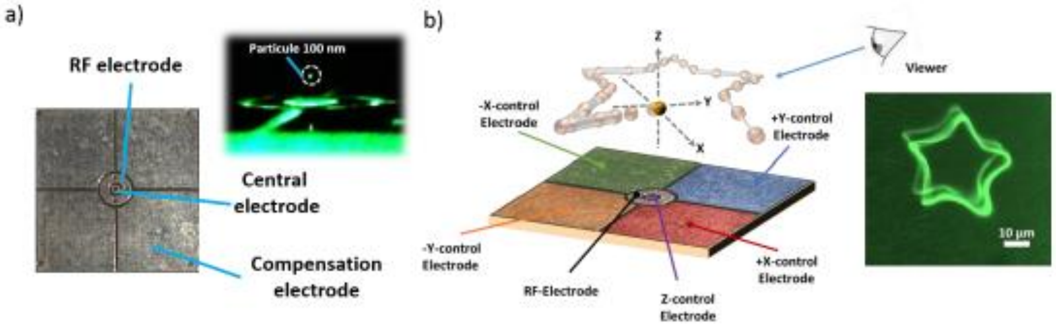
Particle colloids feature excellent structural and optical properties. Measuring their intrinsic optical properties requires the absence of influence of their surrounding environment, in particular the influence of substrates. In this talk, we will present our latest advances in order to perform optical spectroscopy of single particles levitating in air.

Ashkin developed the optical levitation of nano-objects such as particles or viruses as early as 1970 and he was awarded in 2018 the Nobel Prize for this discovery [1]. Besides optical nano-tweezers, electric fields acting on small electrically charged objects are very interesting to levitate objects in water but also in air or vacuum. Levitation of ions with radiofrequency traps, also called Paul traps, has benefited from intense efforts and has become a ubiquitous method to manipulate ions [2-3]. RF traps were recently introduced in the field of nanosciences to manipulate nanoparticles and quantum emitters [4-5]. In this context, planar Paul traps were proposed in 2017 as an efficient alternative to bulky Paul traps to levitate particles [6].

In this talk, we will present our latest advances to manipulate individual gold nanoparticles in air with a planar radiofrequency trap coupled with a confocal microscope (figure 1a). The set-up allowed us to perform optical spectroscopy of individual gold particles with sizes ranging between 80 nm and 200 nm and to monitor the localized plasmon resonance of these "flying" particles. Additional DC electrodes offer a tight and dynamic control of the particle trajectory in the 3 dimensions of space (figure 1b) [7].



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Congrès 2018, Toulon

11, 12 & 13 septembre

Session (ex : Nano-optics, nanophonics and plasmonics)

Keywords: 'Nano-particles, diffraction, dipole model, scattered light'

Examining diffracted light from nanoparticles at variable distances from surfaces

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Abstract

The diffraction of light from nanoparticles at variable distances from surfaces is explored. We consider the diffraction of light from a single nanoparticle on a silicon support surface. The surface is illuminated with a collimated laser beam and the diffracted field is recorded with a pointed optical fiber in collection mode. Surface optical standing waves serve to keep the optical fiber parallel to the surface at variable distances without any probe-surface interaction field, which allows to observe diffraction images at variable distances ranging from the near field, intermediate field and far field. A dipole model is used to derive analytic expressions for elliptic diffraction fringes formed in the plane parallel to the surface. By fitting the experimental diffraction fringes to the dipole model we determine the distance of the image plane with respect to the support surface and the exact location of the nanoparticle. The phase-shift of the scattered wave from the nanoparticle is found to influence, however, and the size of diffraction fringes. We show that the error in phase determination is directly correlated to the error in the distance between the image plane and the support surface. We believe that exploring diffracted light from surfaces opens new opportunities for the metrology of nanoparticles or nano-structured surfaces.

Congrès 2018, Toulon

11, 12 & 13 septembre

Session (ex : Nano-optics, nanophonics and plasmonics, calibri 11, black color)

Keywords: graphene, heat conductivity, heat flow, Raman spectroscopy

Determination of the heat conductivity of graphene in large graphene bubbles

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Abstract (No longer than 250 words, Calibri 12, single line spacing, black)

Raman images of large graphene bubbles showed oscillations in spectral intensity and frequency, which originate from optical standing waves formed in the vicinity of the graphene surface[1]. At high laser power, local heating creates a large temperature gradient in the bubble. Based on the Raman shift (after subtracting strain induced spectral shifts) the temperature distribution within the graphene bubble was determined and compared with theoretical heat flow calculations. This gave the opportunity to deduce the heat conductivity in graphene bubbles which was found to be comparable to previously determined values for previously determined values for suspended, flat graphene. It is observed that the heating effect of the laser is reduced when moving from the center of a bubble to its edge. The derived temperature of the bubble is as high as 1400 K. Degradation and collapse of the graphene bubble was observed after longer exposure of the bubble to the laser beam. The chemical reactivity of graphene was investigated and it was found that when exposed to hydrogen plasma, areas with bubbles are found to be more reactive than flat graphene.

1 Y Huang, X Wang, X Zhang,X Chen, B Li,1 B Wang, M Huang, C Zhu, X Zhang, WS Bacsa, F Ding, RS Ruoff, Phys. Rev. Lett. 120 (2018) 186104

Session: Nano-optics, nanophonics and plasmonics
Keywords: TIRF metasurface bioimaging microscopy

Metasurface-based total internal reflection bioimaging

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In recent years there has been a significant effort to push electromagnetic metasurfaces with the ability to abruptly change light properties into visible wavelengths. These advancements have opened a new range of possibilities to reshape light using ultra-thin optical devices and there is one field that is starting to gather attention: bioimaging. One technique particularly well suited for the study of molecules near a cell membrane is Total Internal Reflection Fluorescence (TIRF) microscopy, which relies on an evanescence field created by light being totally internally reflected within a glass substrate due to its high incidence angle. As of today, TIRF is generally implemented using bulky high-NA, small field of view oil objectives. We introduce the realization of metasurface-based TIRF microscopy substrates consisting of periodic arrays of asymmetric grooves fabricated in titanium dioxide on glass substrates. These grooves, as small as 48nm, were optimized through rigorous coupled-wave analysis to couple 50-90% of the incoming normally incident light into the first diffraction order, which outputs at an angle that suffices total internal reflection in water and eliminates the requirement for high NA objectives or prisms to achieve TIRF. Our optical analysis show that we have an intensity up to 5 times higher on the first order than on the other orders, meaning that most of the light is being redirected asymmetrically and propagates throughout the length of the glass substrate. Being able to utilize lower-magnification air objectives and having a large evanescence field area provide unique TIRF conditions not accessible by traditional methods. Additionally, these structures are compatible with soft UV nanoimprint lithography, for cost-effective scale production, to give TIRF's high contrast, low photodamage and low photobleaching capabilities to inexpensive wide-field microscopes.

Congrès 2018, Toulon

11, 12 & 13 décembre

Session: Nano-optics, nanophonics and plasmonics

Keywords: complex media, scattering, information, speckle

Information content of speckle patterns for optical imaging inside scattering materials

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Imaging inside a strongly scattering medium is a challenging task due to light absorption and scattering, respectively lowering the collected intensity and shuffling its spatial distribution. A fundamental question arise: what is the amount of information theoretically enclosed in the light escaping complex media? We propose to answer this question with a model based on a set of sub-wavelength particles, which are described by their position and their polarizability. The amount of information enclosed in the scattered light about the position of the particles can be formally assessed using the Fisher information, a concept which is widely used to study the localization precision in single-molecule localization microscopy. Using the coupled dipole method, we numerically study the parameters driving the Fisher information in a disordered scattering media illuminated by a coherent light source. We notably make the connection between the Fisher information and the number of degrees of freedom in the measured images. Moreover, we investigate the large variance observed in the multiple scattering regime, which originates not only from intrinsic properties of the medium but also from the optical modes which are excited. This work paves the way toward the implementation of efficient strategies to achieve information-driven imaging in the multiple scattering regime.

Congrès 2018, Toulon

11, 12 & 13 septembre

Session Nano-optics, nanophonics and plasmonics

Keywords: 'self-organized nanoparticles', 'random metallic films', 'ultra-low-energy ion sputtering', 'Surface Differential Reflectance Spectroscopy'

Evolution of plasmonic nanostructures under ultra-low-energy ion bombardment

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Applications of plasmonic nanostructures demand a full control of their morphology, organization and composition. While the plasmonic response of metal nanoparticles can be tailored by post-fabrication treatments such as thermal annealing, it has been shown that it can also be modified by ultra-low-energy ion bombardment (< 100 eV, i.e. near the sputtering threshold). Indeed, ion-induced soft-sputtering associated with enhanced atom mobility result in progressive but irreversible changes of both the morphology and organization of the nanoparticles. In this work, we focus on the evolution of percolated Ag films and self-assembled Ag nanoparticle chains under bombardment with ultra-low-energy Ar ions. Percolated Ag films were grown by magnetron sputtering deposition whereas self-assembled Ag nanoparticle chains were prepared by glancing-angle deposition onto pre-patterned rippled surfaces. By combining post-mortem structural characterizations and real-time optical measurements, we show that the broadband character of the percolated films gradually moves towards narrow surface-plasmon-resonance bands arising from the formation of disconnected irregularly-shaped nanoparticles that later evolve into isolated spherical nanoparticles. Regarding the structural evolution of the self-assembled Ag nanoparticle chains, our observations show that ultra-low-energy ion bombardment induces a progressive increase of the nanometer gaps between neighboring particles as well as a preferential sputtering of the smallest particles. The dichroic character of the resulting plasmonic nanostructures can thus be finely modulated by modifying the coupling between particles. In addition, the kinetics of ion-induced modifications can be easily controlled by varying the ion energy and flux, which enables the plasmonic properties of nanostructures to be tuned with great flexibility.