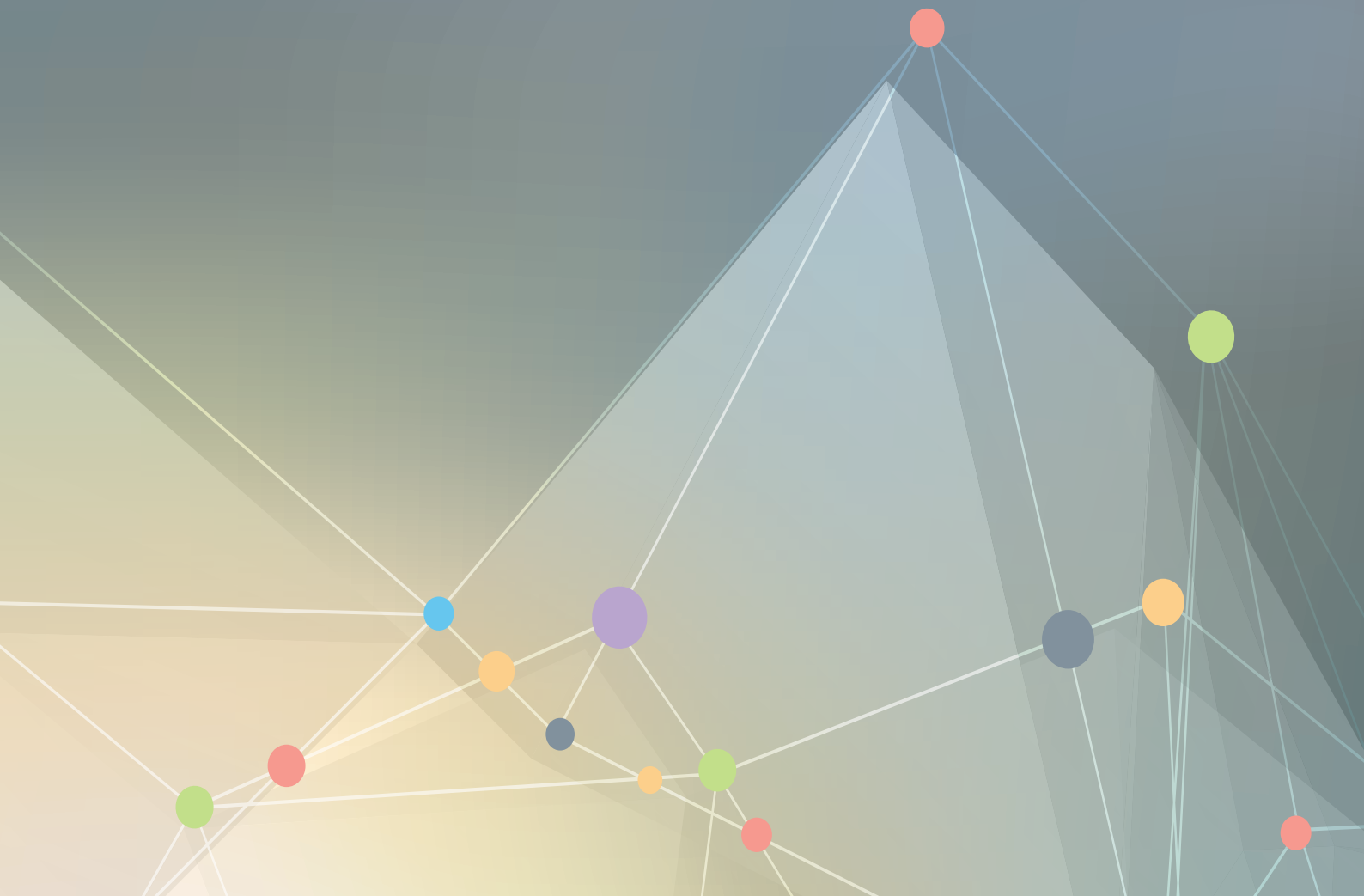


# BOOK OF ABSTRACTS

## Oral Presentations



# 2023



## Nanophotonics & nano-optics

(Last update: July 8<sup>th</sup>, 2022)

### Description

The « nanophotonics and nano-optics » session will cover recent developments in the field of the interaction of light with nano-objects, nanophotonic devices or nanomaterials

The session will particularly focus on:

- Plasmonics: surface plasmons, ultra-fast plasmonic, plasmonic nanostructures for tight field confinement and field enhancement,
- Dielectric metasurfaces, 2D arrays of nanostructures, topological photonic metamaterials
- Electromagnetic modeling, artificial intelligence and deep learning applied to nanophotonic inverse design and optimization
- Nanophotonic-enabled devices and applications: nanoantenna, nanostructures and metamaterial-based techniques, dynamically tunable nanophotonic systems, active and non linear nanophotonics, nano-optomechanical systems.
- Advanced fabrication and optical characterization/imaging techniques for nanophotonic structures

### Keywords

Plasmonics; nanomaterials for optics; quantum nano-optics; opto-mechanics; nanophotonic devices

### Scientific committee

**Anne-Ségolène CALLARD\*** (EC Lyon – INL, Lyon)

**Yannick DE WILDE** (CNRS – I. Langevin, Paris)

**Erik DUJARDIN\*** (CNRS – ICB, Dijon)

**Jean-Luc DUVAIL** (Nantes Univ. – IMN, Nantes)

**Anne-Laure FEHREMBACH** (AMU – Institut Fresnel, Marseille)

**Antoine MONMAYRANT** (CNRS – LAAS, Toulouse)

\* *Session Coordinator*

**2023**

**Wednesday March 15<sup>th</sup>**

**11.00 am – 1.00pm**

**Amphi 150**

**Program of the session**

**Chairs: Erik DUJARDIN & Nicolas BONOD**

**NANOPHOTONICS & NANO-OPTICS**

<b>11:00</b>	<b>Engineering Quantum States in 2D semiconductors</b>	<b>Bernhard URBASZEK • IPKM, Darmstadt – Germany</b>
11:30	Complete design of a fully integrated graphene-based compact plasmon coupler for the infrared	<b>Gilles RENVERSEZ • AMU - Inst. Fresnel, France</b>
11:45	A Chiral Inverse Faraday Effect Mediated by an Inverse-designed Plasmonic Antenna	<b>Ye MOU • Sorbonne Univ. - INSP, France</b>
12:00	Light Confinement in photonic moiré	<b>Chirine SAADI • EC Lyon - INL, France</b>
12:15	Digital harmonic holographic microscope for the study of nanostructures in nonlinear regime	<b>Serena GOLDMANN • CNRS - Inst. Langevin, France</b>
12:30	Excitation of a magnetic dipole transition through a plasmonic nano-antenna	<b>Benoit REYNIER • Sorbonne Univ. - INSP, France</b>
12:45	Super-resolution imaging of the formation of emitting sites for exciton localization in carbon nanotubes	<b>Benjamin LAMBERT • CNRS - LP2N, France</b>

# Keynote Speakers

## NANOPHOTONICS & NANO-OPTICS



### **Bernhard URBASZEK**

**TU Darmstadt I Professor**

*Institute of Condensed Matter Physics*

[https://www.ipkm.tu-darmstadt.de/research\\_ipkm/aq\\_urbaszek/index.en.jsp](https://www.ipkm.tu-darmstadt.de/research_ipkm/aq_urbaszek/index.en.jsp)

### **BIOGRAPHY**

After obtaining a doctorate at the Heriot-Watt University of Edinburgh, Bernhard URBASZEK joined the department of quantum optoelectronics of the Laboratory of Physics and Chemistry of Nano-Objects in Toulouse in 2003. He was then appointed lecturer at the National Institute of applied sciences of Toulouse before joining the CNRS in 2008 as a tenured senior researcher. In 2013, he obtained an ERC Consolidator Grant Award, Optically controlled carrier and Nuclear spintronics: towards nano-scale memory and imaging applications and became CNRS Director of research in 2014. He was elected Fellow at the American Physical Society in 2022 and is now Professor at the TU Darmstadt at the Institute of Condensed Matter Physics. His main research focuses on the physics of light-charge-spin interactions in low-dimensional materials, in particular quantum dots, as well as the manipulation of quantum states in new atomically thin semiconductors.

### **ENGINEERING QUANTUM STATES IN 2D SEMICONDUCTORS**

The physical properties of atomic monolayers often change dramatically from those of their parent bulk materials. Prime examples are monolayers of graphite (graphene) and MoS<sub>2</sub>, as their ultimate thinness makes them extremely promising for applications in electronics and photonics. Transition metal dichalcogenide monolayers (TMD) MoS<sub>2</sub> and WSe<sub>2</sub> show remarkable light-matter interaction and tunable non-linear optical properties such as strong second harmonic generation [1]. Their optical properties are governed by excitons, Coulomb bound electron-hole pairs, even at room temperature [2]. In this talk we discuss how tuning optical properties is achieved through engineered growth of monolayers and also by coupling these TMD monolayers to the optical resonances in silicon nanostructures.

In lateral (in-plane) MoSe<sub>2</sub>-WSe<sub>2</sub> monolayer heterostructures grown by chemical vapor deposition the two materials form a junction region as narrow as 2 to 3 nm. We report uni-directional exciton transport experiments across the junction (an 'exciton diode') in tip-enhanced photoluminescence with a spatial resolution of 30 nm [3].

We show exciton spectroscopy results on Janus monolayer structures SeMoS with different top and bottom chalcogen atoms obtained through a novel growth approach [4]. These systems host excitons with an intrinsic static dipole and give rise to strong optical non-linearities.

Finally, we discuss how emission and absorption for monolayers can be enhanced and tuned via near field coupling to Mie resonances of silicon nanostructures that are compatible with CMOS technology [5].

This work is carried out in collaboration with the LPCNO Toulouse, CEMES and LAAS Toulouse, FSU Jena (Germany) and NIMS Tsukuba (Japan).

### **KEYWORDS**

2D Materials; Photonics ; Optoelectronics

### **REFERENCES**

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**Thematic Session:** Nanophotonics & nano-optics

**Keywords:** plasmon, graphene, integrated coupler, infrared

**Disciplinary field involved:** Physics

## Complete design of a fully integrated graphene-based compact plasmon coupler for the infrared

**Aswani Natarajan, Guillaume Demésy, and Gilles Renversez**

*1 Aix Marseille University, CNRS, Centrale Marseille, Institut Fresnel, 13013 Marseille, France, gilles.renversez@univ-amu.fr*

With the renewal of plasmonics, the generation and launching of surface plasmon polaritons (SPPs) has been a crucial problem both theoretically and experimentally [1]. The concept of coupler to generate a SPP has already been proven experimentally in the mid-infrared near  $8 \mu\text{m}$  [2]. We have developed a general methodology to study rigorously such couplers. It relies on a full vector description given by Maxwell's equations in the framework of the finite element method [3]. Here, the discontinuities in the waveguides are provided by the graphene patches that are modelled as a 2D conductivity pieces. The leaky modes of the invariant structure are first computed and then injected as incident fields in the full structure with the graphene patches and sheet using a scattered field approach. These couplers are designed to work in the far infrared regime due to its potential for applications. The TAS chalcogenide glass is considered for the guiding layer due to its good optical properties in this wavelength range. The studied waveguide is a ridge waveguide with a core thickness smaller than the wavelength. The coupler region of the device is made of a finite number of graphene patches located just above the core guiding layer. The role of this coupler is to generate electromagnetic fields in the next continuous graphene sheet also located on the top of the core where the surface plasmon polariton part of the field is propagating. The studied device is fully integrated and no taper region is needed, ensuring the compactness and robustness of the device. Theoretical and numerical studies as a function of the waveguide thickness and of the duty cycle parameter describing the coupling patches have been conducted in order to maximize the plasmonic part of the generated field near the graphene layer leading to a compact and efficient plasmon coupler.

References

- [1] D. Costantini, L. Greusard, A. Bousseksou, et al., "In situ generation of surface plasmon polaritons using a near-infrared laser diode," *Nano Letters*, 12, (9), p. 4693, 2012.
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**Keywords:** plasmonic nanoantenna, inverse Faraday effect, inverse design, light-matter interactions, chirality

**Disciplinary fields involved:** Physics

**Sustainable Development Goals\* eventually involved in your research:** Affordable and Clean Energy (Goal 7)

## A Chiral Inverse Faraday Effect Mediated by an Inverse-designed Plasmonic Antenna

Ye Mou<sup>1</sup>, Xingyu Yang<sup>1</sup>, Bruno Gallas<sup>1</sup>, Mathieu Mivelle<sup>1\*</sup>

1. Sorbonne Université, CNRS, Institut des NanoSciences de Paris, INSP, F-75005 Paris, France

The inverse Faraday effect (IFE) allows the generation of stationary magnetic fields through optical excitation only [1,2]. This light-matter interaction in metals results from the creation of drift currents via nonlinear forces that light applies to the conduction electrons [1]. The IFE was believed, until now, to be a symmetrical phenomenon, meaning that a right-handed circularly polarized wave will create a magnetic field oriented toward light propagation. In contrast, excitation by a left-handed circularly polarized wave will generate a magnetic field opposite this propagation. Here we demonstrate, via the manipulation of light in the near field of an inverse-designed plasmonic nanostructure, the generation of a chiral IFE. Specifically, using a genetic algorithm, we inversely design a chiral plasmonic nanostructure creating a stationary magnetic field by IFE for one specific light helicity (Figure 1a-c). Furthermore, we demonstrate that using the enantiomer opposite to the optimized structure generates a magnetic field for an opposite helicity of light (Figure 1d-f). The results presented here are remarkable since the plasmonic approach is nowadays the only one allowing the generation of stationary magnetic fields at the nanoscale and at the femtosecond timescale [3]. Therefore, using chiral plasmonic nanostructures to generate a chiral IFE opens the door to producing a stationary magnetic field by unpolarized light. The outcomes of these results are multiple, in particular, the manipulation of magnetic processes at ultrashort timescale, such as spin precession, spin currents, and skyrmions, becomes possible. This would find applications, for instance, in data storage at an ultrahigh rate.

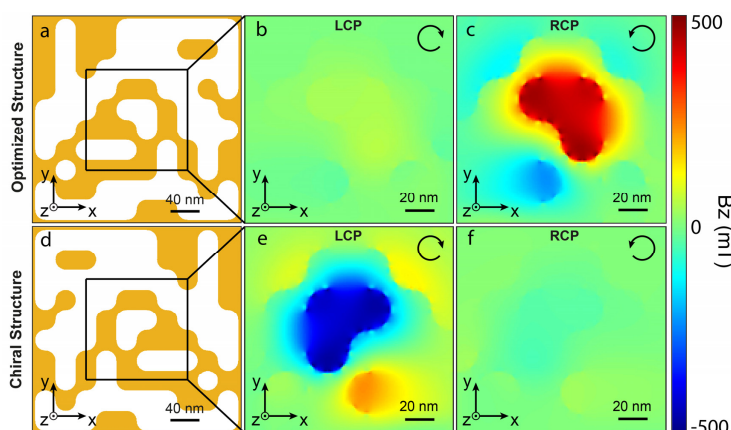


Figure 1. Magnetic response of the optimized plasmonic nanostructures. a) Schematic, in an XY plane, of the GA-optimized structure. b) and c) Spatial distributions of the stationary magnetic fields oriented along Z and generated in the Z-center of the structure shown in a) for the left and right circular polarizations of excitation, respectively. d) Schematic, in an XY plane, of the mirror structure. e) and f) Spatial distributions of the stationary magnetic fields oriented along Z and generated in the Z-center of the mirror structure shown in d) for the left and right circular polarizations of excitation, respectively.

# C'Nano

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# Positiers

March, 15, 16 and 17

# 2023

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## **References:**

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## **Acknowledgment:**

We acknowledge the financial support from the Agence Nationale de la Recherche (ANR-20-CE09-0031-01), from the Institut de Physique du CNRS (Tremplin@INP 2020). Two of the authors (Y.M. and X.Y.) acknowledge the support of the China Scholarship Council.

**Keywords:** moiré photonic crystals, magic configurations, microcavities, localization of light

**Disciplinary field involved:** Physics

## Light confinement in photonic moiré

Chirine Saadi<sup>1</sup>, Sébastien Cueff<sup>1</sup>, Hai Son Nguyen<sup>1</sup>, Lydie Ferrier<sup>2</sup>, Serge Mazauric<sup>3</sup>, Ségolène Callard<sup>1</sup> and Xavier Letartre<sup>1</sup>.

1. Univ Lyon, Ecole Centrale de Lyon, CNRS, INSA Lyon, Univ Claude Bernard Lyon 1, CPE Lyon, CNRS, INL, UMR5270, 69130 Ecully, France
2. Univ Lyon, INSA Lyon, CNRS, Ecole Centrale de Lyon, Univ Claude Bernard Lyon 1, CPE Lyon, INL, UMR5270, 69621 Villeurbanne, France
3. Univ Lyon, CPE Lyon, CNRS, INSA Lyon, Ecole Centrale de Lyon, Univ Claude Bernard Lyon 1, INL, UMR5270, 69616 Villeurbanne, France

Moiré structures are receiving increasing attention in Nanophotonics as they support intriguing optical phenomena [1]. As an example, it has been demonstrated recently that one-dimensional moirés give rise, in the so-called “magic configuration”, to fully dispersionless energy bands known as “flatbands”, where the light is localized within one supercell of the periodic moiré [2]. Based on this study, we analyze the optical response of finite moiré structures consisting of one, two, or more supercells. The purpose of this work is to determine to what extent the confinement of light, observed in periodic structures, is preserved in microcavities of finite size. First, the band diagram of periodic moirés is computed numerically using finite element method in order to determine the parameters of the “magic configuration”. Thus, we demonstrate that the cavities based on one moiré supercell can confine light efficiently with a high-quality factor  $Q \sim 10^7$ . However, for one supercell, the “magic configuration” does not appear to have a significant impact on the electric field confinement. On the other hand, when two supercells are linked, we observe a situation with zero coupling between the supercells, which is provided by the “magic distance”. To conclude, we describe the technological ways allowing the fabrication of these structures which can be advantageously exploited in optoelectronics.

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**Acknowledgment:** The authors thank the NANOLYON platform facilities for assistance in the development of this study as well as METAONDEMAND ANR project ANR-20-CE24-0013.



**Keywords:** Holography, Second Harmonic Generation, Tomography

**Disciplinary fields involved:** Physics, Optics

## Digital harmonic holographic microscope for the study of nanostructures in nonlinear regime

Serena Goldmann<sup>1</sup>, Samuel Grésillon<sup>1</sup>, Ignacio Izeddin<sup>1</sup>, Gilles Tessier<sup>2</sup>, Yannick De Wilde<sup>1</sup>

1. Institut Langevin, ESPCI Paris, Université PSL, CNRS, 75005 Paris, France

2. Sorbonne Université, INSERM, CNRS, Institut de la Vision, 17 rue Moreau, 75012, Paris

Digital holography is an imaging technique that enables a 3-dimensional reconstruction of the electromagnetic field scattered by an object in both amplitude and phase. We demonstrated its use in microscopy for the full 3-D mapping of the field scattered by single nanostructures such as nano-antennas [1] and near-field probes [2]. Holography is an interference process, which can be obtained at the laser illumination wavelength, but also with Second Harmonic Generation (SHG) since it is produced in a coherent process [3].

Here, we describe the development of a harmonic holographic microscope for single-shot mapping of the second harmonic 3D radiation pattern near samples with nonzero second harmonic susceptibilities. The knowledge of the scattered field (amplitude and phase) in a given plane (that of the camera) allows its reconstruction in any other plane using e.g. the angular spectrum representation of optical fields [4], and assuming propagation in homogeneous media, a process called 3D numerical back-propagation [5].

In addition to providing 3D reconstruction, thus enhancing the imaging capabilities beyond those of back focal-plane imaging, the harmonic holography microscope also benefits from an amplification effect since the signal from the sample is multiplied by an intense reference in the interference term, making the method particularly well suited to measure the weak SHG signals produced by metallic nanostructures.

After a first validation on dielectric samples made of nonlinear micro-crystals and cornea collagen, we are currently implementing it to unravel the SHG field radiated by plasmonic nano-antennas.

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**Acknowledgment:** The authors are very grateful to Marie-Claire Shanne-Klein for stimulating discussions regarding SHG microscopy. This research is supported by the French National Research Agency (ANR-20-CE24-0021), and LABEX WIFI under references ANR-10-LABX-24 and ANR-10-IDEX-0001-02 PSL\*.

**Keywords:** plasmonic antenna, magnetic light, light-matter interactions imaging

**Disciplinary field involved:** Physics

## Excitation of a magnetic dipole transition through a plasmonic nano-antenna

B. Reynier<sup>1</sup>, E. Charron<sup>1</sup>, O. Markovic<sup>1</sup>, X. Yang<sup>1</sup>, B. Gallas<sup>1</sup>, A. Ferrier<sup>2</sup>, S. Bidault<sup>3</sup>, M. Mivelle<sup>1</sup>

1. Sorbonne Université, CNRS, Institut des NanoSciences de Paris, INSP, 75005 Paris, France
2. Chimie ParisTech, PSL University, CNRS, Institut de Recherche de Chimie Paris, 75005 Paris, France
3. Institut Langevin, ESPCI Paris, PSL University, 75005 Paris, France

Light-matter interactions are often considered to be mediated by the optical electric field only, discarding half of the energy stored in the optical magnetic field. Although interactions between light and matter are very weak, they can be studied in a certain class of materials, such as metal ions.

For instance, it was demonstrated in  $\text{Eu}^{3+}$  ions that magnetic emission could be manipulated by tuning the local magnetic quantum environment surrounding magnetic dipoles by means of dielectric or plasmonic nanostructures [1,2]. Along the same line, it is also possible to manipulate the electric and magnetic excitation of these ions by controlling the electric and magnetic fields distribution of the excitation light [3].

Here, by using a plasmonic nano-antenna placed at the end of a local probe (Figure 1), we demonstrate the localization and enhancement at sub-wavelength scales of the optical magnetic field (Figure 2). This magnetic hot spot is then used to excite a luminescent nanoparticle doped with  $\text{Eu}^{3+}$  ions, demonstrating an energy transfer from the optical magnetic field to matter at the nanoscale. Moreover, by selectively exciting an electric or magnetic transition of the particle, the nanoscale scanning capabilities of our near-field system allow us to image the spatial distribution of these fields of the localized plasmon in the antenna (Figure 2). This research opens the way to increasing the all-magnetic light-matter coupling, with applications in quantum optics, in studying chiral phenomena, or the generation of photon avalanches.

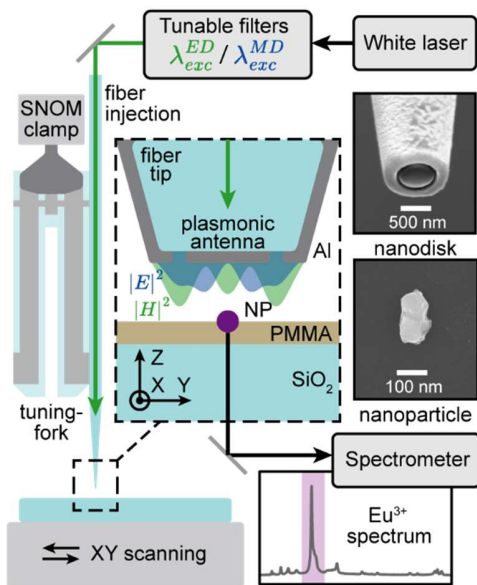


Figure 2 : Schematic of the experimental set-up. A plasmonic nano-antenna, designed at the end of a tapered fiber is excited using an injected linear polarization. By means of a near-field setup, a  $Y_2O_3:Eu^{3+}$  doped nanoparticle can scan in the XY plan the electric and magnetic intensity distributions of the localized plasmon. The luminescence is then collected and analyzed by a spectrometer for each antenna-particle position.

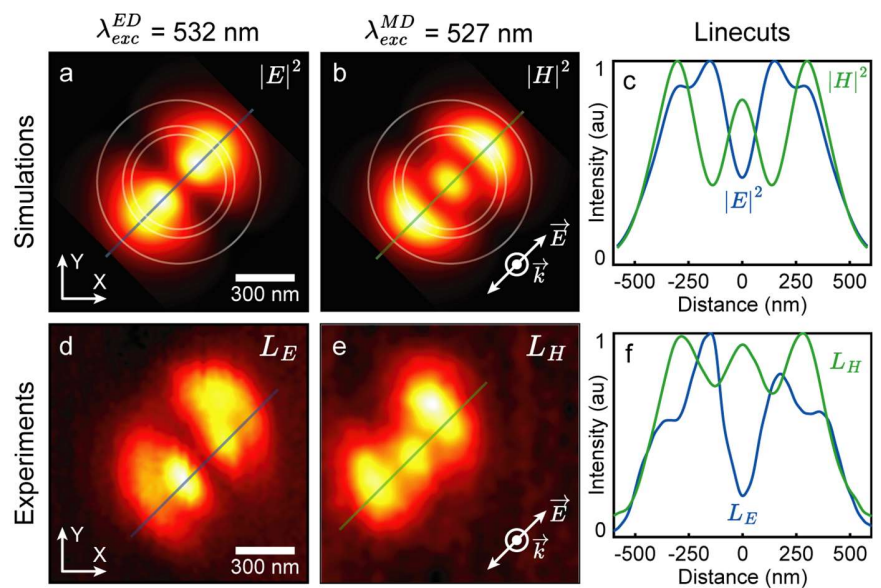


Figure 1 : Simulation results in the XY plan below the plasmonic antenna (white circles) of the (a) electric and (b) magnetic intensity distributions. (c) Linecuts along the polarization direction for the electric (blue) and magnetic (green) intensity distributions. Collected luminescence in the XY plan below the plasmonic antenna of the (d) electric and (e) magnetic field excitation. (f) Linecuts along the polarization direction for the electric (blue) and magnetic (green) excitation.

## References:

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**Keywords:** super-resolution microscopy, carbon nanotubes, single molecule

**Disciplinary fields involved :** Physics, Chemistry

## Super-resolution imaging of the formation of emitting sites for exciton localization in carbon nanotubes

Benjamin LAMBERT<sup>1</sup>, Laurent COGNET<sup>1</sup>

1. Laboratoire Photonique Numérique et Nanosciences, UMR 5298, Université de Bordeaux, 33400 Talence, France

Semiconducting single-walled carbon nanotubes (SWCNTs) exhibit a photostable excitonic fluorescence in the short wave near-infrared (SWIR). In the recent years, the covalent functionalization of chemical moieties onto nanotubes opened new avenues to manipulate the excitonic fluorescence in SWCNTs [1]. These “organic color centers (OCCs)” act as localized potential wells on the nanotube surface, thereby trapping excitons locally of otherwise diffusing excitons. This effectively results in an increase in the emission of the SWCNTs, preventing the excitons from encountering possible quenching sites along the nanotube surface such as structural defects or the nanotube’s ends [2]. In addition, this new radiative pathway results in a shifting of the SWCNT emission towards longer wavelengths and allows SWCNT excitation on their first-order excitonic transition (SWIR) [3]. Altogether, these properties make OCC-functionalized SWCNTs particularly attractive for various applications ranging from biological imaging to quantum information.

Yet, the functionalization reaction of SWCNTs with OCC is still poorly understood, stochastic and, as a result, poorly controlled. To gain knowledge and control over these reactions, we developed a two-color imaging platform to image simultaneously both the SWCNT emission and the shifted emission of the OCCs *in situ* during the functionalization reaction. By performing super-localization on the OCC emission, we are able to determine the position of the OCCs in real time as they appear on the SWCNT at the nanometer scale. Moreover, this platform also allows us to monitor the kinetics of the functionalization reaction and possible coupling between different OCCs. These findings therefore enable us to understand further how the OCCs interact with the SWCNT surface or between each other, and should allow to help us toward a deterministic control of OCC implantation.

### References:

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### Acknowledgment:

This work is supported by a European Research Council Synergy grant (951294).

**2023**

**Wednesday March 15<sup>th</sup>**

**3.30 pm – 6.00pm**

**Main Amphitheater**

**Program of the session**

**Chairs: Ségolène CALLARD & Jean-Luc DUVAIL**

**NANOPHOTONICS & NANO-OPTICS**

15:30	Playing with plasmons, molecules or dielectric nanoparticles to control light emission at the nanoscale	Celine FIORINI • CEA – SPEC, Saclay – France
16:00	FRET-mediated collective blinking of self-assembled stacks of semiconducting nanoplatelets	Laurent COOLEN • Sorbonne Univ. - INSP, France
16:15	Nanophotonic structures by photopolymerization of functional inks	Ludovic BELHOMME • Univ. Bordeaux - ICMCB/CRPP, France
16:30	Towards an electrically injected optical parametric oscillator	Andrea GERINI • Univ Paris Cité - MPQ, France
17:15	Excitability in a PhC nanolaser with an integrated saturable absorber	Bruno GARBIN • C2N, France
17:30	Time-Scale Dependent Thermo-Optical Coefficient in Titanium Dioxide Waveguides	Jean-Claude WEEBER • Univ. Bourgogne - ICB, France
17:45	Plasmo-electronic effects in self-organised gold nanoparticles	Jérémie GRISOLIA • INSA Toulouse - LPCNO, France

# Keynote Speakers

NANOPHOTONICS & NANO-OPTICS



## Céline FIORINI-DEBUISSCHERT

CEA I Researcher

SPEC Laboratory

[https://iramis.cea.fr/spec/Phoce/Vie\\_des\\_labos/Ast/ast\\_visu.php?id\\_ast=2468](https://iramis.cea.fr/spec/Phoce/Vie_des_labos/Ast/ast_visu.php?id_ast=2468)

### BIOGRAPHY

After graduating from Institut d'Optique Graduate School, I obtained my PhD in Physics, (Optics and Photonics, Paris XI Orsay), in 1995. Since then, I have been working as a scientist in CEA Paris Saclay, going from the applied to the fundamental research division. I am currently part of the condensed matter laboratory, my main research topic being devoted to nanophotonics. More particularly, my studies mainly involve optical nano-antennas and molecular plasmonics, organic nonlinear optics and light emission (time-resolved fluorescence spectroscopy, frequency conversion), photochromism, molecular self-organisation, photoinduced ordering and mass transport ... I have authored or co-authored more than 110 papers. In addition to my research activities, I am coordinating a so-called laboratory of Excellence of Paris Saclay University, aiming at promoting synergies between interdisciplinary scientists of different research fields, from nano(spin)electronics to nanophotonics, nanomedicine and nanochemistry.

### PLAYING WITH PLASMONS, MOLECULES OR DIELECTRIC NANOPARTICLES TO CONTROL LIGHT EMISSION AT THE NANOSCALE

Controlling light emission at the nanoscale is of primary importance, not only from a fundamental point of view, but also in terms of potential applications, be it for the implementation of emitting devices or markers for biology ... To this end, an important point to keep in mind is that spontaneous emission is not only an intrinsic property of a luminescent material, it is also the result of the interaction between this material and its local electromagnetic environment. More precisely, light emission depends directly on the transfer of energy from a given photon source to one or more modes of the electromagnetic field. In this context, many studies have been devoted to the coupling of fluorescent nano-objects to plasmonic nano-antennas, considering either one-photon or two-photon processes. [1] Two-photon excitation processes present indeed the advantage to give rise to much larger enhancement than one-photon-excited fluorescence due to the quadratic dependence of this process on the excitation intensity. However the coupling of fluorophores to a metallic nanoantenna can also give rise to quenching effects (through either Förster or Dexter energy transfer), which requires to control both the position and the orientation of the molecules to the antenna : this issue will be the first point of my presentation. I will show that a promising way towards this goal can be to take advantage of supramolecular molecule-molecule or molecule-substrate interaction processes. In close collaboration with chemists, we could demonstrate the interest of specifically designed molecules from so-called Janus systems [2] to metal-ligand complexes [3]. In the second part of my talk, I will address the case of a nonresonant nonlinear process, i.e. frequency conversion and more particularly second harmonic generation (SHG). I will discuss our recent results obtained with single Barium titanate particles (BaTiO<sub>3</sub>) particles coated with a 10 nm gold shell, for which a factor of 3 SHG enhancement could be evidenced [4]. I will finally show that gold nanoparticles can themselves exhibit a very high two-photon luminescence [5], which happens to be very interesting for characterization, from nanorods organization [6] to nanothermometry [7].

### KEYWORDS

Metallic and dielectric nanoparticles; two-photon luminescence; second harmonic generation; plasmonic antennas

# Keynote Speakers

NANOPHOTONICS & NANO-OPTICS



## Céline FIORINI-DEBUISSCHERT

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SPEC Laboratory

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**Keywords :** Fluorescence microscopy, semiconductor nanoparticles, exciton transfer

**Disciplinary field involved :** Physics

## FRET-mediated collective blinking of self-assembled stacks of semiconducting nanoplatelets

Zakarya Ouzit<sup>1</sup>, Guillaume Baillard<sup>1</sup>, Jiawen Liu<sup>1</sup>, Juan Pintor<sup>1</sup>, Lilian Guillemeney<sup>2</sup>, Benoît Wagnon<sup>2</sup>, Benjamin Abécassis<sup>2</sup> and Laurent Coolen<sup>1</sup>

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Extensive studies have been performed since the 1980s and 1990s on semi-conducting colloidal nanoparticles, usually on isolated emitters in dilute solutions. However, for many opto-electronic applications such as quantum-dot-LEDs or quantum-dot-sensitized solar cells, densely-packed stackings of emitters are used. Interactions between them are then expected and must be understood. Colloidal CdSe nanoplatelets (NPL) can be self-assembled into chains of hundreds of NPLs (up to 4  $\mu\text{m}$  length) [1], with constant platelet center-to-center distance of 6 nm and excellent linear order, therefore constituting a perfect platform for exploring these various collective effects.

We have imaged the fluorescence from individual NPL chains and found a FRET (Förster resonant energy transfer : dipole-dipole non-radiative exciton hopping) migration length of 500 nm (around 90 NPLs). From this, a diffusion-equation model leads us to estimate the characteristic time of FRET transfer between neighbour platelets to 1-2 ps, much shorter than all decay mechanisms known to occur in fluorescent semiconductor nanoparticles [2].

Densely-packed nanoparticles can thus be expected to present, because of FRET, totally new photophysical behaviour involving tens or hundreds of emitters collectively instead of each platelet emitting individually. Notably, we have demonstrated that some portions of NPL chains blink collectively, showing that a single intermittent quencher platelet is able to block the luminescence from an ensemble of around 70 NPLs as excitons in these NPLs migrate by FRET and reach the quencher. The luminescence decay curves also show signs of FRET-induced effects of quencher defects and metastable traps.

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**Keywords:** nanophotonics, nanoparticles, photopolymerization

**Disciplinary field involved:** Chemistry

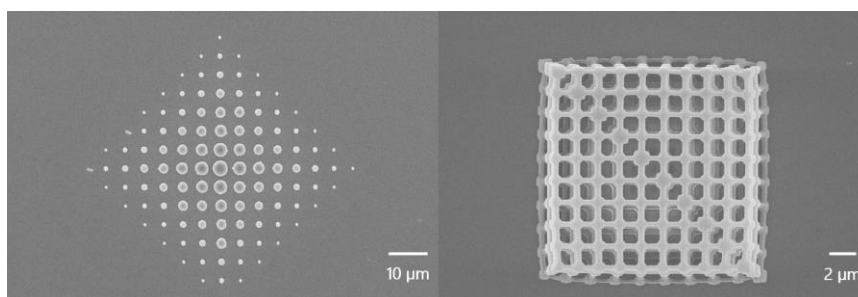
**Sustainable Development Goals eventually involved in your research:** not applicable

## Nanophotonic structures by photopolymerization of functional inks

Ludovic Belhomme<sup>1,2</sup>, Manuel Gaudon<sup>2</sup>, Safi Jradi<sup>3</sup> and Serge Ravaine<sup>1</sup>

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3. Univ. de Technologie de Troyes, CNRS, L2n, EMR 7004, 10004 Troyes Cedex, France

In a context where new technologies require the development of an increasing number of multifunctional devices, functional nanoparticles with unique photoelectric, mechanical, magnetic, and chemical properties have attracted considerable attention. However, the transformation of functional nanoparticles into scalable, controllable, and affordable functional devices remains challenging. Printing is a promising additive manufacturing technology for fabricating devices from NP building blocks because of its capabilities for rapid prototyping and versatile multifunctional manufacturing [1]. In this context, we aim at fabricating two- and three-dimensional nanophotonic structures through the photopolymerization of inks made functional by the incorporation of fluorescent, plasmonic or photochromic nanoparticles. A synergy of the properties of the structure thus formed and of the functional ink is targeted.



*Examples of two- and three-dimensional structures produced by two-photon polymerization.*

### **Reference:**

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**Acknowledgment:** L.B. thanks the financial support of the IdEx University of Bordeaux / Grand Research Program "GPR LIGHT"

**Keywords:** nonlinear photonics, optical parametric oscillation

**Disciplinary field involved:** Physics

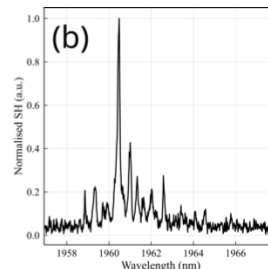
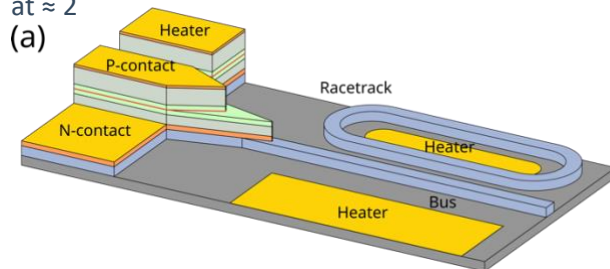
**Sustainable Development Goals:** Industry, Innovation & Infrastructure (Goal 9)

## Towards an electrically injected optical parametric oscillator

A. Gerini<sup>1</sup>, M. Ravaro<sup>1</sup>, C. Théveneau<sup>2</sup>, A. Larrue<sup>2</sup>, M. Garcia<sup>2</sup>, B Gérard<sup>2</sup>, M. Krakowski<sup>2</sup>, G. Leo<sup>1</sup>

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The development of an OPO on-chip would open new horizons from gas sensing to signal processing. To date, monolithic  $\chi^{(2)}$  OPOs have only been achieved under optical pumping, with LiNbO<sub>3</sub> [1], GaAs/AlOx [2] and AlN [3]. Based on recent development [4], here we report on our first experimental results towards an electrically injected AlGaAs OPO. Two distinct resonant cavities are obtained from a single epitaxial growth: the upper for a high-power DFB laser diode; the lower one for the nonlinear interaction (based on type-II modal phase matching between a TE<sub>20</sub> pump mode at  $\approx 1 \mu\text{m}$  and the TE<sub>00</sub>, TM<sub>00</sub> modes at  $\approx 2$



$\mu\text{m}$ ). They are coupled via a vertical mode converter in which the TE<sub>00</sub> laser mode is coupled to the OPO TE<sub>20</sub> mode. The OPO cavity, fed by an evanescently coupled bus waveguide, consists of a

triple resonant racetrack resonator. Wavelength tunability is obtained by separately changing the temperature of both laser and OPO, through the use of independent heaters (Fig. a). After measuring waveguides losses ( $0.4 \text{ cm}^{-1}$ ) and racetrack loaded Q factors ( $4 \times 10^5$ ), design and fabrication have been validated via second harmonic generation (Fig. b). These are key results towards the demonstration of the first OPO on-chip. **Acknowledgment:** ANR-18-ASTR-0007 (SPAIN Project) plus  $\frac{1}{2}$  PhD grant from AID (DGA).

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**Keywords :** Nanolaser; excitability; integrated; photonic crystal

**Disciplinary field involved :** Physics

**Sustainable Development Goals\* eventually involved in your research:**

## Excitability in a PhC nanolaser with an integrated saturable absorber

**M. Delmulle,<sup>1,2</sup> B. Garbin,<sup>1</sup> L. M. Massaro,<sup>1</sup> A. Bazin,<sup>1</sup> I. Sagnes,<sup>1</sup> K. Pantzas,<sup>1</sup> S. Combrié,<sup>2</sup> A. De Rossi,<sup>2</sup> and F. Raineri<sup>1,3</sup>**

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3. Université Côte d'Azur, Institut de Physique de Nice, CNRS-UMR 7010, Sophia Antipolis, France

Although machine learning (ML) algorithms are already applied in many fields (e.g. language recognition, temporal series prediction) using software computed on "Von Neumann" architectures, numerous technological advances (e.g. robotics, autonomous driving) require dedicated hardware. Integrated optics constitute a highly promising platform that could be harnessed for achieving portable ML chips with unprecedented power-efficiency and bandwidth [1]. Despite recent observations of ML key functionalities using integrated Silicon photonics, such as reconfigurable matrix multiplication [2] and nonlinear activation functions [3], excitability observation, the spiking mechanism of our biological neurons, remains incomplete in all-integrated systems; they are based on opto-thermal (slow) effects [4] that drastically limits its applicability in ML systems with high bandwidth requirements. Here, we use InP-based photonic crystal nanocavities heterogeneously integrated on top of a Silicon on Insulator (SOI) waveguide to demonstrate the first all-integrated (fast) excitable nanolaser.

The nanolaser relies on a InP-based nanobeam cavity, coupled to a SOI waveguide, with a 8  $\mu\text{m}$  cavity length that includes 2 regions, respectively for the gain and saturable absorber. We demonstrate the excitable property of our device by optically pumping the nanolaser in the vicinity of the lasing threshold and perturbing with short optical pulses ( $\sim 4\text{ps}$ ); it is observed as the emission of pulses shorter than 100ps triggered on-demand with femtojoule perturbation levels. Our observations are in good agreements with simulations based on the Yamada model. Our system has high potential for scalability over non-integrated systems [5]; this represents a first step towards a network of excitable nanolasers.

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**Keywords :** Hybrid waveguides, Titanium dioxide, Thermo-Optical dynamics

**Disciplinary field involved:** Physics

## Time-Scale Dependent Thermo-Optical Coefficient Polarity in Titanium Dioxide Waveguides

J.-C. Weeber<sup>1</sup>, A. Andrieux<sup>1</sup>, M.-M. Gourier<sup>1</sup>, J. Arocas<sup>1</sup>, L. Markey<sup>1</sup>, A. Bouhelier<sup>1</sup> and K. Hammani<sup>1</sup>

1. ICB UMR 6303 uB-CNRS, Département de Photonique., Université de Bourgogne, 9 av. A. Savary, BP47870, Dijon, France.

Titanium dioxide (TiO<sub>2</sub>) is a versatile material deployed for many optical applications including scratch-resistant optical coatings, self-cleaning glasses or non-linear integrated optics configurations [1]. Among key properties of TiO<sub>2</sub> in the context of photonics is its large negative Thermo-Optical Coefficient (TOC) successfully exploited for development of athermal integrated micro-resonators [2]. The unconventional large negative TOC along with the broad range of TOC values reported in literature [3] make physical origins of Thermo-Optical (TO) properties of TiO<sub>2</sub> rather difficult to elucidate.

In this work [4], we operate unconventional metallo-dielectric micro-waveguides integrated in a Mach-Zehnder interferometer to demonstrate that TO properties of amorphous TiO<sub>2</sub> depends on observation time-scales.

Specifically, we establish that, as already recognized by many authors, TOC of TiO<sub>2</sub> is indeed negative in the static or quasi-static regime corresponding to a time-scale around one second. However, by electrically activating our metallo-dielectric waveguides, we show that this TOC turns to be positive in the micro-second regime, unambiguously demonstrating that TO properties of TiO<sub>2</sub> rely on very different phenomena at different time-scales. Our results suggest that the properties of TO materials should be carefully considered beyond quasi-static characterizations (such as spectral ellipsometry of Peltier module based experiments) to prevent misuse of those materials for TO-based photonic applications.

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**Acknowledgment:** This work was supported by the EC through H2020 project ICT-PlasmoniAC (contract 871391), <http://www.plasmoni.ac.eu>

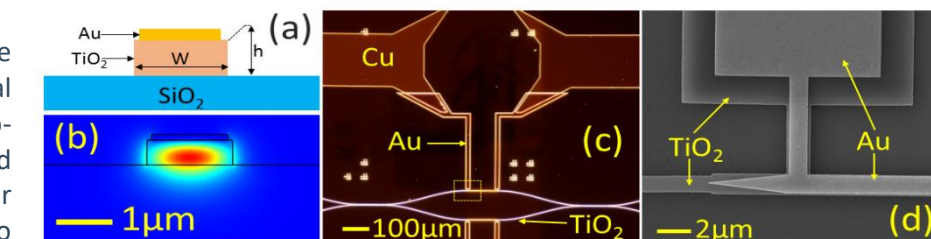


Figure 1 : (a) Cross-section of metallo dielectric hybrid waveguide and (b) fundamental TE mode field intensity distribution. (c) Optical microscopy view of TiO<sub>2</sub> hybrid Mach-Zehnder interferometer. (d) Scanning Electron Microscope image of TiO<sub>2</sub>-hybrid waveguide transition.

**Keywords:** gold nanoparticles, photo-induced charge transport; surface plasmons

**Disciplinary fields involved:** Physics and Chemistry

## Plasmo-electronic effects in self-organised gold nanoparticles

Louis Merle<sup>1</sup>, Adnen Mlayah<sup>2</sup>, Jérémie Grisolia<sup>1</sup>

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The coupling between charge transport and surface plasmons in metal nanostructures is the driving force of the emerging field of “plasmo-electronics”. Complex phenomena involving several fundamental interaction mechanisms between elementary excitations (plasmons, electron-hole pairs, phonons) are responsible for the conversion of light into charge carriers. In this study, we report on the plasmo-electronic properties of self-assembled monolayers of colloidal gold nanoparticles (NPs). Impedance spectroscopy measurements performed under optical excitation is used to investigate the plasmo-electronic properties of the NP assembly as a function of the laser irradiation intensity and wavelength. In particular, the role of the surface plasmon resonance is pointed out. The impedance spectroscopy data are interpreted using a multi-scale approach in which a local nano-junction model, composed of parallel inter-particle resistance  $R_{ij}$ , capacitor  $C_{ij}$  and photo-resistance  $g_{ij}^{-1}$ , serves as a building block. Each nanoparticle size and position within the network is extracted from transmission electron microscopy data and used to generate the spatial distribution of the nano-junctions. The interparticle photo-conductance  $g_{ij}$  is calculated using electro-dynamic simulations based on the discrete dipole approximation (DDA) and accounts for the local plasmonic properties. The electric characteristics of the macroscopic circuit formed by the nano-junctions network are calculated using a numerical resolution based on Kirchhoff's laws. The results of DDA-Kirchhoff numerical simulations are compared quantitatively to the experimental data. The good agreement between the calculated and the measured macroscopic photo-conductance allows to determine the photo-electric conversion efficiency at the nanoscale. The presented work thus provides insight into the plasmo-electronic characteristics of self-assembled nanoparticle networks.

### References:

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- Enhanced Dielectric Relaxation in Self-Organized Layers of Polypeptides Coupled to Platinum Nanoparticles: Temperature Dependence and Effect of Bias Voltage. Louis Merle, Ghada Manai, Adeline Pham, Sébastien Lecommandoux, Philippe Demont, Colin Bonduelle, Simon Tricard, Adnen Mlayah, Jérémie Grisolia\* *J. Phys. Chem. C* 2021, 125, 41, 22643–22649
- Multiscale modeling of the dynamical conductivity of self-assembled nanoparticle networks: Numerical simulations vs analytical models, L. Merle, Delpoux, A. Mlayah, J. Grisolia. *Journal of Applied Physics* 132, 015107 (2022); <https://doi.org/10.1063/5.0097997>

**Acknowledgment:** This study has been supported by the EUR grant NanoX No. ANR-17-EURE-0009 in the framework of the Programme des Investissements d'Avenir. This work was performed using HPC resources from CALMIP (Grant 2020-P0996).

# Thursday March 16<sup>th</sup>

3.30 pm – 6.00pm

Amphi 150

## Program of the session

***Chairs: Ségolène CALLARD & Erik DUJARDIN***

### NANOPHOTONICS & NANO-OPTICS

15:30	Predicting and designing the visual appearance of macroscopic nanostructured surfaces	Kevin VYNCK • CNRS – ILM, Lyon – France
16:00	Mechanisms and applications of laser-induced self-organization in plasmonic quasi-random metasurfaces	Nathalie DESTOUCHES • Univ. Jean MONNET - LabHC, France
16:15	The iridescence of disordered resonant metasurfaces	Adrian AGREDA • Univ. Bordeaux- LP2N, France
16:30	Multiresonant behavior and strong coupling in aluminum optical antennas	Davy GÉRARD • UTT - L2n, France
16:45	Nanostructuring of Hybrid Organic-Inorganic Perovskite to tailor light-matter interactions for optoelectronic devices	Nguyen Ha My DANG • CNRS - INL, France
17:00	Coffee & tea break	
17:30	Fine structure of excitons and their interactions with phonons in single CsPbCl <sub>3</sub> nanocrystals	Victor GUILLOUX • Sorbonne Univ.- INSP, France
17:45	Controlling giant polarisation rotation in the Poincaré sphere with a single quantum dot spin	Elham MEHDI • Univ. Paris Cité - C2N, France
18:00	Thermopolymerization induced by thermoplasmonics	Olivier SOPPERA • CNRS - IS2M, France
18:15	Local and Deterministic Integration of Luminescent Nanostructures on Photonic integrated circuits	Abdelrahman ABDELAAL • UTT - L2n, France

# Keynote Speakers

## NANOPHOTONICS & NANO-OPTICS



### Kevin VYNCK

CNRS I Researcher

*Institute of Light and Matter*

[https://ilm.univ-lyon1.fr/index.php?option=com\\_directory&task=profile&id=1730](https://ilm.univ-lyon1.fr/index.php?option=com_directory&task=profile&id=1730)

#### BIOGRAPHY

Kevin VYNCK is a CNRS Researcher at the Institut Lumière Matière (iLM) in Lyon, specialized in the theoretical and numerical modelling of light scattering by complex nanostructures. He received his PhD from the University of Montpellier in November 2008, and was post-doctoral fellow at LENS in Florence (Italy) and at the Institut Langevin in Paris. Between 2013 and 2021, he was CNRS researcher at the Laboratoire Photonique, Numérique et Nanosciences (LP2N) in Bordeaux. With his colleagues, he was amongst the firsts to propose using resonant silicon nanostructures for metamaterial applications, to exploit correlated disorder in planar photonic structures for light trapping in thin films, and to investigate the potential of disordered metasurfaces for visual appearance design. In 2019, he was awarded the CNRS Bronze Medal.

#### PREDICTING AND DESIGNING THE VISUAL APPEARANCE OF MACROSCOPIC NANOSTRUCTURED SURFACES

Nature offers us beautiful visual appearances. The most resplendent of them, from the iridescence of opals and the wings of some butterflies to the bright colors of some birds and fruits, are mostly due to interference effects created by nanostructures. These last decades have witnessed the emergence of new research themes aiming at understanding the microscopic origin of visual effects produced in nature, at reproducing these effects by artificially structuring matter, and at creating new ones- without equivalents in the natural state- for new applications in visual arts.

Research in nanophotonics has mainly focused so far on creating a broad palette of structural colors, as illustrated by many successful reproductions of famous photographs and paintings at the millimeter scale [1]. Our perception of macroscopic objects however strongly depends on attributes other than color, such as gloss, haze and translucency, as well as object shape and lighting environment [2].

In this talk, I will show how concepts and techniques in nanophotonics, mesoscopic wave physics and computer graphics can be combined to predict and design the visual appearance of macroscopic nanostructured surfaces in realistic settings [3]. We will see how certain nano and mesoscale features, such as layered substrates and correlated disorder, translate into distinct, impressive visual effects at the macroscale.

#### KEYWORDS

Structural colors; Visual appearance; Waves in complex media; Computer graphics

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**Keywords:** Laser-matter interaction, self-organization, plasmonics, nanomaterials, color

**Disciplinary fields involved:** Physics and chemistry

**Sustainable Development Goals\* eventually involved in your research:** Industry, Innovation, and Infrastructure (Goal 9)

## Mechanisms and applications of laser-induced self-organization in plasmonic quasi-random metasurfaces

H. Ma<sup>1</sup>, Z. Liu<sup>1</sup>, N. Dalloz<sup>1,2</sup>, V. D. Le<sup>1</sup>, F. Vocanson<sup>1</sup>, M. Hébert<sup>1</sup>, N. Destouches<sup>1</sup>

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Laser processing is a flexible technology for transforming the morphology and organization of metallic nanoparticle assemblies. While their size is usually larger than 10  $\mu\text{m}$ , laser beams can trigger the formation of self-organized periodic patterns whose period is only a fraction of the laser wavelength [1-2]. Even though these patterns are never perfectly reproducible at the nanometer scale, because of a certain randomness in the size and location of individual nanoparticles, their macroscopic optical properties, namely their optical spectra under different observation conditions, are reproducible. This property makes the laser processing technology very powerful for using plasmonic colors in advanced color printing, like the printing of multiplexed images [3,4]. This presentation will give an overview of the coherent self-organization mechanisms that can be triggered by cw and pulse lasers in plasmonic random metasurfaces. It will explain why the macroscopic optical properties of these laser-generated quasi-random plasmonic metasurfaces can be described by statistical parameters of the nanoparticle ensembles. And, it will show how their color variations in different modes of observation can be used to encode multiplexed images that can be observed under white light. The technology is being matured further for application in secure documents.

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### Acknowledgment:

The authors thank the ANR for the funding of project MIXUP (ANR-18-CE39-0010)



**Keywords:** Metasurfaces, structural color, plasmonics

**Disciplinary fields involved:** Physics.

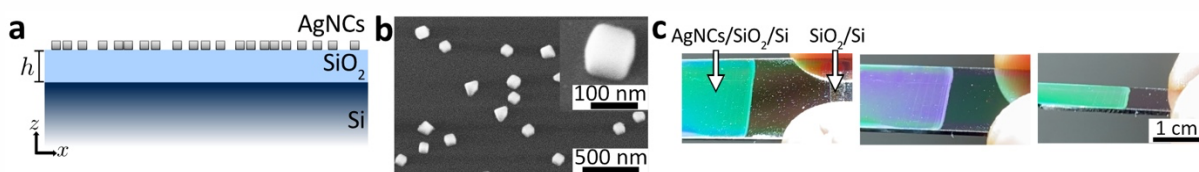
## The iridescence of disordered resonant metasurfaces

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Due to the intrinsic environmental, durability and resolution limitations of pigment coloration, the generation of colorful, bright and largely tunable nanostructured coatings has received considerable interest. Main control knobs include plasmonic, Mie and Fabry-Pérot resonances [1]. In fact, natural or engineered surfaces that change in hue or intensity with the viewing or illumination geometry are known to offer outstanding color and visual effects [2]. They drive attention in diverse research fields and inform the design of cosmetics, advanced coatings and paints.

Here, we exploit the rich palette of optical resonances offered by metasurfaces composed of a non-close packed assembly of metallic nanoparticles deposited on a reflective substrate coated with a low-index spacer (See Fig. 1).



**Figure 1.** **a**, Schematic profile view of the metasurface configuration. **b**, Scanning electron microscope (SEM) micrograph of a typical metasurface with a ~8% surface coverage. A high magnification of a single Ag nanocube is shown in the inset. **c**, Photographs of a diffuse iridescent metasurface.

This geometry, which combines plasmonic and Fabry-Perot resonances, offers uncommon non-specular iridescences not found in nature. We report on a particular iridescence that produces only two distinct colors for all illumination and observation directions. We theoretically investigate its origin with an intuitive and accurate model that unveils the rich physical mechanisms at play. The interpretation paves the way towards the design of easy-to-make and universal building blocks with a large resilience to fabrication imperfections, and great potential for innovative coatings and fine-art applications.

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## Acknowledgements:

This work has received financial support from the French State and the Région Nouvelle-Aquitaine under the CPER project "CANERIIP", from CNRS through the MITI interdisciplinary programs, and from the French National Agency for Research (ANR) under the project "NANO-APPEARANCE" (ANR-19-CE09-0014).

**Keywords:** plasmonics, nanoantennas, strong coupling, electron energy-loss spectroscopy

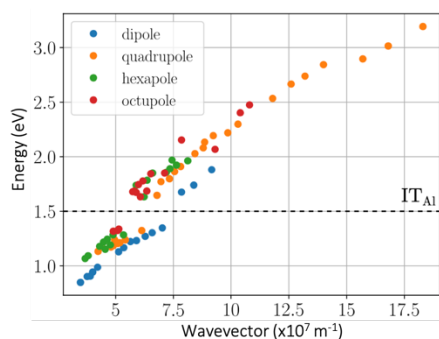
**Disciplinary field involved:** Physics

## Multiresonant behavior and strong coupling in aluminum optical antennas

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Aluminum is an appealing plasmonic material, combining a broadband metallic behavior, a wide availability and CMOS compatibility [1]. Here, we study the optical properties of aluminum nanostructures using electron energy-loss spectroscopy (EELS), a powerful technique allowing direct imaging and spectroscopy with nanoscale spatial resolution. First, we use a fractal-like design, the Cayley tree, to create optical antennas sustaining plasmonic resonances over an ultra-broadband spectral range (from UV to thermal IR) [2]. Then, we explore the coupling between the plasmonic modes of an Al nanorod and the interband transition of aluminum. Using both EELS and optical spectroscopy, we experimentally evidence a strong coupling between the antenna's plasmonic resonances and the interband transition (Fig. 1). This interesting phenomenon (as the antenna couples *with itself* to create hybrid modes) is analyzed using a model for strong coupling.



**Figure 1:** Dispersion curves of the plasmonic resonances of an Al nanorod, as obtained from EELS measurements. The horizontal dotted line shows the position of the interband transition at 1.5 eV. A clear energy gap is observed around the interband, associated with strong coupling (Rabi splitting).

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**Keywords :** hybrid perovskites, nanostructurations, light-matter interaction

**Disciplinary fields involved:** Physics, chemistry

## Nanostructuration of Hybrid Organic-Inorganic Perovskite to tailor light-matter interactions for optoelectronic devices

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Hybrid Organic-Inorganic Perovskite (HOP), as direct bandgap semiconductors with excellent absorption and long carrier diffusion length, has recently emerged as a material of choice for a wide range of optoelectronic applications. Recently, several groups have demonstrated that performance of HOP-based devices can be greatly improved via nanophotonic concepts when patterning the HOP into micro/nanostructures. They suggested that nanostructured HOP can lead to light-trapping mechanism for HOP solar-cells, improvement of light-extraction in HOP LEDs, light-matter interaction enhancement for HOP lasers, and very recently the control of photon-exciton strong coupling regime for polaritonic devices. In this work, we develop two distinctive methods to structure HOPs into nanostructures. Subwavelength metasurface lattice of HOP are fabricated by either i) Infiltration of a solution based perovskite within a pre-patterned back bone structure, or ii) Direct nanoimprint lithography of a flat HOP layer. These two methods have been successfully implemented for both 2D, 3D and quasi 2D HOPs to fabricate large-scale metasurfaces. The nanostructures allow a strong control of light-matter interaction within the perovskite layer. As illustrations, we will present experimental demonstrations of dispersion engineering of perovskite polaritons[1,2], enhancement of photoluminescence extraction, and observation of vortex beam lasing at high oblique angles[3]. Our results pave the way to make low-cost and wafer-size of perovskite devices in which light-matter interaction is tailored in the subwavelength scale.

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**Keywords:** perovskite nanocrystals, CsPbCl<sub>3</sub>, exciton fine structure, exciton-phonon couplings

**Disciplinary field involved:** Physics

## Fine structure of excitons and their interactions with phonons in single CsPbCl<sub>3</sub> nanocrystals

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Over the last years organic and inorganic lead halide perovskites nanocrystals have come to light as a new generation of promising semiconductor materials for a large variety of optoelectronic technologies such as LEDs, lasers and photodetectors but also for more advanced applications in quantum optics or spintronics<sup>1,2</sup>. Among these materials CsPbCl<sub>3</sub> has the largest energy band gap showing an absorption threshold and photoluminescence (PL) in the blue spectral range. Excitons are at the center of all the optical and electronic properties of CsPbCl<sub>3</sub> nanocrystals and are characterized by the smallest Bohr radius amongst all the lead halide perovskites materials<sup>3</sup>.

In this work, we study the bright exciton PL of CsPbCl<sub>3</sub> nanocrystals. We underline that the bright exciton splitting is the largest obtained in any other single halide nanocrystals of comparable size. We correlate these results with calculations of the exciton fine structure considering the interplay between the e-h exchange interaction and the crystal field, the dielectric environment and the effect of the slight shape anisotropy observed experimentally<sup>4</sup>.

Likewise, we take advantage of the emission polarization properties to track the energy and the linewidth of individual peaks with increasing temperature<sup>5</sup>. We observe a linewidth broadening characterized by low and high temperature regimes and dominated respectively by acoustic or longitudinal optical phonons couplings. We deduce the respective strengths of the interactions. Our results indicate the decisive role of either intrinsic or environmental parameters on the response of individual perovskite nanoparticles.

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### Acknowledgments:

This work was financially supported by the French National Research Agency (project ANR IPER- Nano2, ANR- 18-CE30), the Tunisian Ministry of Higher Education and Scientific Research, the French Ministry of Foreign Affairs through the project PHC Utique (No. 22G1305). EL thanks the support ERC starting grant blackQD (n°756225). We warmly thank for their technical assistances M. Bernard and F. Margaillan from INSP, respectively for cryogenics and optics.

**Keywords:** quantum optics, qubit, polarisation, spin, quantum dot

**Disciplinary field involved:** Physics

## Controlling giant polarisation rotation in the Poincaré sphere with a single quantum dot spin

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The development of a future quantum network requires an efficient light-matter interface implementing conditional operations on flying qubits, using their deterministic interaction with a single stationary qubit. In our work, we use the polarisation of a photon as the flying qubit and the spin of a charge as the stationary one. Our interface is built with a deterministically coupled, electrically contacted pillar cavity device, embedding an InAs quantum dot (QD). Such a cavity-QED device enables the efficient coupling of incoming photons with the spin of a charge in the QD [1, 2], and the polarisation rotation of reflected photons conditioned to the spin state [3–5].

Here, we report on the observation and control of giant polarisation rotations induced by a single electron spin, and fully characterise the polarisation state of the reflected photons in the Poincaré sphere. Rotation amplitudes such as  $\pi/2$  and  $\pi$  are obtained, as required for numerous applications based on perfect spin-polarisation mapping and spin-mediated photon-photon gates.

We also show how, by a proper tuning of the control parameters, any orientation of the output Stokes vector can be reached, with only a slight degradation of the polarisation purity in the presence of environmental noise. This is possible because the rotated polarisation state, ideally of the form  $\alpha |R\rangle + \beta |L\rangle$ , can be entirely controlled.

These results represent an important step in the quest towards ideal receiving nodes, implementing conditional operations on incoming photons, for various implementations of deterministic and fault-tolerant quantum computing and quantum communications.

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## Acknowledgment:

This work was partially supported by the Paris Ile-de-France Région in the framework of DIM SIRTEQ, the European Union's Horizon 2020 Research and Innovation Programme QUDOT-TECH under the Marie Skłodowska-Curie Grant Agreement No. 861097, the European Union's Horizon 2020 FET OPEN project QLUSTER (Grant ID 862035), the French RENATECH network and a public grant overseen by the French National Research Agency (ANR) as part of the "Investissements d'Avenir" programme (Labex NanoSaclay, reference: ANR-10-LABX-0035).

**Keywords:** thermoplasmonics, thermopolymerization, gold nanoparticles

**Disciplinary fields involved:** Physics & Chemistry

## Thermopolymerization induced by thermoplasmonics

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Localized surface plasmon-induced polymerization of free-radical acrylate monomers is an efficient, smart, and versatile method for preparing metal/polymer hybrid nanoparticles (NPs) with accurate control of the thickness and spatial distribution of the polymer on the NP surface. Despite a growing number of practical demonstrations, the mechanism leading to polymerization of the acrylate monomer by localized surface plasmon resonance is still controversial. Indeed, through decay processes, the plasmon emitted light, hot charge carriers and heat. If these processes are well-known, the main difficulty is to discriminate between them.

Previous experiments performed in the laboratory, highlighted the photochemical pathway as the main mechanism under mild irradiation [1]. The thermoplasmonic pathway was already used to cure InZnO thin films [2].

Here, we investigated thermoplasmonic to graft thermopolymer onto gold NPs. Different parameters were considered to address specifically thermopolymerization through the plasmonic excitation of NPs such as the NPs resonances, laser power and regime. Overall, to generate thermopolymerization through thermoplasmonic effect, high irradiation condition is required. Moreover, we observed thermopolymerization in ns-pulsed and continuous laser regime with different grafting features.

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**Keywords:** Nano emitters, Direct laser writing, Single photon sources

**Disciplinary fields involved:** Physics, Chemistry

**Sustainable Development Goals\*:** Industry, Innovation and Infrastructure (Goal 9)

## Towards local and deterministic Integration of Luminescent nanostructures on photonic integrated circuits

Abdelrahman ABDELAAL<sup>1</sup>, Sylvain BLAIZE<sup>2</sup>, Safi JRADI<sup>3</sup>. (Calibri 11, bold, RVB 52 73 94 color)

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Local and deterministic trapping of nanoparticles (NPs) has always been a challenging topic due to the difficulties faced at such a small particle size. These difficulties are related to the stability, simplicity, robustness and efficiency of the used trapping technique. We introduce a new method that provides high degrees of stability, precision and flexibility. We use two photon polymerization (TPP) of a pre-functionalized photopolymer to obtain a nanometric polymer layer and selectively attract single colloidal NPs. Thanks to a deep photochemical study of the threshold energy, we identified a photopolymerization regime allowing to tune the polymer size and to immobilize single nanoparticles. The size of these layers is precisely adjusted by controlling the photo-chemical parameters of the photopolymer used in the TPP process. This method is promising to be used with all types of NPs, due to the ability of controlling the size of the fabricated layer in order to match the required size to trap the corresponding NP. We have succeeded in immobilizing single gold NPs and single luminescent nanodiamonds (NDs). Which make our method very promising to obtain single photon sources via controlling the number of light emitting particles attached to the fabricated structure.

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### Acknowledgment:

- Région Champagne ardenne (Projet PHOBOS)
- Partially supported by NANO-PHOT Graduate school – contract ANR-18-EURE-0013

