

# Symposium LAPHIA 2017

11 – 13 décembre 2017

Agora, université de Bordeaux



# LAPHIA

**Laser and Photonics  
in Aquitaine**



université  
de BORDEAUX



## **Laser & PHotonics in Aquitaine**

Photonics, defined broadly as "the science of the photon", is present in multiple disciplines with a rapidly growing importance in society. It uses photons to understand, probe and modify matter, while designed materials allow the control of light propagation and generation. This discipline is identified in the European R&D roadmaps as one of the most prominent cutting-edge fields in science and technology for the 21st century.

Financed by the Excellence Initiative of the University of Bordeaux, LAPHIA aims to create a consortium around sciences of light – optics, photonics, lasers. The Bordeaux pole in optics is already recognized as leading in several fields: high energy lasers, hot plasmas, laser-matter interaction physics, material science. The Aquitaine Region has brought together businesses and research scientists to create France's biggest regional laser-optics industry.

In this favorable context, LAPHIA aims to federate the whole relevant academic community around coherent and innovative projects in lasers and photonics, while strengthening the links with the CEA. The unique Centre of excellence structure will promote Bordeaux among the most visible centres in Lasers and Photonics at European and international levels, attracting students, researchers and private companies.

**Each year, an international symposium is organized, an opportunity for all to enrich and expand the scientific debate around lasers and photonics.**

## 5th annual LAPHIA Symposium

The 5th annual LAPHIA Symposium will take place from 11 to 13 December 2017 at the Agora of the University of Bordeaux. This new edition of the LAPHIA Symposium will be an opportunity to present the work of the Bordeaux community on Laser, Photonics and Innovative Imaging. We will also welcome international collaborators and many students during poster sessions

This year, the Symposium will be an opportunity to highlight the valorization and education activities of LAPHIA and, as usual, scientific presentations on LAPHIA research topics.

A "valorisation" session will be organized in partnership with Aquitaine Science Transfert (Technology Transfer Acceleration Company of the Aquitaine Region - SATT Aquitaine) on Tuesday 12 December. Companies and researchers will present "tools" that had strengthen the valorization of academic research and the development of start-ups.

Wednesday (Dec. 13) will be dedicated to education activities with Christian Spielmann (Abbe Photonics School, Germany) and Younès Messaddeq (COPL, University of Laval, Canada) as international guests. LAPHIA collaborators will speak about innovation projects and support for student mobility. Finally, in partnership with the Photonics Training Platform (led by Marie-Bénédicte Vieules), a Students / Researchers / Companies workshop on the theme of "Innovative Materials in Photonics" will close the symposium.

You will find during the three days of the event more than 16 scientific presentations, "poster" sessions for students, and a Quiz organized by the student chapter of Bordeaux ...

## Monday December 11th, 2017

10:00 - 10:30 am	<i>REGISTRATION - welcome coffee</i>
10:30 - 11:00 am	Welcome / facts 2016
11:00 - 11:30 am	IDEX : les grands outils - Carlos Mendoza, Camille LeBorgne
11:30 - 12:00 am	<b>Sylvain Danto</b> : Intermediate-Tg Glasses For Multi-materials Fiber
12:00 - 12:30 am	<b>Dario Bassani</b> : Controlling the emissive properties of organic materials using supramolecular interactions
12:30 - 2:00 pm	<i>Lunch</i>
02:00 - 02:30 pm	<b>Bruno Bousquet</b> : LIBS : Analyses élémentaires à partir d'un plasma induit par laser. Des grottes préhistoriques jusqu'à la surface du sol martien
02:30 - 03:00 pm	<b>Lionel Hirsch</b> : Printed organic photodetectors - fabrication and failure mechanisms
03:00 - 03:30 pm	<i>Flash poster presentation</i>
03:30 - 04:00 pm	<i>Coffee break</i>
04:00 - 04:30 pm	<b>Valentin Nagerl</b> : Super-resolution imaging of brain extracellular space
04:30 - 05:00 pm	<b>Serge Ravaine</b> : Rational synthesis of plasmonic nanostructures for SERS and light guiding
05:00-05:30 pm	<b>Kevin Vynck</b> : Electromagnetic modeling of complex resonant nanostructures
05:30 - 06:00 pm	<i>Flash poster presentation</i>
06:00 - 06:30 pm	Poster session // cocktail
06:30 - 07:00 pm	
07:00 - 07:30 pm	

## Tuesday December 12th, 2017

09:00 - 09:30 am	<b>Benjamin Canuel</b> : MIGAPHYS: new tools for MIGA and future long baseline atom interferometers
09:30 - 10:00 am	<b>Mona Treguer-Delapierre</b> : Customizing nano-objects for engineering hybrid nanoparticles
10:00 - 10:30 am	<b>Emmanuel D'huimères</b> : Generation of high amplitude magnetic fields, high energy radiation and collimated energetic particle beams using snail and chiral targets irradiated by high power lasers
10:30 - 11:00 am	<i>Coffee break</i>
11:00 - 11:30 am	<b>Christian Spielmann (IOQ Jena, Germany)</b> : High resolution microscopy using table-top XUV light sources
11:30 - 12:00 am	<b>Session Valorisation - Industriels / LAPHIA - AST</b>
12:00 - 12:30 am	Bertrand Viellerobe (Poietis), Marc Dussauze (ISM ), Julien Michelon (Neta), Sylvain Danto (ICMCB), Antoine Dubrouil (Femtoeasy), Jean Paul Gillet (IMS)
12:30 - 2:00 pm	<i>Lunch</i>
02:00 - 02:30 pm	<b>Andrea Bertoldi</b> : Phase-locking an atomic clock
02:30 - 03:00 pm	<b>Giorgio Santarelli</b> : Starlight+, a stable light lab
03:00 - 03:30 pm	Poster session
03:30 - 04:00 pm	+ Coffee break 03:30
04:00 - 04:30 pm	<b>Ashod Aradian</b> : "Spasing" and nano-lasing in plasmonic nanoparticles
04:30 - 05:00 pm	<b>Laurent Cognet &amp; Mireille Blanchard Desce</b> : Single particle tracking with carbon nanotubes and organic nanoparticles for imaging the brain at the nanoscale
05:00-05:30 pm	<b>Emmanuel Abraham</b> : Geometric phase shaping of terahertz vortex beams
05:30 - 06:00 pm	Quizz - Student Chapter Bordeaux
06:00 - 06:30 pm	
	<i>End of the 2<sup>nd</sup> day</i>
08:00 pm ---	<i>Conference dinner La Ligne Rouge - Bordeaux</i>

## Wednesday December 13th, 2017

09:00 - 09:30 am	Introduction Bureau Education - <b>Evelyne Fargin</b>
09:30 - 10:00 am	Abbe Photonics School - <b>Christian Spielmann</b>
10:00 - 10:30 am	EUR LIGHT S&T - <b>Brahim Lounis</b>
10:30 - 11:00 am	<i>Coffee break</i>
11:00 - 11:30 am	Innovative training strategy for higher education: the UBx photonics training platform - <b>Marie Bénédicte Vieules</b>
11:30 - 12:00 am	<b>Baptiste Battelier</b> : Three axis cold atom accelerometer for inertial navigation
12:00 - 12:30 am	Poster prize celebration
12:30 - 2:00 pm	<i>Lunch</i>
02:00 - 05:00 pm	
05:00-08:00 pm	05:00 -08:00 pm Workshop / Plateforme Formation en Photonique "Matériaux innovants en Photonique"

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# Emmanuel Abraham (LOMA) - "Geometric phase shaping of terahertz vortex beams"

*A. Minasyan, J. Degert, E. Freysz, E. Brasselet, and E. Abraham Univ. Bordeaux, CNRS, LOMA, UMR 5798, F-33400 Talence, France*

We propose a topological beam-shaping strategy of terahertz beams using geometric phase elements made of space-variant birefringent slabs. Quasi-monochromatic terahertz vortex beams are produced and characterized both in amplitude and phase from the reconstructed real-time two-dimensional imaging of the electric field. Nonseparable superpositions of such vortex beams are also obtained and characterized by two-dimensional polarimetric analysis. These results emphasize the versatility of the spin-orbit electromagnetic toolbox to prepare on-demand structured light endowed with polarization-controlled orbital angular momentum content in the terahertz domain, which should find many uses in future terahertz technologies.

## I. INTRODUCTION

In the field of terahertz (THz) science and technology developments, a recent attention corresponds to topological beam shaping that refers to tailor-made structured fields endowed with phase and/or polarization singularities. Such vortex beams will find a number of applications for sensing, microscopy, trapping and manipulating as well as communication technologies. Although a few papers presented singular THz optics developments, there is not yet well-established topological shaping approach enabling simple yet efficient generation of THz beams with arbitrary orbital angular momentum states. In this communication, we propose to exploit the geometric phase in order to achieve polarization-controlled THz vortex beams and superposition of them from "regular" THz beams free from any singularities [1].

## II. RESULTS

The experimental setup employs an amplified Ti:Sa femtosecond laser source splitted into pump and probe beams for THz field generation and detection. Broadband linearly polarized THz pulses over the typical range 0.1-2.5 THz are prepared by optical rectification of the laser pulses in a ZnTe nonlinear crystal and a quasi-monochromatic beam is obtained by placing a 1 THz bandpass filter after the crystal. Then, topological shaping of THz pulses basically relies on the use of a half-wave quartz birefringent retarder whose optical axis orientation angle  $\psi$  in the transverse plane has the form  $\psi = q\phi$  ( $q$  half-integer and  $\phi$  the usual azimuthal angle), as introduced in the framework of optical vortex generation in the visible domain [2].

First, the effect of this space-variant anisotropic optical element on an incident circularly-polarized field, easily grasped from Jones calculation, leads to the generation of a circularly polarized vortex beam with helicity-controlled topological

charge  $\ell = \pm 1$ . The real-time generated THz vortex electric field

is fully reconstructed in two dimensions using a pump-probe detection scheme composed of a high-speed CMOS camera coupled to a 2D electro-optical detection. The resulting image of the modulated probe light intensity is then read-out on the

camera, from which the time-dependent THz electric field amplitude is deduced. For  $\ell = -1$  and  $q = 1/2$ , Fig. 1a shows the

THz intensity transverse pattern obtained by averaging the THz pulse intensity for different time delays. As expected, the doughnut-shaped intensity pattern is reminiscent of an on-axis phase singularity that is associated to a zero of THz intensity. Instantaneous amplitude transverse



patterns are shown in Fig. 1(b) over half a THz period duration (i.e.  $T \sim 1$  ps, that is  $\sim 300$  mm free-space delay). The spatiotemporal spiraling structure of the electric field corresponds to the presence of a phase singularity with topological charge  $\neq -1$  since a  $2\pi$  rotation of the pattern per wavelength is observed. Nonseparable superpositions of such vortex beams have also been obtained and characterized by a two-dimensional polarimetric analysis. Then, we will demonstrate that, by preparing an initial linearly polarized THz beam, we can also generate a radially (Figs. 1(c) and (d)) or azimuthally polarized beam, in good agreement with theoretical predictions.

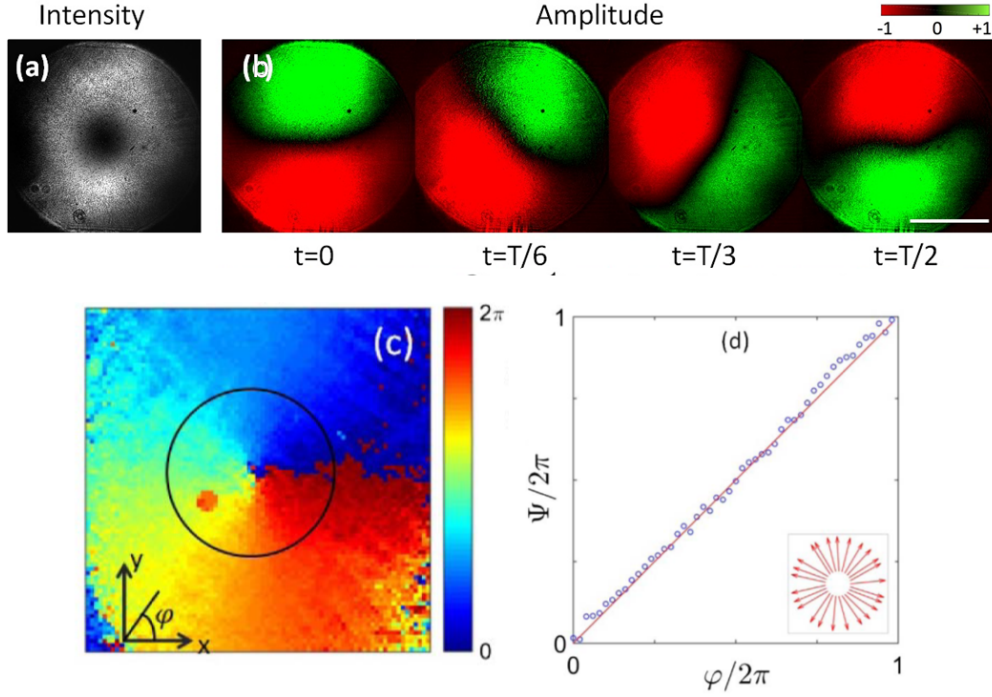


Fig. 1. (a) Intensity pattern of the 1 THz vortex beam. (b) Temporal evolution of the THz electric field transverse distribution revealing phase singularity of topological charge  $\neq -1$ . Scale bar: 10mm. (c) Radially polarized THz beam: spatial distribution of the azimuth angle  $\arctan(E_y/E_x)$ . (d) Dependence of the polarization azimuth  $\Psi$  of the radial vector beam: circles, experimental data along the circle line shown in panel (c).

### III. SUMMARY

THz vortex beams and vector beams were generated using geometric phase elements. A high-speed CMOS camera combined with an electro-optical detection were used to characterize the beams by employing a simple and direct measurement of the THz electric field.

### REFERENCES

- [1]. A. Minasyan et al., Opt. Lett. 42(1), 41 (2017).
- [2]. L. Marucci et al., Phys. Rev. Lett. 96, 163905 (2006).

## Ashod Aradian (CRPP) - “Spasing’ and nano-lasing in plasmonic nanoparticles”

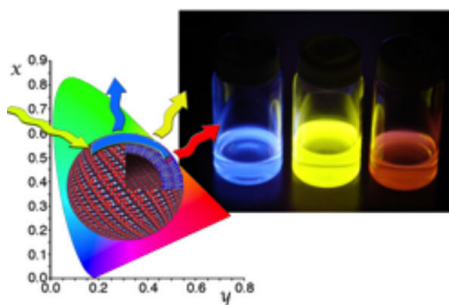
Metamaterials, and more generally nanophotonics, based on plasmonic nanostructures, suffer from significant Ohmic losses linked to the plasmon resonance. One of the classical way to circumvent this issue has been to couple plasmonic structures with active material such as dyes, fluorophores, quantum dots, to mitigate losses. In cases where the amount of optical gain provided exceeds losses, one may observe extremely intense near and/or far fields, with sharp spectral features, unusual for plasmonic materials. These phenomena have been dubbed “spasing” and “nano-lasing”, as they are in several ways akin to macroscopic lasers.

I will present the work carried in the Metamaterials Group within CRPP over recent years, where we have endeavoured to model spasing and nano-lasing in various geometries involving single plasmonic nanoparticles, with the help of theoretical approaches of increasing complexity. This work has allowed us to study optical properties such as lasing threshold, the initial stages of the lasing instability, emission width, and long-term dynamics.

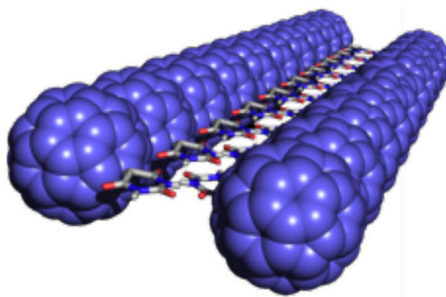
## Dario Bassani (ISM) – “Controlling the emissive properties of organic materials using supramolecular interactions”

Supramolecular interactions, sometimes referred to as weak forces, reveal themselves to be powerful allies in the design of photoactive systems in which excited state reactivity is governed otherwise than by the intrinsic properties of the excited state. Thus, processes that are inefficient can be greatly accelerated by the judicious organization of the chromophores within a supramolecular assembly (Fig. 1 – 3) [1]. The latter does not only operate through an increase in the local concentration of reactants, but can actually steer the product distribution towards otherwise unfavourable photoproducts. In this respect, one may consider that the excited-state potential energy landscape has been modified.

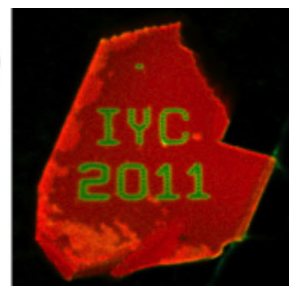
An advantage of supramolecular architectures is their ability to accommodate geometries not easily obtained by conventional synthesis, such as proximal arrangements of distant orthogonal units. This can lead to interesting photochemical and photophysical behavior, such as the observation of additional electronic interactions, or the control of excited-state processes. In this lecture, I will present examples of supramolecular organic materials that self-assemble into specific architectures allowing their inclusion in stacked OLED devices. This allows the chemist, rather than the manufacturer, to control the color, size, polarization, and shape of the emissive pixels. The observation of electronic interactions specific to the presence of complementary molecular recognition sites inducing proximal arrangement of distant chromophores is also of interest in the design of photo- and electro-active devices based on intercomponent energy or electron transfer processes [2,3].



**Fig. 1.** Self-assembly of luminescent nano-spheres.



**Fig. 2.** X-ray structure of a fullerene double-cable.



**Fig. 3.** Photopolymers lithography (80 X 80  $\mu\text{m}$ )

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[2] Tsai, Y.-T.; Liu, H.-F.; Peng, B.-J.; Tseng, K.-P. Kuo, M.-C.; Wong, K.-T.; Wantz, G. Hirsch, L.; Raffy, G.; Del Guerso, A.; Bassani, D. M. ACS Appl. Mater. Interfaces 2017, 10.1021/acsami.7b06640.

[3] Tsai, Y. T.; Tseng, K. P.; Chen, Y. F.; Wu, C. C.; Fan, G. L.; Wong, K. T.; Wantz, G. Hirsch, L.; Raffy, G.; Del Guerso, A.; Bassani, D. M. ACS Nano, 2016, 10, 998.

## **Baptiste Battelier (LP2N) – “3 axis cold atom accelerometer for inertial navigation”**

BATTELIER Baptiste(1), CHICHET L.1, CHEINEY P.(2), BARRETT B.(2), PORTE H.(2), NAPOLITANO F.(2), BOUYER P.(1)

(1) LP2N, IOGS, CNRS and Université de Bordeaux, rue François Mitterrand, 33400 Talence, France

(2) IxBlue, 34 rue de la Croix de Fer F-78100 Saint-Germain-en-Laye France

Spectacular improvement has been achieved in laser cooled atom physics during the two last decades. The ability to manipulate and control cold atoms associated to various accurate measurements allowed the development of matter waves interferometers having measurement noise and long term stability excellent enough to make them candidate for a technological breakthrough in the field of inertial sensors. Nowadays, substantial technical developments have been done and have allowed to bring to market atom gravimeters and clocks enabling static long term measurements. Nevertheless, the use of cold atoms sensors for navigation and positioning still needs to solve a lot of scientific and technological challenges such as compliance with onboard applications, compactness, measurement continuity, operating these sensors in relevant environment and in contact with other measurement instrumentation.

The Joint Laboratory iXAtom brings together the knowledge of a French company of very high technological added value- iXBlue, expert in photonics and inertial navigation of very high performance – and a public laboratory specialized in atom interferometry at the highest worldwide level- LP2N. The goal of the joint laboratory is to bring a technological breakthrough using cold atoms to develop the next generation of inertial sensors for industrial, space and military applications, with an expected improvement of the performances by several orders of magnitude with a device of same size.

The principle of an atom interferometer is to measure the position of an atom in a phase ruler defined by a retro reflected laser beam. We actually compare the trajectory (rotations and accelerations) of the reference mirror attached to the engine with the ideal trajectories of the atom cloud released from a magneto-optical trap. So far, atom interferometers have been capable of measuring rotations or accelerations along only one direction at a time. For inertial navigation, it is necessary to measure the 3 orthogonal rotations and accelerations simultaneously in order to reconstruct the trajectory of a moving body. The goal of the 3DCAA project is to make an important step toward this full inertial measurement system, starting with a simultaneous 3-axis measurement of the vector acceleration using cold atoms.

To achieve a simultaneous three axis accelerometers with cold atoms, we study alternative and simultaneous methods. In the first case, our solution is based on the switching of both the laser interrogation beam and the quantification magnetic field. In the second case, the usual manipulation of internal states is not possible, and we need to play with external states in the phase space domain. We currently develop highly localized atom sources and coherent manipulation of the atoms with multi photonics transitions, associated to spatial detection of the different atom clouds. We designed a new scheme based on these technics which should allow us to extract the three phases of the 3D interferometer.

## Andrea Bertoldi (LP2N) – “Phase-locking an atomic clock”

In atomic clocks the phase evolution of a quantum superposition state is used to measure and correct the frequency drift of a classical local oscillator, implemented as a microwave or an optical signal. The projection of the relative phase between the quantum and the classical oscillator is measured as a population unbalance on two energetic levels of the atomic system, and the phase can be recovered unambiguously only over a limited interval. Resolving phase wrapping requires to consider the effect of the measurement process on the system and specifically on its quantum coherence. Several solutions to extend the interrogation interval - hence the instrument sensitivity - have been proposed for atomic clocks [1,2] and clock comparisons [3]; they use two or more ensembles interrogated simultaneously to monitor the relative phase evolution at different time scales to avoid phase wraps over a longer interval. We extended the unambiguous interval to probe the phase evolution of an atomic ensemble using coherence preserving measurements and phase corrections [4], and obtained the phase lock of the clock oscillator to an atomic superposition state [5]. We propose a protocol based on the phase lock to improve atomic clocks limited by local oscillator noise, which is the case of optical clocks. We finally consider the possibility to combine on the same clock time correlated measurements and quantum correlations between the atoms.

[1] T. Rosenband and D. R. Leibbrandt, “Exponential scaling of clock stability with atom number”, arXiv:1303.6357 (2013)

[2] J. Borregaard and A. Sorensen, “Efficient atomic clocks operated with several atomic ensembles”, Phys. Rev. Lett. 111, 090802 (2013)

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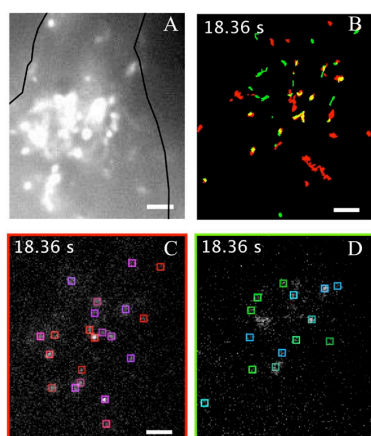
[5] R. Kohlhaas, et al., “Phase locking a clock oscillator to a coherent atomic ensemble”, Phys. Rev. X 5, 021011 (2015)

## Mireille Blanchard Desce (ISM) & Laurent Cognet (LP2N) – “Single particle tracking with carbon nanotubes and organic nanoparticles for imaging the brain at the nanoscale”

Single molecule tracking is a powerful technique allowing fluorescent single molecule to be imaged and tracked, offering great interest for the fine investigation of biological processes and environments.[1] Fluorescent markers having suitable photostability and high brightness are required to allow short exposure times (video rate) and low light dose to minimize photo-degradation of biological materials. In this context, inorganic “hard” nanoparticles (such as QDs) have been most widely used due the limited photostability and brightness of single organic dyes. Yet, they raise concern with respect to toxicity and degradability issues. With this goal in mind, we have developed original bottom-up strategies towards purely organic molecular-based nanoparticles (ONPs) specifically engineered as nanotools for single particle tracking (SPT) in bioenvironments.

Our strategy is based on the design and synthesis of dedicated multipolar dyes as interacting building blocks of ONPs which are readily prepared using expeditious and green protocols. By controlling and operating interchromophoric interactions, we demonstrated that both the ONPs luminescence and nonlinear optical responses can be tuned or enhanced by manipulating molecular confinement.[2-4] Intriguingly, the implemented strategy also enables modulating and improving the ONPs colloidal and structural stability,[3-5] while major fluorescence amplification can be achieved in core-shell binary nanoparticles made from complementary dyes.[4]

The bottom-up supramolecular engineering route led to ONPs which combine tunable fluorescence (in the whole visible down to the NIR1 region[2-7]), remarkable NLO properties, unprecedented brightness (up to  $10^8$  M<sup>-1</sup> cm<sup>-1</sup> and 106 GM), excellent colloidal stability and absence of toxicity, providing superior substitutes to QDs. Among them, Hyper-bright NIR-emitting fluorescent organic nanoparticles (named HiFONs) of controlled size (typically 10 to 60 nm) which show unprecedented photostability and excellent biocompatibility can be successfully imaged and tracked at the single particle level in water[6]. Moreover, they can be used as nanotools in multicolor SPT at video rate experiments to explore cellular compartments within live cells using a monochromatic source of light (@488 nm)[7]. Lastly, new small HiFONs that do not exhibit non-specific interactions in cellular environments have been elaborated thanks to the implemented molecular engineering route. These ONPs could be imaged as the single particle level in organotypic brain slices allowing visualization down to 50  $\mu$ m depth. As such, the engineered HiFONs hold foremost promises as unique probes for the investigation of the brain extracellular space.



< Fig1. Simultaneous multicolor single particle tracking in living cells.[2] Top left: bright field of COS 7 cells; Top right: reconstruction of the trajectories of single nanoparticles in the COS 7 cell; Bottom left and right: tracking of single NIR and green emitting nanoparticles respectively in the living COS 7 cell.

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## **Bruno Bousquet (CELIA) – “LIBS : analyses élémentaires à partir d’un plasma induit par laser. Des grottes préhistoriques jusqu’à la surface du sol martien”**

Laser-induced breakdown spectroscopy (LIBS) is a technique of spectroscopy giving access to the elemental composition of a sample, without any preparation.

Principles of LIBS will be presented as well as the major advantages and drawbacks of the technique.

Then, few applications will be presented, from laboratory setups allowing to perform multi-elemental imaging to transportable or handheld setups allowing on-field measurements. Among the applications involving CELIA, let’s mention the field of prehistorical caves, agricultural soils and Mars exploration.



## **Benjamin Canuel (LP2N) – “MIGAPHYS: new tools for MIGA and future long baseline atom interferometers”**

The LP2N is deeply involved in the realization of the MIGA Equipex, an hybrid detector that couples laser and matter-wave interferometry to study sub Hertz variations of the strain tensor of space-time and gravitation. Using a novel approach exploiting a set of atomic interferometers simultaneously manipulated by the resonant optical field of a cavity, this instrument will allow at the same time a better understanding of the evolution of the gravitational field and a new tool for gravitational waves (GW) detection. The collaborative project MIGA PHYS, funded by the Laphia cluster of Excellence aims to prepare major outcomes of the future antenna.

- A new generation of matter-wave sensors, involving advanced fiber laser technology development that could ultimately lead to a breakthrough for the realization of future long baseline atom interferometers.
- The development of the first theoretical and numerical tools for the study of space-time variation of the gravity field with networks of atom interferometers; with potential applications in GW physics to develop new detector geometries and in Geoscience to map local gravity fluctuations.



## Sylvain Danto (ICMCB) – “Intermediate-Tg Glasses For Multimaterials Fiber”

Sylvain Danto<sup>1</sup>, Clément Strutyński<sup>1,2</sup>, Frédéric Désévéday<sup>2</sup>, Yannick Petit<sup>1</sup>, Jean-Charles Desmoulin<sup>1</sup>, Alain Abou Khalil<sup>3</sup>, Marc Dussauze<sup>4</sup>, Jean-Charles Jules<sup>2</sup>, Grégory Gadret<sup>2</sup>, Frédéric Smektala<sup>2</sup>, Lionel Canioni<sup>3</sup>, Thierry Cardinal<sup>1</sup>

(1) Institute of Chemistry of the Condensed Matter of Bordeaux (ICMCB) University of Bordeaux, 33608 Pessac, France / (2) Laboratoire Interdisciplinaire Carnot de Bourgogne, UMR 6303 CNRS, University of Bourgogne Franche-Comté, 21078 Dijon, France / (3) Center for Intense Lasers and Applications (CELIA) University of Bordeaux, 33405 Talence, France / (4) Institute of Molecular Science, University of Bordeaux, 33405 Talence – France

Research on multimaterial multifunctional fibers flourished in the recent years, proposing an ever growing set of materials suitable for co-drawing as well as of fiber functionalities. So far however advances relied mostly (i) on high-Tg silica-based materials ( $T_g > 1000\text{ }^\circ\text{C}$ ) due to the technological interest of silica, and (ii) on low-Tg chalcogenide glasses ( $T_g < 250\text{ }^\circ\text{C}$ ) that were deployed for integration in multimaterial glass/polymer/metal fibers.

Here we explore the feasibility of fabricating multimaterial fibers using glasses with intermediate glass transition temperatures. The presentation focuses on phosphate glasses ( $T_g \sim 350\text{--}450^\circ\text{C}$ ) and on tellurite glasses ( $T_g \sim 250\text{--}300^\circ\text{C}$ ). Firstly, we explore phosphate-based hybrid fibers (fibers with the active function being embedded within the glass matrix). We report on the drawing of photosensitive, photo-writable Ag-containing glass ribbon fibers. We demonstrate that luminescence properties of the native glass are preserved after shaping. Furthermore, we establish that the unique fiber's flat geometry allows for the direct, accurate Laser writing of complex luminescent silver clusters patterns and functionalities within the glass matrix.

Alternatively, we explore tellurite-based composite fibers (fibers made from a stack of materials with disparate electrical/optical/thermal properties). Here, bringing together the merits of these materials with fiber optic technology, we report on the first tellurite-based core-clad dual-electrodes composite fiber made by direct, homothetic preform-to-fiber thermal co-drawing. The rheological and optical properties of the selected glasses allow both to regulate the metallic melting flow and to manage the refractive index core/clad waveguide profile. We demonstrate the electrical continuity of the electrodes over meters of fiber. We believe the drawing of architectures merging electrical and optical features in a unique elongated wave-guiding structure will enable to develop new in-fiber functionalities based on hybrid electric/optic nonlinear effects. Great challenges lie ahead when it comes to mastering the implementation of intermediate-Tg oxide glasses within multimaterial fibers, but great opportunities lie ahead too, as it would give access to a whole new range of materials properties, and hence of functionalities, in linear/nonlinear optics, photonics, electro-optics or sensing.

## **Emmanuel D’humieres (CELIA) – “Generation of high amplitude magnetic fields, high energy radiation and collimated energetic particle beams using snail and chiral targets irradiated by high power lasers”**

Emmanuel d’Humières<sup>1,2</sup>, Philipp Korneev<sup>3</sup>, Yuki Abe<sup>4</sup>, Yasunobu Arikawa<sup>4</sup>, Farley Law<sup>4</sup>, Kazuki Matsuo<sup>4</sup>, Ho Lee<sup>4</sup>, Alessio Morace<sup>4</sup>, Sergey Bochkarev<sup>5</sup>, Valery Bychenkov<sup>5</sup>, Joao Santos<sup>1</sup>, Yasuhiko Sentoku<sup>2</sup>, Shinsuke Fujioka<sup>4</sup> and Vladimir Tikhonchuk<sup>1</sup>

- (1) Univ. Bordeaux-CNRS-CEA, CELIA, 33405 Talence, France
- (2) Department of Physics, University of Nevada, Reno, NV 89557, USA
- (3) NRNU MEPhI, Moscow 115409, Russian Federation
- (4) Institute of Laser Engineering, Osaka University, Japan
- (5) P. N. Lebedev Physical Institute of RAS, Moscow, Russian Federation

A simple setup for the generation of ultra-intense quasistatic magnetic fields, based on the generation of electron currents with a predefined geometry in a curved snail-shaped target has recently been proposed. Particle-In-Cell simulations and qualitative estimates show that Giga-Gauss scale magnetic fields may be obtained with existing laser facilities. The described mechanism of strong magnetic field generation may be useful in a wide range of applications, from laboratory astrophysics to high energy radiation sources, neutron sources and magnetized ICF schemes. First experiments using such targets at ILE in Japan, using the LFEX laser, and at GSI in Germany, using the PHELIX laser have confirmed the generation of high amplitude magnetic fields and efficient electron acceleration along the curved surfaces.

In a complementary study, we have also demonstrated that targets with a broken rotational symmetry may facilitate the generation of a strong axial (poloidal) magnetic field. An intense laser beam irradiating such a target creates strong electron currents carrying vorticity and producing strong spontaneous magnetic fields. Combined with laser electron acceleration, such targets may be used for generation and guiding of magnetized, collimated particle or plasma beams.

# Lionel Hirsch (IMS) – “Printed organic photodetectors - fabrication and failure mechanisms”

Marcin Kielar<sup>1,2</sup>, Olivier François-Martin<sup>1</sup>, Bruno Flament<sup>1</sup>, Olivier Dhez<sup>2</sup>, Mehdi Daanouné<sup>3</sup>, Raphaël Clerc<sup>3</sup> and Lionel Hirsch<sup>1</sup>

(1) University of Bordeaux, IMS, UMR 5218, F-33400 Talence, France and CNRS, IMS, UMR 5218, F-33400 Talence, France.

(2) ISORG, 60 Rue des berges, Parc Polytec — Immeuble Tramontane, 38000 Grenoble, France.

(3) Institut d’Optique Graduate School. Université de Lyon, UJM-Saint-Etienne CNRS UMR 5516, Laboratoire Hubert Curien, 42023 Saint-Etienne, France

Printed organic photodetectors (OPDs) can transform plastic, paper or glass into smart surfaces. This innovative technology is now growing exponentially due to the strong demand in human-machine interfaces [1, 2]. To date, only niche markets are targeted since organic sensors still present reduced performances in comparison with their inorganic counterparts.

Our work establishes the rules to achieve a state-of-the-art organic photodetector by printing techniques [3]. We demonstrate that it is possible to engineer a highly efficient organic sensor approaching the performances of Si-based photodiodes in terms of dark current, responsivity and detectivity by using low-cost printing technology. As a result, we simplified the device architecture as much as possible to make the whole process compatible with large-area printed technologies and industrial constraints. In a second part, we also report long operational lifetimes of organic photodetectors (OPDs) and the failure mechanisms are investigated with thermally stimulated current and impedance spectroscopy as function of temperature. We stress the importance of this point as no stability study can be found so far in the literature. It is vital to demonstrate that organic photodetectors can reach a competitive level of stability for successful commercialization of this new and promising technology

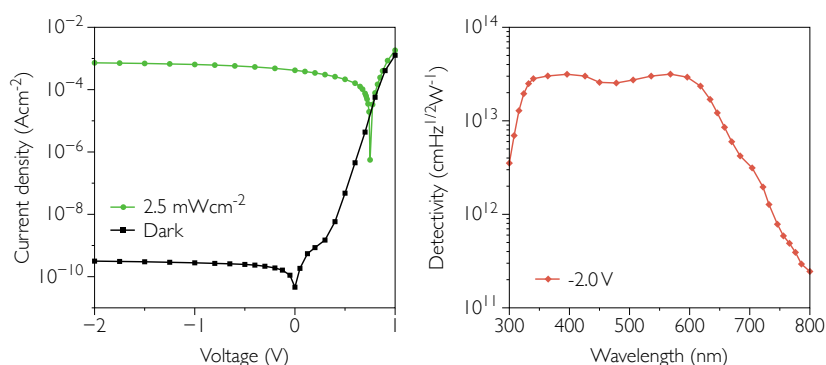


Figure. a) Current density-voltage characteristics under 528 nm irradiation. b) Detectivity spectra at -2 V reverse bias.

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## Valentin Nagerl (IINS) – “Super-resolution imaging of brain extracellular space”

University of Bordeaux, 33077 Bordeaux, France

Interdisciplinary Institute for Neuroscience, CNRS UMR 5297, 33077 Bordeaux, France

All brain cells are surrounded by a narrow extracellular space (ECS), which is filled with interstitial fluid (ISF) and molecules of the extracellular matrix. The ECS has a reticular structure that forms a reservoir for extracellular ions and corridor for nutrients from the blood stream. It is likely to be critical for brain homeostasis and metabolite clearance and to serve as a communication channel for extrasynaptic electrical signaling or ‘volume transmission’.

Because its spatial structure is extremely dense and convoluted, the ECS cannot be adequately visualized by conventional light microscopy techniques like 2-photon or confocal microscopy, appearing featureless and buried in the neuropil of interwoven axons, dendrites and glial processes.

We present a powerful yet straightforward method to visualize the structure and dynamics of the ECS in living brain tissue. It is based on 3D-STED microscopy and fluorescence labeling of the ISF with a freely diffusible organic dye, which remains outside of the cells. This new approach, called ‘super-resolution shadow imaging’ (SUSHI), allows visualization of dense biological tissue, in particular the ECS, at sub-micron resolution and comes with minimal photobleaching and phototoxicity as inherent benefits.

We demonstrate the capacity of SUSHI by applying it to live organotypic hippocampal brain slices. It yields sharp images of the complex structure of the ECS and, inversely, renders all cellular structures visible in the negative stain. We show that the ECS has a highly heterogeneous and regionally differentiated structure, and undergoes pronounced dynamic changes in response to osmotic challenges, seizure-like neuronal discharges and focal release of the excitatory neurotransmitter glutamate. Moreover, we show that SUSHI gives access to quantitative anatomical information about unlabeled micro-anatomical structures like axons and dendritic spines, and can visualize ‘contextualized’ cell migration through brain tissue, where the cell and the surrounding tissue are equally visible at the same time.

## **Serge Ravaine (CRPP) – “Rational synthesis of plasmonic nanostructures for SERS and light guiding”**

Centre de Recherche Paul Pascal, CNRS, Université de Bordeaux, France

Plasmonic nanostructures have attracted great attention in the recent years due to their unique optoelectronic properties. For instance, when the dimensions of metallic nanostructures are smaller than the wavelength of incident light, the strong resonant interaction between electromagnetic radiation and localised surface charges of plasmonic nanostructures induces a sub-wavelength localisation of the electromagnetic field, endowing these nanoparticles with extraordinary properties, including surface-enhanced Raman scattering (SERS).

On the basis on discrete dipole approximation (DDA) calculations, we will firstly present a simple approach to fabricate double-shelled hollow gold nanoboxes with precisely tuned morphology. We will demonstrate that this morphological control allows us to optimize the SERS enhancement factor of the nanostructures, making them promising for applications in bio-imaging and sensing.

Metallic nanostructures also offer a unique way to guide electromagnetic waves at the nanoscale, which makes them attractive as building blocks for the fabrication of plasmonic nanodevices capable of routing light in an active way.

In this context, we will describe a bottom-up fabrication route that makes use of V-shaped gold nanostructures and DNA origami to create a new path selective plasmonic switching device.

Thanks to the precise positioning of different dyes close to the tips of a metallic nanostructure, we will show that a plasmon enhanced energy transfer occurs in the so-created nanodevice, in agreement with theoretical predictions.

## **Giorgio Santarelli (LP2N) – “Starlight+, a stable light lab”**

Laboratoire Photonique, Numérique et Nanosciences (LP2N)  
IOGS - CNRS - Université de Bordeaux

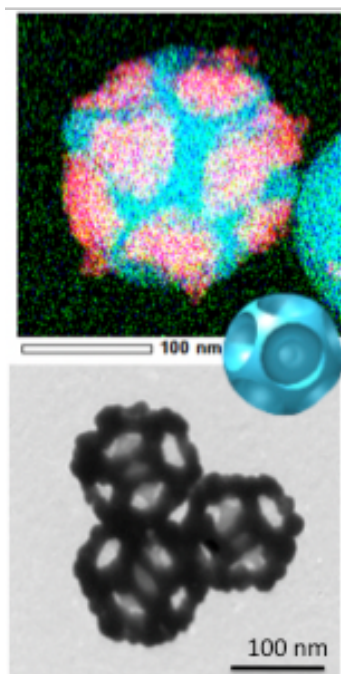
Fiber lasers are crucial tools for a variety of applications. Starlight+ is a fully-integrated Academia/Industry shared laboratory in 2015 between Azur Light Systems and LP2N. This joint photonics laboratory was founded after being selected by the competitive ANR program LabCom and mainly focuses on the investigation high-power stable narrow linewidth fiber-based lasers in continuous wave operation. This class of lasers has been thoroughly investigated in many aspects of fundamental research due to their competing applications in atom cooling, atomic clocks, laser spectroscopy, gravitational wave detection among other, but also in an ever increasing number of real-world applications (coherent LIDAR, holography, industrial instrumentation, high resolution spectroscopy.....), where fine control of amplitude, frequency and phase is extremely important. We will give an overview of the different activities carried out in the framework of the joint laboratory.

## **Christian Spielmann (Helmholtz Institute Jena – Abbe Photonics School) - “High resolution microscopy using table-top XUV light sources”**

Institute of Optics and Quantum Electronics, Abbe Center of Photonics, Friedrich Schiller University Jena, Max-Wien-Platz 1, 07743 Jena Germany  
Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena, Germany

Owing to the enormous progress made in ultrashort pulse laser technology, producing bright short wavelength radiation e.g. via high harmonic generation (HHG) or x-ray lasing are interesting approaches for making “laser-like x-ray radiation” available to small university laboratories. These kind of spatially and temporally coherent XUV light sources meet also the requirements for high resolution lensless imaging. Lensless imaging include coherent diffractive imaging (CDI) and ptychography and in both techniques a sample is imaged by recording the far field intensity diffraction pattern and subsequently phase retrieval by iterative computer algorithms. In a recent collaboration, we employed a state of the art HHG source for CDI and were able to demonstrate a spatial resolution of 13nm which is less than the illuminating XUV wavelength of 18nm with a decent exposure time of a few minutes. The exposure time can be further reduced by using laser driven x-ray lasers, which have a higher flux, an almost perfect temporal coherence but only a limited spatial coherence. As we have shown, with table-top XUV lasers we can not only take single shot CDI images, but also using ptychography to reconstruct the sample and the illumination function. Moreover we also succeeded in the first real world application of these novel imaging techniques and were able to classify breast cancer cells without staining or any other complicated preparation technique.

## Mona Treguer-delapierre (ICMCB) – “Customizing nano-objects for engineering hybrid nanoparticles”



Combining material components of different nature in the same nanoparticle is a new challenge in nanosciences and offers a wide range of new and largely unexplored possibilities for developing novel materials. In particular, proper design of the hybrid nanoparticle should permit a control over the interaction of the material components to combine different confinement-induced properties, create new ones or introduce new functionalization. In this presentation, I will focus on the synthetic route of metallo-dielectric components targeting photonic materials. I will show how to build stable and robust raspberry-like nanostructures with close-packed plasmonic satellites with high purity as well as their unusual optical properties. I will also demonstrate how to get control of positioning of each component with respect to the other by using the concept of patchy particles. The self-assembly of these elemental building units offers interesting possibilities to create complex supracolloids for optical metamaterials or for the ultrasensitive screening of analytical targets, such as those relevant to medical and environmental sciences.

*Examples of hybrid nanoparticles produced by customizing silica particles surface*

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Baron A., Iazzolino, Ehrhardt K., Salmon J.B., Leng J., Aradian A., Kravets V., Grigorenko A., Le Beulze A. Tréguer-Delapierre M., (2013), *Opt.Mat.Express* 3, 11, 1792-1797.



## **Kevin Vynck (LP2N) – “Electromagnetic modeling of complex resonant nanostructures”**

Kevin Vynck, Alexis Devilez, Philippe Lalanne

Disordered ensembles of complex, strongly resonating nanoparticles in planar geometries are ubiquitous in emerging photonic materials and devices. Their high scientific and technological potential is due to the richness of their optical properties, coming from the individual nanoparticles (e.g., mixing metallic and dielectric materials, of varying shape), their interaction with a structured substrate (a thin-film stack) and their mutual interaction at both short and long ranges. Theoretically predicting the optical properties of such complex nanostructures has however remained a seemingly insurmountable challenge up to now, due to the difficulty to consider simultaneously the coherent phenomena occurring down to the nano-scale – at the level of the individual nanoparticle – up to the mesoscopic scale – at the level of the nanoparticle ensemble.

In this talk, we will describe a novel computational method, based on the numerical retrieval of the polarizabilities of ensembles of dipoles to reproduce the near-field scattered by a nanoparticle, which enables the modeling of disordered ensembles of complex nanoparticles strongly interacting with planar interfaces.

## Student's posters

- Alberto Álvarez Fernández ( CRPP / LCPO ) : " Block copolymer based nanoplasmonic surfaces "
- Giedre Marija Archipovaite ( CELIA ) : " 3  $\mu\text{m}$  Parametric Laser Source Driving High Order Harmonic Generation in ZnSe "
- Maxime Bertrand ( IOA - LP2N ) : " Modal formalism to predict the appearance of complex nanostructured surfaces "
- Jonathan Daniel ( ISM ) : " Bottom-up approach to bright and non-toxic molecular-based luminescent nanoparticles for bioimaging "
- Romain Dezert ( CRPP ) : " Broadband Isotropic Huygens' Sources Made of Spherical Nanoclusters for Metasurfaces Applications "
- Jessica Flores ( ISM ) : " Broadband Isotropic Huygens' Sources Made of Spherical Nanoclusters for Metasurfaces Applications "
- Mikael Ghadimi Nassiri ( LOMA, CNRS ) : " Agile spin-orbit shaping of polychromatic light "
- Mayte Gomez Castano ( CRPP ) : " Bottom-up fabrication of double fishnet metamaterials working at visible and near infrared frequencies "
- Alexandre Gras ( LP2N ) : " Quasi-normal modes in Large Resonating Systems "
- Marcin Krasnodebski ( SPH ) : " Throwing Light on Photonics: Genealogy of a Technological Paradigm "
- Nina Kravets ( LOF / LOMA ) : " Multiple star optical vortex coronagraphy "
- Hernando Magallanes González ( LOMA ) : " Macroscopic observation of helicity-controlled lateral optical forces "
- Mingming Pan ( IMS ) : " Terahertz waveguide for reflection imaging applications "
- Sergio Rota ( LP2N ) : " Watt-level single-frequency tunable Neodymium MOPA fiber laser operating at 915-937 nm "
- Jan Vábek ( CELIA ) : " The polarisation gating applied for asymmetric pulses to controlling the XUV-frequency in the HHG setup "

## Block copolymer based nanoplasmonic surfaces

Alvarez-Fernandez, Alberto<sup>1,2</sup>, Pecastaings, Gilles<sup>2</sup>, Aissou, Karim<sup>2</sup>, Hadziioannou, George<sup>2</sup>, Fleury, Guillaume<sup>2</sup> and Ponsinet, Virginie<sup>1</sup>

*1 Centre de Recherche Paul Pascal, Univ. Bordeaux, CNRS UPR 8641, Pessac, France*

*2 Laboratoire de Chimie des Polymères Organiques, Univ. Bordeaux, CNRS UMR 5629/ENSCBP, Pessac, France*

Metal-dielectric nanocomposites are attracting a lot of attention for optical applications, due to their capacity to support designed surface plasmon waves. These nanocomposites are prominent in optical metamaterials, which are artificially structured materials engineered to gain optical properties not only from their composition, but from their design. Their geometry, size and arrangement can affect the propagation of light in an unconventional manner, giving rise to properties which are not available in bulk materials. Metamaterials and nanophotonic devices are classically fabricated by lithography techniques, but alternative simpler techniques are needed to reach characteristic sizes of a few tens of nanometers.

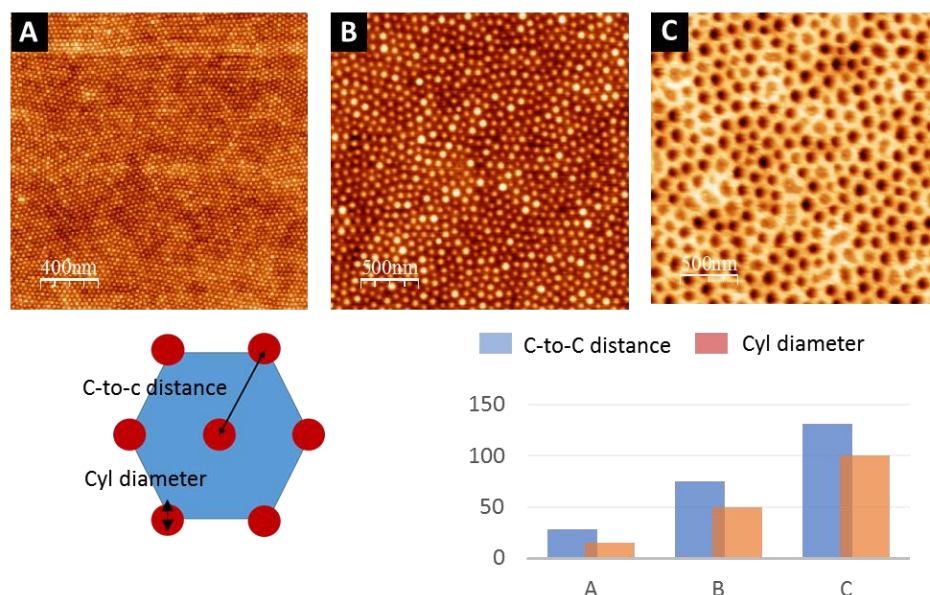


Figure 1: AFM micrographs of  $PS_{26k}$ - $b$ - $P2VP_{5k}$  (A),  $PS_{247k}$ - $b$ - $P2VP_{57k}$  (B) and  $PS_{440k}$ - $b$ - $P2VP_{353k}$  (C) and scheme of the different parameters modulated with the controlled synthesis.

In this work, we present a straightforward method to obtain patterned metal-dielectric nanocomposites, from continuous gold lines to discrete gold nanoparticles hexagonal arrays, using the self-assembly of block copolymers as nanostructured templates. Different molecular weight block copolymers were synthesized by living anionic polymerization in order to control the center-to-center distance (from 20 to 130 nm) and the object size (from 15 to 100 nm). Perpendicular lamellar or cylindrical structures of poly(styrene)- $b$ -poly(2-vinyl pyridine) (PS- $b$ -P2VP) copolymers were obtained in thin films by spin-coating, followed by the metallic precursor deposition, which is selectively incorporated into the P2VP domains and reduced in a subsequent step by  $O_2$  RIE. Grazing-Incidence Small Angle X-ray Scattering, Atomic Force Microscopy, Scanning Electron Microscopy, X-ray Photoelectron Spectrometry, and Kelvin Probe Force Microscopy have been used to follow each step of the process. Besides, the plasmon resonances of the nanostructures are studied by variable-angle spectroscopic ellipsometry.

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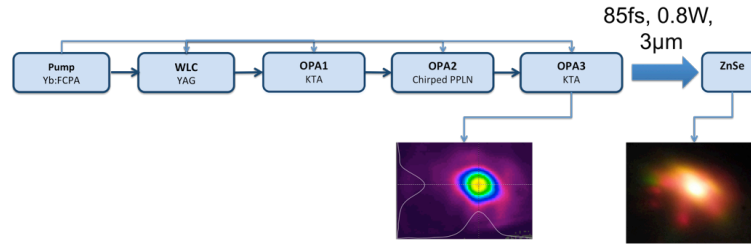
# 3 $\mu\text{m}$ Parametric Laser Source Driving High Order Harmonic Generation in ZnSe

*Giedre Marija Archipovaite, Stéphane Petit, Jean-Christophe Delagnes, Eric Cormier*

*Université Bordeaux-CNRS-CEA-UMR 5107, Centre Lasers Intenses et Applications, 351 Cours de la Libération, F-33405 Talence, France*

*Author e-mail address: giedre-marija.archipovaite@u-bordeaux.fr*

High power ultrashort pulse light sources in the near- to middle-infrared spectral region are in high demand for strong field physics in atoms, molecules and condensed matter. Indeed, these laser sources are used for various experiments such as bright and coherent soft x-ray generation [1], conventional or multidimensional spectroscopy [2], and ultrafast magnetism [3]. According to the three step model [4], the energy cut off of generated high harmonics scales as  $I\lambda^2$ , which favors longer driving wavelengths in order to generate more energetic XUV photons, and potentially shorter attosecond, soft X-ray pulses. Unfortunately, photon energy extension is at the cost of an efficiency drop scaling as  $\lambda^{-5.5}$  [5]. Here, the availability of a high-repetition-rate laser system is paramount to mitigate the efficiency issues and still produce high photon fluxes. Even though there are a few laser gain media suitable for intense femtosecond pulse generation in the mid-IR spectral region the overall scalability of the pulse repetition rate, the duration and power are still challenges [6,7]. Thus parametric systems based on a nonlinear three wave – mixing, are certainly an attractive alternative to generate the required ultrashort pulses for those experiments.



**Fig. 1.** Scheme of a three-stage OPA, delivering 85 fs pulses at 3  $\mu\text{m}$ . The insets show the spatial beam profiles measured at the output of the OPA and after harmonic generation in polycrystalline ZnSe.

The OPA (Fig. 1.) is pumped by a high repetition rate home built Yb:FCPA laser, the system works at 100 kHz repetition rate and delivers 350 fs pulses with the average power of 37 W. We obtain a 3  $\mu\text{m}$  parametric laser source with an output of 8  $\mu\text{J}$  and pulse duration of 85 fs, which corresponds to 8 optical cycles at this wavelength [8].

The system is suitable to drive strong field experiments, which require ultrashort, intense pulses in the mid-IR spectral region. Spectral broadening together with high order harmonic generation is observed in polycrystalline ZnSe sample.

The 3  $\mu\text{m}$  beam was focused on the ZnSe sample with an intensity of 0.3  $\text{TW}/\text{cm}^2$ . Here, the peak power is more than two times higher than the critical power required for white light generation in ZnSe. The initial spectrum is broadened and covers the region from 2 to 4.3  $\mu\text{m}$  and up to 6<sup>th</sup> harmonic generation is observed.

The obtained results of HOH in ZnSe by a fiber laser pumped OPA is comparable with other lower repetition rate, bulk laser systems [9,10] and shows how fiber-laser-based systems are already very promising tools for driving solid state physics experiments.

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# Modal formalism to predict the appearance of complex nanostructured surfaces

Maxime Bertrand, Philippe Lalanne & Kevin Vynck  
LP2N, CNRS – Institut d’Optique Graduate School - Univ. Bordeaux, F-33400 Talence, France  
kevin.vynck@institutoptique.fr

Mastering the appearance of objects is a key challenge for modern industry, as it would allow to meet the more and more demanding requirements of applications in a wide range of areas, from architecture and interior design, to cosmetics, security holograms or augmented reality. The design process for materials is currently undergoing a revolution, stimulated by research in computer graphics, which allows to generate synthetic rendering of an object of interest in a precise environment. In parallel, nanostructured materials, such as ensemble of optical nanoresonators embedded in thin-film stacks, are known to exhibit rich optical properties due to the high number of degrees of freedom of such systems and could lead to very exotic visual effects. Predicting the appearance of nanostructured materials with realism and physical sense is thus a critical issue. Nowadays, however, there is a blocking gap between the tools and models used by scientists in nanophotonics and in computer graphics. Collaborative efforts are currently being undertaken at LP2N to enable the physico-realistic rendering of nanostructured objects [1].

The keystone of our approach is the computation of the bidirectional reflection distribution function (BRDF) of a disordered ensemble of nanoparticles on a stack from the radiation pattern of an individual nanoparticle interacting with the substrate. This step is quite straightforward under the independent scattering approximation, which assumes that the field exciting a particle is only due to the field incident on the system and not to the field scattered by the other particles. It is, nevertheless, extremely time-consuming, since the calculations need to be repeated for each wavelength, incident angle and polarization. The first results were obtained for the case of spherical particles above a thin-film stack [1], which can be modeled with a high degree of analyticity. For more complex geometries though, numerical calculations, such as finite-elements calculations, are required. The radiation pattern of the nanoparticle upon excitation are then obtained by performing a plane wave decomposition of the scattered field on a box surrounding the nanoparticle [2]. Satisfying results can thus be obtained, but at the price of very heavy computation.

Here, we will present a more effective implementation making use of the concept of quasi-normal modes (QNM), recently investigated in the group [3]. QNMs are the solutions of Maxwell’s equations without a source and are thus intrinsic to the resonator. Once computed and normalized, the optical response of the resonator to any excitation (wavelength, angle of incidence, polarization) can be retrieved semi-analytically. In addition to providing more physical insight, this method is significantly faster and thus ideal for interactive design purposes.

## Acknowledgments

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## Bottom-up approach to bright and non-toxic molecular-based luminescent nanoparticles for bioimaging

Jonathan Daniel<sup>1</sup>, Guillaume Clermont<sup>1</sup>, Florence Ottonnes<sup>2</sup>, Adina Lazar<sup>1</sup>, Gisèle Clofent-Sanchez<sup>2</sup>, Michel Vaultier<sup>1</sup>, Mireille Blanchard-Desce<sup>1</sup>.

<sup>1</sup> ISM, CNRS UMR 5255 Talence, France

<sup>2</sup> CRMSB, CNRS UMR 5536, Bordeaux, France

**Contact:** [jonathan.daniel@u-bordeaux.fr](mailto:jonathan.daniel@u-bordeaux.fr)

Nowadays, natural or manufactured nanoparticles are everywhere, from cosmetics to food, drugs or manufacturing. This abundance of nanomaterials is due to their intrinsic properties obtained by the confinement of atoms or molecules into small volumes. For instance, the confinement effect can lead to highly luminescent materials with excellent photostability which are key parameters in bioimaging fields. Up to recently, these properties were associated to semiconductor-based inorganic quantum dots (QDs). Yet recently, intensive research was focused on safer alternatives to QDs with improved luminescent properties [1]. Here we will show that molecular-based nanoparticles with remarkable photoluminescence properties can be obtained using green synthesis protocols and following bottom-up strategies. We will focus more specifically on fluorescent carbon dots (FCDOTs) which can be obtained on large scale by simple pyrolysis or hydrothermal treatments of cheap, small, accessible and usually biosourced organic precursors [2]. In this work, we investigate the structure and properties of small FCDOTs ( $D_{\text{TEM}} < 30$  nm) which show very large water solubility, intense well-defined blue fluorescence and strong two-photon absorption properties in the NIR region. These FCDOTs are found to be biocompatible and good labels for cell imaging (both for confocal and two-photon fluorescence imaging). Moreover, we demonstrate that they are internalized in human macrophages.

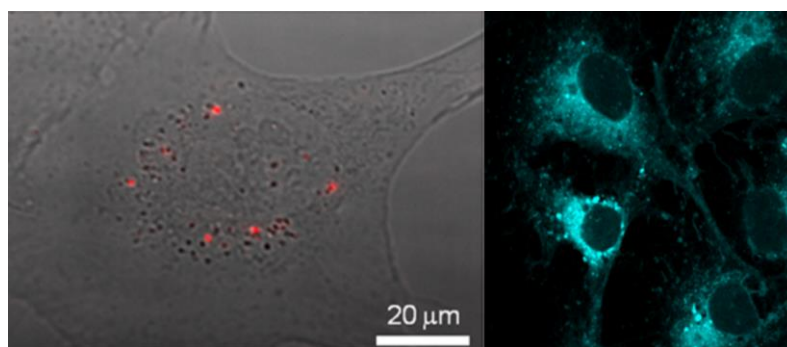


Fig1. Left: single particles of NIR emitting FCDOTs (red dots) in fibroblast cells [1]; Right: imaging of fixed macrophage cells stained with our FCDOTs. The colours are artificial.

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# Broadband Isotropic Huygens' Sources Made of Spherical Nanoclusters for Metasurfaces Applications

R. DEZERT<sup>1</sup>, A. BARON<sup>1</sup>, P. RICHETTI<sup>1</sup>

<sup>1</sup> University of Bordeaux, CNRS, CRPP, UPR 8641, 115 avenue Schweitzer, F-33600, Pessac, France  
[dezert@crpp-bordeaux.cnrs.fr](mailto:dezert@crpp-bordeaux.cnrs.fr)

Huygens' sources are particles exhibiting forward scattering exclusively. This spatial asymmetry in their scattering patterns results from interferences between their optically induced electric and magnetic modes. Indeed, analytical works from Kerker & al [1] in the 1980s, shown that backward scattering can be suppressed at specific wavelength for spherical particles, when their electric and magnetic multipoles are excited with same amplitude and phase.

With this work we propose new designs of Huygens' sources: spherical clusters of dielectric or plasmonic inclusions describing colloidal aggregates. We show with T-matrix numerical simulations, that the control of the effective refractive index of the structure allows to superimpose electric and magnetic multipole resonances. As a consequence of the overlapping, our clusters exhibit high efficiencies, with scattering cross sections around 3 or 5 times their geometrical section. We present two kinds of clusters, the first ones acting as Huygens dipoles, the second ones, as multimodal and large band sources working over intervals of more than 1000nm in the visible and near infrared.

Inclusions of different natures can be considered, either metallic (Ag, Au,...) or dielectric with high refractive index (Si, Ge, GaAs...). As an illustration, Fig 1 (a) and (b) present the scattering efficiency and transmission of a cluster with a radius of 100nm consisting in 60 silver inclusions of radius 15nm in water. The electric and magnetic dipoles contributions to the scattering are presented in colors. For this structure, a Huygens' dipole is obtain around the resonance wavelength at 500nm. This working wavelength is almost exclusively related to the total size of the cluster, and thus, can be adjust along all the visible and near infrared domain.

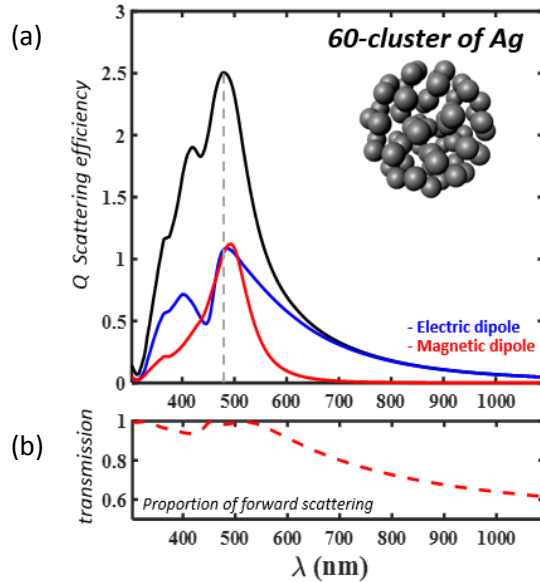


Figure 1. Optical properties of a silver cluster

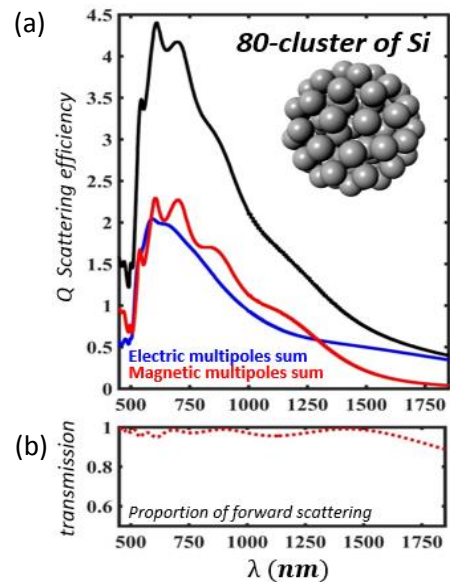


Figure 2. Optical properties of a silicon cluster

On the other hand, Fig 2 (a) and (b) present optical properties of a silicon cluster for which electric and magnetic dipoles, quadrupoles, octupoles and hexadecapoles are approximately overlapped two by two. It consists in 80 particles of radius 50 nm in water. The size of the cluster is 300nm. Fig (b) reveal strong forward scattering neighboring 100% transmission over a range of wavelength of nearly 1000 nm.

Such structures could be used as building blocks to develop high transmission metasurfaces, and because of their colloidal nature, they could provide an isotropic alternative to the meta-atom commonly obtain by lithographic methods.

## Acknowledgments

This work was support by the LabEx AMADEus (ANR-10-LABX-42) in the framework of IdEx Bordeaux (ANR-10-IDEX-03-02), France.

## Bottom-up approach to controlling non-specific interactions between red-NIR emitting ultra-bright organic nanoparticles and epithelial cancer cells

Jessica Flores<sup>1</sup>, Chiara Paviolo<sup>2</sup>, Camille Malrieux<sup>2</sup>, Jonathan Daniel<sup>3</sup>, Laurent Cognet<sup>2</sup>, Mireille Blanchard-Desce<sup>3</sup>.

<sup>1</sup> Stony Brook University, Department of Physics and Astronomy, Stony Brook, NY USA

<sup>2</sup> Univ. Bordeaux, LP2N-IOGS, CNRS UMR 5298 Talence, France

<sup>3</sup> Univ. Bordeaux, ISM CNRS UMR 5255 Talence, France

**Contact: jessflores95@gmail.com**

Through non-covalent routes, molecular confinement of tailor-made dyes in water is achieved. Based on this original molecular-based design, we present hyperbright red-near IR emitting fluorescent organic nanoparticles (HiFONs). These fully organic nanoparticles are prepared from specifically designed quadrupolar dyes using a simple, fast and green protocol that yields molecular-based fluorescent nanoparticle suspensions in water. Following a bottom-up approach, we investigate the luminescence and morphological properties of very small ( $r_{TEM} < 10$  nm) red to NIR emitting HiFONs with highly negative surface potential values. Owing to their brightness, size and composition, these HiFONs were imaged as *isolated nanoparticles* and as such, represent utmost nanotools for use in single particle tracking applications. Based on their remarkable surface properties, we exploit electrostatic interactions with cationic polymers to amplify the HiFONs optical properties [1]. Moreover, these non-covalent interactions are used as a route to control/modulate interactions between HiFONs and epithelial cancer cells. No evidence of cytotoxicity was found upon incubation of live cells with HiFONs and cell membrane (or absence of) interaction and internalization were observed in both live and fixed cells, where their motion could be tracked at a video-rate. These ultra-bright, stable (as well as photostable) yet non-polymeric nanoparticles which maintain their integrity under high dilution represent a unique class of novel tools for bio-imaging applications. Their distinctive surface properties and their compatibility with live cell imaging open a promising route for specific targeting of cell membrane receptors.

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# Agile spin-orbit shaping of polychromatic light

M. Ghadimi Nassiri and E. Brasselet

Univ. Bordeaux, CNRS, LOMA, UMR 5798, F-33400 France

[mikael.ghadimi-nassiri@u-bordeaux.fr](mailto:mikael.ghadimi-nassiri@u-bordeaux.fr)

The coupling between the polarization state of light and its spatial degrees of freedom (i.e., the spin-orbit optical interaction) is a rich and powerful tool to engineer the properties of light. A prototypical example is the generation of optical vortex beams that carry on-axis optical phase singularities. Many options based on optical spin-orbit coupling have been developed to generate vortex beams, the most popular being based on the use of inhomogeneous and anisotropic materials. Practical implementations have been realized using either artificial or natural birefringent materials, both options being nowadays available commercially.

However, such spin-orbit photonic devices are designed to operate at a given wavelength, which prevents the use of polychromatic light fields. Solutions have been proposed, which come at the expense of technologically demanding three-dimensional structuring of space-variant birefringent media [1]. Here we propose an alternative approach that consists to achieve broadband topological shaping of light by independent optimal spin-orbit processing of a finite set of spectral bands.

The proposed approach is based on the integration of small-size spin-orbit couplers made of spontaneously formed liquid crystal topological defects under quasi-static electric fields. In practice, this is achieved by using patterned electrodes enabling the generation of arrays of spin-orbit micro-optical elements [2]. The initial approach has been optimized and now allow full control of the orbital angular momentum content of a polychromatic light field. Experiments are made using a supercontinuum laser source and recent demonstrations will be discussed. One example is illustrated in Figure 1 that shows spectrally distributed broadband optical vortex generation.

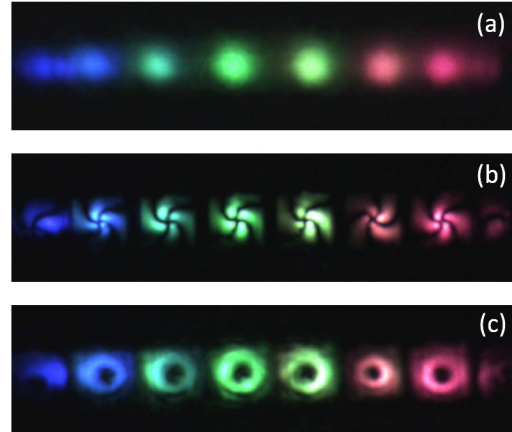


Figure 1: Illustration of the topological shaping of a supercontinuum light field owing to individual control a discrete set of spectral bands. (a) Spectrum-to-space redistribution of an incident polychromatic field. (b) Visualization of the micro-array of liquid crystal topological defects between crossed linear polarizers. (c) Generated spectrally distributed vortex beams.

These results allow considering the elaboration of spin-optical devices to modulate in an agile manner the spectral dependence of the orbital angular momentum content of broadband light sources.

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# Bottom-up fabrication of double fishnet metamaterials working at visible and near infrared frequencies

Mayte Gómez-Castaño<sup>1,2</sup>, Renaud Vallée<sup>1</sup>, Agustín Mihi<sup>2</sup>, Serge Ravaine<sup>1</sup>

<sup>1</sup> Centre de Recherche Paul Pascal, CNRS, University of Bordeaux, France

<sup>2</sup> Institute of Materials Science of Barcelona, CSIC, Autonomous University of Barcelona, Spain

gomez-castano@crpp-bordeaux.cnrs.fr

Fishnet metamaterials are commonly studied systems for achieving a negative refractive index. Their basic structure is composed by a two-dimensional array of holes completely perforating a metal-dielectric-metal stack of layers, the size of these parameters being what defines the wavelength of operation. Although previous studies have already shown the possibility of obtaining a negative index from the microwave to the visible range, all these processes involved expensive top-down fabrication techniques such as electron beam, focused ion beam or laser interference lithographies [1-3].

Here we present an alternative bottom-up route that makes use of colloidal lithography and electrodeposition of metals to fabricate double fishnet nanostructures working at visible and near infrared (NIR) frequencies on large surfaces. Our process implies the deposition of a monolayer of polystyrene (PS) beads by self-assembly on a conductive substrate. It is known that this array can be used as a template to infiltrate metallic layers by electrodeposition [4]. In this way, alternating different films of nickel and gold, we can develop a symmetric structure as shown in Figure 1 left. After removing the nickel parts by chemical etching, we obtain a double fishnet metamaterial composed by two gold layers separated by a nanometric air layer on a transparent substrate (Figure 1 right).

Scanning electron microscopy complemented with vis-NIR microspectroscopy and finite difference time domain (FDTD) simulations confirm our successful process of fabrication, opening the door to a low-cost fabrication of metamaterials over large areas.



**Fig 1.** Schematic side-view illustrations of (left) an electrodeposited sample and (right) the final fishnet metamaterial after Ni dissolution.

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## Quasi-normal modes in Large Resonating Systems

By Alexandre Gras, Philippe Lalanne

LP2N, Institut d'Optique Graduate School, CNRS, Univ. Bordeaux, 33400 Talence, France

And Jean-Paul Hugonin

Laboratoire Charles Fabry, Institut d'Optique Graduate School, CNRS, Université Paris-Saclay, 91127 Palaiseau Cedex, France

Resonance is one of the physical phenomena that has enabled the creation of precise nanoparticle sensing devices. The use of the quasi-normal mode (QNM) expansion of the electromagnetic field allows for precise and analytical calculations of the characteristics of such devices.

$$E(r, t) = \sum_m A_m E_m(r) \exp(-i\tilde{\Omega}_m t) \exp(-\frac{\tilde{\Gamma}_m t}{2}) \quad (1)$$

An electric field written using the QNM expansion is written as a sum of its resonant modes of complex eigenfrequency  $\tilde{\omega}_m = \tilde{\Omega}_m + i\tilde{\Gamma}_m/2$  wherein  $\tilde{\Omega}_m$  is the resonance frequency and  $\tilde{\Gamma}_m/2$  is the damping rate of the "leaky" mode. We can also define the quality factor  $Q$  of the mode:

$$Q = \frac{\text{Re}(\tilde{\omega}_m)}{2 \text{Im}(\tilde{\omega}_m)} = \frac{\tilde{\Omega}_m}{\tilde{\Gamma}_m} \quad (2)$$

However, these quasi-normal modes, that are dampened with time, are amplified the further they propagate from the resonator.

One of the questions we ask ourselves here is the effect of the QNM formalism in systems of nanoparticles which are relatively large.

### Case of a 2-dipole interaction

An incident field  $E^L$  is applied to a system of two identical dipoles which share the same polarisability  $\alpha(\tilde{\omega}) = -\frac{3\pi\epsilon_0\tilde{\omega}^3}{c^3} \frac{\Gamma}{\tilde{\omega}-\Omega}$ , where  $\Omega = \Omega_0 + i\frac{\Gamma}{2}$  is the complex resonant frequency of the isolated dipole in free space. The dipoles are separated by a distance  $z$ .

The dipole moment of either dipole can be written as a function of the incident field and the dipole moment of the other dipole:

$$P_1(z, \omega) = \alpha(\tilde{\omega})[E^L + E_{2 \rightarrow 1}] = \alpha(\tilde{\omega})[E^L + A(\tilde{\omega}, z)P_2] \quad (3)$$

where  $E_{2 \rightarrow 1}$  is the field emanating from dipole 2 that's applied onto dipole 1,  $P_2$  the dipole moment

for the second dipole and  $A(\tilde{\omega}, z) = \frac{1}{4\pi\epsilon_0} \left( \frac{c^3}{(\tilde{\omega}z)^3} + i \frac{c^2}{(\tilde{\omega}z)^2} - \frac{c}{(\tilde{\omega}z)} \right) e^{-\frac{i\tilde{\omega}}{c}z}$  contains the Green Tensor expressing the propagation of this field from one dipole to another. Writing the dipole moment for the dipole 2 is done in the same manner giving us the following system:

$$\begin{cases} P_1 = \alpha(E^L + A P_2) \\ P_2 = \alpha(E^L + A P_1) \end{cases} \quad (4)$$

Using iterative methods and mathematical solvers, we're able to calculate the complex eigenfrequencies of the two aforementioned modes. However, a surprising and counterintuitive result is seen when the dipoles are far apart.

We expect the resonant frequencies  $\tilde{\omega}$  to converge towards  $\Omega$  as the dipoles get further apart, since we expect the coupling between the dipoles to be undone and therefore for them to act as if isolated from one another. However, the resonant frequencies of the superradiant and subradiant modes greatly diverge from  $\Omega$  at distances beyond  $d = Q\lambda_0 = Q\frac{c}{\Omega_0}$ .

### Acknowledgments:

We would also like to thank Kevin Vynck, and Louis Bellando for their help on this subject.

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# **Throwing Light on Photonics: Genealogy of a Technological Paradigm**

Marcin Krasnodebski, Ph.D.

Postdoc researcher, EA 4574 Sciences, Philosophie, Humanités (SPH)

## **Abstract**

The ongoing photonic revolution transforms our lives. Lasers and optical fibers have already opened the opportunities undreamt of a few decades ago and photonics is poised to continue to surprise us in the following years. But what exactly is photonics? Does this term denote a “science of light” incorporating all the studies involving photons, as suggest numerous scientists? Or perhaps photonics should be understood as an applied science, or even simply as industrial applications of optics? The term appeared in the 1970s and has its roots in the French fiber optics research community and in the Dutch high speed photography one, but its meaning evolved over the years competing with alternative terminologies, such as optoelectronics. As photons were supposed to replace electrons in the vast majority of uses, photonics meant to replace electronics in the near future. Interestingly, the popularity of the term “photonics” peaked in the late 1980s due to the hopes the wider public had in optical computing, a technology that has never delivered its promises. The failure of optical computing put photonics in disrepute in the 1990s but it became popular anew in the early 2000s.

In spite of its complexities, history of science can help us to understand the tangled past of photonics as well as plurality of meanings that are attributed to this term. Photonics appears to be a “technological paradigm”, a complex set of interconnected technologies and the related expertise. Not a full-fledged academic discipline but neither a mere branch of industry. Properly defining the term may allow to us to unify the underlying technologies and produce more consistent policies to stimulate the development of light-related technologies.

## Multiple star optical vortex coronagraphy

Nina Kravets, Artur Aleksanyan, Etienne Brasselet

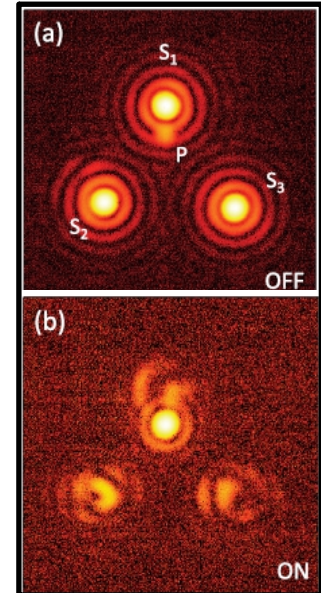
Université Bordeaux, CNRS, LOMA, UMR 5798, 33400 Talence, France

We discuss the latest developments of reconfigurable multiple-vortex phase mask made of a liquid crystal thin film and its application for a high-contrast imaging. We demonstrate that it can be used for simultaneous and selective nulling of several light sources in particular in multiple star optical vortex coronagraph. We report on results of recent laboratory demonstration and the latest and coming tests toward the on-sky implementation.

A coronagraph is an instrument that provides selective starlight rejection. It allows astronomers to observe directly faint astronomical objects nearby the stars. Nowadays all the main telescopes are equipped with coronagraphs [1-3]. Up-to-date most coronagraphs are designed to reject one light source at the time. We demonstrate that a vortex coronagraph able to reject  $N$  ( $N=1,2,3...$ ) light sources can be made using naturally occurring umbilical defects in nematic liquid crystal film confined in the cell with a photosensitive wall.

Umbilical defects are demonstrated to be excellent optical vortex generators and having a great potential in coronagraphy [4]. In the geometry with the photosensitive wall, unlimited number of independent umbilical defects can be generated and located at will. Ensemble of  $N$  umbilical defects can be used as vortex mask to reject  $N$  corresponding point light sources in the coronagraph.

In the laboratory demonstration we mimic  $N=3$  stars and a planet system in which “planet” ( $P$  in Fig.(a)) is several orders fainter than “stars” ( $S$  in Fig.(a)). We demonstrate a simultaneous rejection of three “stars” and direct imaging of “planet” (see Fig.(b)) [5]. We discuss potential improvements toward the on-sky application of proposed technique.



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# Macroscopic observation of helicity-controlled lateral optical forces

H. Magallanes and E. Brasselet

Univ. Bordeaux, CNRS, LOMA, UMR 5798, F-33400 France

[hernano.magallanes@u-bordeaux.fr](mailto:hernano.magallanes@u-bordeaux.fr)

Optical forces driven by light-matter exchanges of linear momentum are nowadays a common tool in many areas of science to manipulate microscopic object. In general, at given light-matter interaction geometry, the magnitude of the optical force is driven by the incident photon flux and its direction may depend on the incident polarization state. In the recent years, a particular interest has been devoted to situations where the photon helicity is used as a control parameter to monitor the direction of the optical force. In particular, an intriguing situation corresponds to lateral forces (i.e., forces directed in a direction perpendicular to the average photon flux) controlled by the photon helicity.

To date, only a few experimental demonstrations of helicity-controlled lateral optical forces have been reported. This has been realized at the microscopic scale and involve force magnitudes of the order of  $\sim 10$  fN [1] to  $\sim 1$  pN [2]. Here we report on the direct observation of lateral forces of the order of 1 nN that induces the displacement of a solid-state macroscopic object (dimensions of several mm).

The experiment is achieved by using a structured anisotropic dielectric material enabling helicity-dependent redirection of the optical linear momentum. The sample is placed at a curved liquid-air interface that behaves as a stable capillary trap. A typical measurement is illustrated in Figure 1 where is reported the dynamics of the lateral displacement of a macroscopic parallelepiped ( $0.1 \times 1 \times 6$  mm<sup>3</sup>) illuminated by a right-handed or left-handed circularly polarized Gaussian beam with optical power is in the range 0.1 to 1 W. The relaxation of the object as the laser is switched off is also presented. Experimental data is quantitatively analyzed by a simple model.

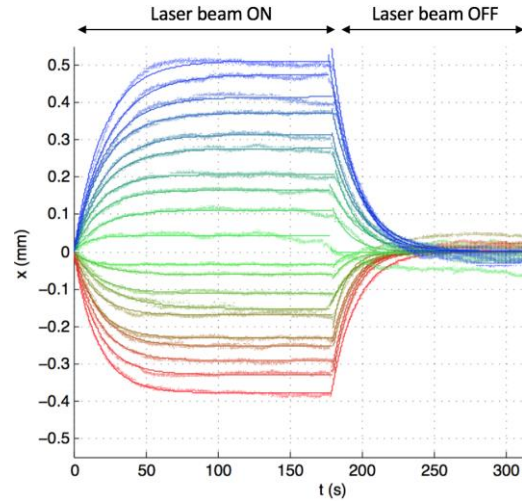


Figure 1: Lateral displacement  $x$  as a function of time of structured dielectric parallelepiped placed at a fluid interface under the influence of circularly polarized light beam of increasing incident optical power with positive (green-to-blue) and negative (green-to-red) helicity. Markers: experimental data. Curves: simulations.

These results extend previous works on unconventional optomechanics driven by the photon helicity to the macroscopic scale and extension to helicity-controlled push/pull optical forces will also be discussed. Our approach thus offer an original platform for naked eyes observation of optomechanical effects that are were restricted so far to subtle and highly demanding instrumentation.

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# Terahertz waveguide for reflection imaging applications

Mingming Pan,<sup>1</sup> Patrick Mounaix,<sup>1</sup> Frédéric Fauquet,<sup>1</sup> Georges Humbert,<sup>2</sup> Dean Lewis,<sup>1</sup> and Jean-Paul Guillet<sup>1,\*</sup>

<sup>1</sup>University of Bordeaux, IMS Laboratory, UMR CNRS 5218, Talence, France

<sup>2</sup>XLIM, UMR CNRS 7252, Limoges, France

Generally terahertz system contains a large amount of optics in order to control the THz radiation propagating behaviors in the free-space. However, this kind of set-up suffers from the diffraction limits when subwavelength resolution is required for the imaging application. Waveguide is proposed as one possible solution owing to the capacity of confining electromagnetic field in the end facet. Several types of waveguides have been investigated and integrated in the near-field microscopy system which exhibit excellent performance [1,2]. In addition, some applications like electronic package test benefit also from the guided terahertz radiation [3]. In this work, we present a new set-up with a glass waveguide and a double photoconductive antenna described in figure 1c-d. This microprobe (show in figure 1 a-b) works as THz emitter and detector so that less alignment work with optics is required. As the dimension of the probe and waveguide is comparable, most of THz signal is coupled into the waveguide and propagates in it. A part of the THz radiation is reflected when it leaves the waveguide and arrives at the interface with the sample.

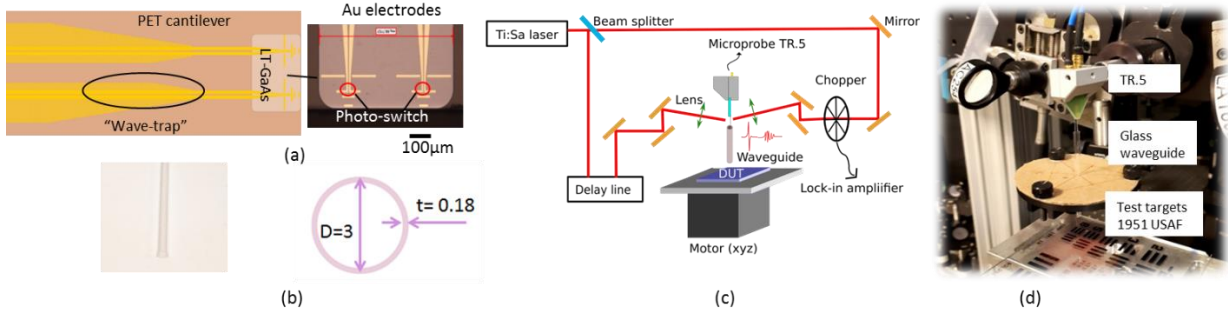


Figure 1 : (a-b) Double photoconductive antenna (c) GTPR system configuration (d) Photography of the setup

The detected signal is shown in figure 2c, which contains an initial THz pulse due to the direct cross-talking between 2 PC antennas as well as some internal reflections from the probe base. Then the signals reflected from the sample near the end of the waveguide are presented. We obtain the image in reflection mode for the elements in the group-2 and -1 by doing a raster scan with an USAF 1951 target.

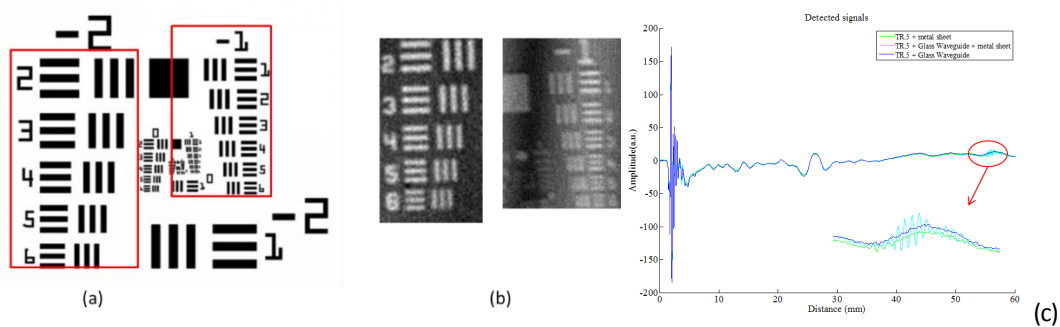


Figure 2: (a) USAF 1951 target (b) Terahertz reconstructed image (c) Temporal data for one point

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# Watt-level single-frequency tunable Neodymium MOPA fiber laser operating at 915-937 nm

**S. ROTA-RODRIGO,<sup>1,\*</sup> B. GOUHIER,<sup>1</sup> M. LAROCHE,<sup>2</sup> J. ZHAO,<sup>1</sup> B. CANUEL,<sup>1</sup> A. BERTOLDI,<sup>1</sup> P. BOUYER,<sup>1</sup> N. TRAYNOR,<sup>3</sup> B. CADIER,<sup>4</sup> T. ROBIN,<sup>4</sup> AND G. SANTARELLI<sup>1</sup>**

<sup>1</sup>LP2N, Univ. Bordeaux – CNRS – Institut d'Optique Graduate School, F-33400 Talence, France

<sup>2</sup>CIMAP, ENSICAEN, CNRS, CEA/IRAMIS, Université de Caen, 14050 Caen cedex, France

<sup>3</sup>Azur Light Systems, Pessac, France

<sup>4</sup>IXBLUE Photonics, Rue Paul Sabatier, Lannion, France

Single-frequency lasers are crucial tools for a variety of applications such as atom cooling, metrology and sensing, among others. However, to date there are still uncovered wavelength domains due to technological challenges, especially in the 910-940 nm window for applications demanding robust systems, and around 455-470 nm for the generation of blue light via non-linear frequency doubling. Such wavelength bands will find applications in laser-cooling of atoms, high resolution 3D lithography, and underwater communications. The outstanding features of fiber laser technology make it the best option to surpass the power limitations of other technologies. To date multi-Watt neodymium-doped fiber lasers have only been demonstrated in a longitudinal multimode operation using resonant cavity configurations. In this project we have developed for first time, a Watt-level single-frequency tunable fiber laser in the 915-937 nm spectral window. The laser is based on a neodymium-doped fiber master oscillator power amplifier architecture, with two amplification stages using a 20 mW extended cavity diode laser as seed. The system output power is higher than 2 W from 921 to 933 nm, with a stability better than 1.4% and a low relative intensity noise.



The polarisation gating applied for asymmetric pulses to controlling the XUV-frequency in the HHG setup

Jan Vábek<sup>1,2,3</sup>, Fabrice Catoire<sup>1</sup>

<sup>1</sup>Centre Lasers Intenses et Applications CNRS-CEA-Univ. de Bordeaux, 351 Cours de la Libération, Talence F-33405, France

<sup>2</sup>ELI Beamlines, Institute of Physics ASCR, Na Slovance 1999/2, Prague, 182 21, Czech Republic,

<sup>3</sup>Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague

High-harmonic generation (HHG) produced by interaction of IR-radiation in gaseous targets is one of the intensively studied sources of XUV radiation during recent decades. For some applications, there are several aspects needed to be improved. In our work, we focus on controlling the XUV properties using special configurations of the IR-field. In a basic configuration, XUV-field is generated by a linearly-polarised laser in a pulse regime. It leads, in frequency domain, to odd multiples of the IR-field frequency. A way to control the XUV is to employ a more advanced configuration of the IR-field. We have chosen so-called polarisation gating for our study. The polarisation gating is using an elliptically polarised IR-pulse superposed with its temporally delayed counter-rotating replica. The XUV is effectively generated only when the resulting field is nearly linear. This configuration has been investigated theoretically in details.

First, we show an extent of the cut-off as compared to the linear case. We have performed simulations for investigating the modified cut-off as a function of the gate-intensity, ellipticity of the pulses and the pulse-delay.

Next, the peak intensity of the replica has been allowed to change with respect to the peak intensity of the original pulse. We have simulated cases with two delayed counter-rotating elliptical pulses of different amplitudes and demonstrated, for the first time, that it allows for controlling XUV-photon frequency. These results are of prime interest in the context of tomography where controlling the cut-off of harmonics spectra allows for defining a good spatial resolution of the molecular orbitals. Being able to tune the central frequency of the XUV comb will allow for studying the orbitals of large molecules.

For our purposes, only the microscopic aspect of the XUV generation has been considered. All results have been retrieved from simulations based on the Strong Field Approximation (SFA) for a Hydrogen atom.

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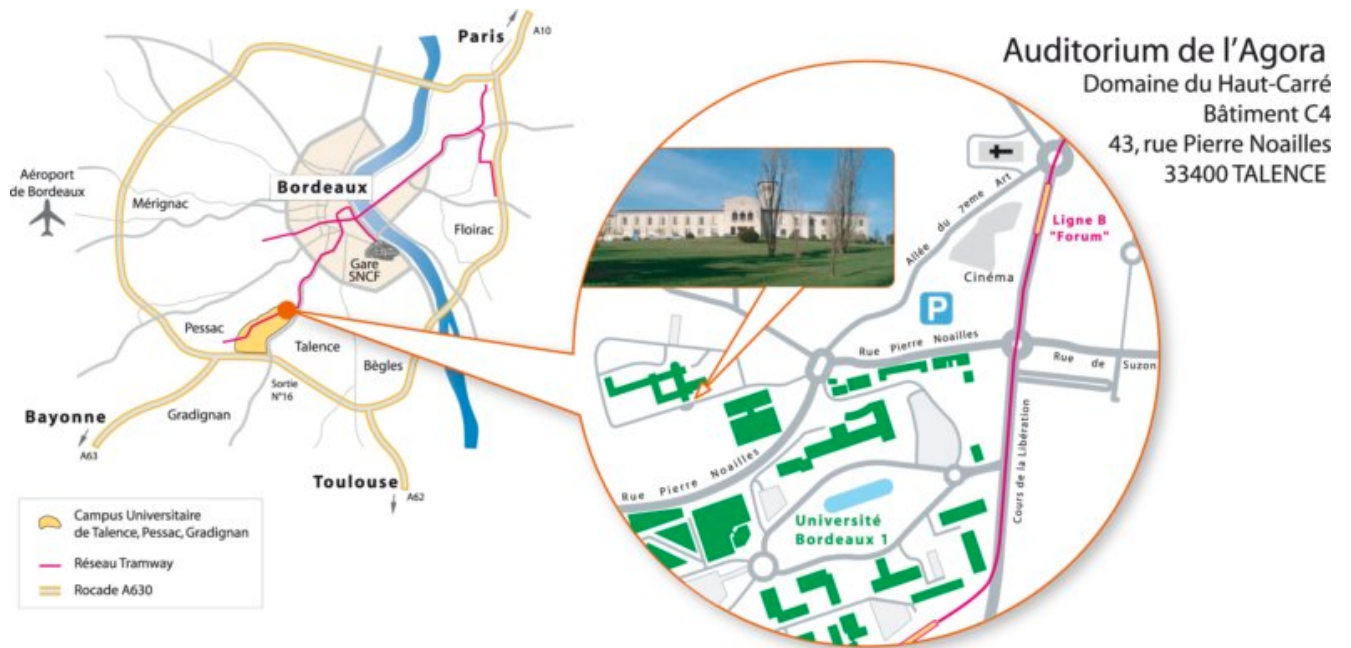
## SYMPOSIUM LOCATION

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**Espace Agora**, Domaine du Haut-Carré

43 rue Pierre Noailles

33400 Talence



## LAPHIA UNIVERSITÉ DE BORDEAUX

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Institut d'Optique d'Aquitaine  
Rue François Mitterrand  
33405 Talence  
France

+33 (0)5 57 01 71 11  
[info.laphia@u-bordeaux.fr](mailto:info.laphia@u-bordeaux.fr)  
[www.laphia.labex.u-bordeaux.fr](http://www.laphia.labex.u-bordeaux.fr)