LAPHIA

Laser and Photonics in Aquitaine

4^{th} edition - Symposium

Sept. 22 – 23, 2016

http://laphiasymposium.u-bordeaux.fr/en/

ICMCB laboratory – Pessac - France

Welcome to the 4th annual symposium of the Cluster of Excellence LAPHIA (Excellence Initiative – University of Bordeaux). This event will run from September 22 to 23 2016 at ICMCB laboratory in Pessac, France.

The objectives of the LAPHIA symposium are to bring together the renowned specialists who work in the fields of photonics/laser/imaging, to present the actual state of the art, and to exchange their meanings on the evolution of the relevant technologies.

Once a year, the Cluster organizes a symposium in Bordeaux. This 4th edition is an excellent opportunity to gather the global community of the **"Nouvelle Aquitaine"** around the three following axes: laser, photonics and innovative imaging. This event is also a key moment for the students to participate through the poster sessions in order to highlight their research works and also to reinforce the network with the members of the community. The best poster prizes will be attributed during the closing session of the symposium.

Apart from this exciting scientific program, we welcome you to the 4th annual Symposium to embrace and enjoy what Bordeaux has to offer – its unique blend of contemporary and traditional ways of life as well as its cultural landmarks, attractions, and entertainment.

We wish you all a most interesting, rewarding and stimulating symposium.

The Board of Directors
Evelyne Fargin, Lionel Canioni, Philippe Balcou, Philippe Bouyer

Website: http://laphiasymposium.u-bordeaux.fr/en/
Contact: info.laphia@u-bordeaux.fr

Overview – Program

9:00 - 9:30 am		**D.PAGNOUX** - XLIM (Limoges) ***Recent breakthrough in advanced imaging techniques through optical fibers for biomedical applications***
9:30 - 10:00 am		**B.AUDOIN** - I2M (Bordeaux) ***All optical single cell ultrasonography to image inhomogenous cell impedance and adhesion***
10:00 - 10:30 am	**REGISTRATION** - Hall ICMCB	**P.LEPROUX** - XLIM (Limoges) ***Multimodal imaging under supercontinuum illumination and electric field stimulation***
10:30 - 11:00 am	**L.CANIONI, P.BOUYER, P.BALCOU, E.FARGIN-** LAPHIA (Bordeaux) ***Presentation of the mid-term report***	*Coffee break - Hall ICMCB*
11:00 - 11:30 am	**A.LARGETEAU** - ICMCB (Bordeaux) ***Fluoride optical ceramics for infrared and other optical applications (FOCI passport project)***	**E.DI FOLCO** - LAB (Bordeaux) ***La formation planétaire et l'imagerie à haute résolution angulaire des régions de formation d'étoiles***
11:30 - 12:00 am	**G.SANTARELLI** - LP2N (Bordeaux) ***GHz repetition rate agile frequency comb for laser picosecond acoustic spectroscopy (GigaPico risky project)*** **V.RODRIGUEZ** - ISM (Bordeaux) ***Integrated Photonic Architectures (INPHOTARCH Collaborative project)***	**C.PRADERE** - I2M (Bordeaux) ***Thermal imaging and processing devoted to multiphysics problem***
12:00 am - 2:00 pm	***Poster session*** *+ lunch - Hall ICMCB*	***Poster session*** *+ lunch - Hall ICMCB*
2:00 - 2:30 pm	**V.COUDERC** - XLIM (Limoges) ***Coherent wavelength generation in multimode fibers***	**Y.LOUYER** - LOMA (Bordeaux) ***Dynamics of an optically trapped nanomechanical oscillator in vacuum***
2:30 - 3:00 pm	**D.PENNINCKX** - CEA-CESTA (Bordeaux) ***Evolution of high-power >kJ-class lasers***	**E.CORMIER** - CELIA (Bordeaux) ***High-intensity laser sources in the midIR***
3:00 - 3:30 pm	**S.FEVRIER** - XLIM (Limoges) ***Specialty optical fibers and femtosecond lasers***	**R Boulesteix** - SPCTS (Limoges) ***Rare-earth oxides transparent ceramics for high power laser applications***
3:30 - 4:00 pm	*Coffee break - Hall ICMCB*	*Coffee break - Hall ICMCB*
4:00 - 4:30 pm	**C.PEYCHERAN** -IPREM (Pau) ***Ultra trace and Isotopic analysis by high repetition rate Femtosecond Laser Ablation coupled to ICPMS (HRfsLA-ICPMS) as a response of major Societal Challenges.***	**R.DEVILLARD** - INSERM (Bordeaux) ***Tissue engineering and laser assisted bioprinting***
4:30 - 5:00 pm	**Guillaume BOUTOUX** - CELIA (Bordeaux) ***Towards the first experiments with PETAL***	**S.SKUPIN** - CELIA (Bordeaux) ***Nonlocal Nonlinear Optics***
5:00-5:30 pm	**P.THOMAS** - SPCTS (Limoges) ***Synthesis, structure, nonlinear optical and lasing properties of tellurium oxide based glasses, glass-ceramics and ceramics***	**A.DEL GUERZO** - ISM (Bordeaux) ***Photo-patterning at the microscale of anisotropic nanofibers emitting linearly polarized light***
5:30 - 6:00 pm	**S.JOLY** - IMS (Bordeaux) ***Time-Resolved Multispectral Imaging: Application to the characterization of photonic devices***	**Poster prize celebration**
8:00 PM	**Conference dinner (invitation only)**	

SEPT 22, 2016

MORNING SESSION

· **10 : 00 am – 10 : 30 am** – Hall ICMCB : Registration

· **10:30 am – 12:00 am** – Auditorium : Presentation of the LAPHIA Cluster mid-term report

a) 10:30 am –11:15 am : General presentation

Board of Directors – **E.Fargin, L.Canioni, P.Bouyer, P.Balcou**

Funded by the Excellence Initiative of the University of Bordeaux, LAPHIA (Laser and Photonics in Aquitaine) boosts research through collective site projects, drawing on the excellence of materials science and physics teams. LAPHIA gathers 22 research teams with around 120 Researchers and Professors.

During the 1st period of exercise, our work allowed to federate the entire scientific community through interdisciplinary projects in the field of lasers and photonics that contributed to raise the international profile and excellence of Bordeaux research. Considered as "the pillars" of the scientific program, **4** collaborative projects have been launched and have strengthened interactions between researchers of the photonic cluster. In addition of these 4 collaborative projects, **30** other projects (all typologies) have been selected to boost the excellence of the research.

In strong partnerships with industrials, laboratories, Aquitaine Science Transfer (AST), the Competitiveness Cluster Route des Lasers and international partners, we succeeded in initiating an efficient area for collaborations in research but also in innovation - technology transfer and education.

We implemented a strategy to boost technologic transfer through the passport projects. We combined our strengths with AST and the Competitiveness Cluster Route des Lasers to ensure research meets the requirements of the industrial world. Up to now, we supported **5** passport projects (**60%** of them have a socio-economic partner included in their consortium; **2** of them are pursuing thanks to a maturation funding from AST (FOCI and PROXMI) and 2 patents have been issued). In parallel of this program, the risky project "GigaPico" obtained a common laboratory with the company ALS (*LabCom*) and allowed to launch the start up "Irisiome". We also helped entrepreneurs to launch their start-up: as an example, after 2 work experiences within Swinburne University in Australia and Politecnico di Milano in Italy, A. Dubrouil has been recruited by the cluster in the framework of the risky project "AttoFlower", he's now creating a start-up "FemtoEasy" in ultrafast instrumentation thanks to several supports.

The main achievements in Education are at the international level, with educational networks that enhance the exchanges for students and the Bordeaux attractiveness (**1** SPIE student chapter has been created (4e in France) / 1 "ETN – Fun Glass" is in progress). Thanks to our education call, we recruited **17** interns (**71%** of them are international and have been recruited directly abroad) and we strongly encouraged student exchanges with our main international partners: **13** mobility grants awarded (co-tutelle PhD/ Master). At the local level, new Master programs are under construction and it will be a good opportunity for LAPHIA to increase the visibility of education in photonics in Bordeaux.

Through a proactive action, we developed an efficient activity of promotion of international networking: 1 International Laboratory Associated "LUMACQ" with Laval University and INRS has been created, a R&D Center with Yonsei University and LG Innoteck is in progress. We also increased our involvement and participation in international networks such as Photonics 21 and SPIE. As attractiveness is one of our priorities, we succeeded in recruiting international talents within the LAPHIA projects: up to now, **40** recruitments (**9 PhD, 28 Post doc and 3 research engineers**) have been done and **76 %** of them have an international nationality.

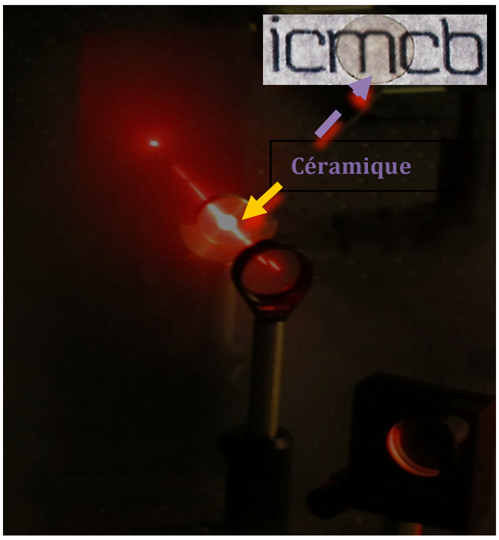
The annual LAPHIA symposium is a key-structuring event for the dissemination of knowledge (up to now, **3** symposia with **57** talks, **91** posters and an average of **150** attendees per symposium). In addition, **29** LAPHIA seminars have been organized. We also worked on different communication actions to a large audience in close interaction with Science Philosophy Humanity laboratory and Bordeaux Montaigne University. Common actions have been reinforced during the International Year of Light (1 photo contest, 1 exhibition with CNAM, 3 large audience conferences…).

b) 11:15 am –12:00 am : 3 LAPHIA project highlights

> Fluoride optical ceramics for infrared and other optical applications (FOCI passport project)

Alain Largeteau *ICMCB (Bordeaux)*

CO_2 lasers are the highest power continuous wave lasers that are currently available. The CO_2 laser's versatility allows it to operate in the part of the spectrum providing an even more efficient material processor. Because CO_2 lasers operate in the infrared, special materials are necessary for their construction to transmit optically in the desired wavelength spectrum. CO_2 lasers use windows on the laser housing, which are single crystals and are available only in the US market. Typically, the mirrors are silvered, while windows and lenses are made of either Germanium (Ge) or Zinc Selenide (ZnSe). ZnSe and Ge are available commonly in the form of polycrystals obtained as thin films or as single crystals. The aforesaid materials have many disadvantages. In general, many of the devices constructed for CO_2 lasers are from ZnSe because of the transparency region of 0.5–20 μm, with the advantage of transparency in the visible region in comparison to Ge which has a transparency region only between 2-12 μm. ZnSe has a comparatively low mechanical strength, is expensive due to the surface finishing and extreme toxicity of ZnSe polishing & AR coating. Further, the AR coating required for 10.6 μm of ZnSe make it fragile due to the humid surface finishing conditions.



Laser beam of HeNe (633 nm) through a CaF2 ceramic fabricated at ICMCB

The current project entitled *FLUORIDE OPTICAL CERAMICS FOR INFRARED AND OTHER OPTICAL APPLICATIONS (FOCI)*, proposed to construct a CO_2 laser IR viewport and laser head of CO_2 laser for CO_2 laser cutting tool. Hence it is necessary to identify another set of materials with the wavelength range transparent from the visible (necessary to align the optical beam) to long wavelength infrared (LWIR) as well as which is non-toxic, less expensive, mechanically strong and that allows to become independent from the international market. In this project we have successfully fabricated transparent ceramics of BaF_2 and CaF_2 (Fluorides), which are cubic crystalline structures and therefore easy to fabricate as transparent ceramics in comparison to its non-cubic counterparts, where birefringence will lead to light diffusion inhibiting the transparency. FOCI focuses on the fabrication of transparent polycrystalline ceramics of these fluorides by Spark Plasma Sintering (SPS) for IR window and CO_2 laser applications. The prime intent was to replace the ZnSe/ Ge with fluoride transparent ceramics to avoid inconveniences caused by ZnSe / Ge in terms of toxicity and surface finishing. The promising results through the financial support of LAPHIA passport project 2014-2015 / FOCI has led to a patent. With the potential promise of the developed technology for fabricating transparent fluoride ceramics through our patent, the project continue at present with support of AST for the development in industrial applications. The financial support provided by LAPHIA «Investissements d'avenir» Programme IdEx Bordeaux - LAPHIA (ANR -10- IDEX -03-02) has been great source of aid for the successful execution of this project and is greatly acknowledged for its support in the development of this project between Institut de Chimie de la Matière Condensée de Bordeaux (ICMCB) and Centre Lasers Intenses et Applications (CELIA - université Bordeaux / CNRS / CEA).

> Tunable GHz frequency comb for laser picosecond acoustic spectroscopy (GigaPico risky project)

Giorgio Santarelli *LP2N (Bordeaux)*

We present a watt level laser system generating picosecond pulses by means of electro-optical modulation of a 1030 nm single frequency low noise laser diode. The repetition rate is continuously tunable between 11GHz and 18 GHz. Residual intensity noise and additive phase noise measurements of the source are also presented and a novel concept applicable to picosecond acoustic spectroscopy is proposed.

> Integrated Photonic Architectures (INPHOTARCH collaborative project)

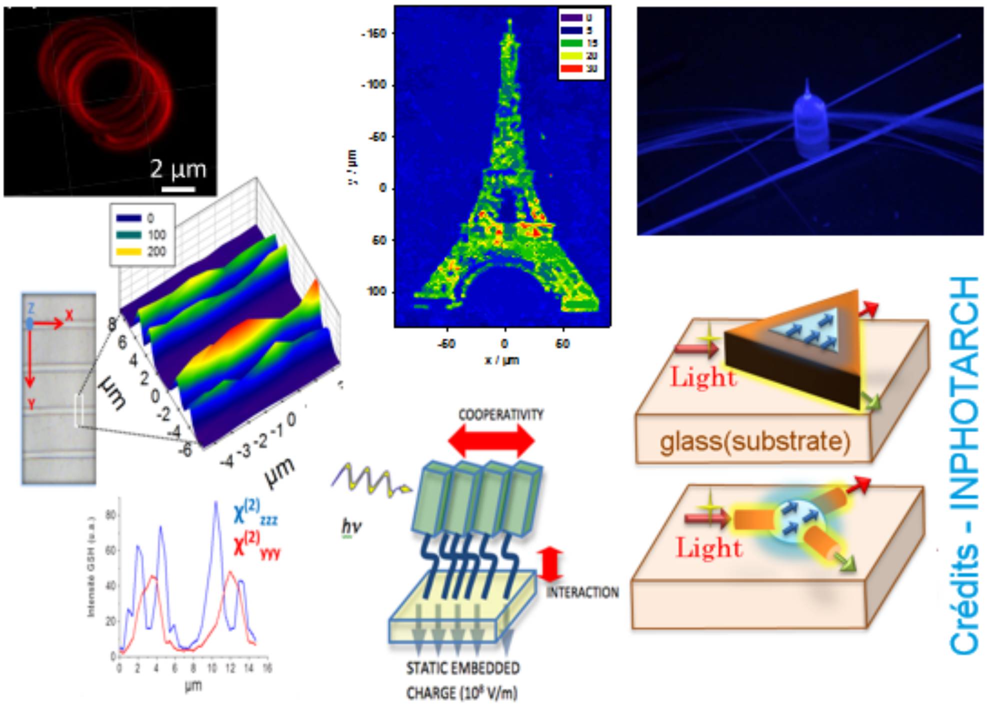
Vincent Rodriguez *ISM (Bordeaux)*

Within the LAPHIA program, collaborative projects are of central importance as they bring together researchers from local cutting-edge laboratories in the field of imaging, lasers and photonic materials. INPHOTARCH ("Integrated Photonic Architectures" – 25 researchers, 4 laboratories) is one of them. This project aims at developing a new generation of hybrid (organic/inorganic) photonic structures, using molecular and supramolecular photonic engineering, laser and electric field structuring at different scales that will be compatible with their integration into functional devices. INPHOTARCH includes a wealth of expertises and experimental and theoretical methodologies: Hybrid Fiber Devices, Linear and nonlinear optical techniques including spectroscopic and imaging multimodal facilities are currently used to investigate these multi-scale photonic architectures. The originality of the project stems from our interdisciplinary and complementary expertise which is further strengthened by successful international student exchange and scientific collaborations with Photonics centers - CREOL in UCF Florida and COPL in ULaval Québec, including a recent launching of a project "Laboratoire International Associé (LIA)" between the University of Laval - Québec and the University of Bordeaux.

INPHOTARCH is composed of two major impacting Workpackages.

1-Laser Structuring and electric field structuring: For numerous applications, new glass material compositions are necessary as well as new hybrid composite materials including optical fibers. For example, complex plasmonic structures and nanometric metallic structures have been engineered by direct laser writing and/or heat treatment. Electric field structuration of glass material at the μm scale has recently emerged from fundamental studies towards technology transfer in the framework of InPhotArch (2 patents submitted).

2-Addressable photonic molecular structures on unconventional designed interfaces: In this highly challenging workpackage, functional organic molecules grafted/deposited on original glass substrates (including space-charge embedded glass substrates) and addressable nanopolaritonics structures (molecular-induced path selective nanoscale plasmonic switching architecture) are designed and studied.



· **12:00 am – 02:00 pm** – ICMCB Hall: **Poster sessions & lunch**

SEPT 22, 2016

AFTERNOON SESSION

· **02:00 pm – 02:30 pm** – Auditorium

> Coherent wavelength generation in multimode fibers

K. Krupa[1,2], R. Guenard[1], A.Tonello[1], A. Bendahmane[2], R. Dupiol[2], B. M. Shalaby[1,4], M. Fabert[1], C. Louot[1], D. Pagnoux [1], P. Leproux[1], A. Barthélémy[1], G. Millot[2], S.Wabnitz[3], **V. Couderc[1]**

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Supercontinuuum generation in single-mode microstructured optical fiber has been widely investigated in the last ten years. Spectral broadening from UV to near infrared domain has been demonstrated thanks to the strong mode confinement and the dispersion engineering obtained in photonic crystal fibers. Unfortunately, the output converted energy remains limited owing to the small core diameter of microstructured fibers. One solution may consist in using multimode optical fibers that have large core area. However theses fibers support the propagation of several tens of modes which in turn spoil the initial spatial coherence and then limit their use for applications. To overcome such limitation one can use graded-index (GRIN) multimode fibers where the linear mode mixing can be suppressed, at high optical powers, by means of nonlinear processes phase-matched by the periodic beatings between the excited modes [1].

In this talk we will explain how the interaction between modes propagating in a multimode GRIN fiber can induce a degenerated spatial four-wave mixing effect able to transfer the energy toward the fundamental mode. Such nonlinear mixing is observed at peak powers lower than the catastrophic collapse, and the observed behavior is more similar to a condensation of optical waves [2]. We also investigated the role of several control parameters like the input polarization state, the input power, or the refractive index profile of the fiber. The spatial nonlinear evolution can be accompanied by an efficient modulation instability (MI) and the consequent formation of a series of n sidebands with large frequency detunings of $125\sqrt{n}THz$ [3-4]. Growing further the input power, we can generate a supercontinuum covering all the main part of the silica transparency window (0.4 – 2.4μm) with all wavelengths carried by the same fundamental transverse mode [5-6]. The competition between Raman scattering and MI generates a flat output spectrum with large spectral power density.

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[4] K. Krupa, A. Tonello, A. Barthelemy, V. Couderc, B. M. Shalaby, A. Bendahmane, G. Millot and S. Wabnitz, "Observation of Geometric Parametric Instability Induced by the Periodic Spatial Self-Imaging of Multimode Waves," Phys. Rev. Lett. 116, 183901 (2016).
[5] Lopez-Galmiche, G.; Sanjabi Eznaveh, Z.; Eftekhar, M. A.; Antonio Lopez, J.; Wright, L. G.; Wise, F.; Christodoulides, D.; Amezcua Correa, R., Optics Letters **41**(11) 2553-2556 (**2016).**
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· **02:30 pm – 03:00 pm** – Auditorium

> Evolution of high-power > kJ-class lasers

D. Penninckx *CEA CESTA (Bordeaux)*

Above a few-hundred Joules, laser technology relies only on neodymium-doped glasses since the sixties i.e. almost since the beginning of laser which was invented in 1960. As a matter of fact, because of laser-induced damage, fluence is still limited to around 10 J/cm² in the nanosecond regime. Because of his ideal saturation fluence (~4-5J/cm²) and its relatively low cost for wide aperture, Nd:glass still remains today the best choice for kJ-class lasers. Hence, Laser Mégajoule (LMJ) and the National Ignition Facility (NIF) use this technology reaching up to 20kJ/beam at 1ω. For energies higher than 20kJ, the number of beams has to be increased because of the physical barrier of amplified spontaneous emission (ASE). So far, there is no obvious alternative technology to Nd:glass for kJ-class laser and Nd:glass will remain the key in the mi-term. Thus, an increase in energy, i.e. >MJ, is today unlikely. The main trends are an increase in the repetition rate and the use of these lasers as pumps of other slave lasers to decrease the pulse width. In the latter case, the slave laser may be either a Ti:Sa or an OPCPA with different requirements on the pump quality. Moreover, because of their cost, the lifetime of such >kJ-class lasers must be a few decades. Hence, research on high-power >kJ-class laser conducted by CEA-CESTA has two purposes:

- evolution of the existing facilities for the own needs of CEA. Two main activities are needed:
    - Improving the resistance of large optics in order to reduce the operating cost and complexity by avoiding a periodic change of the optics.
    - Improving the features of the low-energy (~J) small-scale (~cm) part of the laser, called the front-end. Two tasks are considered: 1) study of the influence of the temporal and spectral characteristics of the generated pulse on the laser performance, and 2) modification of the amplification scheme of the front-end to increase its repetition rate and its reliability. Higher reliability and easier maintenance may be reached with an increase use of optical fibers. Increasing the repetition rate from 1 shot every 10 minutes to 10 shots per second (i.e.: from 10^{-3}Hz to 10Hz) would ease the alignment procedure and improve its accuracy. Because Nd:glass has a poor thermal behavior, a different laser medium is required. Due to various constraints including the required wavelength (1053nm), amplification with neodymium-doped calcium fluoride has been chosen and is under study.
- preparation of new laser facilities for the needs of regional and national laser industry. Increasing the shot rate of high power lasers may be reached either by reducing the thermal load or by advanced cooling schemes. Since diode pumping will remain too costly still for a long time, we only consider flash pumping for now.

Acknowledgment: This work is partly supported by the Conseil Régional de la Nouvelle Aquitaine and by European Regional Development Funds through the LEAP project.

· **03:00 pm – 03:30 pm** – Auditorium

> Specialty optical fibers and femtosecond lasers

Sébastien FEVRIER *(XLIM – Limoges)*

Thanks to key advantages such as high gain, diffraction limited beam, compactness, stability, and excellent heat dissipation optical fibers are gaining popularity for ultrafast laser construction. Expanding the application space of ultrafast fiber lasers will require intense research efforts on waveguides and fibers in order to increase our control on modal properties such as chromatic dispersion and effective area. In this context, the first section of this communication will briefly describe the physics of waveguidance in optical fibers. Then, we will describe several examples of optical fibers with enhanced modal properties for generation of ultrashort pulses. We will show how specialty fibers can allow us to transpose the potential held by modern laser architectures (*e.g.* chirped pulse oscillator) to unexplored long wavelengths. We will conclude with recent developments of ulfrafast lasers for bio-imaging.

· **03:30 pm – 04:00 pm** – ICMCB Hall : **Coffee break**

· **04:00 pm – 04:30 pm** – Auditorium

> Ultra trace and Isotopic analysis by high repetition rate Femtosecond Laser Ablation coupled to ICPMS (HRfsLA-ICPMS) as a response of major Societal Challenges.

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Keywords: (Femtosecond Laser ablation, Ultratrace analysis, ICPMS)

Laser ablation - Inductively coupled Plasma Mass Spectrometry is now recognised a tool of choice for direct bulk and micro-scale trace element analysis in solid samples. LA-ICPMS complements LIBS in terms of micro-scale analysis or imaging as it provides lower limits of detection (at the ppb level or even less) and makes possible precise determination of the isotopic composition when using multicollector ICPMS .

The development of IR-Vis-UV high repetition rate femtosecond lasers has permitted the expansion of the LA/ICPMS applications. This relies first on the unsurpassed analytical performances of fs pulses in terms of spatial resolution, elemental and isotopic fractionation and precision. In a second step, the combination of high repetition rate femtosecond pulses with a fast laser beam scanning allows adapting the apparent shape of the laser beam to the sample structure (virtual beam shaping). This approach provides higher signal sensitivity while keeping high spatial resolution. A panel of those emerging applications will be presented in combination with some fundamental aspects related to particles generation/atomization and isotope ratio of short transient signals. The benefits of HRfsLA-ICPMS for ultratrace elemental and isotopic imaging will then be highlighted in the context of wine counterfeiting, non-proliferation of nuclear weapons, and some of the first artistic objects of modern mankind.

· **04:30 pm – 05:00 pm** – Auditorium

> Towards the first experiments with PETAL

Guillaume BOUTOUX - CELIA, University of Bordeaux – CNRS – CEA
guillaume.boutoux@u-bordeaux.fr (on behalf of the PETAphys collaboration)

LAPHIA collaborative project PETAphysThe PETAL laser (PETawatt Aquitaine Laser) is a short-pulse, ultra-high-power, high-energy laser beam at the Laser MegaJoule (LMJ) facility, located in Aquitaine at CEA/CESTA. Recently, a record power of 1.2 PW in a 700 fs pulse in one single beam has been reached with PETAL. The year 2016 is dedicated to the tuning of the experimental system up to the target chamber center in preparation of the experimental shots in 2017.
The project PETAphys brings together the scientists and engineers of two partners – CELIA and CEA/CESTA, in order to coordinate the actions related to planning and realization of the first stage of the PETAL operation: measuring the performance of the laser beam, assuring that it is compatible with all safety requirements, qualifying the characteristics of the diagnostic equipment and preparing the planned regular operation of the PETAL together with the LMJ as an international user facility.

In this presentation I will describe the research axis developed within the PETAphys project:
1) Modeling and the control of the electromagnetic pulses (EMP) from the laser-target interaction. They are expected to reach 1 MV/m in the vicinity of the target. Such huge EM fields pose very

serious issues with respect to the correct laser operation, and even the survival of diagnostics based on electronics. The EMP mitigation techniques are developed and tested.
2) Evaluation of the particles and radiation production in the PETAL experiments. The proton and X-ray emissions were evaluated by using a set Particle-in-Cell and Monte-Carlo simulations and used to estimate the dose rates and material activation induced in the target chamber and diagnostics. These data were used for the diagnostics design and will be verified in the upcoming experiments.
3) Development of new diagnostics that will characterize the focal spot on target and provide information on plasma characteristics using the radiation emission in the optical (2 and 3ω) and hard X-ray domains.
4) Preparation of the first plasma experiments with PETAL planned for 2017. They aim at qualifying the PETAL performance and a suite of diagnostics developed by the academic community.

PETAL will be operated together with the LMJ as an open access academic facility. It will allow unique experiments in the field of ultrahigh intensity sciences, high energy density physics, astrophysics, radiography, and inertial confinement fusion

· **05:00 pm – 05:30 pm** – Auditorium

> Synthesis, structure, nonlinear optical and lasing properties of tellurium oxide based glasses, glass-ceramics and ceramics.

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Tellurium dioxide-based materials and especially glasses are currently considered as very promising materials for high-index and nonlinear optical devices because of their high nonlinearities (χ(3) hyper-susceptibility far (50 times) exceeding that of glassy SiO_2), their high Raman gain coefficients (60 times higher than that measured on a reference Corning 7980-2F silicate glass) and their good visible and infrared light transmittance (up to 7 mm). Therefore, some substantial literature has been devoted to the studies of such tellurite glasses during the last decade. Many binary and ternary phase diagrams were investigated and the existence of large glass-forming domains was evidenced for most of them [for example see 1 and references therein].
This communication will present some activities developed in the SPCTS laboratory of Limoges since more than 15 years on these materials in concentrating mainly on the following topics: (i) synthesis of glasses, transparent glass-ceramics and ceramics using classical methods (i.e. quenching and crystallization) and non-conventional spark plasma sintering (SPS); (ii) structural characterization using the total scattering technique and atomic scale modelling methods (molecular dynamics or Reverse Monte-Carlo simulations), (iii) structure/nonlinear optical properties relationships, (iv) lasing properties. Our challenge was to elaborate the optimal chemical composition of TeO_2-based materials that affords a compromise between structural, mechanical and thermal properties on the one hand, and desirable nonlinear optical properties on the other hand. Our results have confirmed the high potentiality of TeO_2-based materials in the field of nonlinear optics. Especially, the high third-order susceptibilities of glasses have been demonstrated. All these properties have been clearly related to specific structural characteristics of tellurite phases, i.e; the presence of different structural units and the nature of their linking (in particularly the chain-like polymerization), the presence of the lone pair on tellurium atom. Using *ab initio* calculations we have demonstrated that the mechanism of the nonlinear electronic polarization in tellurite glasses was mainly associated with the electron mobility within the chains formed by polymerized Te-O-Te bridges. Laser emission has been successfully obtained in the Nd^{3+}-doped (1 mol%) $75TeO_2$-$20NbO_{2.5}$-$5WO_3$ glass, with a slope efficiency of 4.6% and a laser threshold reached at 5 mW.

Innovative transparent (in the 3-5 μm range) polycrystalline ceramics have been elaborated by full and congruent crystallization of the $75TeO_2$-$12.5Bi_2O_3$-$12.5Nb_2O_5$-$5WO_3$ parent glass.

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· **05:30 pm – 06:00 pm** – Auditorium

> Time-Resolved Multispectral Imaging: Application to the characterization of photonic devices

Simon Joly, Western Bolanos, Yannick Deshayes, Laurent Bechou

EDMiNA Team, IMS Lab, CNRS CNRS 5218, Bordeaux INP, 33405 Talence, France

Optoelectronic and photonic technologies are emerging as key sectors to overcome some limits in the microelectronic applications, such as ICT (Information and Communication Technologies), aeronautic, space, automotive… Since the 2000s, optical fiber transmission has become essential to the development of broadband telecommunications systems associated to multimedia applications; the objective is to reach 100Gb/s per channel. Such requirement implies the development of reliable photonic devices in the light of submarine networks application where a quality of "zero defect" for 20 years of operating life must be guaranteed.

Our research efforts are mainly focused in the field of the reliability of high-performances semi-conductor lasers, particularly high power lasers emitting at a wavelength close to 1μm used for pumping Erbium Doped Fiber Amplifiers (EDFAs) in telecom applications. The deep understanding of the physic of failure and the associated degradation laws are essential to identify early failure signatures of these mature and reliable components and their vulnerability to onset events leading to Catastrophic Optical Damage (COD).

Previous works in our team demonstrated atypical responses of these lasers diodes when driven under specific conditions. A set of electro-optical characterizations as current-voltage, optical power, degree of polarization of luminescence, optical spectrum and near field imaging measurements has led to highlight microplasma effect and short thermal events for some components. Both are generated by microscopic local defects in the laser structure, which locations remain unknown.

We present the development of a new test bench, devoted to time-resolved multispectral imaging: based on the use of three highly sensitive cameras covering the visible (VIS), near (SWIR) and mid-infrared (MWIR) ranges, synchronized with the driver of the component under study. We will mainly focus on the performances/limitations of the MWIR camera that has been set up especially for our specifications. The multispectral imaging test bench is designed, on one hand to localize the defects within the component, and on the other hand to analyse simultaneously their fluorescence and thermal signatures. These images, coupled with electro-optical measurements, will provide us a better understanding of the degradation mechanisms in photonic devices and a sophisticated method for technological improvement.

SEPT 23, 2016

MORNING SESSION

· **09 : 00 am – 09 : 30 am** – Auditorium

> Recent breakthroughs in advanced imaging through optical fibers for biomedical applications

Jérémy Vizet, Sandeep Manhas, Colman Buckley, Pierre Leclerc, Charles-Henri Hage, Julien Brevier, Marc Fabert, Frédéric Louradour, **Dominique Pagnoux**

Xlim Institute, photonics department, UMR CNRS 7252, University of Limoges, 123 avenue Albert Thomas, 87060 Limoges cedex Corresponding author : dominique.pagnoux@xlim.fr

Imaging the human body, *in vivo in situ* in real-time, by means of minimally invasive label-free techniques represents a challenge of paramount importance. In the recent years, it has been demonstrated that multiphoton imaging and polarimetric imaging represent two promising techniques for early detection of diseases in biological tissues. In this context, we develop a research field that aims to perform these two types of biological images through an optical fiber (endoscopic imaging).

In this communication, we first report recent results obtained at Xlim Institute with a home-made two- photon microendoscope capable of *in vivo* label-free deep-tissue high-resolution fast imaging (8 images/s) through a very long optical fiber (5 meters-long). In particular, the experimental results concerning the following issues will be discussed: (i) femtosecond pulse delivery through a specially designed double-clad photonic crystal endoscopic fiber, (ii) efficient collection of relevant native optical signals (*examples*: 2-photon-excited autofluorescences of fundamental cellular metabolites (NADH and FAD), second harmonic generation of collagen in the extracellular matrix), (iii) tissue imaging within a living organism by means of a miniaturized fiber-scanner (O.D. = 2.2 mm).

For its part, polarimetric imaging allows to perform structural analysis of the extracellular matrix (Type I collagen) at the submicrometric scale. In this communication, we will focus on a two-wavelength differential technique developed in our laboratory, which allows, for the time, to perform full 4X4 Mueller polarimetry through an optical fiber, allowing simultaneous measurements of retardance and diattenuation induced by a targeted tissues. We will present some examples of our polarimetric images and we will discuss the issue of the determination of the depolarization through a single mode fiber, which is a crucial parameter in polarimetric characterization of biological tissues.

Finally, further improvements currently under study in our group, in both nonlinear and polarimetric imaging topics, will be presented.

The authors thank the Région Limousin, the Cancéropôle Grand Sud Ouest, the Physicancer/INSERM program, the Agence Nationale de la Recherche (IMULE Project) and the French CNRS (mission interdisciplinarité) for their financial support to this work.

· **09 : 30 am – 10 : 00 am** – Auditorium

> All optical single cell ultrasonographyto image inhomogenous cell impedance and adhesion

Maroun Abi Ghanem[1], Thomas Dehoux[1], Jean-Michel Rampnoux[2], Stefan Dilhaire[2], Marie-Christine Durrieu[3], **Bertrand Audoin**[1]

1 Univ. Bordeaux, I2M, UMR CNRS 5295, F-33400 Talence, France.
2 Univ. Bordeaux, LOMA, UMR CNRS 5798, F-33400 Talence, France.

The mechanical properties of cells play a key role in several fundamental biological processes, such as migration, proliferation, differentiation and tissue morphogenesis. The complexity of the inner cell composition and the intricate meshwork formed by transmembrane cell-substrate interactions demands a non-invasive technique to probe cell mechanics and cell adhesion at a subcell scale.

Picosecond ultrasonics is a technique where femtosecond light pulses are used to both induce and detect acoustic pulses of unequal frequency content. On the basis of this technique, we have developed an inverted pulsed opto-acoustic microscope (iPOM), where the reflections of broadband ultrasonic pulses from a cell-substrate interface are used to probe cell-biomaterial adhesion and impedance with a subcell resolution. This unconventional single cell imaging modality is based on the mechanical properties as the contrast mechanism. The diameter of the optical probe spot sets the lateral acoustic resolution, comparable to conventional diffraction limited optical imaging techniques.

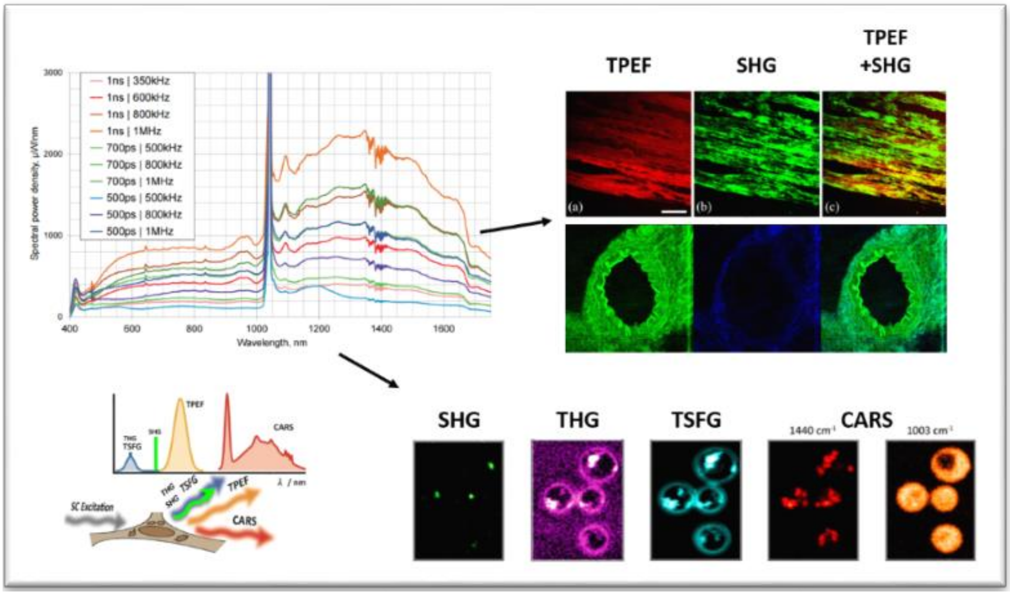
The high resolution capabilities of iPOM allows the study of the structure of single cells and of cell-substrate interactions. We have demonstrated the method on migrating human mesenchymal stem cells and show that acoustic images can reveal the structure of the nucleus, the fine details of the actin network and of the adhesion pattern. In addition, the ability of the technique to quantify the heterogeneity of cell adhesion and impedance and its relation with cell activity during biologic processes will be commented.

· **10 : 00 am – 10 : 30 am** – Auditorium

Multimodal imaging under supercontinuum illumination and electric field stimulation

Philippe Leproux,[1,2] Vincent Couderc,[1] Erwan Capitaine,[1] Nawel Ould Moussa,[1] Christophe Louot,[1] Claire Lefort,[1] Dominique Pagnoux,[1] *XLIM (Limoges)*

We introduce the potential of (sub)nanosecond supercontinuum sources for implementing different methods of multiphoton imaging (SHG[(a)], THG[(b)], TSFG[(c)], TPF[(d)], CARS[(e)]). On this basis, we show that a multimodal micro(spectro)scopy instrument can be developed around a single, compact supercontinuum source. We also introduce the opportunities offered by the application of an electric field (static or pulsed) to the sample. The impact of such an electric stimulation is investigated and demonstrated in the case of a non-polar molecule by means of multiplex CARS and electric-field-induced SHG measurements. The obtained results suggest a reorientation of the molecule due to the presence of the electric field. This phenomenon can be exploited to increase the chemical selectivity or the signal-to-noise ratio of multiphoton spectroscopy/microscopy.



(a) second harmonic generation(b) third harmonic generation(c) third-order sum frequency generation (d) two-photon fluorescence(e) coherent anti-Stokes Raman scattering

· **10 : 30 am – 11 : 00 am** – ICMCB Hall : **Coffee Break**

· **11 : 00 am – 11 : 30 am** – Auditorium

Planet formation at high-angular resolution: GG Tau, the Ring World

La formation planétaire et l'imagerie à haute résolution angulaire : GG Tau, l'anneau-monde

E.DI FOLCO - *LAB (Bordeaux)*

Star forming regions are so distant that only high angular resolution techniques (such as long baseline interferometry) can reveal the birth of planetary systems around other stars in details. Most stars in our galactic neighborhood are binary stars, and stellar multiplicity is expected to impact the planet formation process, especially in those systems where the star separation is shorter than 100 astronomical units (the Sun-Earth distance). Exoplanet searches in binary stellar systems have revealed planetary mass companions orbiting both in circumstellar and in circumbinary orbits. Modeling studies suggest an increased dynamical complexity around the young stars that form such systems: circumstellar and circumbinary disks likely exhibit different physical conditions for planet formation compared to single star systems.
With its large and massive ring of dust and gas surrounding its triple star, the proto-planetary system GG Tauri A, has become a unique laboratory for investigating the physics of gas and dust evolution. In this talk, I will present our most recent discoveries on this young, multiple stellar system with the millimeter and infrared interferometers ALMA and VLTI. I will especially focus on the observational constraints of the dynamical processes which sustain proto-planetary disk accretion, and on the new hints for on-going planet formation in this spectacular "Ring World".

Les distances astronomiques qui nous séparent des régions de formation d'étoiles les plus proches nous imposent l'emploi de techniques d'imagerie à très haute résolution angulaire (en particulier l'interférométrie à longue ligne de base) pour percer les mystères de la formation planétaire au sein des pouponnières d'étoiles. La plupart des étoiles dans notre environnement galactique proche sont des systèmes d'étoiles doubles. Les processus de formation de planètes peuvent être affectés par la présence de compagnons stellaires proches, en particulier lorsque leur séparation est plus petite que 100 unités astronomiques (la distance Terre-Soleil). Les recherches de planètes extra-solaires autour de systèmes d'étoiles doubles ont déjà permis de révéler des candidats de masse planétaire en orbite autour de l'une des étoiles ou bien autour du couple d'étoiles. Les études théoriques prédisent pourtant

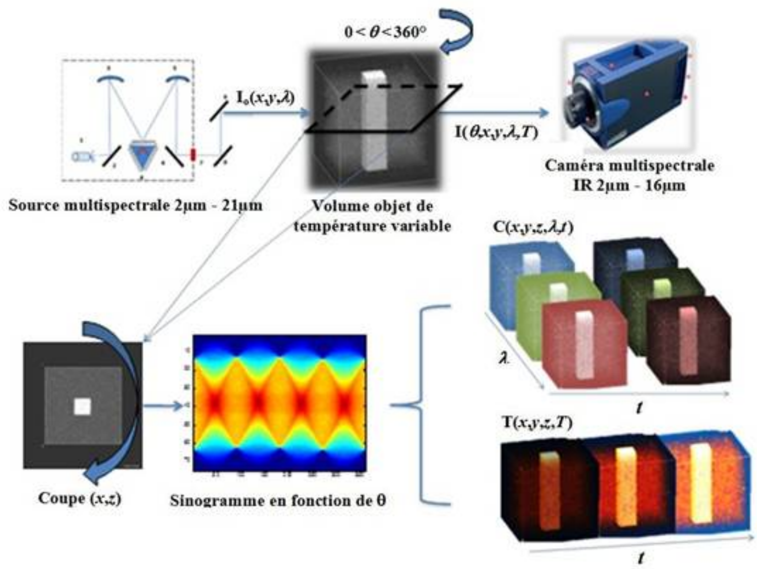
que la formation de planètes devrait être rendue plus complexe dans ces environnements dynamiquement perturbés.
Avec son gigantesque anneau de gaz et de poussières en orbite autour d'un trio de jeunes étoiles, le système GG Tauri A s'impose comme un laboratoire unique pour étudier les processus physiques de formation planétaire. Dans cet exposé, je présenterai nos dernières découvertes autour du disque proto-planétaire GG Tau avec les interféromètres ALMA et VLTI (aux longueurs d'onde millimétrique et infrarouge). Je montrerai en particulier comment nos observations peuvent contraindre les processus dynamiques qui soutiennent l'accrétion dans ces disques proto-planétaires et quels indices observationnels suggèrent qu'une (des) planète(s) serai(en)t en cours de formation dans ce spectaculaire "Anneau-Monde".

· **11 : 30 am – 12 : 00 am** – Auditorium

> Thermal imaging and processing devoted to multiphysics problem

C. Pradere, A. Sommier, M. Romano and J.C. Batsale - *I2M (Bordeaux)*

This scientific works is at the frontier between optics, materials and chemistry. Thanks to the expertise present on the Bordeaux campus, many academic and industrial collaborations on multidisciplinary topics couple these three areas. In this context, it was necessary to develop efficient tools and methods to maintain a consistent research able to generate knowledge and understanding of systems. Around this thread, our desire was to develop instrumentation for measuring multiscale (spatial, temporal and spectral) thermal fields.



This tool, combined with quantitative methods of estimation (based on obtaining property maps) helped to address multiphysics applications. These applications are summarized in three coupled problems: (i) diffusion + transportation, (ii) diffusion + source distribution and (iii) diffusion + transportation + source. In the word "source" hide acoustic waves, mechanical dissipation, chemical reactions and generally an energy conversion. The particularity of this work was to directly use this energy conversion (or source) to characterize the environment and quantify the original source. Finally, the latest advances now make it possible to consider extending this work to the type of multispectral analysis and thermal tomography. In this seminar, the focus will be on existing methods and early prospects of 3D Thermal.

· **12:00 am – 02:00 pm** – ICMCB Hall: **Poster sessions & lunch**

SEPT 23, 2016

AFTERNOON SESSION

· **02:00 pm – 02:30 pm** – Auditorium

> Dynamics of an optically trapped nanomechanical oscillator in vacuum

Yann Louyer – *LOMA (Bordeaux)*

We study the dynamics of an optically trapped particle in gas phase. Such a system belongs to the broader class of nanomechanical oscillators. They exhibit high resonance frequencies, low active masses, and high quality factors. These features are well suitable for sensing, transduction, and signal processing. Nanomechanical systems are also expected to open up investigations of quantum behavior. The very debated predictions of quantum theory on mesocopic scales is one of today outstanding challenges of modern physics and addresses fundamental questions on our understanding of the laws of Nature. In contrast to micro-fabricated devices, optically levitated nanoparticles in vacuum do not suffer from clamping losses. This leads to much larger quality factors enabling to improve applications related to mechanical oscillators.

We present results on the dynamics of a vacuum trapped silica nanoparticle from the overdamped to the underdamped regime. We experimentally measure and fully characterize the center of mass motion with sensitivity $< 1\, pm/\sqrt{Hz}$. The particle dynamics down to around 1 mbar is well described by the stochastic Langevin equation of a harmonic oscillator. Below this pressure, the nanoparticle enters in a nonlinear regime driven by the increase of thermal excitations. The interplay of thermal random forces and the nonlinearity of the oscillator gives rise to rich dynamics.

· **02:30 pm – 03:00 pm** – Auditorium

> High-intensity laser sources in the midIR

Eric Cormier *CELIA (Bordeaux)*

Strong field physics has been investigated for many years by studying the interaction between intense lasers and solid or gaseous media. Because intense lasers only emit in the near infrared (around 800 nm), most studies are restricted to that wavelength. Few years ago, we started to develop new laser sources emitting in the mid-infrared between 2 and 8 microns. As most of the physical processes scale as $I.l^2$, we expect to observe novel behaviors in laser-matter interaction with these mid-IR intense sources. I will present the different technologies we develop in this context that are based on fibers, solid state gain media and optical parametric amplification.

· **03:00 pm – 03:30 pm** – Auditorium

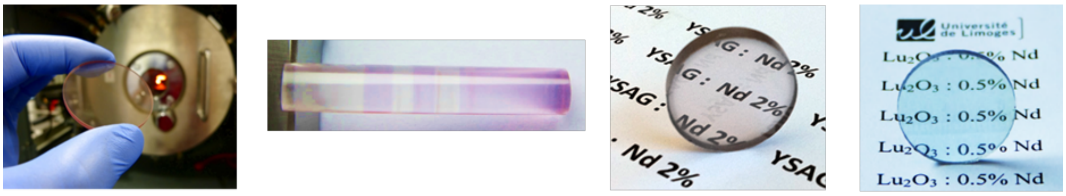
> Rare-earth oxides transparent ceramics for high power laser applications

Rémy BOULESTEIX[1,2], Rémy BELON[1,2,3], Loïck BONNET[1,2], Fabien BOUZAT[1,2], Alexandre MAITRE[1,2], Lucie CHRETIEN[2,3], Christian SALLE[2,3]

[1] *University of Limoges, CNRS, ENSCI, SPCTS, UMR CNRS 7315, F-87068 Limoges, FRANCE*
[2] *LCTL, SPCTS, UMR CNRS 7315, F-87068 Limoges, FRANCE*
[3] *CILAS, F-45063 Orléans, FRANCE*

Transparent ceramics used for laser applications are developed since twenty years but high laser power and efficiency can be only reached under numerous criteria. At first, the ceramic material should present a thermal conductivity as high as possible (> 6-8 $W.m^{-1}.K^{-1}$) and a thermal expansion coefficient sufficiently low (< 10.10^{-6} K^{-1}) to be resistant to thermal shock and to ensure high repetition rate during high power lasing operation. Second, the ceramic matrix must be highly transparent in a large wavelength range comprising the emission and pumping wavelengths, generally from the visible to the near infrared range. It is now well admitted that Nd^{3+} or Yb^{3+}-doped ceramic materials of garnet ($Y_3Al_5O_{12}$ - YAG) and rare-earth sesquioxide (Y_2O_3, Lu_2O_3, Sc_2O_3) families are of primary interest as amplifier media for high power lasers [1,2].

Several research works were carried out in the order to better understand and control each elaboration step of these ceramics: powder synthesis, powder shaping and thermal treatment (sintering). At SPCTS laboratory in Limoges, an integrated approach of ceramic processes (i.e. from powder synthesis to the final piece with desired properties) allows understanding and mastering each step of the process. In order to obtain highly efficient laser ceramics, it is first of primary interest to limit optical losses, thus to promote porosity elimination with limited grain growth and to remove all the microstructural defects. This presentation will show how the final microstructure and optical properties can be controlled thanks to suitable thermal treatment. In this context, this presentation will show that non-conventional sintering treatments like post-HIP (Hot-Isostatic Pressing under 150-200 MPa of argon gas) or SPS (Spark Plasma Sintering with sintering rates > 100°C.min^{-1} under an uniaxial pressure of 50-150 MPa) allow to reduce drastically the grain growth and to promote densification. Another way to improve laser efficiency is to develop amplifier media with complex architectures tailored to obtain positive effects of laser beam quality, shape, power, stability, etc. This presentation will show that the mastering of shaping processes allows elaborating transparent ceramic bodies with large dimensions and/or complex architectures (Fig. 1).



(a) (b) (c) (d)

Figure 1: transparent ceramics of Nd:YAG with homogeneous doping (a) with concentration gradient (b), of Nd:YSAG (c), of Nd:Lu_2O_3 (d).

[1] A. Ikesue, Y.L. Aung, Ceramic laser materials, Nature Photonics. 2 (2008) 721–727

[2] A. Ikesue, Y.L. Aung, T. Taira, T. Kamimura, K. Yoshida, G.L. Messing, Progress in ceramic lasers, Ann. Rev. Mater. Res. 36 (2006) 397–429

· **03:30 pm – 04:00 pm** – ICMCB hall : **Coffee break**

· **04:00 pm – 04:30 pm** – Auditorium

> Tissue engineering and laser assisted bioprinting

R.DEVILLARD - *INSERM (Bordeaux)*

During the last decades, many technologies have been developed or modified in the field of biofabrication in order to get the ability to print living cells. Laser Induced Forward Transfer has been modified to transfer living cells or biomolecules. Laser assisted bioprinting (LAB) has emerged as an alternative to ink-jet or extrusion bioprintings techniques due to its resolution. Cell bioprinting by Laser-Assisted Bioprinting (LAB) provides significant advantages in terms of precision, reproducibility, rapidity, creation of two- or three-dimensional patterns, and potential in vitro or in vivo applications, if compared to other printing technologies. Many studies have also demonstrated its excellent capacity to preserve cell viability and proliferation after printing. Depending on the clinical application, the accurate control of the jet's characteristics is required in terms of maximal height, velocity and diameter. The benefit of picosecond and femtosecond laser sources compared to nanosecond sources is to induce optical breakdown and the creation of bubbles without absorbing sacrificial layer. For LAB applications, femtosecond sources inducing lower speed and lower acceleration could minimize cell damages during droplet landing with high resolution optimized by the production of fine jets. At the opposite, needle-free injection would benefit of high velocity and acceleration at high distance to optimize penetration and minimize dispersion with picosecond pulse duration. The selection of specific pulse duration is therefore critical for each biomedical application. These properties make LAB a useful tool for cell biology studies and a promising technology for tissue engineering applications, as it will be described in the presentation through the example of the creation of capillary-like network for bone tissue engineering.

Au cours des dernières décennies, de nombreuses technologies ont été développées ou modifiées dans le domaine de la biofabrication pour permettre l'impression de cellules vivantes. La technique du Laser Induced Transfer Forward a été modifiée pour transférer des cellules vivantes ou de biomolécules. La bioimpression assistée par laser (LAB) a émergé comme une alternative aux techniques de jet d'encre ou d'extrusion pour la bioimpression en raison notamment de sa résolution. La bioimpression celllulaire par LAB fournit également des avantages significatifs en termes de précision, de reproductibilité, de rapidité, de création de modèles en deux ou trois dimensions, et dans des applications in vivo. De nombreuses études ont également démontré son excellente capacité à préserver la viabilité et la prolifération cellulaire après l'impression. En fonction des applications cliniques, le contrôle précis des caractéristiques d'impression est nécessaire en termes de hauteur maximale atteinte, de vitesse et de diamètre. L'avantage des sources laser picoseconde et femtoseconde par rapport aux sources nanoseconde est d'induire un claquage optique et ainsi la création de bulles sans couche sacrificielle d'absorption. Pour les applications de LAB, les sources femtoseconde induisent des vitesses inférieures et une accélération plus faible pouvant minimiser les dommages cellulaires au cours de atterrissage des gouttelettes avec une résolution optimisée par la production de jets fins. A l'opposé, l'injection sans aiguille bénéficierait d'une grande vitesse et d'une accélération à haute distance pour optimiser la pénétration et minimiser la dispersion avec une source picoseconde. Le choix d'une source à durée d'impulsion spécifique est donc essentiel pour chaque application biomédicale. Ces qualités font du LAB un outil utile pour les études de biologie cellulaire et une technologie prometteuse pour des applications d'ingénierie tissulaire, comme il sera décrit dans la présentation par l'exemple de la création d'un réseau de capillaires pour la bio ingénierie du tissu osseux.

· **04:30 pm – 05:00 pm** – Auditorium

Nonlocal Nonlinear Optics

Stefan SKUPIN *CELIA (Bordeaux)*

It is nowadays well appreciated that nonlocality has a dramatic impact on the dynamics in nonlinear systems. Nonlocality in spatial domain is usually associated with transport processes or inter-molecular long-range interactions. After a brief introduction to nonlocal nonlinear systems, with special emphasize on optics, I will first focus on wave collapse in systems with attractive spatially nonlocal nonlinarities. I will present rigorous collapse criteria for systems with singular nonlocal nonlinear interaction, similar to those known for the famous local nonlinear Schroedinger equation. In the second part of my talk I will switch to self-organization of light in optical media with competing nonlinearities. Self-organization constitutes one of the most fascinating phenomena appearing in nonlinear systems. During the process, strong interactions among the system components lead to the formation of spatial structures and long-range ordering. We recently demonstrated that the nonlocality of competing focusing and defocusing nonlinearities gives rise to self-organization and stationary states with stable hexagonal intensity patterns. Signatures of this long-range ordering turn out to be observable in the propagation of light in optical waveguides and even in free space.

· **05:00 pm – 05:30 pm** – Auditorium

> Photo-patterning at the microscale of anisotropic nanofibers emitting linearly polarized light

Christiaan de Vet,[1] Philip Schäfer,[1] Leire Gartzia Rivero,[1] Guillaume Raffy,[1] **André Del Guerzo**[1]

[1] *Institut des Sciences Moléculaires (ISM-UMR5255), Université de Bordeaux, CNRS, 351 Cours de la Libération – 33400 Talence, France. Email: andre.del-guerzo@u-bordeaux.fr*

The precise organization and patterning of optically active nano-objects in space is of high interest for future applications in photonics and opto-electronics. Nano-ribbons and –fibers are obtained by self-assembly of organic fluorophores (anthracenes and tetracenes). Moderate or highly linear polarized emission is obtained depending on the organization of the molecules within the object, as shown by fluorescence polarization microscopy. The degree of organization is determined by the self-assembly process, which has been shown to depend on the molecular design and on the experimental conditions.

Two methods have been shown to further control the optical properties at the nano-scale. In the first method, nano-ribbons are dispersed on a surface, and their optical properties are patterned at a sub-micron scale by photo-irradiation and photo-oxydation of one of the components. Thereby, multi-color ribbons can be obtained. In a second method, the self-assembly of the photo-sensitive precursor of an anthracene gelator is induced by a focused laser beam. Fluorescent nano-fibers can be "written" as desired on a surface by controlling the location of the nucleation site. The fibers grow upon soft irradiation and display the same properties as those of the thermally induced self-assembled fibers. In addition, an anisotropic coverage of a glass surface can be obtained with a controlled direction of the alignment. In contrast to other methods, the photo-induced self-assembly allows to pattern several orthogonally oriented surfaces on the same surface with micrometric precision.

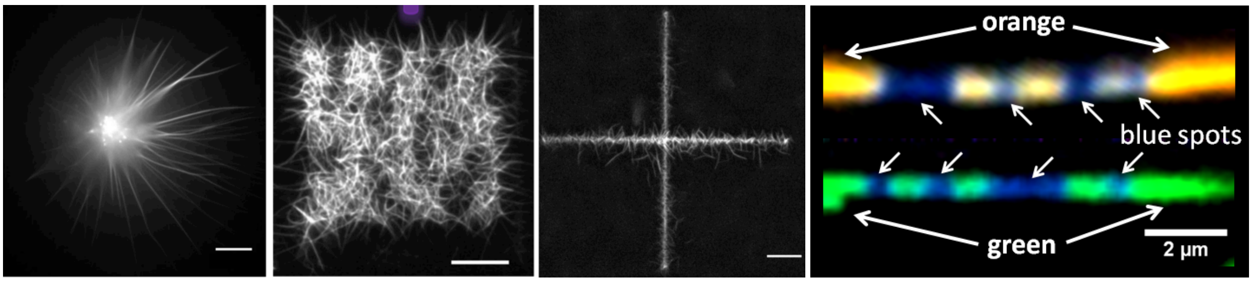


Figure: (left to right) *(a,b,c) Examples of nanofiber structures patterned with a 473 nm diode laser on the glass surface. Fluorescence images were recorded exciting at 375 nm. (d) Color-patterning of single nano-ribbons.*

· **05:30 pm – 06:00 pm** – Auditorium : Poster prize celebration

POSTER SESSIONS – LIST

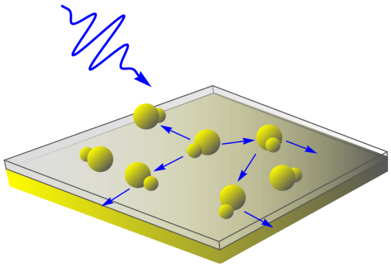
Poster number	*Name*	*Title*
1433	Devilez- Alexis	Electromagnetic modeling of complex optical stacks
1419	CASNER - Alexis	Nonlinear Hydrodynamics Experiments in HED Plasmas
1408	Volte - Alix	Characterization of non-linear phases and spatio-temporal couplings in chirped-pulse amplificators by the d-scan technique
1430	SANCHEZ PADILLA - Benjamin	Wrinkled axicons : shaping light from cusps
1435	Chafer-Matthieu	Compact Raman gaz self-organizing into deep nano-trap lattice
1441	Hage -Charles-Henri	Collaborative developments for in-depth biological multiphoton imaging
1432	Mailliet - Corentin	Long duration Direct Drive Planar Hydrodynamics Experiments on the National Ignition Facility
1412	PAPAGIANNOULI - IRENE	X-ray photoemission spectroscopy of free carbon dots
1438	Alvarez Fernandez - Alberto	Block copolymers based nanoplasmonic surfaces
1410	Condon - Gabriel	Ultra-cold atomic sources for equivalence principle tests in microgravity
1439	Archipovaite - Giedre Marija	Generation and parametric amplification of broadband phase stabilized few cycle pulses at 2.9 µm
1434	Ivaskovic - Petra	Design and fabrication of a plasmonic switching device
1411	Gartzia-Rivero - Leire	Multifunctional Nanomaterials: Self-Assembled Organic Building Blocks
1440	Maurel - Martin	Giant compression of high energy optical pulses using a commercially available Kagome fiber
1426	Klausen - Maxime	Cooperative veratryle and nitroindoline cages for two-photon uncaging using near infrared light
1421	Pagano - Paolo	Engineering of Hyper-Bright and Stable Fluorescent Organic Nanoparticles
1437	Leclerc - Pierre	Quantitative metabolic microendoscopy within a living organism based on two-photon excited endogenous molecular imaging of intracellular NADH and FAD.
1429	BABY - Reenu	3D Optical Nanoscopy with Excited State Saturation Microscopy
1436	Du Jeu - Rémi	Fully-aperiodic large-pitch fibers: current state and prospects
1441	Romain Trihan	Diagnosis and Therapy of early tumors with inkjet-printed mesoporous silica dots

Electromagnetic modeling of complex optical stacks

Alexis Devilez, Philippe Lalanne & Kevin Vynck

LP2N, CNRS – IOGS – Univ. Bordeaux, 33400 Talence, France

Disordered ensembles of complex, strongly resonating nanoparticles in planar geometries are ubiquitous in emerging photonic materials and devices [1, 2], ranging from organic light-emitting diodes to biosensors, to transparent displays for augmented reality. Their richness in terms of optical properties comes from the individual nanoparticles, 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 communication, we will present the approaches we are currently following to unlock this key modeling challenge. The first step consists in finding a clever way to model an individual complex nanoparticle placed in the close vicinity or in contact with a planar interface. We will introduce the concept of "numerical dipoles" and discuss the possible use of a "quasi-normal mode" formalism [3] to gain in computational efficiency.

This study is being carried out thanks to financial support from the French State, managed by the French National Research Agency (ANR) in the frame of the "Investments for the future" Programme IdEx Bordeaux – LAPHIA (ANR-10-IDEX-03-02), and from the "Mission for Interdisciplinarity" of CNRS through the project NanoCG.

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Nonlinear Hydrodynamics Experiments in HED Plasmas

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Abstract
The advent of novel MJ class laser facilities, such as the National Ignition Facility (NIF) [1] and LMJ-PETAL [2] are real game-changers in the field of High Energy Density (HED) physics. These unique energy drivers allow accelerating targets over larger distances and longer time periods than previously achieved [3], allowing for the first time to study the transition to turbulence in hot dense plasmas. We will quickly review experiments devoted to the study of the Rayleigh-Taylor Instability at the ablation front. On the NIF a highly nonlinear development stage of the RTI has been reached [4,5], whereas a novel mitigation mechanism using underdense foams has been demonstrated on OMEGA [7]. Plasma conditions relevant for laboratory astrophysics [2] could also be achieved. The case of scaled experiments mimicking the mechanism of creation of pillars in photoevaporated clouds [7] will be presented. Future LMJ-PETAL experiments scheduled at the end of 2017 will address the question of dynamo amplification of magnetic field in turbulent plasma [8].

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CHARACTERIZATION OF NON-LINEAR PHASES AND SPATIO-TEMPORAL COUPLINGS IN CHIRPED-PULSE AMPLIFICATORS BY THE D-SCAN TECHNIQUE

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ABSTRACT

After decades of research and technology improvement, ultra-short and intense pulses are nowadays easily generated with oscillators based on Ti:Sa or Ytterbium technology. However, manipulating ultra-short pulses all along the laser chain until their final use modifies the features of the generated pulses. Actually, during chirped-pulse amplification (CPA, FCPA, OPCPA), compression and pulse-shaping processes, pulses undergo linear ($\varphi^{(2)}, \varphi^{(3)}, \varphi^{(4)}$,…) or non-linear (self-phase modulation) phase effects, as well as spatio-temporal couplings, like spatial "chirp", angular "chirp" or Bor effects [1]. Most of the time, these effects lead to duration and temporal/spectral phase inhomogeneities through the transverse profile of the beam.

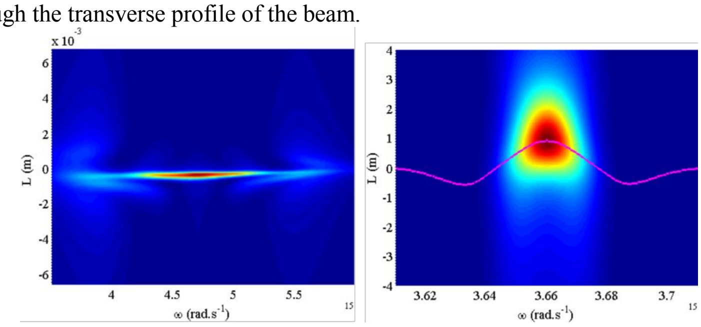

Figure 1 : d-scan traces for pulses having experienced SPM, on the left : in compressed regime (temporal field-dependance of the phase) and on the right : in stretched regime (frequential field-dependance of the phase)

Resulting spectra are very structured and present a non-trivial phase. Moreover, modifications in the spatio-temporal intensity and phase profiles [2], being intentional or not, spoil the interaction between the laser and the target (atom, solid).

Among the different techniques of pulse-characterization (FROG, SPIDER,…), the d-scan method [3] shows several advantages, including the fact that it is single-beam and offers a "direct" reading of the spectral phase (Fig.1). This technique is based on the use of a dispersive element (wedges, stretcher), which modifies the spectral phase of the pulse to characterize. The analysis of the doubled spectrum of this pulse allows then to determine the initial spectral phase. However, until now the d-scan was only used to characterize the shortest pulses (around 10 fs on Ti:Sa). Therefore, adapting the d-scan to longer pulses measurement (Yb), along with a spectrally-resolved measurement, shows particular interest. It is especially the case regarding Kerr effect in FCPA (fibered CPA) architectures, where the pulse can accumulate substantial and complicated phases experiencing self-phase modulation in compressed regime (Fig.1) or a strong B-integral ($B \approx 2\pi/\lambda . \int_0^L n_2 I_{peak}(z)dz$) in stretched regime (Fig.1), due to confinement in the fiber (*rod-type fiber*).

We present the results of numerical simulations and experimental d-scan traces interpretation on Ti:Sa and Yb laser systems. Last, being a single-beam method, the d-scan technique is well-adapted to measure duration and phase inhomogeneities across the transverse profile of the beam [4]. We discuss the method we propose to characterize these spatio-temporal inhomogeneities.

KEY-WORDS : *d-scan ; ultra-short pulses ; laser metrology*

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Wrinkled axicons : shaping light from cusps

SANCHEZ PADILLA - Benjamin

Abstract: We propose a novel class of refractive optical elements by wrinkling the conical surface of a usual (conical) axicon, which leads to geometrical singularities (cusps). Such wrinkled axicons have been fabricated at the micron scale by using three-dimensional femtosecond-laser photopolymerization technique and we report on their experimental and numerical characterization. The beam shaping capabilities of these structures are discussed for both intensity and phase, which includes topological beam shaping that results from azimuthally modulated optical spin-orbit interaction.

GPPMM Gas-Phase Photonic & Microwave Materials

GLOphotonics The Hollow-Core PCF and Photonic MicroCell™ Company

Compact Raman gaz self-organizing into deep nano-trap lattice

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Keywords: Stimulated Raman Scattering, Hollow-core fiber, Optical lattice, Molecular trapping

This project is to generate a high power and narrow linewidth continuous wave (CW) Raman laser based on a Hollow-Core Photonic Crystal Fibers (HC-PCF) filled in with hydrogen at high pressure for frequency conversion via Stimulated Raman Scattering (SRS). Such a laser will permit to fulfill one of the requirements for the long term objective to develop an optical waveform synthesizer akin to an electronic one. Beyond the possibility of generating a high power narrow linewidth Raman laser, the linewidth is found 6 orders of magnitude lower than the expected Raman pressure broadened linewidth with a spectrum witnessing a Lamb-Dicke regime with sub-Doppler spectral-width emission. This counter-intuitive result stems from an original dynamics whereby molecules self-organize to be trapped into nano-meter wide and ultra-deep potential array [1][2]. Here we report on theoretical and experimental analysis of such original dynamics. The experimental set-up comprises a narrow linewidth (400kHz), high power (100W) CW laser working at 1061 nm coupled in a Photonic Band Gap (PBG) HC-PCF filled with hydrogen at high pressure (5-50bar), a core radius of 3.2µm and a loss of 70dB/km. Thanks to its transmission window (1-1.2µm) we can filter any other Raman conversion but the targeted resonance, namely the Raman rotational transition $S_{00}(1)$ ($\upsilon_{S00(1)}$ =17.2THz). We can see in Fig. 1a numerical results of the evolution of pump, Forward Stokes (FS), Backward Stokes (BS), and the Raman gain coefficient (g_r) power versus the fiber length typical of a SRS process, *i.e.* a gradual depletion of the pump and a quick rise of the FS and BS in the Raman generation length. The zoom in the gain region (Fig. 1b) shows that the normalized population difference between the two levels of the Raman transition D (black curve), the g_r (red curve) and the medium energy potential (blue curve) are spatially modulated with a period of half the Stokes wavelength. They alternate between nanometers wide Raman active regions where the SRS occurs and a saturated Raman region. The active regions create 3D trapping wells for the hydrogen molecules with depths of 55THz and 200MHz in the longitudinal and the transversal direction. This self-assembled nanostructured optical lattice corroborates with the Lamb Dicke regime and sub-Doppler structure seen experimentally (see Fig. 1c). The linewidth measured using the self-heterodyne technique is as low as 3kHz, instead of the 2GHz Raman pressure broadened linewidth, with sidebands at 200kHz. These sidebands are associated with the transversal motion of the molecules inside the traps. Fig. 1d shows the linewidth over a larger span exhibiting additional sidebands at 8MHz, which is the signature of the Rabi frequency splitting set by the mixing of the pump field with that of the Stokes, in good agreement with the 10MHz calculated. The sidebands at 16 and 24MHz are caused by Four Wave Mixing (FWM) between the lower-order sidebands. The sidebands at 10-17GHz (Fig. 1e), measured via diffracting the FS, are the longitudinal motional sidebands which is in the range of the 3-17GHz calculated. We can also observe an asymmetry in the amplitude of the red shifted sideband and the blue one indicating a thermal distribution in quantized harmonic oscillator. Finally, in changing the fiber length and the gas pressure we can tailor the power and the linewidth of the Raman laser. For a 7m long fiber at 20bar we can generate a high power Raman laser up to 58W for FS, with a linewidth smaller than 200kHz. For a 30m long fiber filled at 5bar we can get a linewidth of 3kHz.

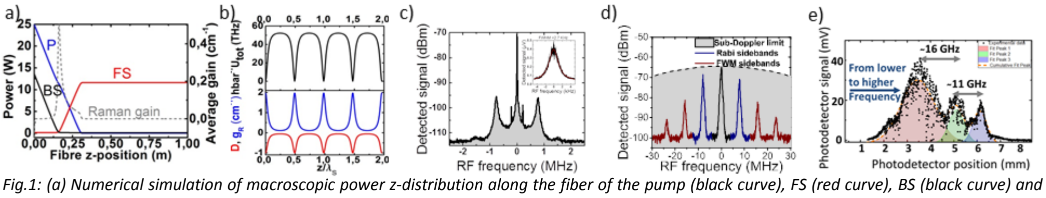

Fig.1: (a) Numerical simulation of macroscopic power z-distribution along the fiber of the pump (black curve), FS (red curve), BS (black curve) and g_r (grey curve); (b) Microscopic z-distribution of g_r (red curve), population difference (black curve) and potential (blue curve); (c) 4MHz span and 20kHz span for P_{in}=11W and P=5bar; (d) 60 MHz span of FS P_{in}=11W and P=5bar; (e) Photodetector signal versus its position for P_{in}=20W and P=15bar

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Collaborative developments for in-depth biological multiphoton imaging

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Recent studies showed that the excitation spectral window lying between 1.6 and 1.8 µm is optimal for in-depth three-photon microscopy of intact tissues due to reduced scattering and absorption in this wavelength range. Hence, millimeter penetration depth imaging in a living mouse brain has been demonstrated with a major potential for neurosciences [1].

Serious improvements are nevertheless required, especially towards much higher imaging rates (up to 15-20 s/frame in [1]). In that scheme, people of Bordeaux (ISM) and Limoges (XLIM, Novae, Leukos) investigate the use of optimized laser sources, along with the development of specifically designed molecular optical probes, in a rising collaborative approach.

On one side, novel molecular-based fluorescent organic nanoparticles (FONs) which combine strong absorption in the green-yellow region, remarkable stability and photostability in aqueous and biological conditions have been designed using a bottom-up route at the ISM. Due to the multipolar nature of the dedicated dyes subunits, these nanoparticles show large nonlinear action cross-section in the NIR region.

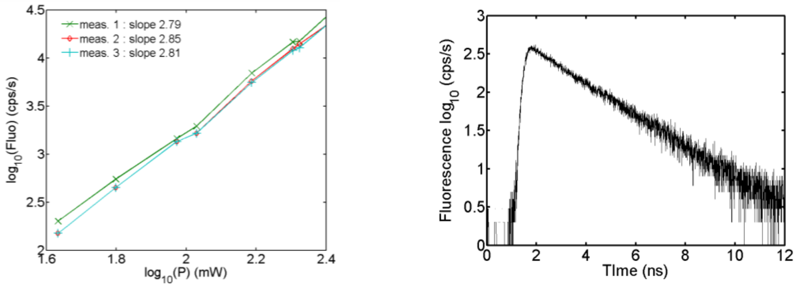

Figure 1 : Left: fluorescence power dependence of FONs excited at 1680 nm. Right: fluorescence lifetime trace of the same FONs (unpublished results)

On the other side, three-photon action cross-sections, fluorescence spectra and lifetimes of these new dyes are currently characterized using a XLIM-Novae all-fiber femtosecond laser providing 9 nJ, 75 fs pulses at 1700 nm. First results show brightnesses potentially several orders of magnitude higher than the common Texas Red dye. First comparisons with a XLIM-Leukos partially coherent fiberized supercontinuum providing up to 500 µW/nm in the 1000-2000 nm band are conducted.

Experiments involving the use of these new dyes for *in vivo* cerebral angiography on a mouse model are scheduled and the route towards three-photon endomicroscopy will be discussed.

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Long duration Direct Drive Planar Hydrodynamics Experiments on the National Ignition Facility

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The advent of high-power lasers facilities such as the National Ignition Facility (NIF) and the Laser Megajoule (LMJ), opens a new era in the field of High Energy Density Laboratory Astrophysics. These laser facilities provide unique conditions to study the rich physics of nonlinear and turbulent mixing flows [1]. To do so requires timescales of tens to a hundred nanoseconds of drive, with velocities of a few tens $\mu m.ns^{-1}$ and sample lateral size of a few millimeters to avoid the detrimental effects of lateral rarefaction waves. Accelerating samples over such long time duration with a hohlraum generated x-ray drive (even multi-barrel hohlraums [2]) without stagnation effects seems difficult.

Here we report on the first results of the Long duration Direct Drive Planar Discovery Science proposal on the NIF. The goals are to commission a 20-30 ns, long duration, direct-drive acceleration platform for future academics experiments. Planar plastic samples are irradiated by 300 to 500 kJ of 3w laser light distributed over a 2-mm wide flat laser spot customized by adequate beams repointing. It is first shown that a shock could be sustained during 30 ns with almost no curvature over a 1 mm central area. Then the Rayleigh-Taylor growth of preimposed and laser imprinted modulations is quantified through face-on radiograph conditions. These novel results and their benchmark against two-dimensional radiative hydrocodes simulations will pave the way for future experiments requesting long duration drive on NIF [3,4]

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X-ray Photoemission Spectroscopy of free Carbon Dots

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Abstract:

Carbon dots (C-dots) are the newest class of carbon-based nanomaterials, which have drawn attention mainly due to their stable multicolor light emission. During the past decade significant progress has been achieved in their synthesis, while their properties and applications have been also reported. However, even if the ability to tune their fluorescent emission by varying their size, chemical composition, and surface functionality is well manifested, the origin of this feature is not yet completely understood since C-dots comprise systems with complex chemical composition and subsequently complex electronic properties.

To gain insight in the structural and electronic properties of *N*-hydroxysuccinimide C-dots, X-ray photoelectron spectroscopy (XPS) has been performed on free nanoparticles, avoiding any effects from the substrates. More precisely, an aerodynamic lens system was used to focus the C-dots into the interaction region with synchrotron radiation and electron spectra obtained with a VG-Scienta R4000 electron energy analyzer at the PLEIADES soft X-ray beamline at the SOLEIL synchrotron facility. C1s, O1s, N1s and valence band XPS spectra have been measured with high resolution. By varying the photon energy, and hence the kinetic energies of the emitted electrons, the surface sensitivity of the XPS was tuned to preferentially probe either the surface or the bulk of the nanoparticles. Complementary characterisation by DLS and HRTEM measurements has also been performed.

Taking into account the sp^2-to-sp^3 ratio determined from the C1s spectrum, complemented with the O1s and N1s spectra recorded with different probing depths, information on the extent of the functionalized groups to the nanoparticles' volume and the hybridization of the C-dots have been obtained. In addition, the valence band spectrum has been recorded for the first time, showing a well-defined structure which has been compared with that of pure diamond and graphite. The novelty of the present results is expected to promote a deep understanding in the electronic structure of C-dots, boosting their possible functionalisation in view of direct applications.

BLOCK COPOLYMER BASED NANOPLASMONIC SURFACES

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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.

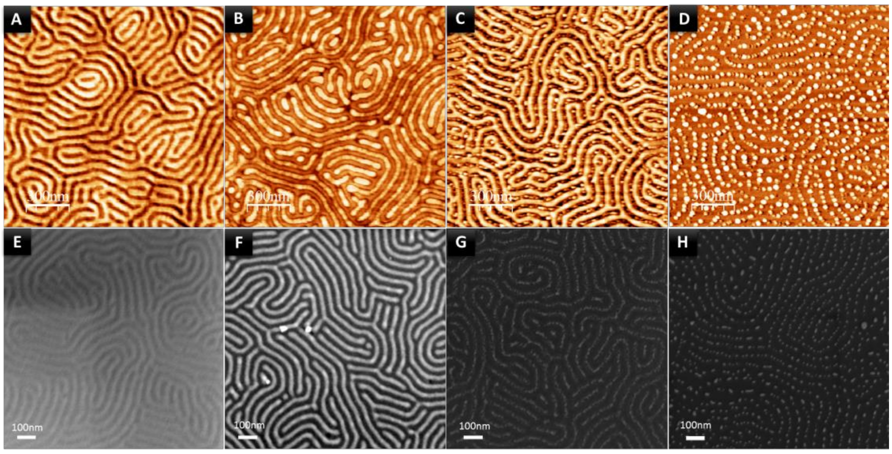

Figure 1: AFM and SEM micrographies of PS-b-P2VP lamellar films (A,E) after, spin coating of the gold precursor (B,F), 10 s of oxygen plasma at 60W (C,G), 60s of oxygen plasma at 60W (D,H).

In this work we present a straightforward method to obtain patterned metal-dielectric nanocomposites, from quasi-continuous gold lines to discrete gold nanoparticles arrays, using the self-assembly of block copolymers as a nanostructured templates. Perpendicular lamellar structures of poly(styrene)-bpoly(2-vinyl pyridine) (PS-P2VP) copolymers were obtained using chemically modified substrates, followed by the metallic precursor deposition, which is selectively incorporated to the P2VP domains. Tuning the subsequent oxygen plasma treatment used to reduce the gold precursor allows obtaining different structures as shown in Figure 1. Grazing-Incidence Small Angle X-ray Scattering, Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), 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 ellipsometric.

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

Ultra-cold atomic sources for equivalence principle tests in microgravity

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The ICE experiment at LP2N is designed to test the weak equivalence principle (WEP) in the microgravity environment produced during parabolic flight (Fig. 1a) [1]. The WEP postulates that the acceleration of a body in free fall with a gravitational field is independent of its internal structure and composition. Recently, we carried out the first quantum test of the WEP in weightlessness [2] using a dual-species interferometer with laser-cooled samples of ^{87}Rb and ^{39}K (Fig. 1c). With these quantum inertial sensors, we compare the difference between gravitationally-induced phases and measured the Eötvös parameter at the 10^{-4} level. This first test was limited in sensitivity due to the motion of the aircraft and the temperature of the samples. In order to reach state-of-the-art precisions (with interrogation times $T > 1$ s), it is necessary to reach ultra-cold temperatures with Bose-Einstein condensates (BECs). We are currently implementing a time-averaged far off-resonant optical dipole trap [3] to evaporatively cool both atomic species to quantum degeneracy using a 25 W laser at 1550 nm. This type of trap allows one to decouple the trapping frequency from the trap depth in order to evaporate on short timescales (~ 1 s). We describe the transportable ICE experiment, including our latest results of the WEP test in microgravity. We also present progress toward the first realization of a mobile dual-species BEC interferometer, which is directly applicable to future Space missions such as STE-QUEST [4].

Keywords: Ultra-cold atoms, weak equivalence principle, dual-species interferometers, dipole trap

Presentation Type: Poster

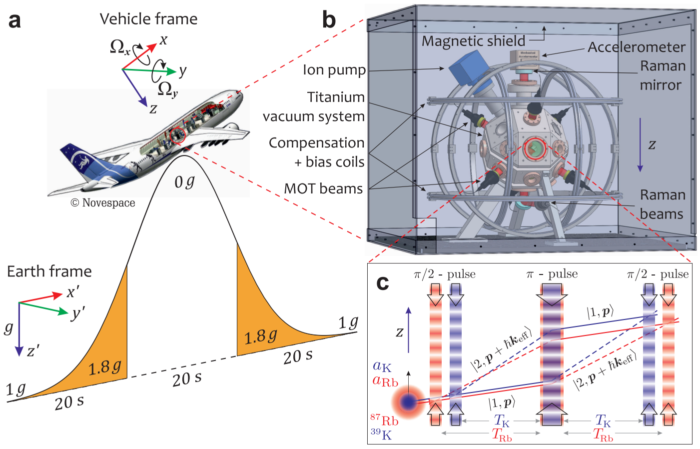

Figure 1: Dual matter-wave sensors onboard the Novespace Zero-G aircraft. (a) Basic trajectory during parabolic flight which produces 20 s of weightlessness per maneuver. (b) The science chamber mounted onboard the aircraft. Samples of ^{87}Rb and ^{39}K are laser-cooled in a vapor-loaded magneto-optical trap contained within a titanium vacuum system and enclosed by a mu-metal magnetic shield. (c) Schematic of the simultaneous dual-species interferometers.

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GENERATION AND PARAMETRIC AMPLIFICATION OF BROADBAND PHASE STABILIZED FEW CYCLE PULSES AT 2.9 µm

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INTRODUCTION

Ultrashort pulse light sources in the short wave and mid infrared are in high demand for different applications such as shorter attosecond pulse generation, ultrafast spectroscopy and explosive or gas detection. The $I.I^2$ scaling law inherent to the high order harmonic generation (HHG) process favors longer driving wavelengths in order to produce more energetic XUV photons, and potentially shorter attosecond, soft X-ray pulses [1].

EXPERIMENTAL SET UP AND RESULTS

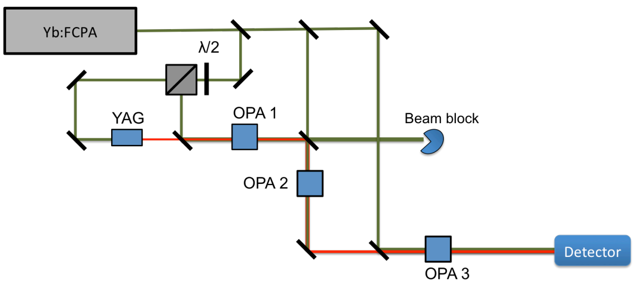

Fig.1. Optical parametric amplifier at 2.9 µm.

The three-stage OPA system is pumped by a home made Yb doped Fiber Chirp Pulse Amplification system, which delivers 370 µJ, 350 fs pulses (> 1 GW) with a 100 kHz repetition rate at 1030 nm [2]. Firstly, a white light continuum (WLC) is generated which spectra spreads up to 2 µm into the red side. The red part of the WLC is further amplified in the first and second parametric amplifiers. In the first OPA stage, a 140 nm broadband signal around 1.7 µm was amplified in a nonlinear crystal. Then, pulses amplified in a first stage were further amplified in an OPA 2 and a broadband idler around 2.9 µm was generated.

In the last stage, either the signal at 1.7 µm or the idler at 2.9 µm could be amplified. Here, we present results for idler amplification. After the OPA2, the idler beam is filtered by germanium filter, which also compensates the accumulated spectral phase in a way such that, after the OPA 3 the pulses are optimally compressed. Second harmonic generation FROG measurements let us estimate the pulse duration of 80 fs, which corresponds to 8 optical cycles at this wavelength. The output pulse energy was 15-16 µJ. Also, since the WLC and the DFG stages are pumped by a single pump laser, intrinsic CEP stability was implemented.

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Design and fabrication of a plasmonic switching device

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Over the past decades, significant experimental and theoretical advances were made in the field of light manipulation with hybrid plasmonic nanostructures [1]. In integrated plasmonic nanodevices, noble metal nanostructures are commonly used as building blocks because they possess geometry-dependent localized plasmon resonances which can be easily tuned [2]. However, it has been a challenge to incorporate such nanoparticles in functional devices with a high precision in a nanometer scale [3].

In this context, we are designing a new path selective plasmonic switching device by directing the assembly of gold hollow nanotriangles (GHTs) through the selective deposition on DNA-based scaffolds. Basic designs and predictions of the device's properties have been performed by FDTD.

In such systems, after the excitation of one tip of the structure, the resulting plasmon propagating through the other two branches will be detected via the emission of a fluorescent dye attached to their tips (Figure 1a).

GHTs are synthesized via a two-step method using silver nanoprisms as seeds [4] (Figure 1b) and deposited on the DNA origami with specific gold-binding sites (Figure 1c).

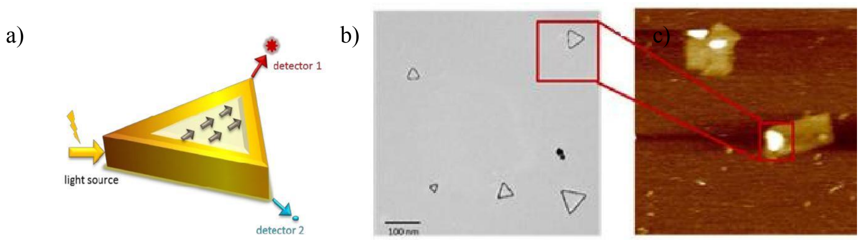

Figure 1: a) Scheme of the targeted device, b) TEM image of GHTs, c) AFM image of GHT deposited on DNA origami template.

In conclusion, we are designing and fabricating nanostructures able to direct the polariton flow toward the desired direction, forming an optical switch and providing access to nanoscale light manipulation.

Acknowledgment

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Multifunctional Nanomaterials: Self-Assembled Organic Building Blocks

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The fine design of self-assembling acene derivatives gives rise to a variety of fluorescent nanostructures, such as organogels, nano-fibers, ribbons, crystals and composite materials with finely tunable emissive properties. In this regard, one of the main challenges lies in the elucidation of the self-assembly mechanism that will finally define the morphology and last properties of the nanostructures, crucial to decide the field of application. Self-assembly pathways can be controlled by molecular design, concentration, additives, solvent conditions, and temperature [1]. Their optical properties result from molecular packing, shape and size, incorporation of suitable dopant-molecules and excitation dynamics [2].

A recent breakthrough in this research field has been obtained by the development of a new photo-synthetic approach based on light-triggered self-assembly, which provides several advantages, such as contactless, as well as accurate spatial and temporal control. Thereby, a controlled structure of supra-molecular nano-fibers patterned on a transparent surface can now be achieved. This paves the way to completely new strategies in designing optically active nanostructures.

A separation of optical properties has also been obtained by controlling the self-assembly pathways of an orthogonal network composed by a blue and a red-emitting acene-derivative. These two alkoxylated dyes show the quality of self-sorting, growing separately to form two different types of ribbons emitting two different colors within the initially blended system. However, the mechanisms responsible for self-sorting and formation of orthogonal systems is still not well understood, as shown by the great efforts put in for its elucidation by the scientific community [3]. In this regard, and trying to understand the reason for the orthogonal growth, the influence of the solvent composition and concentration of the compounds in the mixture is being studied using real-time imaging and characterization of the optical properties by state-of-the-art microscopy.

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Giant compression of high energy optical pulses using a commercially available Kagome fiber

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Keywords: Self-compression, Femto laser, Ultra-short pulse compression

Recent results in laser beam delivery and ultra-short pulse (USP) compression using hypocycloid-core Kagome hollow-core photonic crystal fibers (HC-PCFs) [1] proved that this type of optical fiber is an excellent candidate as a photonic component for these applications. For example, it has been demonstrated that the fiber guided up to 1 mJ of 500 fs wide pulses with no damage, and by a simple combination in the choice of gas and fiber dispersion, the authors achieved both USP guidance with no pulse broadening nor narrowing, guidance with self-phase modulation (SPM) spectral broadening, and finally guidance with over 10-fold self-compression using solitonic dynamics. However, these compression results necessitated both fiber gas-loading-system and bespoke fiber-fabrication, which are not necessarily accessible to the broader research community. Here, we report on a set of results of self-compression of a USP laser based on a commercially available Kagome fiber (PMC-C-YB-7C from GLOphotonics [2]) and with no need of gas loading management. The compression relies on pulse dynamics near the photoionization threshold, which shows a strong and abrupt self-compression via the formation of a soliton at a well-defined pulse energy value and then its break up at higher energy values [3]. By simply adjusting the fiber length from 10 cm to 4 m, we achieved compression of an initial 500 fs from Yb-doped USP-laser down to ~20 fs (a compression ratio >25) over an energy span of 10 µJ- 800 µJ. Figure 1 summarises these self-compression results by showing the typical evolution of pulse width (*lhs*) and FROG (*rhs*) with increasing input energy for a fiber length of 2.5 m. The maximum compression achieved corresponds to a FWHM of 20 fs and occurs at an energy of 70 µJ. The spectral broadening, the soliton red-shift and compression is visible on the FROG [4] evolution with input energy.

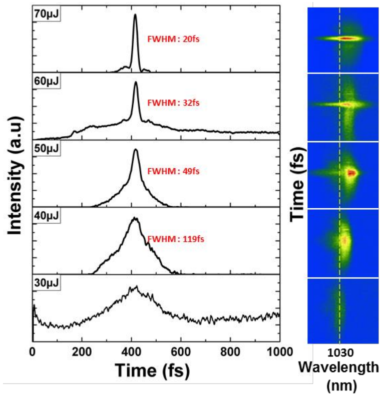

Figure 1. Autocorrelator and FROG traces for different input energy with 2.5 m of Kagome fiber.

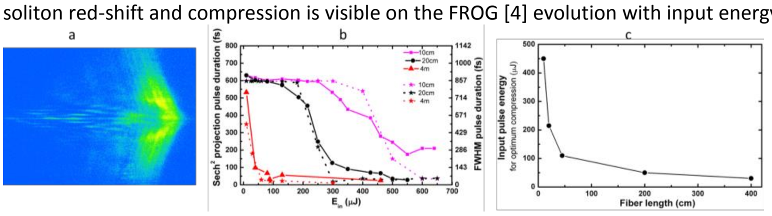

Figure 2. (a) FROG trace of the soliton fission for 2.5 m at 260 µJ. (b) USP compression calculated and measured for different fiber length. (c) Input energy necessary to achieve the maximum of compression at different fiber length.

For higher energy, the pulse breaks up via soliton fission as illustrated in the FROG trace at input energy of 260 µJ [Fig. 2(a)]. Figure 2(b) shows calculated (dotted curves) and measured (solid curves) pulse duration evolution with input energy for different fiber lengths. All curves show a "step shape" corresponding to the sudden compression, and the input energy value at which the self-compression occurs increases with shortening fiber length. Consequently, by simply optimizing the fiber length to the available laser input energy, one achieve optimum compression as shown in Fig. 2(c).

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Cooperative veratryle and nitroindoline cages for two-photon uncaging using near infrared light

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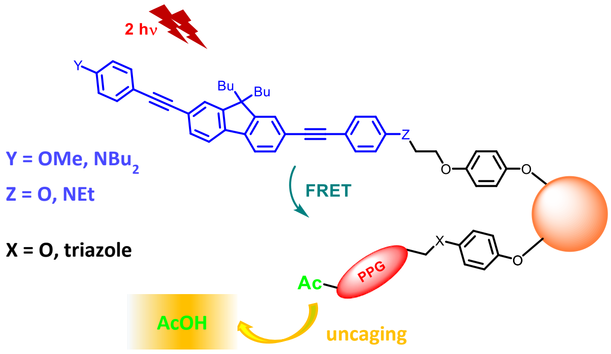
Photolabile protecting groups [1] (PPGs) have attracted growing interests in many fields of chemistry, and in particular biology. [2] Light-induced release of biological agents, commonly known as "uncaging", has thus emerged as an interesting perspective for drug delivery [3] or investigation of biological phenomena. [4] Combining this tool with the intrinsic advantages of two-photon absorption [5] is however a challenge. Herein, we report the development of new tandem uncaging systems in which a two-photon absorbing and a cage module, linked via a phosphorous clip, are meant to act together by FRET process. A library of these compounds, using different linkers and known cages (nitroindoline [6] or nitroveratryle [7]) has been synthesized. The investigation of their uncaging and two-photon absorption properties demonstrates the scope and versatility of this engineering strategy, and reveals surprising cooperative and topological effects. The interactions between the 2PA module and the caging moiety are found to promote cooperative effects on the 2PA response, while additional processes that enhance the uncaging efficiency are operative in well-oriented nitroindoline-derived dyads. These synergic effects combine and eventually lead to record two-photon uncaging cross-section values (i.e. up to 20 GM) for uncaging of carboxylic acids.



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Engineering of Hyper-Bright and Stable Fluorescent Organic Nanoparticles

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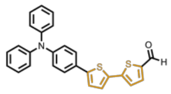
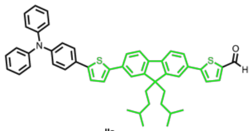
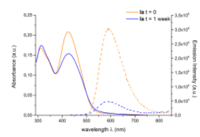
In the course of our approach towards molecular-based fluorescent organic particles as biocompatible ultra-bright luminescent alternatives to QDs for bioimaging purposes, we have recently shown that molecular engineering of multipolar dyes could indeed lead to FONs displaying giant brightness, tunable luminescence and exceptional stability and photostability.[1-4] These FONs can be easily prepared in water using a robust, expeditious and simple nanoprecipitation process. Of major importance is the realization that modification of the dye subunits structure can be used to tune both the photophysical and the colloidal and structural stability of the FONs, thus opening an intriguing bottom-up engineering route.[1-2,5] With the aim of extending the scope of this route, we here investigate the effect of the modification of the π-conjugated system of a "push-pull" dipolar generic dye (**Ia**) by inserting a fluorene unit in the middle of the conjugated system (**IIa**). This was aimed both at enhancing the two-photon absorption (2PA) response,[2,4,6] and tuning interchromophoric interactions so as to control the FONs optical and luminescence properties.

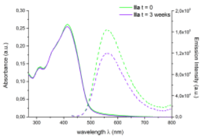


Ia



IIa





The new synthesized dye was found to produce hyper-bright yellow-emitting FONs (λ_{abs}^{max}= 414 nm, λ_{em}^{max}= 559 nm, $\varepsilon^{max}\Phi_f$ = 4.2 10^{7} $M^{-1}cm^{-1}$) of about 34 nm diameter *via* nanoprecipitation in water. Interestingly, a broadening of the absorption band of FONs **IIa** is observed as compared to that of the monomeric dye dissolved in $CHCl_3$, revealing that molecular confinement of **IIa** promotes excitonic coupling (not observed with dye **Ia**). FONs made from dye **IIa** are found to be slightly blue-shifted compared to FONs **Ia** and show larger 2PA response in the biological spectral window (σ_2^{max} = 7.5 10^6 GM at 730 nm). Even more importantly, FONs **IIa** show largely improved structural and colloidal stability overtime, in relation with a highly negative surface potential (-73 mV).

In conclusion the present study shows that subtle engineering of the dye subunits of this new class of nanoparticles is indeed operative in improving key criteria for use as contrast agents for (bio)imaging purposes. Furthermore, control of interchromophoric interactions allows tuning photophysical properties and enhancing 2PA responses, producing hyper-bright molecular-based nanoparticles that show much larger 1P and 2P brightness compared to QDs (2.6 10^5 GM FONs **IIa**; 4.7 10^4 GM QDs[7]) while exhibiting suitable colloidal and structural stability in water have been designed.

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Quantitative metabolic microendoscopy within a living organism based on two-photon excited endogenous molecular imaging of intracellular NADH and FAD.

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Abstract :

Multiphoton microscopy is a cutting edge imaging modality leading to increasing advances in biology and also in the clinical field. To use it at its full potential and at the very heart of clinical practice, there have been several developments of fiber-based multiphoton microendoscopes. The application for those probes is now limited by few major restrictions, such as the difficulty to collect autofluorescence signals from tissues and cells theses being inherently weak (e.g. the ones from intracellular NADH or FAD metabolites). This limitation reduces the usefulness of microendoscopy in general, effectively restraining it to morphological imaging modality requiring staining of the tissues. Our aim is to go beyond this limitation, showing for the first time label-free cellular metabolism monitoring, in vivo in situ in real time.

The experimental setup is an upgrade of a recently published (Ducourthial et.al, Scientific Reports, 2016) one where femtosecond pulse fiber delivery is further optimized thank's to a new transmissive-GRISM-based pulse stretcher permitting high energy throughput and wide bandwidth. This device allows fast sequential operation with two different excitation wavelengths for efficient two-photon excited NADH and FAD autofluorescence endoscopic detection (i.e. 860 nm for FAD and 760 nm for NADH), enabling cellular optical redox ratio quantification at 8 frames/s.

The obtained results on cell models in vitro and also on animal models in vivo (e.g. neurons of a living mouse) prove that we accurately assess the level of NADH and FAD at subcellular resolution through a 3-meters-long fiber with our miniaturized probe (O.D. =2.2 mm).

Resumé :

Multiphoton microscopy is a cutting edge imaging modality leading to remarkable step forward in biology but also in the clinical field. To use it at its full potential and at the very heart of clinical practice, there has been several development of fiber-based micro-endoscope**.** We demonstrate, for the first time, that it is possible for a multiphoton endoscope, to access and assess fluorescence of weak intrinsic molecule such as intracellular NADH and FAD, thus showing that it is possible to monitor cellular metabolism, in real time, *in vivo in situ*, without staining, minimally invasively within a living organism.

Mots clés : multi-photon microendoscopy, fluorescence endoscopic imaging, label free *in vivo in situ* minimally invasive imaging, cellular energetic metabolism readout, optical redox ratio quantification, fiber-based optical biopsy, endogenous molecular imaging.

Three-Dimensional Optical Nanoscopy with Excited State Saturation

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Super resolution microscopy has emerged in recent years due to its ability to achieve a spatial resolution beyond the diffraction limit by exploiting reversible saturable/switchable fluorescence transitions. Among the methods, the most important techniques are referred to by the acronyms STED (stimulated emission depletion), GSD (ground state depletion), SSIM (saturated structured illumination microscopy), PALM (photo-activated localization microscopy) and STORM (stochastic optical reconstruction microscopy). We introduced a simpler super resolution optical microscopy method based on excited state saturation of fluorescent molecules at liquid helium temperature. This technique can achieve sub-nanometer resolution with extremely low excitation intensities.

Through this work, we are trying to outspread the excited state saturation (ESSat) microscopy to three dimensions. This is achieved by making use of two gaussian beams which are reshaped such that, when focused have a spatially varying intensity profile featuring an isolated intensity zero, steeply bordered by bright light peaks (forming a hollow sphere like structure). The excitation patterns are created by inserting appropriate phase shifting masks. The use of a circular 2π ramp phase mask to produce a doughnut shaped beam was shown to yield an effective increase in lateral resolution, leaving the axial resolution unaffected. For confinement in the axial direction, we are using a phase mask consisting of a central area with a π-phase retardation.

The perspective of this work is to image single molecules with sub-nanometer resolution in three dimension with ESSat microscopy. This will pave the way to study the dipole-dipole coherent interactions between single emitters and to the manipulations of their degree of entanglement.

FULLY-APERIODIC LARGE-PITCH FIBERS: CURRENT STATE AND PROSPECTS

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ABSTRACT

Power scaling of pulsed high power laser has dramatically benefit from outstanding evolutions of the internal structure of optical fibers. Huge progresses have been done to achieve efficient amplifications of increasingly larger modes. Some of the most efficient designs are the large pitch fibers (LPF), the photonics crystal fibers (PCF) and the distributed mode filter (DMF). In the last few years, the power scaling in these fibers has been thwarted by the appearance of transverse modal instabilities, which suddenly degrades the emitted beam quality [1]. In this context we present an improved design of Large Mode Area fibers for high power application. The guiding properties, taking advantage of an improved delocalization of higher order modes (HOMs) outside the active area, will be presented. Our so-called fully-aperiodic large-pitch fiber (FA-LPF) presents several improvements among which an all-solid aperiodic inner-cladding (Figure 1) in order to (i) efficiently confine the fundamental mode into the gain region, (ii) enhance the delocalization of the HOMs [2]. The proposed structure has been first theoretically studied and optimized. First prototypes of Ytterbium-doped FA-LPFs have been fabricated and good experimental laser performances have been proven, notably with demonstrations in continuous wave and pulsed regimes of average output powers up to 252W [3]. Although the FA-LPFs are intrinsically more resistant to modal instabilities than other LPFs, we have performed theoretical simulations to go further towards higher emitted powers. A pre-compensation to thermal effect is possible to increase the transverse modal instabilities threshold and will be detailed in the poster [4]. At high pulsed power levels, unexpected nonlinear rotation of polarization may also strongly compromise the exploitation of the emitted power. The propagation of a single-polarization of the fundamental mode has been recently experimentally observed into a polarizing FA-LPF up to 140µm core. Selective coupling of one of the fundamental mode polarization is operated with a cladding mode thanks to the use of stress applied parts which are judiciously displayed into the inner cladding [5].

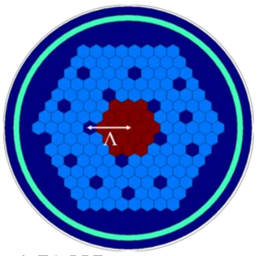

Figure 1. FA-LPF transverse cross section

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Diagnosis and Therapy of early tumors with inkjet-printed mesoporous silica dots

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Cancers represent a major health challenge. Early detection of tumors is advantageous for treatments efficiency. Consequently, new biotechnologies are focusing on a way to solve that disease. In 2011, a study has been initiated at the SPCTS laboratory, in order to develop an endoscopic device suitable for an early detection and treatment of tumors [1]. At first, this device is to be used for lung and bowel cancers, and for breast and prostate cancers with time.

Inkjet Printing (IJP), combined with Evaporation Induced Self-Assembly (EISA), affords to produce mesoporous silica microdots that can be specifically functionalized by click chemistry [2].

For the diagnosis, bio-receptors are labeled with appropriate fluorophores and anchored to the microdots surface. When interacting with the specific cancerous biomarkers on tumor cells, a conformation change of the bio-receptors occurs, and the fluorophores get closer. Consequently, a Fluorescence Resonance Energy Transfer (FRET) occurs and is spectrally detected by confocal laser microscopy. The functionalization with labeled bio-receptors affords a specific detection of cancerous biomarkers, as an identification technique for different types of tumors.

Once the diagnosis is effective, the endoscopic device can be upgraded with therapy function. On that purpose, the mesoporous silica microdots are specifically functionalized with photosensitizers, by click chemistry. A laser source is used to excite the photosensitizers, producing singlet oxygen that leads to apoptosis of tumor cells, by PhotoDynamic Therapy (PDT). Such a treatment technique is favorable concerning non-invasive aspects, compared to other existing techniques.

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General Information

Transport & Access

Symposium location : ICMCB Laboratory
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Tramway B - Stop « Doyen Brus » http://www.infotbm.com