Optics & Photonics Day

15 November 2011

FEMTO-ST Institute - UMR CNRS 6174

University of Franche-Comté

16 route de Gray

25030 Besançon, France

FEMTO-ST OSA Student Chapter, Besançon

The OSA Student Chapter of Besançon

is proud to announce its first

« Optics and Photonics Day »

Organized by the PhD student association supported by OSA, this conference day intends to gather young scientists in the Optics & Photonics field to collaborate on their research and outreach activities. Apart from **Pr. Kuipers** seminar highlight, student chapter presentations as well as technical session will be held by PhD students. With the aim of sharing scientific knowledge and research experience, Master students of PICS specialty from Besançon and Optics & Photonics specialty from Karlsruhe are also attending the conference.

Maps & Conference venue at the end of the booklet.

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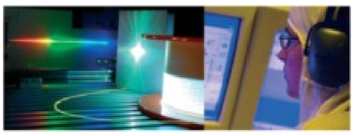
Master PICS



The Master PICS specialty

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This Master's course provides a comprehensive program of courses covering theoretical, experimental and engineering aspects of photonics, optoelectronics, micro and nano-optics, frequency-time metrology, bio-photonics, and complex systems.

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Optics and Photonics Day

Program

08h00 - 08h30		Registration
08h30 - 08h40		Opening
08h40 - 09h00		Optics Department presentation - FEMTO-ST
09h00 - 09h15		Caen Student chapter presentation
09h15 - 09h30		Paris Student chapter presentation
09h30 - 09h45		Karlsruhe Student chapter presentation
09h45 - 10h15		*Coffee break*
10h15 - 11h15	**Pr. K. Kuipers** *AMOLF*	Seminar from OSA Fellow Pr. K. Kuipers, Head of Nano Optics group at AMOLF, Amsterdam, Netherlands
11h15 - 11h45		Questions
12h00 - 14h00		Poster session & Lunch
14h15 - 14h30	B.Stiller *FEMTO-ST*	SBS mitigation in a microstructured optical fiber by periodically varying the core diameter
14h30 - 14h45	B.Wetzel *FEMTO-ST*	Randomness and extreme events in nonlinear supercontinuum generation
14h45 - 15h00	F. Starecki *ENSICAEN*	Émission Rouge Vert Bleu de fluorures dopées praséodyme
15h00 - 15h15	C–H. Liang *ENSICAEN*	Effect of the Si content on the structure and the photo-luminescence properties of Nd-doped Si-rich silicon oxide
15h15 - 14h30	A. Frölich *KIT*	Towards visible-wavelength titania-based three-dimensional photonic-band-gap materials via direct laser writing
15h30 - 15h45	I. Mbodji *FEMTO-ST*	Efficient control of frequency-bin entangled photons pairs using sideband modulation architecture
15h45 - 16h00	E. Barakat *FEMTO-ST*	Metallic Annular Apertures Arrays filled by Lithium Niobate to Enhance Non-Linear Conversion: Theory and Fabrication
16h00 - 16h15	Y-T An *ENSICAEN*	Optical properties of silicon-based thin films doped with Pr^{3+} ions
16h15 - 16h30	M. Roblin *ENSICAEN*	Imagerie en champ proche optique à 1,55µm de structures plasmoniques par rétro-injection sur laser à fibre
16h30 - 17h00		*Coffee break*
17h00 - 18h00		Laboratory Visit

11/15/2011

Oral presentations

SBS mitigation in a microstructured optical fiber by periodically varying the core diameter

B. Stiller[1]*, A. Kudlinski[2], M. W. Lee[1], G. Bouwmans[2], M. Delqué[1], J.-C. Beugnot[1], H. Maillotte[1] and T. Sylvestre[1]

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We experimentally demonstrate 4 dB increase of the stimulated Brillouin scattering threshold in a microstructured optical fiber (MOF). This result is obtained by periodically varying the size of air-hole-structure by only 7% amplitude while keeping a low attenuation coefficient. The efficiency of this passive technique is verified by use of Brillouin-echoes distributed sensing technique where the Brillouin frequency shift oscillation is clearly observed.

Index Terms: stimulated Brillouin scattering, Brillouin threshold, microstructured optical fiber, distributed Brillouin measurement

Randomness and extreme events in nonlinear supercontinuum generation

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We provide an analysis of both intensity and phase spectral fluctuations during the generation of broadband optical supercontinuum generation which has recently been studied in the context of optical rogue wave formation. Such fluctuations, arising from the way in which input noise feeds and transfers into broadband nonlinear fibre propagation are investigated trough a statistical viewpoint. We here consider how these fluctuations due to intrinsic nonlinear dynamics could be used to generate randomness over a broadband spectrum. We also develop a complementary analysis of coherence and randomness properties of supercontinuum generation considering random walk theory, well known as a powerful mathematical tool in the statistical description of many physical processes.

Effect of the Si content on the structure and the photoluminescence properties of Nd-doped Si-rich silicon oxide

C–H. Liang, O. Debieu, Y-T. An, J. Cardin and F. Gourbilleau

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A great research effort has been focused on Si technology during these years because of its wide industry applications. Moreover, the recent discovery of the efficient sensitizing action of Si nano-clusters (Si-nc) toward rare earth ions such as Er^{3+}ror Nd^{3+} ions has paved the way for the achievement of significant optical gain and therefore the fabrication of Si-based optical devices. In this work, we investigated the effect of the Si content on the structure and the optical properties of Nd-doped Si-rich silicon oxide thin films produced by magnetron co-sputtering technique with three cathodes: Si, SiO_2 and Nd_2O_3. The Si content was tuned by Si cathodes power density and was estimated by FTIR and spectroscopic ellipsometry. Furthermore, the FTIR and Raman scattering were used to investigate the effect of annealing on the film structure. Then, the Photoluminescence properties were studied as a function of the Si content and of the annealing temperature, reaching the aim to maximize the energy transfer between the Si-nc and Nd^{3+} ions.

Optical properties of silicon-based thin films doped with Pr^{3+} ions

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Showing quantum cutting from ultra violet to visible lights, the material doped with Pr^{3+} ions has been greatly detailed [1] in recent years because it is a promising candidate for solar cell with high efficiency. However, to this day no studies have been reported on Pr-doped Si-rich silicon oxide thin films. Such a structure could be a really interesting solution on the issue of converted layer for Si solar cell application. In this work, we propose to study Si-rich SiO_2-Pr thin films deposited by reactive magnetron co-sputtering. The structure and optical properties of samples were investigated as a function of the deposition parameters (H_2 content, Pr_6O_{11} chips, total plasma pressure, etc…). FTIR and spectroscopic ellipsometry experiments have been carried out to study the samples structure, while the emission properties were explored by the photoluminescence (PL) and PL excitation measurements. PL peaks attributed to Pr^{3+} ions have been detected after an excitation at 280 nm. The presence of PL emission of Pr^{3+} ions under indirect excitation demonstrates the efficient energy transfer from sensitizer toward Pr^{3+} ions.

[1] Y. Katayama, S. Tanabe. *Materials* 2010, *3*, 2405-2411

Efficient control of frequency-bin entangled photons pairs using sideband modulation architecture

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Ever since the work of Ekert in 1991, the possibility to use entangled photons pairs, for quantum cryptography became a good way to distribute quantum information.

Here, we report a new theorical and experimental method for manipulating frequency entangled photons. This study is conducted to determine if our frequency bin entangled architecture is a legitimate candidate for realization of quantum communication.

In order to achieve quantum communication in standard optical fibers, we have implemented radio-frequency architecture for frequency entangled photons leading to a two-photon interference pattern in frequency domain. Using electro-optic phase modulation and narrow spectral filtering we obtain high visibility showing that the radio-frequency parameters control very accurately the interference pattern. We then derive a formulation to optimize the expected value of a Bell inequality and experimentally demonstrated it. We conclude on the use of this architecture for potential applications such as Quantum Key Distribution (QKD).

A schematic of our setup is shown in Fig. 1. A narrow-band pump laser of wavelength 773.86 nm is directed through in a 3 cm long Periodically poled lithium niobate (PPLN). The PPLN waveguide produces pairs of entangled photons in the response to the input photons produced by a pump laser. Photons Alice and Bob are directed respectively through phase modulators of normalized amplitudes a and b and phases α and β which generate frequency shifts of the modulating frequency 25 GHz. Coincidences counts are obtained by detecting with avalanches photodiodes those photons which pass through Bragg frequency filters

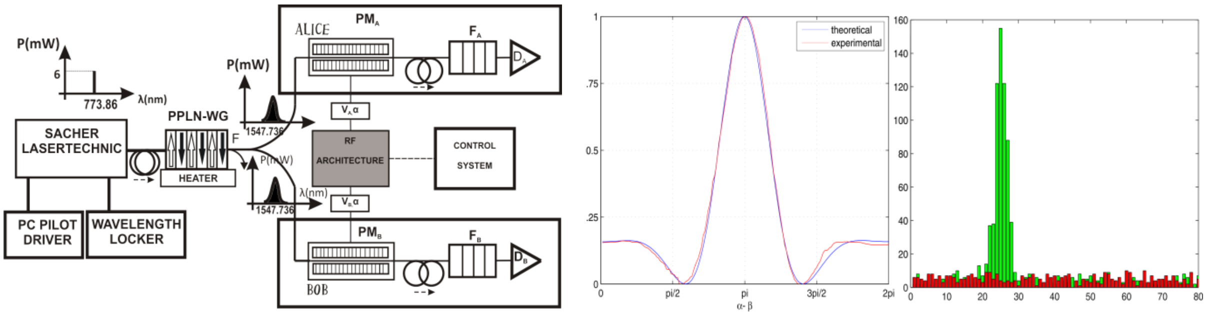

Fig 1: Experimental setup.

We obtain the value 2.386 ± 0.021 for the CH_{74} expression, ie a maximal violation of CH_{74} by 18 standards deviations. This experimental result shows that our method for manipulating frequency-bin entanglement is reliable.

Acknowledgements.

We acknowledge support from the European Union under project QAP(contrat 015848), from the Belgian Science Policy under project IAP-P6/10 (Photonics@be, from the French Agence Nationale de la Recherche under project HQNET and from the Conseil Régional de Franche Comte. Ismaël Mbodji acknowledges support from Conseil Général du Doubs.

References

[1] L. Olislager, J. Cussey, A.T. Nguyen, P. Emplit, S. Massar, K. Phan Huy, J-M Merolla '' Frequency –bin entangled photons '', Phys. Rev A 82, 013804 (2010)
[2] J. F. Clauser and M. A. Horne, Phys. Rev. D 10, 526 (1974

Metallic Annular Apertures Arrays filled by Lithium Niobate to Enhance Non-Linear Conversion: Theory and Fabrication

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Enhanced Second Harmonic Generation was theoretically predicted from a nanopatterned non linear material ($LiNbO_3$) located inside the subwavelength cavities of a metallic Annular Aperture Arrays(AAA). The signal strength is compared to that from a bulk LN. Such a crystal has 2D periodic large second-order susceptibility $\chi^{(2)}$. We found an optimal structure design thanks to the relations that link the aperture radii and the metal thickness to the operating point namely the wavelength of the fundamental and SHG signals. Because the patterned $LiNbO_3$ thickness is much shorter than the wavelengths (both fundamental and SH) involved and much shorter than the coherence length, no phase matching is required. A slow light phenomenon, which occurs at the cut-off frequency of the TE11 guided mode through the annular cavities, is at the origin of the SHG signal enhancement. Theoretical results using a homemade NL-FDTD code shows that the conversion of 1550 nm excitation light into 775 nm emission is theoretically enhanced by a factor of **27** with respect to a bulk $LiNbO_3$. The field distribution at the pump and the SH wavelength shows that light is confined inside the cavities and thus it confirms the non-linear enhancement. The benefit of the AAA is demonstrated through a comparison with cylindrical aperture arrays. By referring to the non-linear tensor we choose an X-cut wafer to benefit from the greater non-linear coefficient d_{33}. We used e-beam, ICP-RIE and CMP technologies for the fabrication. Experiments are in progress in order to verify our theoretical results.

Imagerie en champ proche optique à 1,55µm de structures plasmoniques par rétro-injection sur laser à fibre

M. Roblin*, S. Girard, C. Dufour, J. Cardin, H. Gilles, M. Laroche et U. Lüders

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Différentes structures plasmoniques basées sur une couche mince d'or déposée sur un substrat de silice ont été fabriquées par lithographie électronique. Les fonctionnalités optiques de ces structures intégrées photoniques ont été caractérisées expérimentalement autour de 1,55µm à l'aide d'un montage de microscopie en champ proche optique (SNOM) fonctionnant par rétro-injection laser sur un laser DFB à fibre dopée Erbium. Ce dispositif expérimental permet d'imager simultanément la topographie de surface de l'échantillon ainsi que la répartition du champ électromagnétique optique avec une résolution spatiale inférieure à 20nm. Les images SNOM obtenues sont comparées avec des simulations numériques réalisées par des modélisations FDTD 3D.

Émission Rouge Vert Bleu de fluorures dopées praséodyme

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Cet exposé traite de l'émission dans le visible de cristaux massifs de fluorures d'yttrium dopés praséodyme, LiYF4 et KYF4. La spectroscopie de ces matériaux y est abordée, ainsi que quelques résultats laser. L'émission dans l'orange à 605.997 nm, pour des applications de traitement quantique de l'information, est présentée également. Une dernière partie concernera la production de ces matériaux en couches minces par la technique d'épitaxie en phase liquide.

Towards visible-wavelength titania-based three-dimensional photonic-band-gap materials via direct laser writing

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One of the holy grails in the field of photonic crystals has been and continues to be achieving sizable complete three-dimensional photonic band gaps in the visible part of the electromagnetic spectrum. Regarding approaches based on direct-laser-writing (DLW) optical lithography, at least two obstacles had to be removed. First, the resolution of regular DLW has not been sufficient to achieve the necessary feature sizes and lattice constants. For example, to achieve visible band gaps using titania, the rod spacing, a, of a three-dimensional woodpile photonic crystal needs to be around 300 nm. Second, the polymer templates made by DLW need to be converted into a transparent material with sufficiently large refractive index, such as titania. Depending on its phase, its refractive index is around 2.4, which is sufficient to open a complete gap with a gap-to-midgap ratio around 5%.

In this work, we overcome both problems. The first one is solved by employing stimulated-emission-depletion (STED) inspired DLW lithography using a photoresist with 7-Diethylamino-3-thenoylcoumarin as photo-initiator. This resist has recently been introduced by us. Along these lines, rod spacings down to $a = 250$ nm have become possible. The second problem is solved by modifying our previously introduced silicon-double-inversion procedure. In a first step, we invert the polymer templates made by STED DLW using atomic-layer deposition (ALD) of ZnO. After calcination of the polymer, we apply another inversion step using titania ALD. Finally, the ZnO is etched out selectively, leaving behind a titania replica of the original polymer woodpile.

Poster presentations

Periodic variations in the wavelength distributions following photon interferences: analogy with electron interferences

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A few years ago we performed a Young's double slit experiment with electrons. The goal of this experiment was to demonstrate Young's interferences for a single electron and to show that each electron interferes with itself. But here, we would like to use the results of this experiment with another objective. We know that electrons and photons have the same behavior under certain conditions. Both hit the detection screen like a particle but they pass the slits like a wave. These similarities provide an analogy between electron and photon interferences. The question arises can we go further with this the analogy by using the results of electron interferences experiment. With this aim, we revisit the photon interference experiment in order to determine the wavelength distribution as a function of the position on the detection screen.
The optical set-up is based on the classical Lloyd's mirror experiment. The light source is a *superluminescent erbium-doped* silica fibre. The output facet of the optical fiber acts as a coherent light source. A plane mirror is positioned at razing angle close to the optical fiber to create a virtual light source. Moving the fiber allows to adjust the distance between the real and virtual light sources. The reflected light interferes with the direct light. The pattern of interference fringes is detected point-by-point and is analyzed using an optical spectrum analyzer. The results will be presented during the conference.

Enhanced-transmission metamaterials as anisotropic plates

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We present an original design of anisotropic metamaterial plates exhibiting extraordinary transmission through perfectly conductor metallic screens perforated by a sub wavelength double-pattern rectangular aperture array. The polarization properties of the fundamental guided mode inside the apertures are at the origin of the anisotropy. The metal thickness is a key parameter that is adjusted in order to get the desired value of the phase difference between the two transversal electromagnetic field components. As an example, we treat the case of a half-wave plate having 92% transmission coefficient. Such a study can be easily extended to design anisotropic plates operating in terahertz or microwave domains.

Rare-earth doped fluorides for silicon solar cell efficiency enhancement

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Improving silicon solar cells efficiency involves a better exploitation of the solar spectrum. Solar cells generate a single electron–hole pair upon absorbing a photon above the bandgap. However, multiple electron–hole pair generation becomes possible by using a luminescent down converter, with quantum efficiency greater than unity, to “cut” a high energy photon into several lower energy photons [1] The doping of KY_3F_{10} and CaF_2 with rare earth ions is investigated as a possible down conversion system to enhance solar cells efficiency. A series of bulk single crystals were grown in our laboratory using a standard Bridgman technique. We discuss here results obtained from KY_3F_{10} and CaF_2 (Pr^{3+}, Yb^{3+}) codoped crystals presenting absorption of blue light by the praseodymium ^3P_J (J=0,1,2) levels, and showing ytterbium infrared emission (around 1 µm) after two subsequent energy transfers from Pr^{3+} to Yb^{3+}.

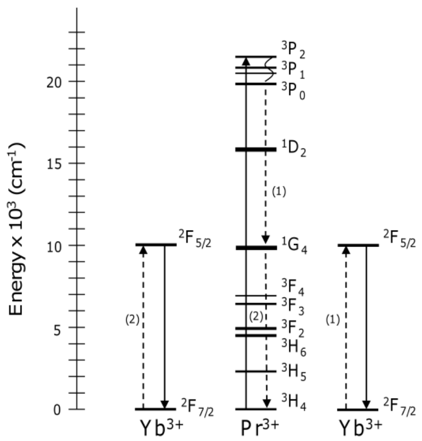

Fig. 1 Quantum cutting scheme in Pr^{3+}, Yb^{3+} codoping

Emission spectra and lifetime decays in both KY_3F_{10} and CaF_2 codoped Pr^{3+} and Yb^{3+} reveal an increase of the energy transfer efficiency from Pr^{3+} to Yb^{3+} when increasing the Yb^{3+} concentration (Fig. 1). For the first Pr^{3+} to Yb^{3+} energy transfer, an efficiency of 97% is achieved in KY_3F_{10}: 0.5%Pr^{3+}- 20%Yb^{3+}. However, this promising result faces challenging issues since a high Yb^{3+} concentration induces energy migration between Yb^{3+} ions, which impairs the Yb^{3+} luminescence. CaF_2 appears then to be particularly interesting. A low Yb^{3+} concentration, only 2%, is sufficient to obtain 97% energy transfer efficiency because of the creation of Pr^{3+}/Yb^{3+} clusters [3]. This clustering effect limits the need for a high Yb^{3+} concentration and therefore reduces the Yb^{3+} concentration quenching in CaF_2. A detailed study of the CaF_2 clustering process is then required for a better understanding of the experimental results so as to assess precisely the potential of CaF_2: Pr^{3+}, Yb^{3+} as an effective luminescent converter.

References

[1] T. Trupke et M. A. Green, *J. Appl. Phys.* 92 (3), (2002), 1668-1674
[2] D. Serrano et al., *Opt. Mat.* 33, (2011),1028-1031
[3] D. Serrano, A. Braud, J.-L. Doualan, P. Camy, et R. Moncorgé, *J. Op. Soc. Am. B* 28 (7), (2011), 1760-1765

Real-time imaging through scattering medium in the therapeutic window with optical phase conjugation

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Scattering is the main obstacle to imaging in diffusing medium: the ballistic component decreases exponentially and is quickly masked by the scattered part. Recent experiments have shown that scattering is an elastic process and could be compensated using phase conjugation, the optical version of time-reversal [1,2]. The presented experiment uses a near infra-red wavelength, polarization control and acquistion times of the order of the nanosecond. Image reconstruction quality and fidelity are discussed and systematically compared with direct imaging, through thick and thin samples. Potential applications include imaging in biological tissues, thanks to a wavelength in the therapeutical window and acquisition times well below the decorrelation time of biological tissues (0.1 ms).

[1] «Optical phase conjugation for turbidity suppression in biological samples,» Z. Yaqoob et. al., Nature Photonics 2 (2008).
[2] «Image transmission through an opaque material,» S. M. Popoff et. al., Nature Communications 1 (2010).

Extraordinary transmission through nano-slits to actively control the optical near-field distribution

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The spatial confinement of light is limited by diffraction to about $\lambda/2$, that is to say a few hundreds of nanometers (l is the wavelength of the light in question). However, many applications (data storage, addressing, miniaturization of optical components, fluorescence of single molecule...) would benefit from a sub-wavelength confinement (i.e. less than $\lambda/2$). To this end, many studies propose to exploit plasmon resonance [1,2]. Nevertheless, it has been recently demonstrated that a sub-wavelength confinement could be obtained without plasmon thanks to a guided mode excited in nano-apertures engraved in an opaque metallic film [3]. In that theoretical paper, phase, amplitude and polarization of the incident field are simultaneously controlled to successively "turn on“ the five letters of the nano-word “FEMTO” which consists of rectangular slits of different sizes. The simultaneous control of phase, amplitude and polarization is not obvious to achieve experimentally, so we propose to limit our study to spatial control. This latter is obtained by exciting the fundamental mode of rectangular nano-apertures.

Bowtie nano-aperture as polarizing near-filed probe

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In this paper, we propose to use a single bowtie nanoaperture (BNA) to interface diffraction-limited single-mode optical fibers with near-fields and nano-optical structures. To improve the nanoantenna-to-fiber optical coupling, the BNA is opened at the apex of a specially designed metal-coated tapered tip. As a first application, we propose to use our nanoantenna fiber probe as an integrated nanocollector for Scanning Near-Field Optical microscopy (SNOM). We demonstrate that it behaves as a high resolution polarizing nanocollector with little sensitivity to the magnetic field. This fiber probe opens new perspectives in SNOM imaging, nanolithography, addressing and telecommunications as well as in situ biological and chemical probing and trapping.

Diabolo magnetic nano-antenna

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Inspired by the Babinet's Principle, which is strictly valid only for infinitely thin ideal conductors, we propose the complementary bowtie nanostructure of a pair of tip-to-tip oriented triangular apertures in a metal film as a new concept of a magnetic nanoantenna aimed at confining and enhancing the optical magnetic field. The electromagnetic process at the origin of the generation of the magnetic hot spot will be presented and the antenna's optical performance will be discussed. This new magnetic antenna may be applied to locally create high magnetic fields or sensitively detect magnetic fields at optical frequencies.

$LiNbO_3$ Photonic Crystals on ridges: toward 3D tunable micro-components

Nadège Courjal, Gwenn Ulliac, Jean Dahdah, Blandine Guichardaz, Clément Guyot, Hui-Hui Lu, Maria-Pilar Bernal, Benattou Sadani et Fadi Baida

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Keywords: Lithium niobate, Photonic Crystal, Micro-waveguides

We present the performances of $LiNbO_3$ Photonic Crystals made on deep ridges. The PhCs were patterned by Focused Ion Beam (FIB) milling, and the ridges were machined with a circular precision saw. The first optical characterizations show a partial photonic bandgap with an extinction of -14 dB for 10µm-large PhCs. The developed technologies are opening the way for 3D structures of the material on thin $LiNbO_3$ films with strong index contrasts.

Tunable optical delay using parametric amplification in highly birefringent optical fibers

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We theoretically study parametric amplification in highly birefringent optical fibers and demonstrate that tunable sub-nanosecond pulse optical delay or advancement can be achieved via slow and fast light propagation. We provide a clear derivation of the formula for the optical delay that originates from the imaginary part of the parametric gain. We also perform numerical simulations in both normal and anomalous dispersion regimes. In the latter case, results show that nanosecond optical delay could, in principle, be obtained at 1550nm in a 1-km-long polarization-maintaining fiber. We further demonstrate that the optical delay and advancement rely on a group-velocity locking between the two cross-polarized signal and idler pulses.

Keywords: parametric amplification; birefringent optical fiber; slow and fast light

Electro-optic lithium niobate photonic crystal nano-wire

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The optics community has been using lithium niobate for applications like integrated and nonlinear optics due to its manifold properties like ferroelectricity, piezoelectricity, electrooptics, acoustooptics, nonlinearity etc. Going towards lithium niobate components with small footprints presents an enormous interest since all its intrinsic physical properties can be potentially enhanced by the design of suitable geometries based on slow-light propagation. Only recently it has been demonstrated theoretically as well as experimentally that photonic crystal devices realized on LN show numerous interesting effects. However, etching or structuring this material is far from trivial because of the material's high chemical stability.
In this work we will present electro-optically tunable photonic crystal filters fabricated on thin membranes of lithium niobate.

The Soliton Self-Frequency Shift: a tool for noise detection and spectral shaping

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We present possible applications of the Soliton Self-Frequency Shift (SSFS, spectral shift of a single pulse), making it a multipurpose tool. The first application is the enhancement of low intensity fluctuations of an ultrashort pulse train to detect them more easily than with usual direct detection systems. The second application is the production of quasi-supercontinua made by a quick periodic shift (several kHz to MHz) of the central wavelength of the pulses which can be used to improve the spatial precision of Optical Coherence Tomography (OCT).

Theoretical study of resonance in the near infrared of a nano-antenna (bowtie)

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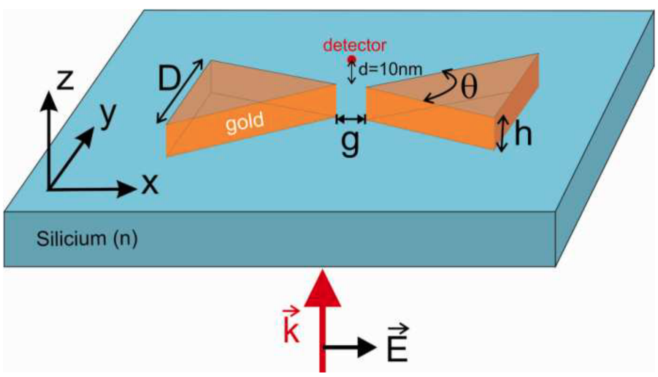
The objective is to study the optical properties of nano antenna resonance (bowtie) using thenumerical method (FDTD). The main feature of these structures lies in their potential to confine the light at the center (gap). We present a theoretical study by the method (FDTD) to determine the geometry of the nano antenna to present a resonance in the near-infrared (telecom frequencies) accompanied by a strong spatial confinement of the electric field. Many applications are concerned, for example study of single molecule, nano-lithography and storage of information.



Resonant diode-pumping of Er:YAG single crystal fiber operating at 1617 nm

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In the majority of configurations, resonantly pumped Er:YAG laser emission occurs at 1645 nm. However, a methane absorption line exists at this wavelength in the atmosphere with a typical value of 0.1 km^{-1}. One way to improve the range and efficiency of Lidar systems is to use the 1617 nm emission line which is free of absorption. We demonstrate for the first time that multiwatt output power at 1617 nm is possible with a resonant diode-pumped Er:YAG system. For that, we investigate the potential of single crystal fibers for pump confinement, high inversion population ratio and thermal management.

One way to increase the range and the efficiency of Er:YAG Lidar systems (or any Er:YAG laser systems requiring kilometer range propagation in the atmosphere) is to use the 1617 nm emission line which is free of absorption, instead of the 1645 nm emission line, absorbed by methane. Even if its emission cross section is higher, laser operation at 1617 nm is more difficult to obtain since the population inversion needed to reach the transparency is 14% of the total population (at 300 K) whereas it is only 9% at 1645 nm. Without any selective element in the cavity, the line competition is generally won by the 1645 nm transition. We demonstrate for the first time that multiwatt output power at 1617 nm is possible with a resonant diode-pumped Er:YAG system. For that, we investigate the potential of single crystal fibers for pump confinement and consequently for high inversion population ratio. We obtained cw output powers of 5,5W at 1617 nm for 65 W of incident pump power at 1532 nm with a measured M^2 less than 1.8. In Q-switched operation, we achieved a maximum energy of 0.5 mJ at 100 Hz with a pulse duration of 28 ns at 1617 nm. This short pulse duration can be attributed to the high gain available thanks to the pump confinement offered by the 600 µm diameter single crystal fiber. The Er: YAG single crystal fibers have the potential for simple, compact and efficient eye-safe lasers at 1617 nm.

Group birefringence cancellation in highly birefringent photonic crystal fibre at telecommunication wavelengths

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The spectral dependence of the group modal birefringence in a highly birefringent nonlinear photonic crystal fibre is studied both numerically and experimentally. The sign of inversion and the cancellation of the group modal birefringence in the telecommunication window is demonstrated. Such a property is advantageous when the suppression of polarization-dependent nonlinearities is desirable.

High energy, high peak power (2.6mJ/5.6MW) or high average power (20W) Nd:YAG single-crystal fiber amplifier in a sub-ns kHz system

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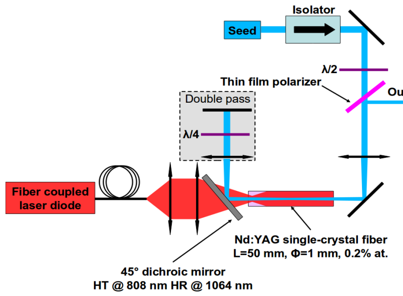
The MOPA (Master Oscillator Power Amplifier) configuration is very useful to extend laser performance of passively Q-switched sub-nanosecond Nd:doped microlaser addressing applications like material processing or instrumentation. Recently the millijoule level with sub-nanosecond pulses at 10 kHz has been demonstrated, but with complex system [1]. Yb fiber amplifiers [2,3] provide more simplicity and higher efficiency but are limited to the MW peak-power due to non-linear effects. Bridging the gap between bulk crystals and glass fibers, single-crystal fibers (SCF) are long and thin rod where the pump is guided (like in fibers) and the signal is unguided (like in bulk materials) propagating with beam size much larger than in typical glass fibers. In this paper, we investigate the potential of SCF as amplifier for different short pulses seed sources.

The experimental setup (Fig. 1-a) consisted in a simple or double pass amplifier using a Nd:YAG SCF (provided by Fibercryst SAS) pumped by a high power fiber coupled laser diode (60 W@808 nm, core diameter 100 µm). After an optical isolator, the signal was sent through a half-wave plate and a polarizer and then focused in the SCF (450 µm diameter). Next, a quarter-wave plate and a concave mirror could be used to send the signal back for a double pass amplification stage. In this case, the output is coming from reflection on the polarizer.

To test the performance in energy, we firstly used a Powerchip^{TM} (Teem Photonics). This seed provided 470 ps, 1 kHz, 80 µJ pulses with an average power of 80 mW. The pump laser diode was run in QCW mode with pulse duration of 310 µs. The Fig. 1-b shows the output pulse energy versus the average incident pump power: we obtained 2.61 mJ pulses for 23 W of average pump power in double pass configuration. This corresponds to a gain of 32.6 and a peak power of 5.6 MW, clearly beyond the typical limit of fiber amplifiers. There was no visible change in the pulse duration and the M² factor remained below 1.33 (M^2 seed was 1.2).



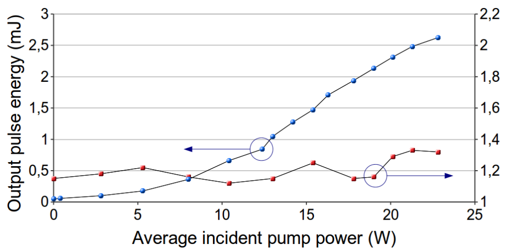


Fig. 1 a) Experimental setup. b) Output pulse energy (blue circle) and M² factor (red square) versus the incident pump power with the Powerchip^{TM} in a double pass configuration.

To test the performance in average power, we used a PicoSpark^{TM} (Teem Photonics) providing 1 ns, 42 kHz, 120 µJ pulses with an average power of 5 W. The Fig. 1-c shows the output average power versus the incident pump power in single pass: we obtained an output power of 20.5 W for an incident pump power of 60 W. This corresponds to a pulse energy of 490 µJ, a peak power of 490 kW and to an efficiency higher than 25%. After amplification, the M^2 factor stood below 1.3 (M^2 seed was 1.2), for output power up to 17.4W, then increased to 1.6 at maximum pump power.

In conclusion, the very good performance reached by the SCF demonstrate that it combines the advantages of fibers and bulk crystals for high peak power and high average power. As bulk amplifiers, the SCF is able to produce high peak power pulses and as fiber amplifiers, it can reach good efficiency with a simple design.

References

[1] A. Gaydardzhiev, D. Draganov and I. Buchvarov, 4th EPS-QEOD EUROPHOTON CONFERENCE, Hamburg, Sept 2010, WeP18.
[2] A. Galvanauskas, M. Cheng, K. Hou and K. Liao, IEEE J. of Quant. Elec. 13, 559 (2007).

Autofocalisation adiabatique par une non linéarité accordable

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Notre travail porte sur la mise en forme spatiale de faisceaux par propagation dans des milieux non linéaires. L'étude s'intéresse en particulier à la focalisation adiabatique dans un milieu à non linéarité variable. La formation de guides adiabatiques induits par des faisceaux auto-piégés est présentée. Le concept proposé est basé sur l'utilisation d'une nonlinéarité focalisante dont l'amplitude varie au cours de la propagation. Les démonstrations expérimentales sont réalisées dans des cristaux de LiNbO3 où l'effet non linéaire photoréfractif est contrôlé par la température.
La théorie des solitons spatiaux [1] montre que pour une nonlinéarité focalisante donnée, il n'existe qu'un seul diamètre de faisceau qui peut se propager en conservant un profil invariant. Si un faisceau aux caractéristiques inadaptées est injecté dans ce milieu, la distribution de lumière va être modifiée et, au final, une dislocation du faisceau peut se produire sous l'effet de l'instabilité de modulation [2]. Nous proposons d'utiliser des milieux dont la non linéarité est modulée spatialement afin de contrôler les propriétés autofocalisantes et ainsi d'augmenter les capacités de mise en forme de faisceaux par effet non linéaire.
Nous appliquons ce concept afin de focaliser progressivement un faisceau initialement large. L'autofocalisation de la lumière est contrôlée par une non linéarité photoréfractive dont l'amplitude augmente au cours de la propagation. La focalisation adiabatique progressive obtenue (figure 1) permet d'induire un guide circulaire formant un guide adiabatique mémorisé dans le milieu. Les démonstrations expérimentales sont réalisées dans le LiNbO3 dont les propriétés non linéaires photoréfractives sont ajustées spatialement à l'aide d'un gradient de température. Ce contrôle de la non linéarité est basée sur l'exploitation de l'effet pyroélectrique qui permet, comme nous l'avons récemment démontré [3], d'obtenir un effet non linéaire focalisant efficace permettant la génération de solitons spatiaux à l'aide d'une élévation modeste de la température du LiNbO3.

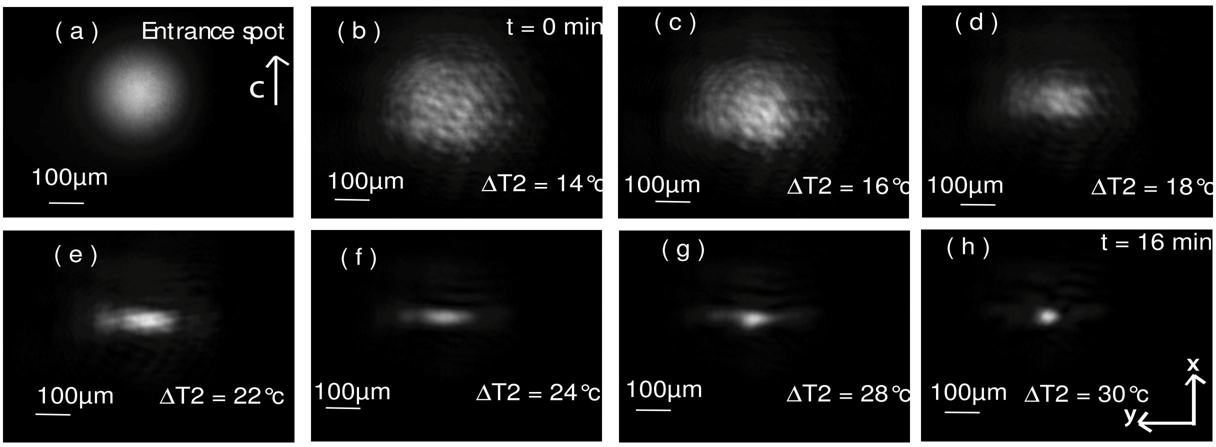


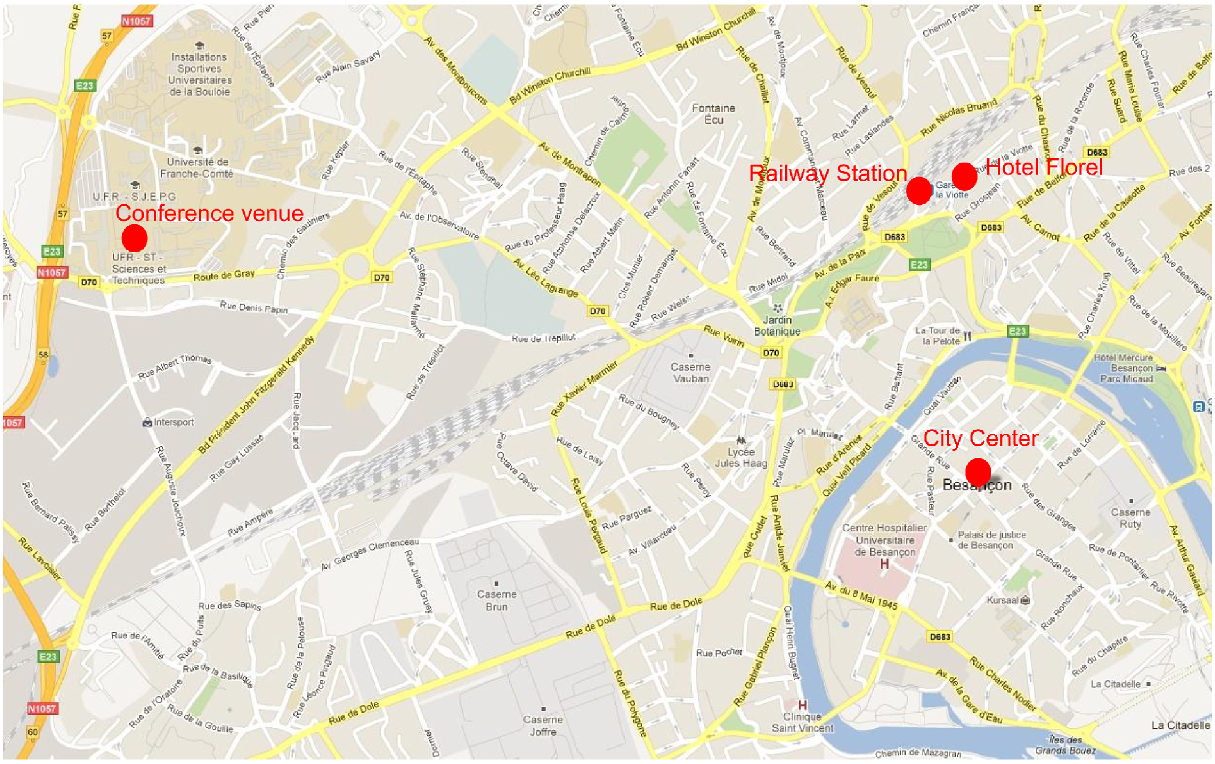
Fig. (1): Dynamique de l'autofocalisation induit par une augmentation de la température de sortie T_2
. Paramètres : T_1=30°C, P= 60µw

Un faisceau similaire au précédent est injecté (fig. 1a) dans le cristal et les températures initiales sont T1=30°C, à l'entrée du cristal, et T2=32°C à la sortie (fig. 1b). Ces températures légèrement au dessus de la température ambiante (température d'équilibre du cristal) font apparaître une focalisation très faible (Fig. 1d) car l'effet non linéaire est proportionnel à l'écart de température avec l'ambiant. On constate qu'avec cette méthode la lumière se focalise sans apparition de dislocation. En augmentant la température T2 jusqu'à 48°C (ΔT2=30°C).

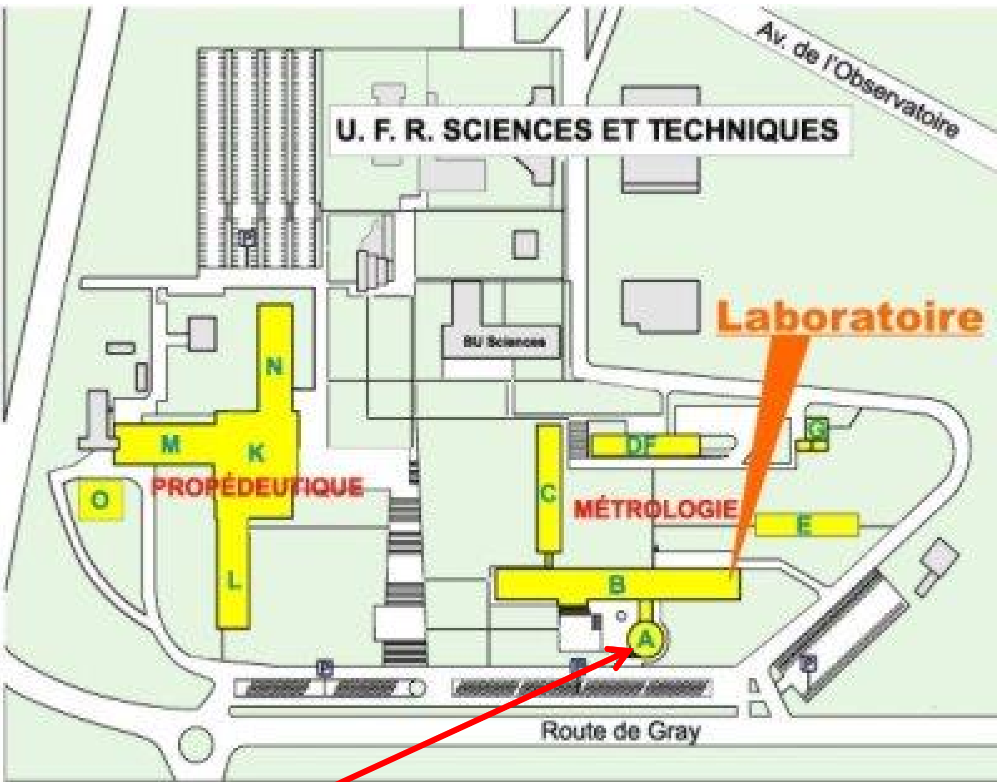
Références

[1] A. D. Boardman, A. P. Sukhorukov, Soliton Driven Photonics (Kluwer Acad. Publ., Dordrecht, 2001).
[2] A. V. Mamaev, M. Saffman and A. A. Zozulya. "Breakup of two-dimensional bright spatial solitons due to transverse modulation instability", Europhys letters. **35**, pp. 25-30 (1996).
[3] J. Safioui, F. Devaux, M. Chauvet, "Pyroliton: pyroelectric spatial soliton," Opt. Express, **17**, no. 24, p. 22209, 2009.

Besançon Map



Campus Map



Conference venue : Amphi A, Métrologie Building