

Fabrication of Large Scale Nanofocusing Device Based on Negative Refraction Index Photonic Crystals

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The Molecular Foundry at Lawrence Berkeley National Laboratory is a User Facility charged with providing support to research in Nanoscience underway in academic, government and industrial laboratories around the world. The Foundry provides users with instruments, techniques and collaborators to enhance their studies of the synthesis, characterization and theory of nanoscale materials. Its focus is on the multidisciplinary development and understanding of both “soft” (biological and polymeric) and “hard” (inorganic and nanofabricated) nanostructured building blocks and the integration of those building blocks into complex functional assemblies. The Molecular Foundry houses six facilities and offers access to a variety of affiliated laboratories in support of users as well as the in-house research programs. The nanofabrication facility provides instruments and techniques dedicated to state-of-the-art lithographic and thin-film processing. Processes and techniques relevant to the integration of advanced semiconductor nanofabrication technologies with chemical and biological nanosystems are emphasized. The facility also features high-resolution nanolithography and etching capabilities as well as thin-film deposition of a variety of materials, and thermal and wet processing.

Photonic crystals (PhCs) are an especially promising tool for the on-chip integration of silicon based ultra-compact nanophotonic circuits that manipulate the light signals. Typical design of a PhC devices exploits the photonic band gap, in general introducing some defect state to manage the gap property.

The negative refraction is another very exciting property of PhCs. The propagation in an opposite direction with respect to the usual refraction laws allows new devices, such as the superlens that make possible a subwavelength definition in the far field domain [1]. In this work we present the fabrication of a photonic device for an unconventional application based on the negative refraction properties of PhC in combination with positive index region. From one side the negative index allows an impedance matching, maximizing the coupling with external medium. The theoretical limitation of coupling efficiency, given by the numerical aperture, is overcome enhancing the evanescent component of the incident wave. This is possible creating resonance states on the surface, thanks to an accurate determination of the PhC termination [2]. Using a Silicon On Insulator (SOI) 200 nm thick silicon crystalline layer on 1 μm thick oxide substrate [3], we spun 300 nm ZEP 520A e-beam positive Resist. We exposed the pattern by Vistec VB300 EBL System and we transferred the pattern by ICP RIE by HBr recipe [4]. The pattern was transferred selectively on the silicon layer only. By using focused ion beam lithographic system, a big section just external of the PhC of about 200 μm x 300 μm of the oxide layer and of the silicon substrate was removed to allow the positioning of an optical fibre probe; from one side to illuminate the pattern and from the other side to receive the light. Furthermore alternating properly dimensioned positive and negative index region produces a tightly confined guided light where the beam FWHM is less than 1 μm in correspondence of a free space wavelength equal to 1.55 μm . In order to investigate potentialities for practical applications, we analyze the robustness respect to small fabrication defects randomly distributed

studying experimental performances of negative refraction devices over a large scale region (several millimeters). Some preliminary optical characterization will be discussed in the paper.

[1] R. Moussa, S. Foteinopoulou, Lei Zhang, G. Tuttle, K. Guven, E. Ozbay, C. M. Soukoulis, "Negative refraction and superlens behavior in a two-dimensional photonic crystal", *Phys. Rev. B* **71** 085106 (2005)

[2] S. Xiao, M. Qiu, Z. Ruan, S. He "Influence of the surface termination to the point imaging by a photonic crystal slab with negative refraction" *Appl. Phys. Lett.* 85(19) 4269-4271 (2004).

[3] W. Bogaerts, D. Taillaert, B. Luyssaert, P. Dumon, J. Van Campenhout, P. Bienstman, D. Van Thourhout, R. Baets, V. Wiaux, and S. Beckx "Basic structures for photonic integrated circuits in Silicon-on-insulator" *Optics Express*, Vol. 12, Issue 8, pp. 1583-1591(2004)

[4] D. Olynick, A. Liddle, I. Rangelow "Profile evolution of Cr masked features undergoing HBr-inductively coupled plasma etching for use in 25 nm silicon nanoimprint templates" *J. vac. sci. technol., B.*, Microelectron. nanometer struct. process. meas. phenom 2005, vol.23, n5, pp.2073-2077

TOPIC: New active and passive devices in optoelectronics.

DEMONSTRATION OF AN OPTICAL FIBER FRESNEL LENS: THEORY AND EXPERIMENT

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The light output of an optical fiber end face generally expands through diffraction and is not usable for many devices. It is often desirable to have a collimated or focused beam for coupling, detection or even microscopy. Traditionally this is achieved by the addition of bulk optical elements such as lenses, which requires added integration complexity to a system. Many of these elements are difficult to fabricate. We demonstrate the application of a novel alternative lens created at the end face of a fiber which is based on a Fresnel lens design. The lens is intrinsically aligned with the core of the fiber and is simple to manufacture singly, or in large quantities. Further, it takes advantage of the natural fabrication processes used in making optical fibre. A model of the lens' focusing properties is presented based on the lens geometry and scalar-wave diffraction simulations. Measurements of the lens' focusing properties are also presented, and are found to be in excellent agreement with the model. We demonstrate a complete method by which an optical fiber Fresnel lens can be manufactured to provide a specific focal length lens at the end face of a fiber and the means to verify that the lens indeed performs to that specification.

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TOPIC: High-super resolution methods in optical microscopy (INVITED)

3D RESOLUTION IN OPTICAL SCANNING MICROSCOPY

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Since Abbe formulated his wave theory for microscopic imaging, the improvement of resolution of optical microscopes has been the aim of many research efforts. In the search for the maximum resolution, emphasis has been generally placed on the use of modern microscope objectives with the highest available numerical aperture (NA). But even with the best optical elements the use of conventional optical microscopes to image three-dimensional fluorescent samples has the drawback that any image focused at certain depth in the sample contains blurred information from the rest of the sample. This fact gives rise to 3-D images with strongly deteriorated contrast. In this context, this talk will be mainly devoted to optical-sectioning fluorescence techniques. Among them we cite single-photon confocal microscopes, confocal theta microscopy, structured-illumination microscopy, or selective plane illumination microscopy. Other solution is achieved by the use of two-photon excitation scanning microscopy, like in the case of 4Pi microscopes or the stimulated emission depletion microscopy.

Silicon-based Nanomaterials and Plasmonic Structures

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The big scientific challenge behind silicon (Si) photonics is the development of Si-based active devices, i.e. efficient LEDs, sensors, modulators and ultimately of silicon-based lasers [1]. It has been widely recognized that the development of efficient silicon-based light emitting diodes (LEDs) and laser structures would constitute a technology with an enormous societal impact, enabling full on-chip integration of optical functions within the impressive volume market of integrated microelectronics, namely CMOS technology.

The purpose of my research activities is: a) to engineer novel, nanostructured-based materials solutions for CMOS-compatible light sources and lasers, b) to design and fabricate novel metal/dielectric plasmon-coupled nanostructures for the control of local electromagnetic fields on Si chips.

In this talk **I will give a panoramic overview of my research activities in Silicon-based photonics and plasmonics**. The research is aimed at engineering potential new solutions for CMOS-compatible light emission and light control in silicon-based systems of reduced dimensionality, where quantum confinement, surface chemistry and plasmonic coupling play a crucial role in determining the optical properties of nanomaterials.

I will review the main results obtained along two closely related research directions: the use of nano-sized silicon to achieve efficient light emission and optical amplification²⁻⁴ and the possibility to control and manipulate deeply confined light states in metal-dielectric nanostructures without translational invariance⁵. Finally, I will discuss our recent work on E-beam fabrication of aperiodic metal/dielectric nanostructures and plasmonics slot waveguides as a very promising approach for transport and sub-wavelength manipulation of electromagnetic fields on Si chips⁶.

References:

1. N. Savage, "Light from Silicon: Holy Grail", IEEE Spectrum, 59, January 2004.
2. L. Pavesi, L. Dal Negro, C. Mazzoleni, G. Franzo and F. Priolo, *Optical gain in silicon nanocrystals*, Nature 408, pp. 440-444, 2000.
3. L. Dal Negro, J.H. Yi, Y. Yi, V. Nguyen, J. Michel, L.C. Kimerling, "Spectrally enhanced light emission from aperiodic photonic structures" Appl. Phys. Lett., 86, 261905, 2005
4. L. Dal Negro, J.H. Yi, J. Michel, L. C. Kimerling, T.-W. F. Chang, V. Sukhovatkin, E. H. Sargent, "Light Emission Efficiency and Dynamics in Silicon-rich Silicon nitride films", Appl. Phys. Lett., 88, 233109, 2006
5. L. Dal Negro, A. Gopinath, N. Feng, M. Brongersma *A Method for the extension in 2 and 3 dimensions of deterministically generated aperiodic optical materials*, patent disclosure Boston University and Stanford University, 2006

6. Ning-Ning Feng, Mark Brongersma, & Luca Dal Negro “*Metal-dielectric slot waveguide structures for the propagation of surface plasmon polaritons at 1.55 μm* ”, accepted for publication in IEEE Journal of Quantum Electronics, 2007.

NANOPHOTONICS DEVICES BASED ON PLASMONICS STRUCTURES

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The subwavelength structures formed in metal materials can create fantastic optical phenomena to the incident light by mean of the generated surface plasmon resonant wave and their coupling activities. Based on the principle, a series of subwavelength structures for generating either surface plasmon resonant wave or localized surface plasmon resonant mode are designed and fabricated. Consequentially, the nanophotonics devices like chips for biosensor, nano-lenses, nano-prisms as well as their optical properties are presented and discussed.

Nanophotonics in Information Systems

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Abstract

The field of nanophotonics is finding myriad applications in information technology, health care, lighting, sensing and national security. Experts predict that nanolithography will reach a resolution of 16 nm by 2020, and that both top-down and bottom-up integration methods will become feasible, enabling reliable, scalable, power-efficient and cost-effective methods for the miniaturization of future systems. Over the past decade, significant progress has been made in the engineering of inhomogeneous composite materials (e.g., dielectrics, semiconductors, metals, organic, quantum dots) and nanophotonic devices with unique optical properties such as polarization and spectral dispersion, negative refraction, nonlinear polarization and quantum effects. Numerous applications, however, rely on our ability to create adaptive and reconfigurable optical devices as well as interfacing with biological and biochemical processes. These applications led to establishing a new research area that we call optofluidics, where fluids are used to create adaptive optical elements, control them, as well as establish interfaces with biochemical systems. We will present our recent research results on nanophotonics and optofluidics, as well as on their integration into sub-systems.

Metamaterials: A Route for Molecular Scale Imaging

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Abstract

Recent theory predicted a new class of materials made of artificial atoms and molecules that offer unusual optical and acoustic responses that are nonexistent in nature. For example, a theoretical superlens is proposed, which has potential of focusing the light far below the diffraction limit. These metamaterials could have profound impact in a wide range of applications such as real-time imaging and manipulation at molecular scale.

In this talk, I will discuss the progress of making these artificial metamaterials for optical and acoustic imaging purposes. We demonstrated, for the first time, the THz magnetic resonance and ultrasonic materials with negative stiffness via artificially structured elements. Furthermore, we confirmed a key proposition of superlens theory: the recovery of evanescent waves via excitation of surface plasmons. Using silver as a natural optical superlens, we recently demonstrated sub-diffraction-limited near-field imaging with 30nm half-pitch resolution, or 1/12 of the illumination wavelength. The plasmonic structures indeed promise exciting avenues to nanoscale optical imaging and highly compact optoelectronic devices.

Biosketch:

Nicholas Xuanlai Fang is an assistant professor of Mechanical Science and Engineering at the University of Illinois at Urbana-Champaign. He received his PhD of Mechanical Engineering in February 2004, majoring MEMS/Nanotechnology from the University of California-Los Angeles(UCLA), under Professor Xiang Zhang. He also holds MS (1998) and BS (1996) degrees in Physics from Nanjing University, China. Dr. Fang is very active in the field of nanophotonics and nanofabrication, with several key publications in *Science*, *Nature Materials* and *Nano Letters*. His research highlight includes first demonstration of optical superlensing (listed by SCI as a fast breaking paper of physics in April 2006), invention of far IR magnetic/plasmonic metamaterials, and development of 3D micro/nanolithography systems. He is also interested in the design and manufacturing of photonic bandgap structures and devices and energy and mass transport phenomena in micro- and nanoscale systems. Dr Fang is the recipient of the ASME Pi Tau Sigma Gold Medal of 2006, in recognition of his outstanding achievement in mechanical engineering. He served as a symposium co-organizer of MRS spring 2006 meeting, with focus on optical negative index materials.

Tunable Superprism Structures

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Photonic crystal superprism structures exhibit a rapid change in the group propagation direction with wavelength. For a fixed wavelength, a small change of the refractive index in such a superprism structure also results in a rapid change in the group propagation direction. The angular tuning is significantly enhanced compared to a bulk material allowing for compact devices on the sub-millimeter scale.

The proper design of the tunable superprism structure is essential for optimizing device performance. We compare different design approaches for active one-dimensional photonic nanostructures. Such structures can be realized as multilayer thin-film stacks or alternatively in a planar waveguide geometry. We evaluate the most effective position for integrating active layers and compare designs with respect to performance parameters such as switching energy and necessary number of active layers.

We experimentally demonstrate thermo-optic tuning of the effective group propagation direction in an active thin-film stack. A hybrid organic-inorganic resonator design is used to achieve a large change in the group propagation angle with temperature. Tunable superprism devices are interesting for reconfigurable optical systems without moving parts.

IMPROVED PERFORMANCE THREE DIMENSIONAL SENSING AND VISUALIZATION BY INTEGRAL IMAGING

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This Plenary Address is an overview of recent advances in Three-dimensional (3D) sensing, imaging and display based on integral imaging. There are numerous applications of this technology including, computer-aided design, medical 3D imaging, 3D visualization, 3D identification and inspection, 3D television, 3D video, 3D multimedia, interactive communication, education, entertainment, and commerce.

Linear and Nonlinear Processes in Crystalline Whispering Gallery Mode Resonators: Physics and Applications

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And
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Recent progress in fabrication of crystalline whispering gallery mode resonators (WGM) has produced structures with varied morphologies, sizes, and extremely narrow linewidths. Resonators with quality factors (Q) exceeding 3×10^{11} have been produced, allowing realization of a host of linear and nonlinear applications, ranging from filters to low threshold Raman lasers. Resonators made with electrooptic materials, such as lithium niobate, allow study of photorefractivity with extremely low input power, providing the opportunity to perform material studies and the mechanisms for change of index with input light. These resonators, on the other hand, enable realization of extremely efficient modulators and widely tunable filters, which in turn lead to new and powerful architectures for microwave signal processing in the optical domain. Finally, material with second order nonlinearity can be used to fabricate resonators that produced entangled photon pairs and squeezed vacuum for quantum information processing applications, and metrology. In this talk an overview of crystalline WGM resonators will be followed by the discussion of linear and nonlinear properties. A wide range of applications in science and technology will be presented, together with the latest results in demonstration of these capabilities.

NON LINEAR OPTICAL MANIPULATION IN LIVING CELL

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In this contribution, optical manipulation of living cell functionality with laser light will be shown. In particular, it will be described how it is possible to obtain information on cell division mechanism by optical microtrapping and nano-surgery operation on subcellular part. Furthermore, it will be shown the possibility to control ERG channel current via light, up to the complete inhibition of pump channel current. Finally, a nanosurgery experiment will be shown on a living mice, demonstrating the Central Nervous System reaction to a local damage in an intact neural network. From the methodological point of view, it will be shown the principle of operation of optical micro-trapping, optical nanosurgery and optical knock-out. Some methodological studies and results will be shown regarding the nanosurgery features of label subcellular samples, and the optical knock-out of proteins, comparing photodamage with photobleaching

Quantitative phase imaging of live cells

Gabriel Popescu

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Phase contrast (PC) and differential interference contrast (DIC) microscopy have been used extensively to infer morphometric features of live cells without the need for exogenous contrast agents. These techniques transfer the information encoded in the phase of the imaging field into the irradiance distribution of the final image. However, both PC and DIC are *qualitative* in terms of optical path-length measurement, i.e. the relationship between the irradiance and phase of the image field is generally nonlinear. *Quantifying* the optical phase shifts associated with cells gives access to information about morphology and dynamics at the nanometer scale. Over the past decade, the development of *quantitative phase imaging* techniques has received increased scientific interest. The technology can be divided into *single-point* and *full-field* measurements, according to the experimental geometry employed. The single-point techniques, often extensions to optical coherence tomography, allow for fiber-optic implementation and also high-speed punctual phase measurement by using a single fast photodetector. Full-field phase measurement techniques, on the other hand, provide simultaneous information from a large number of points on the sample, which has the benefit of studying both the temporal and spatial behavior of the biological system under investigation. I will review the main quantitative phase imaging techniques reported in the literature and their current biomedical applications. Potential future cell imaging applications will be discussed.

NEW FRONTIERS IN ADAPTIVE OPTICS

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Adaptive Optics is a complex of techniques and technologies that has been demonstrated over the past twenty-five years. The discipline has reached a level of maturity and respects and it is a forum of specialized conferences around the world on a yearly basis. However, the arrival of new technologies is generating a renaissance of the discipline. The use of MEMs , MOEMs and liquid crystal devices is creating new compact and more cost effective systems. This trend has opened the flood-gate for applications in various areas such as medical and industrial applications. In this talk I will review the general principles of Adaptive Optics, with some historical background. I will, then, proceed to examine our experience with MEMs/MOEMs and liquid crystal devices for adaptive optics. Both theoretical and experimental results will be presented. I will also present some new trends that our group is working on like Carbon Fiber Reinforced Polymers (CFRP) has a material for the manufacturing of deformable mirrors of large format. An overview of the growing field of applications of Adaptive Optics will be given.

TOPIC: New characterization methods for materials and devices

Performance advances in interferometry for imaging and testing

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Interferometric techniques have been for almost two decades key tools for inspection of surface profile of engineering surfaces. Their non-contact, fast and full-field measurements delivered results with down to fraction of a micron lateral and down to fraction of nanometer vertical resolution. Over last decade the advancements have allowed for the analysis of not only static objects but also dynamic objects, like cantilevers and other MEMS devices that move or vibrate at over 1 MHz frequencies.

Recently, special objectives and illumination sources have allowed for imaging and testing surfaces in environmental or protective chambers or those immersed in liquids. In addition, advanced analysis of interference signals has allowed for the measurement of not just the surface profile but also transparent coatings along with surface profiles. While the measurement of thick (over 2 micron) transparent films has been possible for many years, recent advancements have enabled the measurement of thicknesses down to a few tens of nanometers.

Interferometry has been integral to the development of many hi-tech devices because these interferometric techniques have allowed for the precise characterization of the properties and structures of many advanced engineering technologies. For example, interferometry is used to determine the degree of structural uniformity of statistically significant samplings of micro-opto-electromechanical (MOEMS) mirrors, and interferometric techniques can ascertain physical, chemical or biochemical stimuli by measuring the behavior of cantilevers vibrating at very high frequency resonant modes.

A recent application for interferometric techniques involves real time diagnostics of cell structure, metabolism and movement. This understanding of cell behavior is gained through the measurement of “nanomirrors” attached to the cell membrane; however, it is also possible to observe some cells directly without any staining or labeling techniques. The focus of this talk will be a description of both recent advances in interferometric imaging and testing as well as newly emerging applications.

TOPIC: Micro-nano engineering of ferroelectric materials.

DOMAIN ENGINEERED DEVICES IN FERROELECTRICS FOR BEAM MANIPULATION

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Ferroelectrics provide a versatile solid-state platform for microphotonics. Domain engineering in ferroelectric single crystals offers the ability to integrate diverse optical functions, such as frequency conversion, dynamic focusing, and beam deflection, seamlessly integrated in a single device.

In this talk, we describe the design, fabrication and performance of an array of electro-optic tunable microphotonic devices on a ferroelectric chip of LiNbO₃ and LiTaO₃ using domain micropatterning. Electric poling methods to create domain structures will be covered including in-situ monitoring techniques. The performance of several novel devices will be described, including a dynamical focusing lens stack of bi-convex parabolic lenses, and various beam deflectors including a cascaded scanner capable of deflection of 25.4 deg, a beamlet scanner capable of deflecting 10 deg a 6.5 mm diameter beam at a wavelength of 1064 microns, and a hybrid two dimensional scanning system incorporating both a piezoelectric and an electro-optic deflector.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

UV WRITTEN WAVEGUIDES – APPLICATIONS IN TELECOMS AND SENSORS

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In recent years, ultra-violet laser direct writing has been recognized as a technique that provides a powerful way of creating integrated optical devices. We will describe the developments in this field, concentrating on the use of two-beam writing to create Bragg gratings in planar integrated format. In this paper we will show how our UV writing technique can be used to fabricate structures required in a wide range of applications, from the creation of wide-band couplers, through to highly sensitive integrated sensor devices. The direct computer control in UV direct writing removes many of the constraints that normally limit planar integrated optics. In particular, it dispenses with the photolithography and etching steps traditionally required to make low-loss waveguide devices. The work reported will show how this flexibility of UV writing may be enhanced by using novel substrate structures that allow new device types.

Results will be presented on Bragg grating sensors for solvent purity, biological layer measurement, phase changes and strain. Further results will include a demonstration of Liquid Crystal tuned Bragg grating devices yielding greater than 100GHz spectral tuning. Novel substrate configurations include a flat-fibre geometry based on MCVD fibre preform manufacture allowing devices with millimetre scale widths and 10's of cm lengths.

SEMICONDUCTOR LASERS

SOME NEW ROLES FOR SEMICONDUCTOR LASERS

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We will discuss progress with optical phase locking of semiconductor lasers for two purposes: (1) coherent power combining and (2) coherence transfer from master reference lasers to off-the-shelf and relatively noisy semiconductor lasers. The relevant laser physics, control theory, and the electronic feedback issues and solutions will be reviewed.

Photonic Transistors in Silicon

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In this paper we present various techniques for realizing all-optical and electro-optical transistors in silicon. Three main concepts are presented. In the first we show the realization of an all-optical transistor in which the information as well as the control command are optical. The concept includes activation of the plasma effect in silicon in special miniaturized interferometer. The transistor is turned ON and OFF by using spatially non uniform illumination that breaks the balancing between the two interferometer arms. The second concept includes realization of an electro-optical transistor where the control is electronic and the information is optical. The operation principle is based upon photons interacting with metal-oxide-semiconductor (MOS) structure while the external electronic command generates population inversion which affects the absorption of the light passing through the silicon waveguide. The third concept is based upon photo-activated transistors in which the information is electronic and the control command is optical. The free carriers are generated in the silicon due to the external illumination and this varies the electronic resistance of the channel through which the information electrons are passing. The photonic transistors that are realized in all these concepts have nano scale dimensions and fast operation rates.

TOPIC: New materials and technologies

**PLANAR META-MATERIALS
– THE NEW ELEMENTAL BASE FOR NANOPHOTONICS**

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Patterning of thin metal films on the sub-wavelength scale can yield a range of functionalities invaluable for nanophotonic application. This includes mimicking properties of conventional bulk media such as anisotropy and gyrotropy, but most importantly nanoscale patterning can lead to new functionalities, not available in natural materials. This includes stop bands and narrow resonances with strong dispersion analogues to that of the EIT media, invisibility and optical frequency superconductor behaviour. Nano-structured films can enforce asymmetry of light's propagation in the opposite directions and create sub-wavelength far-field concentrations of light.

TOPIC: Application of optical systems.

OPTICAL CHOPPERS REVISITED

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The study achieves a rigorous mathematical analysis of the optical choppers, considered in their general constructive solution, with n symmetrical wings. The characteristic parameters and working functions of the device are ascertained: the function of the transmitted flux, the transmission coefficient, and the significant energetic relationships that result. Both aspects that may be used in the optical systems are considered: the simplified case, of a light fascicle of small diameter in the plane of the chopper, and the general case, of a fascicle of large diameter. A top-hat distribution of the light beam is presumed. Different cases are taken into account for the large diameter beam, with regard to the relationship between the angular dimensions of the chopper (the angle of the wings and of the space in-between) and those of the light beam. A complete discussion regarding the transmitted flux that may be obtained (its different functions) results. From this mathematical analysis, the designing calculus of the device is developed, in its essential steps. Final remarks are made on the most general case, of a distribution of the light beam that is not a top-hat one. These considerations are useful in order to be able to design the chopper in the way a specified, desired shape of the function of the transmitted flux may be obtained. An experimental stall has been build for the study of the choppers, and the most significant results are presented, verifying the theoretical ascertainments.

TOPIC: Genomics and proteomics

SYNERGY BETWEEN FLOW CITOMETRY AND RT-PCR IN THE STUDY OF CANCER CELLS APOPTOSIS

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The paper focuses on the synergy of two modern methods - flow-citometry and Real-Time PCR - used in the study of the apoptosis dynamics in rat cancer cells treated with natural compounds. The differences between the two methods, and the way the collected and analyzed data match and support each other are discussed. The natural extracts have been tested both *in vitro* and *in vivo* experiments, in order to obtain the main purpose: to stimulate the induction of apoptosis in rat cancer cells. Several examples concerning the *in vitro* results are considered. The *in vivo* study confirms the previous, *in vitro*, results. We highlight the way the *in vivo* part of the study raises more questions, opening a broader horizon for further investigations. The study is also expanded to human cancer cells. The purpose is obtaining a more complete image regarding the molecular mechanisms involved in apoptosis dynamics, in different types of animal and human cancer cells.

TOPIC: Optical microsystems and microsensors

SELF-ALIGNED POLYMER MICROLENSES FABRICATION FOR VCSEL BEAM SHAPING

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We report on the design and fabrication of polymer microlenses fabricated on patterned SU-8 layers in view of integrating microlenses on VCSEL arrays for laser beam shaping. Such an integrated optical system allows for reduction in packaging costs and makes VCSEL integration in microsystems easier. For a standard top-emitting VCSEL, the lens has to be fabricated on a thick intermediate layer (pedestal). The optimal thickness of this pedestal can be modelled as a function of the initial and of the aimed optical properties of the VCSEL beam. In this work, pedestals are fabricated with SU-8, which is a negative-tone photoresist transparent at the lasing wavelength. Lens deposition is realized using a robotized silicon microcantilever spotter technique [1] after a simple SU-8 photolithography step in order to define high aspect ratio cylindrical pedestals with wide range diameters [40-140 μm]. The effect of pedestal diameter on the final contact angle and curvature radius has been investigated using non contact optical profilometry and scanning electron microscopy (SEM). We show that this technique leads to a complete delimitation of the polymer droplets and to a better control of the final lens size. Moreover, lens positioning is fully ensured by the self-alignment of the droplet with the pillar center and consequently with the VCSEL source, and allows for meeting the stringent requirement on VCSEL alignment. Corresponding optical properties will be also detailed.

[1] V. Bardinal et al., "Design and fabrication of polymer microlenses arrays for VCSELs using a cantilever based microsystem", Proc. SPIE 6185, 618510, 2006

TOPIC: Photonic crystals and metamaterials, Numerical methods.

RAYLEIGH METHOD FOR SIMULATION OF OPTICAL DIFFRACTION GRATINGS REVISITED

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In this year optics may celebrate century since Lord Rayleigh's proposed his method of simulating diffraction gratings [1], the simplest one among those ever developed after him. In 1970 - 80's computer simulations revealed divergence of Rayleigh's method for deep well gratings with increasing number of accounted space Rayleigh harmonics [2]. This stimulated development of new nowadays accepted methods, like rigorous coupled wave analysis (RCWA), free of the drawback, but, when it works, Rayleigh's method outperforms in time. Shortening computation time is favorable for real-time industrial applications. In reality, e.g. novel RCWA based microelectronics profile-extraction metrology [3] due to the time limitations works with library of the simulated spectra.

In this contribution we propose an extension of Rayleigh's method which comprises the original simplicity and a possibility to simulate deep, but not lamella, relief gratings. We employed an idea borrowed from RCWA – to add to the EM fields expansions outgoing waves in the line, and ingoing ones in the groove region, which are absent in Rayleigh's original method. The EM boundary conditions prove formally sufficient for determining unknown amplitudes. To avoid numerical instability, surface matching conditions are transformed into an S-matrix fashion. Case studies performed allow us to claim on good performance of thus modified Rayleigh's method.

[1] Lord Rayleigh, Proc. Roy. Soc. Ser. A **79**, 399 (1907)

[2] ed. R. Petit, Electromagnetic Theory of Gratings (Topics in Current Physics Vol. 22, Springer, Berlin, 1980)

[3] X. Niu, et al, IEEE Trans. Semiconductor Manufacturing **14**, 97 (2001)

ALL SOLID-STATE OPTICAL SWITCHES USING REVERSIBLE METAL- INSULATOR TRANSITION OF VO₂ THIN FILMS

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We present an original experimental approach for switching optical signals by using materials presenting a reversible metal-insulator transition (MIT or Mott transition). The most known and studied material presenting such a transition is vanadium dioxide (VO₂). The reversible MIT transition can be triggered by different external excitations: temperature, optically or electrically (by charge injection).

For a thermally induced MIT transition, at room temperature VO₂ is a semiconductor (~1eV band gap). At temperatures higher than 68°C VO₂ undergoes an abrupt transformation to a metallic state, which is reversible when lowering the temperature below 65°C (VO₂ becomes again semiconductor). This remarkable transition which occurs very fast (ps down to ~100 fs) is accompanied by a large modification of its electrical and optical properties: the resistivity decreases by several orders of magnitude between the two states while the reflectivity increases for a large optical spectral domain (from ~1 μm up to the THz frequencies).

The functioning of the optical switching devices we will present is based on the temperature and electrically initiated MIT transition of VO₂ thin films deposited by PLD and integrated in two-terminal devices. We employed the reflectivity change of a VO₂ thin films undergoing an MIT transition for realizing variable reflectivity micro-mirrors as optical modulators which are integrated with miniature fiber lasers (Er-Yb-doped amplifiers) for obtaining short laser-pulses in the Q-switching regime. The optical performances of the laser system (repetition frequency, pulse's FWHM) are correlated with the experimental deposition parameters of the VO₂ films (crystallinity, substrates etc.).

TOPIC: Optical microsystems and microsensors

LIQUID CRYSTAL: FROM MILLIMETER WAVES TO TERAHERTZ

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Liquid crystals (LC) have been successfully used for display applications and have now a more than 40 year experience. Originally they have been mainly studied for visible applications. They have also gained interest for near infrared wavelengths, and most recently they have proven good optical properties in the THz regime.

We first review the merits and constraints of liquid crystals. On one hand, the high optical and electrical birefringences are unsurpassed among the other optical materials. They also permit to achieve low power switching, have low temperature process and are compatible with a large variety of substrates. On the other hand, the requirement for alignment layer, the response delay and the temperature dependence imply a specific attention from the optical designer.

In a second time, we exemplify the behaviour of LC in typical structures for mm and THz devices. Then we introduce the optical design of different devices. Their performance are simulated and crosschecked with some experimental insights.

TOPIC: Optical microsystems and microsensors

SOFT-MATTER PHOTONICS ON PREFERENTIALLY ETCHED SILICON

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Soft-condensed matter like polymers and liquid crystals have been extensively studied and engineered to provide good performance for photonic applications. Their nature of soft or fluid matter makes them able to accommodate a variety of geometries and devices, however they require special attention for encapsulation and packaging.

We propose to use silicon as a substrate for two major reasons: first micromachining of silicon has proven to be capable of achieving microfluidics, and this technique can benefit from much experience from microelectronics process. Second, silicon is often expected to play a central role in photonic integration, as light sources, compact circuits and generic functions have already been demonstrated on silicon substrates.

Here we present the design, fabrication and measurements of some polymers and liquid crystals integrated optic devices. The technology is based on the preferential etching of silicon. It has the merit to provide a smooth, precise receptacle for soft matter by a simple and low cost technique. To complete the optical waveguides, the top interface as well as the input and output have to be defined. We will focus on the technique we have developed for this purpose. Eventually we will give results on devices that span from micrometer to nanometer scale.

TOPIC: Silicon based microsystems

FABRICATION OF MEMS CELL FOR ATOMIC CLOCKS BY LASER INDUCED DISPENSING OF CESIUM VAPOR

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During the last few years, considerable work has been done by different US groups awarded by DARPA on the Chip Scale Atomic Clock (CSAC) [1-2]. The principle of proposed miniature clocks is based on Coherent Population Trapping (CPT), obtained in an extremely compact sealed vacuum cell of few mm³ containing alkali vapors, illuminated by a high-frequency modulated laser beam. In this solution, the CPT frequency standard does not require a microwave cavity to probe the atomic resonance authorizing the very compact physical package of the micro-clock. The key problem of filling the micromachined MEMS cells with Cs vapor is the high chemical reactivity of cesium. To improve this situation, we propose a technique making the fabrication of atomic micro-clock simpler and increasing the potentiality for mass production [3], using a Cs dispenser commercially available from the company SAES Getters, making possible to heat locally the Cs dispenser below temperature range causing degradation of micro-cavity as well as reducing the negative effects of Cs chemistry.

In this paper, the architecture of MEMS cell, formed in a wafer of silicon with glass wafers bonded to both sides, will be described as well as advantages of the procedure of Cs vapor activation. This last uses a Raman laser source, to locally heat the Cs dispenser. Finally, the operation of atomic micro-clock will be demonstrated by measuring of CPT resonances.

Authors gratefully acknowledge CNES and DGA (France) for supports.

REFERENCES

- [1] L. Liew, J. Moreland, V. Gerginov, "Wafer-level fabrication and filling of cesium-vapor cells for chip-scale atomic devices", in *Proc. of Eurosensors 2007*, Göteborg, September 17-20, 2006, pp. 276-277.
- [2] R. Lutwak, J. Deng, and W. Riley M. Varghese, J. Leblanc, G. Tepolt, M. Mescher, D.K. Serkland, K.M. Geib, G.M. Peake, "The chip-scale atomic clock – low-power physics package", in *Proc. of PTTI*, December 7-9, 2004, Washington, DC, pp. 339-354.
- [3] J. Dziuban, C. Gorecki, V. Giordano, L. Nieradko, H. Maillotte, M. Moraja, "Procédé de fabrication d'une cellule à gaz active pour l'horloge atomique à gaz ainsi obtenue", French patent 06/09089, deposition: Octobre 17, 2006.

TOPIC: Solitons, soliton waveguides and 3-D circuits

LINEAR WRITING OF WAVEGUIDES IN BULK PHOTOREFRACTIVES

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We present a novel technique to optically write waveguides in bulk photorefractive crystals using only linear propagation.

A focused light beam is launched through a biased photorefractive sample of potassium-lithium-tantalate-niobate (KLTN). In distinction to soliton studies, the beam is linearly polarized orthogonal to the bias field, so that as it separates charge, the electro-optic response is too weak to affect its propagation. The diffracting beam is allowed to separate charge for a time comparable to that required to observe a quasi-steady-state soliton in a conventional soliton scheme.

In the readout phase the linear waveguiding properties of the pattern are analyzed by observing the propagation of a weaker signal beam, but now with a polarization parallel to the bias field. The index pattern leads to a quasi modal propagation.

The peculiar effect can be ascribed to saturation in the optical response. The writing beam is linearly diffracting and more intense regions lead to stronger screening response, the result being a distributed lensing that decreases along the propagation direction. However, when the more exposed regions reach saturation, this trend is inverted since the distorted response leads to a weaker self-focusing. In appropriate conditions the pattern can have a quasi-degenerate guided mode.

The technique has the major advantage that each stage (i.e., writing and reading) only involves linear propagation. For example, compared to conventional optical volume writing techniques based on solitons (self-writing), here different waveguides can be effectively superimposed in close proximity without manifesting the non-trivial dynamics associated to nonlinear soliton-soliton scattering.

TOPIC: Electro-optic materials

INFLUENCE OF COMPOSITION ON THE ELECTRO-OPTIC COEFFICIENTS OF Mg-DOPED LITHIUM NIOBATE

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Lithium Niobate (LN) electro-optic (EO) switches and modulators are currently employed in laser and telecommunication systems. However, the onset of the photorefractive effect prevents the exploitation of the outstanding EO properties of LN at high power levels. This drawback can be overcome by heating LN crystals at 100-150°C, what is inconvenient in commercial applications. Alternatively, the photorefractive damage resistance at room temperature can be increased by using either stoichiometric LN or congruent LN doped with metallic ions (Mg, Zn, In, Sc, Hf).

Magnesium is among the most effective doping ions for inducing a large reduction of the photorefractive effect in LN. However, to the best of our knowledge, the influence of Mg doping on the EO coefficients of LN was not investigated so far.

We measured the EO coefficients r_{33} , r_{13} and r_c of congruent Mg:LN crystals in the wavelength range from 532 to 1550 nm and compared them to the ones of pure congruent and stoichiometric LN. The composition of Mg:LN crystals was evaluated after growth through an elemental analysis technique. Raman scattering was employed as a probe of the lattice disorder related to magnesium doping and the non-stoichiometric composition.

At the doping concentration of 6 mol%, above the known threshold for a significant increase of the photorefractive damage resistance, the EO coefficient r_{33} of Mg:LN resulted to be at least as large as in congruent LN. An unexpected increase of r_c by 15% with a corresponding decrease of r_{13} was observed in congruent Mg:LN with pronounced Li deficiency.

TOPIC: Nonlinear optic devices (Materials and phenomena)

ULTRAFAST CARRIER DYNAMICS AND CONFINED ACOUSTIC PHONONS IN CdSe NANORODS

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Semiconductor colloidal CdSe nanocrystals have been intensively investigated over recent years, because of their interesting electrical and optical properties, which strongly depend on size and shape. In particular dots and rods result of great interest as novel materials for optoelectronic devices as photovoltaics and lasers or for gas-sensing technologies. Then it is important to clarify their photo-physics and in particular the carrier relaxation mechanisms and the role of surface states in these nanostructures.

In this work we report on the study of ultrafast carrier dynamics in colloidal CdSe nanorods, using the femtosecond pump-probe transient spectroscopy in the visible spectral range, with a resonant and non-resonant pumping energy. Inter and intraband relaxation processes and their related time constants have been identified. Strong evidence has been obtained that the relaxation processes occur due to defect states ascribed to surface defects whose role has been clarified. We also report on the observation of coherent confined acoustic phonons. In fact the photobleaching (PB) and photoabsorption (PA) dynamics of nanocrystals, obtained with a pumping energy resonant to the lowest 1S transition, exhibit oscillatory modulation, due to the modulation of the absorption cross section. In particular the modulation frequency corresponds to the coherent radial breathing modes of the rods, suggesting that only the transverse (radial) mode of coherent phonons is observed. The oscillations are observed with a lower level of photoexcitation (200nJ) with respect to the observations reported in literature ($\sim 5\mu\text{J}$) in the case of non-resonant pumping energy.

APPLIED OPTICAL SYSTEMS IN ANIMAL PRODUCTION

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ABSTRACT – Visual Image Analysis (VIA) has been tested in different domestic species with purposes of morphological evaluation and weight indirect estimation in animal husbandry. A visual image prototype has been developed assembling different hardware and software components. Viable morphological measurements and weight estimations were obtained from a 5 to 10 m distance in milk and meat cattle, buffaloes and sporting horses. VIA linear measurements were compared with traditional instrumental measurements in 210 subjects (50 Friesian cattle, 10 Chianina meat breed, 10 Mediterranean buffaloes and 140 sporting horses). Small differences, ranging from perfect overlapping to 3.0% for each measurement, were observed. Correlation coefficients ranged from $r = 0.86$ to $r = 0.99$. The correlations were highly significant ($P < 0.01$) showing that VIA gives results quite comparable with the traditional measurements but more quickly and without the need of entering in contact with the animals. VIA makes also possible to measure body surfaces which are correlated with weight when specific equations are properly calculated. Simple and multiple correlations are reported. Weight was estimated on a total of 856 subjects (261 Chianina beef cattle; 104 buffaloes and 491 horses) and highly significant correlations were observed ($P < 0.01$), ranging from $r = 0.90$ to $r = 0.99$. The VIA prototype can be considered as an optical system fit to get quick, easy and exact measurements of animal body, suitable to improve data recording for selective purposes of morphological and weight traits.

Nanoscale cell membrane fluctuations quantified by optical interferometry

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ABSTRACT

Red blood cells (RBCs) must withstand large deformations during multiple passages through microvasculature. This essential ability is diminished with age and disease. Therefore, quantifying the mechanical properties of live RBC membranes provides insight into a variety of problems regarding the interplay of cell structure, dynamics, and function. RBC thermal fluctuations (“flickering”) have been studied for more than a century as they offer a potential window into these phenomena. Nevertheless, quantifying these motions is experimentally challenging, as they develop at the nanometer and millisecond scales. Thus, reliable spatial and temporal data are currently limited. Here we use diffraction phase microscopy, a novel, highly sensitive optical imaging technique, to quantify the flickering of RBC membranes. This method relies on quantifying with sub-nanometer accuracy the optical path-length shift associated with the light passing through the cell. The static (spatial) behavior of the membrane displacements allow for the first time extracting the effective membrane tension, which is modulated by the cell cytoskeleton. The dynamic analysis reveals significant properties of both temporal and spatial correlations of the membrane motions. We show that these correlations can be accounted for by the viscoelastic properties of the cell membrane, which strongly correlated with cell morphology. We believe that this type of investigation promises to provide a better understanding of diseases such as malaria and sickle cell anemia. Furthermore, understanding the RBC membrane behavior will be important in studying the membrane of other cell types, for which RBCs are convenient models.

QUANTUM CASCADE LASER-BASED SPECTROMETER FOR HIGH-PRECISION SPECTROSCOPY IN THE MID INFRARED

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Quantum Cascade Lasers (QCLs) [1] are, nowadays, well developed sources for mid infrared spectroscopy, providing high-power, narrow linewidth and continuously tunable radiation.

Basing on their unique features, our group is working toward the realization of a complete QCL-based spectrometer that joins both an unprecedented absolute frequency accuracy and an extremely sensitive detection level.

We have recently performed absolute frequency measurements on CO₂ transitions around 4.4 μm by referring a DFB quantum cascade laser to an optical frequency comb synthesizer [2]. The obtained precision of about $3 \cdot 10^{-8}$ is essentially limited by amplitude and frequency instabilities of our source, that are at the moment under deep investigation.

From the sensitivity point of view, our group has recently demonstrated the suitability of quantum cascade lasers for frequency-modulation spectroscopy, achieving a noise equivalent absorbance of $6 \cdot 10^{-7}$ 1/√Hz, even with a very simple setup [3].

In order to upgrade our spectrometer towards higher sensitivity and resolution levels we are performing a stabilization of our QCL with a high-finesse resonant cavity. By locking the laser to the cavity resonance we want to stabilize the frequency of the emitted radiation, while a low-noise current driver and some mechanical improvements in the laser housing allow a sensible reduction of its amplitude fluctuations. This setup will finally allow sub-Doppler high-sensitive intracavity spectroscopy.

References

- [1] J. Faist, F. Capasso, D. L. Sivco, C. Sirtori, A. L. Hutchinson and A. Y. Cho, *Science* 264, 553 (1994)
- [2] S. Bartalini, S. Borri, P. De Natale, D. Mazzotti, G. Giusfredi, P. Cancio, I. Galli, T. Leveque, L. Gianfrani, *Optics Letters* 32, 988-990 (2007)
- [3] S. Borri, S. Bartalini, P. De Natale, M. Inguscio, C. Gmachl, F. Capasso, D. L. Sivco, and A. Y. Cho, *Applied Physics B* 85, 223-229 (2006)

TOPIC: Environment, geophysics and microgravity

CONTINUOUS IN-SITU MEASUREMENTS OF GASES AT THE FUMAROLE “SOFFIONISSIMO” (SOLFATARA, ITALY)

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In late 2006, a gas monitoring campaign at the Solfatara volcano (Pozzuoli, Italy) was performed (November 29th - December 1st 2006), and repeated in May 2007 for eight days. The primary goal of the experiments was to prove that monitoring is possible with the experimental set-up described below, and to compare the new data obtained with those from a previous continuous gas monitoring (November 2001). Temperature measurements (with a K-type thermocouple) and gas extraction were done at the fumarole “Soffionissimo” very close to the “Bocca Grande”. A continuous gas flow was adjusted with a diaphragm pump and a needle valve, and the gas piped through a 10 m Teflon® tube. The gas phase primary consists of water gas, which was in regular intervals gravimetrically determined after being trapped in a refrigerator. The remaining, almost water-free gas phase was finally dried in a filter and then continuously analysed with a quadrupole mass spectrometer for the following components: H₂, H₂S, CH₄, N₂, O₂, Ar, He, and CO₂. The gas line was also connected to a semiconductor laser based spectrometer for CO₂ concentration measurements. Gas samples were stored for laboratory gas-chromatographic and noble gas analyses.

Although data processing and collection is still ongoing, the residual (=water-free) average gas composition from the first experiment is as follows: CO₂ >97 vol%, H₂S ~0.16 vol%, H₂ ~0.15 vol%, N₂ <2 vol%, O₂ <0.5 vol%, Ar <0.02 vol%, CH₄ ~0.05 vol%, He <20 ppmv. O₂ and most of the N₂ and Ar are due to atmospheric contamination of the system. Besides the varying air contribution, the gas composition shows no significant variations over time within the analytical uncertainties of the experiment.

LOW-TEMPERATURE LUMINESCENCE OF RARE-EARTH IONS DOPED IN DISORDERED CRYSTALS

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Calcium niobium gallium garnet (CNGG) crystal has several advantages because of its non-stoichiometric and disordered crystal structure. For example, broad absorption and emission bands which make possible more efficient diode-pumping for high-power laser action, large doping concentration which gives rise to high emission intensity.

We study the near-infrared photoluminescence spectra of Er³⁺ ions in CNGG crystals at 10-300 K. Comparing with Er³⁺ doped in ordered crystals such as LiYF₄, the emission bands are much broader. With decreasing temperature from 300 K to 10 K, intensity of the 1535 nm ⁴I_{13/2}→⁴I_{15/2} band and 1003 nm ⁴I_{11/2}→⁴I_{15/2} band decrease, while the 860 nm ⁴S_{3/2}→⁴I_{13/2} band and 1240 nm ⁴S_{3/2}→⁴I_{11/2} bands increase. From the spectral line shapes, presence of Er³⁺ ions with various site-symmetries are confirmed. It was observed that the excitation into the band gap of doped and non-doped CNGG gives a broad emission band at 470 nm. This band is suggested to arise from excitons of CNGG host.

We also investigated for Tm³⁺ and Nd³⁺ ions in CNGG. As the case of Er³⁺-doped CNGG, broad f-f emission bands due to these ions are observed at room temperature which are different from the cases of other host crystals. However, no broad f-f emission band is observed at 10 K, indicating that emission bands from rare-earth ions with various different site-symmetries due to disordered crystal structure are narrow and locate close to each other. Discussion is given on the reason why broadening by thermal activation has occurred.

UNVEILING QUASI-PERIODICITY BY PROJECTION PHASE MATCHING IN NONLINEAR PHOTONIC CRYSTALS

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A well known method for mathematically constructing quasi-crystal models is by projecting part of a high dimensional periodic lattice onto a line oriented at an irrational slope with respect to the lattice axes. We demonstrate theoretically and experimentally that this method can be realized by collinear three-wave mixing of a finite-width beam in a periodic nonlinear photonic crystal. In this case, the beam size defines the projection volume, and the projection operation is defined by the phase-matched nonlinear process. The phase matching condition occurs when the projection of the reciprocal lattice vector of the nonlinear photonic crystal on the beams propagation direction is equal to the difference between the wave-vectors of the interacting waves. It is a new phase matching condition, and is different than the commonly used case, where the reciprocal lattice vector itself (and not its projection) is equal to the wave-vectors difference. Projection phase matching is observed only for beams with finite width, and its efficiency is nullified for plane-waves interactions.

We verified this effect experimentally in periodic two-dimensional nonlinear photonic crystal, produced by electric field poling of stoichiometric LiTaO_3 . We have measured collinear second harmonic generation for two fundamental waves, at 1047.5nm and 1550nm. The two different processes exhibited incommensurate momentum conservation relation, thus revealing quasi-periodicity. The same concept may be applied to other scattering processes from periodic structures, in which momentum conservation should be satisfied up to a reciprocal lattice vector, e.g. X-ray diffraction from atoms or light diffraction from linear photonic crystals.

- [1] A. Bahabad, N. Voloch, A. Arie, A. Bruner and D. Eger, "Unveiling Quasi-Periodicity through Nonlinear Wave Mixing in Periodic Media", to be published, *Physical Review Letters* (2007).

TUNABLE OPTICAL FILTER BASED ON 2D-MMI SILICON INTEGRATED DEVICE

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In this paper we present a novel integrated tunable optical filter based on a 2D-MMI device. Due to the possibility to confine both the optical radiation and the liquid, the solution involves as optofluidic path an hollow core antiresonant reflecting optical waveguide (ARROW) that is realized by using two silicon wafer. The channel is formed by deep dry etching (resulting in a $130 \times 130 \mu\text{m}^2$ square-core) of the bottom wafer, followed by a PECVD deposition of silicon dioxide and silicon nitride ($d_1=155\text{nm}$ $d_2=288\text{nm}$ $n_1=2.01$ $n_2=1.47$ at wavelength $\lambda=670\text{nm}$ and $n_{\text{core}}=1$) on both the wafers, that are joined by wafer bonding. Then, two liquid inlets are realized by deep silicon dry etching on the bottom side of the structure. For a given wavelength, the light source, coupled into the waveguide by a single mode fiber, will draw an interferential pattern recombining into a single image at a distance $z = \frac{3L_\pi}{4}$, where $L_\pi \approx \frac{4n_{\text{core}}W^2}{3\lambda}$. The output light is collected still by using an optical fiber positioned inside the core at distance z . By considering a white source, the transmitted spectra exhibits a narrow band-pass behavior that can be explained taking into account the self-imaging phenomenon. In fact, the maximum transmittance is reached at the wavelength for which a single image of the input field is obtained. These filtering capabilities can be modified either by varying the distance z for a fixed the n_{core} or by changing n_{core} and keeping fixed the distance z . In the first case, the collecting output fiber is moved by using a three-axis positioner, whereas in the second case by fixing the distance z , a syringe pump permits to vary the core refractive index by changing the injected liquid.

TOPIC: Application of optical systems in : Environment, geophysics and microgravity

***EXTRA SITU AND IN SITU TIME RESOLVED FLUORESCENCE
POLARIZATION ANISTROPY OF FLAME PRODUCED
NANOPARTICLES***

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There are many uncertainties on the optical properties of the combustion generated nanoparticles. Laser-induced fluorescence has proven to be a very sensitive technique for measurements of small polyatomic species in combustion. For larger molecules, the rates of internal energy redistribution and conversion strongly increase with temperature causing considerable quenching and spectral shifts and broadening. Therefore there is the need to use laser techniques based on short-pulse (in femtosecond to picosecond scale) to resolve the dynamics of larger molecular species and to characterize their size and chemical properties.

The knowledge of the formation mechanism of particulate matter produced by incomplete combustion is fundamental to control the atmospheric impact of combustion systems. The most unclear point of this mechanism is the soot inception, and, consequently, there is an increasing interest in developing and studying innovative techniques for direct analysis of the incipient nanoparticles.

In this experiment, the combustion products are analyzed directly in a propane Bunsen-type diffusion flame at atmospheric pressure. The flame is probed by the second harmonic of a femtoseconds laser. Using the temporal decay of the fluorescence anisotropy ratio, the volume of polyatomic species and nanoparticles can then be measured and, simultaneously, one can explore how the spectral properties of the fluorescence depend on the size of the nanoparticles.

In this work we also report on the TRFPA analysis of nanoparticles collected in water from non-sooting regions of ethylene/air premixed laminar flames. The time resolved fluorescence signals are analyzed as a function of wavelength in order to obtain complementary information on the nature of chromophores and their sizes.

TOPIC: New materials and technologies

SIMPLE REPLICATION TECHNIQUES FOR LOW COST DIFFRACTIVE OPTICAL ELEMENTS

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Replica molding is one of the most simple replication techniques that can be used to generate micro and nanostructures in polymers with a resolution of a few nanometers. We have experimented a simplified replication method, investigated and optimized the molding and demolding parameters that are required for three-dimensional micro/nanofabrication and applied it to the fabrication of micro/nano photonic structures.

We demonstrated the replication of micro/nano photonic structures (diffractive optical elements, micro-lenses, optical waveguides and photonic circuits) with feature size in the range 50nm-50 μ m in PDMS and PMMA using various molds.

Three types of molds have been fabricated for micro-scale diffractive optical elements: (a) silicon dioxide/silicon based molds obtained by optical lithography followed by silicon anisotropic or isotropic etching and thermal oxidation, (b) photoresist based molds obtained by optical lithography and (c) nano-scale molds in PMMA (obtained by electron beam lithography), (d) PDMS molds. For each mold, different types of treatment and released agent were investigated in order to achieve an optimum demolding. The replicas were obtained in polymethylmethacrylate (PMMA) and polydimethylsiloxane (PDMS) doped with metal oxides, in different coating and curing conditions for polymer.

Diffractive optical elements with different shapes, on planar or flexible substrates, with feature size in the range 50 nm - 50 μ m. These structures can be used as antireflection coatings for solar cells and photodetectors, and as diffractive gratings to couple the light into polymer-based optical waveguides.

TOPIC: Optical microsystems and microsensors.

ELECTRO-OPTICAL MODULATION IN AN *a*-Si:H / SiCN WAVEGUIDING MULTISTACK

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a-Si:H has been in practice never considered as an active medium for the design of efficient electrically driven infrared light modulators because of its weak quadratic electro-optic effect.

In this paper we report results on light modulation through field-induced carrier accumulation in a 1.2-cm-long, multi-stack waveguiding structure. The realized device consists of three alternate bi-layers of 1 μ m-thick *a*-Si:H with 30nm SiCN, deposited on a <100> Silicon substrate. The substrate and the stack are separated by a 0.39 μ m-thick Si₃N₄ low refractive index cladding layer so that a strong vertical confinement and low losses (1.11 \pm 0.15 dB/cm) at λ =1.55 μ m is achieved. A transparent conductive ITO thin film forms the top contact, while the bottom contact is the Si substrate itself.

According to the Drude theory, when an electric field is applied, the variation of the free carrier concentration at the multiple *a*-Si:H/SiCN interfaces results in a change of the absorption coefficient. In the realized device the thin SiCN highly insulating layers break the conduction between the *a*-Si:H films so that the device electrically behaves in fact as the series of three capacitors. The effect of introducing three SiCN regions enhances the overall number of electrons and holes distributed across the waveguide cross section, and consequently increases the modulation efficiency with respect to conventional waveguide modulators based on the variation of the absorption coefficient. The carrier distributions under bias were first determined in the structure by performing electrical simulations with *ATLAS*. In this way, we numerically obtained for holes and electrons a concentration change, close to the interfaces, of $\sim 10^{18}$ cm⁻³. By applying to the realized device a square waveform $V_{\text{peak-peak}}=20\text{V}$ a modulation depth of $M_{\%}\sim 7\%$ is obtained. Moreover, increasing the $V_{\text{p,p}}$, which leads to higher carrier accumulation at the opposite sides of the dielectric films, a rise of M is obtained up to 9%, where the phenomenon saturates.

TOPIC: application of optical systems in: Automotive, avionics and aerospace

AN OPTICAL READOUT SYSTEM FOR THE DRAG FREE CONTROL OF THE LISA SPACECRAFTS

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LISA is an ESA-NASA joint project for the realization of a space interferometric gravitational wave (GW) antenna. LISA is designed for the measurement of GWs in a very low frequency band (0.1 to 100 mHz). The antenna is composed by three spacecrafts (SC) in suitable heliocentric orbits placed at the corners of a huge equilateral triangle, each side being 5 million km long. The SCs are linked by lasers, forming a sort of optical transponder. By means of phase locking techniques, any round-trip phase delay change gives a measurement of a change in the SC distance (measured as light transit time), due to incoming GWs. An essential requirement is that the SCs are set as close as possible to pure geodetic motion, in the measurement frequency band. This is hardly fulfilled because the SCs are disturbed by several external forces, like solar radiation pressure, cosmic rays etc. In each SC there are two free falling proof masses (PM) that are isolated by any external force but gravity. The relative position between each PM and the SC, is measured, in six degrees of freedom, by the so-called inertial sensor (IS). The IS signal is then used for drag-free servo-loops that force the SC to follow the geodetic motion of the PMs. The usual solution for the IS is the adoption of capacitive sensing. This gives a reliable device but poses several limitations due to back action and cross couplings. In this work, we present an optical lever sensor as an alternative solution. In particular we analyze the potential sensitivity and discuss the advantages in terms of relaxed specifications for the drag-free control loops. We also report on bench-top measurements that confirm the performance in the required frequency band.

TOPIC: Optical microsystems and microsensors (Electro-optic materials)

MACH-ZEHNDER MODULATORS PATTERNED ON SOL-GEL AND POLYMER MATERIALS WITH POLED CHROMOPHORES

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Mach-Zehnder structures were realised on poled hybrid organic-inorganic sol-gel materials doped with chromophores and on polymer systems endowed with second order non-linear behaviour.

Hybrid organic-inorganic materials doped with an epoxy functionalized dipolar chromophore were synthesized via sol-gel, based on epoxy and amino containing organically modified precursors. Homogeneous films doped with high dye loading, were obtained using *N*-hydroxyethylcarbazole as physical spacer avoiding dye aggregation and the covalent link of the chromophore by the epoxy-amino coupling reaction. Spin-coated doped films were electrically poled in N₂ atmosphere and second harmonic generation measurements have been performed in situ. The waveguiding properties of the films were preliminarily measured by m-line spectroscopy before and after poling and a patterned structure was achieved without evident damage to nonlinear features of poled material, demonstrating feasibility of a hybrid sol-gel electrooptic modulator.

Several polymer systems showing good second order NLO properties were synthesized: metallorganic polymers and organic cross-linked systems. For the fabrication of waveguide and Mach-Zehnder interferometer, a polymeric compound based on a low molar mass cross-linkable chromophore, having an high $\mu^*\beta$ value (3500×10^{-48} esu at 1907 nm) was chosen. Electric poling with simultaneous chemical cross-linking was performed at suitable temperatures for few hours.

Amorphous transparent films with high cross-linking density were thus obtained, in which chromophores are permanently oriented. NLO measurements exhibited fair d_{33} value (20 pm/V at 1368 nm) and very good time stability of NLO performances. Moreover, films showed no solubility in organic solvents, thus being compatible with chemical lithography for waveguide fabrication.

TOPIC: Microscopy, Biophotonic

PARTIALLY SPATIAL COHERENT DIGITAL HOLOGRAPHIC MICROSCOPY FOR BIOMEDICAL APPLICATIONS

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Digital holographic microscopy is an emerging technology that provides accurate information on the phase and the intensity of the optical signal coming from a microscopic sample. This information is used for interferometric measurement and refocusing in depth to fulfill applications in transmission and in reflection. In this way, 3D living cells monitoring, local refractive index measurement, velocimetry, optical tomography, quantitative phase contrast imagery can be performed.

In this presentation, we propose to discuss the specific merits and limitations of digital holographic microscopy for biomedical applications. In particular, the efficiency of this non-invasive tool for fast acquisition rates and for screening or monitoring applications. Several practical implementations using digital holographic microscopes working with partially spatial coherent optical sources will be presented. This type of sources drastically reduces the coherent noise making possible the implementation of applications that cannot be envisaged with coherent illumination. It also provides a direct high quality imaging capability that can be visualize by the users without any processing.

TOPIC: Nonlinear optic devices.

SECOND HARMONIC GENERATION IN PATTERNED III-V SEMICONDUCTOR WGM MICRO-DISK

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We propose to use micro-disk cavities and their associated whispering gallery modes (WGM) to simultaneously obtain phase matching (without domain inversion) in highly nonlinear but isotropic and non-ferroelectric materials such as $\text{Al}_x\text{Ga}_{1-x}\text{As}$ compounds grown along the commonly used [001] crystallographic direction. The WGMs allow the cavity to be doubly resonant for fundamental field (FF) and second harmonic (SH), and transverse fields confinement. The cylindrical micro-cavity is coupled to a bus waveguide allowing the FF to be inserted and the generated SH field to be extracted from the cavity.

We propose a coupled modes analysis and demonstrate that WGMs can be used to obtain a combination of modal and geometrical quasi-phase matching. Due to the strong chromatic dispersion of AlGaAs and to the form dispersion of the micro-disk, we show that it is only possible to obtain modal quasi-phase matching between FF mode with a radial order $n=1$ and a SH mode with a radial order $n=2$ and a phase mismatch $\Delta v = v_{2\omega} - 2v_{\omega} = 2$. By a correct design of the device we obtain a conversion efficiency $\eta = 1\%$ for a FF power of $130 \mu\text{W}$. In this case, the poor overlap between the SH field and the second order nonlinear polarization limits the conversion efficiency. Consequently, we propose a method to increase the effective nonlinear susceptibility associated with WGMs by engineering the refractive index in order to tailor the shape of the electromagnetic fields. The new structure consists of a patterned micro-disk made of AlGaAs whose thickness $h(r)$ depends on r usual radial coordinate.

TOPIC: Application of optical systems in cultural heritage.

A SCANNING DEVICE FOR VIS-NIR MULTISPECTRAL IMAGING OF PAINTINGS

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Multispectral analysis has successfully been growing in the last few years for painting conservation because of its effectiveness and safety. The technique, consisting in irradiating the painted surface with optical radiation and in detecting the diffused radiation within narrow spectral intervals, allows spectral and colorimetric characterization of the analyzed surface. Multispectral data are suitable to document the conservation state of an artwork, to monitor alterations due to restoration process and to study the transparency and colorimetric properties of the paint layer that can be profitably applied for pigment identification.

In this work we present a scanning device based on contact-less single-point measurement of the reflectance properties of painted surfaces. It allows multispectral imaging of paintings in the VIS-NIR spectral region.

An XY motorized translation stage moves both the lighting system and the collecting optics. The first one is made of two low-voltage halogen lamps that irradiate the sample surface at 45° and the back-scattered radiation is collected by a catoptric system that focuses it on a 16-fibre square-shaped bundle. An UV-VIS multimode fibre carries the light to a photomultiplier array equipped with 32 narrow-band interferential filters to cover the VIS spectral range from 380 to 800 nm, whereas 14 VIS-NIR multimode fibres carry the light to an array of 14 photodiodes equipped with pass-band filters to cover the NIR spectral range from 800 to 2300 nm.

Measurement campaigns were performed on several paintings and multispectral data were used for a number of analysis ranging from colorimetric calculation to multivariate analysis.

TOPIC: Fibre-optic sensors.

HIGH-PRECISION FIBRE-RESONATOR SENSORS BASED ON OPTICAL FREQUENCY COMBS

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Interrogation of fibre Bragg-grating (FBG) sensors by laser spectroscopic techniques has proved to be promising for development of ultra-high sensitivity strain sensors. A significant enhancement with respect to conventional sensors may derive from laser-frequency modulation and detection techniques to extract information on the measurand from the reflection radiation. Moreover, the use of high-finesse in-fibre- Fabry-Pérot (FFP) as mechanical gauges has been successfully demonstrated in different laser-to-cavity lock schemes, achieving a pε sensitivity in static and dynamic operation.

In this work, a new class of FFP-based systems is proposed for strain, rotation and acceleration measurements, which benefit from novel technologies recently developed for spectroscopy and frequency metrology. A superior precision and accuracy level can be achieved by proper combination of laser-phase and frequency stabilisation techniques to in-fibre optical frequency comb (OFC) synthesisers. The latter play a key role in this respect, providing an unprecedented short and long-term stability as well as a direct, multiple link to the absolute frequency standard. Possible applications of such devices in various configurations as precision gravimeters, gyroscopes and accelerometers for space and ground-based instrumentation is considered.

TOPIC: Application of optical systems in Material processing.

μ-RAMAN SPECTROSCOPY AND PHOTOLUMINESCENCE IN THE INDUSTRIAL GLASS PRODUCTION

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To improve the quality of the industrial glass products it is essential to eliminate or reduce the presence of so-called “stones”, i.e. crystalline inclusions in industrial glass products. Contamination of the glass melt with high refractory stones can arise from the batch of raw materials (ceramic particles introduced by recycled cullet) or grains coming from refractories of the melting furnace. In order to achieve a better quality of products, a complete knowledge of the chemical and mineralogical nature of the stones and of the reactions occurring between these defects and the molten glass are required. For this reason, laboratory corrosion tests were carried out to analyze the formation and dissolution mechanisms of Al-rich refractory materials in contact with alkaline-lime-silica glasses. The microRaman technique can be very helpful in the frame of a multi-analytical approach for the understanding of the diffusion mechanisms responsible for the stone dissolution due to its ability to distinguish between micro-regions with identical chemical composition but different lattice structures. Raman data allow to determine the reaction products, evidencing the formation of a feldspathoidic phase in a layer around the refractory fragment and in which the K ions are much more mobile than the others glass components (Na, Ca).

Due to the presence of impurity Cr^{3+} ions coming from the refractory, with the same apparatus it is possible to use the luminescence as a tool to determine the glassy degree of the irradiated region by carefully analysing the shape of luminescent emission.

TOPIC: Fibre-optic sensors.

FIBER STRAIN SENSOR BASED ON π -PHASE-SHIFTED BRAGG GRATING AND POUND-DREVER-HALL TECHNIQUE

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Compactness, linearity and low insertion loss are appealing requirements that make fiber Bragg gratings (FBG) particularly suited sensing elements in a wide range of applications to monitor temperature, strain and pressure. To achieve very high sensitivity the interrogation of FBG by means of a Pound-Drever-Hall (PDH) method is widely employed.

We report on a ultra-high resolution optical fiber sensor of dynamic strain based on a π -phase-shifted FBG interrogated by a frequency modulated laser radiation emitted by an extended cavity diode laser (ECDL) and using the Pound-Drever-Hall (PDH) technique. When the laser frequency is locked to the center of the FBG resonance, a broadband strain sensitivity of $8 \times 10^{-13} \text{ Hz}^{-1/2}$ (corresponding to $800 \sim f \varepsilon \text{ Hz}^{-1/2}$, where ε is the applied strain) is obtained for Fourier frequencies larger than 1 kHz.

The 3-cm long homemade grating was fabricated by the continuous writing technique using an UV radiation from a frequency-doubled amplitude-modulated Ar-ion laser. The measured transmission spectrum of the π phase-shifted grating shows a sharp resonance peak, with ~ 47 MHz full width at half maximum, around the center of the FBG stop-band. The laser radiation of the ECDL is phase modulated at 218.7 MHz by direct diode pump current modulation. A frequency discriminator coefficient of ~ 80 nV/Hz, with a typical SNR of ~ 50 dB in 100 kHz bandwidth, was obtained. Assuming a white noise contribution this value corresponds to a frequency noise sensitivity of $\sim 150 \text{ Hz}/(\text{Hz})^{1/2}$, which leads to a strain detectivity of the order of $8 \times 10^{-13} \varepsilon/(\text{Hz})^{1/2}$.

TOPIC: Application of optical systems in: Environment, geophysics and microgravity

THE VIRGO 3-KM INTERFEROMETER FOR GRAVITATIONAL WAVE DETECTION

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VIRGO, a French-Italian collaboration located in Cascina (Pisa, Italy) aiming at the detection of gravitational waves, is a ground based power recycled Michelson interferometer, which arms are 3-km-long Fabry-Perot suspended cavities. The VIRGO first scientific data taking has started in mid may 2007 in coincidence with the corresponding American detectors.

In this talk the optical scheme of the interferometer and the various optical techniques used in the experiment, like the laser source, the high quality suspended optics, control, alignment, stabilization and detection strategies, are outlined.

The future upgrades that are planned for VIRGO from the optical point of view, especially concerning the evolution of VIRGO laser, are presented. In particular, in order to improve the detector sensitivity, as a first step, an increase of the laser power from 20W to 50W using a 4 stages single-pass laser amplifier is described.

Finally, the next generation of gravitational wave detector (advanced VIRGO) is introduced from the point of view of the laser system. Currently, Research and development projects are going on with the goal to have a continuous-wave single-mode 200 Watts laser and improved interferometer optical configurations.

TOPIC: New active and passive devices in optoelectronics.

BISTABLE DIGITAL ALL-OPTICAL MEMORY BASED ON SEMICONDUCTOR MICRO-RING LASER

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Monolithic Semiconductor Ring Lasers (SRLs) are promising devices for all-optical memory and all-optical switching applications, as they can operate in a directional bistable regime where only one directional mode (clockwise or anti-clockwise) is active at one time. The unidirectional bistable regime can be naturally associated to a binary logic, and the SRL represents an elementary digital memory cell that can be written all-optically. In fact, the direction of operation can be switched by injecting an external optical signal pulse into the SRL.

SRLs were fabricated in InGaAs/InGaAlAs/InP MQW material with a racetrack cavity geometry with radius of curvature of 100 and 300 μm . These devices exhibit a CW lasing threshold of 80 mA at room temperature, they operate on a single longitudinal mode with SMSR up to 25 dB, and they emit up to 0.5 mW @ 1575 nm.

Directional switching experiments have been successfully carried out by injecting an external optical signal at the lasing wavelength, with a coupled power into the SRL device as low as -20 dBm, i.e. an amount that is smaller than the power emitted by the SRL. The directional extinction ratio is around 15 dB. These results demonstrate the all-optical memory functionality, and show potential for digital all-optical signal processing like 2R regeneration.

The measured switching time of 0.9 ns (for 300 μm radius device) is in line with theoretical expectations. Design and fabrication of smaller sized devices (with radii down to 30 μm) is in progress, with the goal of achieving switching times of the order of a few tens of ps.

TOPIC: Photonic Crystals and Metamaterials (Numerical Methods).

ANALYSIS OF TWO-DIMENSIONAL PBG DEVICES: A GENERALIZED MACROCELL APPROACH

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An innovative and general approach for the evaluation of the electromagnetic behavior of two-dimensional finite-extent photonic crystals made of a finite set of parallel rods is presented. The proposed approach is a generalization of the Scattering Matrix Method introduced by Maystre and co-workers and of its improved version proposed by present Authors, which exploits a suitable aggregation into "macrocells" to achieve a reduction of the number of unknowns. As a matter of fact, both these approaches can only be applied to those boundary geometries for which analytical modal expansions for the fields hold true. In order to overcome this limitation, we propose a suitable exploitation of the Method of Auxiliary Sources to provide a general and reliable method for the numerical computation of the scattering matrix of an object of arbitrary shape. Taking advantage of this latter, we can then generalize our improved Scattering Matrix Method and further increase its computational effectiveness due to an additional considerable reduction in the number of unknowns, these latter being now represented by the proper excitations of the auxiliary sources which faithfully reproduce the scattered fields within a required accuracy. The proposed method is then applied to the characterization of an hexagonal macrocell (i.e., an aggregation of single cells covering an hexagonal geometry) by means of the numerical computation of its generalized scattering matrix. Finally, a numerical analysis related to some hexagonal-lattice configurations is reported to confirm the accuracy of the proposed method with respect to the original method and the so-obtained computational benefit.

DIGITAL HOLOGRAPHIC MICROSCOPY FOR REAL-TIME MEMS/MOEMS MONITORING

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Digital holographic microscopy (DHM) is a constant-developing technique which enables to retrieve quantitative complex wavefront information with a single full-frame CCD acquisition of an hologram. The wavefront reconstruction is then achieved numerically with a computer to provide a quantitative nanometer-range axial resolution phase map of the sample (directly corresponding to a topographic map for reflective objects), thanks to the interferometer nature of the method, while the lateral resolution is diffraction-limited and depends of the microscope objective numerical aperture (NA). Typically, axial precision below 1 nm can be reached with down to 300 nm transverse resolution.

By being able to digitally propagate the wavefront in the Fresnel approximation, it is possible to focus in different plane along the optical axis, resulting in a virtually extended depth of focus. In top of that, a complete “digital optics” approach can be implemented to compensate for aberration by a pure software process. Short integration time for the acquisition makes DHM very robust regarding environmental conditions (vibrations, etc...) and the only theoretical speed limitation of the technique depends on the camera framerate.

Here we present real-time DHM measurements on micro-electro-mechanical systems (MEMS) or micro-optical-electro-mechanical systems (MOEMS), which is an ideal application for the technique. Indeed, the characteristics described above make the method fully compatible with stroboscopic modes of operations, thus accessing MHz-range operating frequencies. Furthermore, advanced DHM capabilities, like real-time dual-wavelength measurements to avoid use of unwrapping algorithms are also presented.

TOPIC: Nonlinear optics devices: Materials and phenomena.

SECOND HARMONIC GENERATION FROM METALLO DIELECTRIC MULTILAYER STRUCTURES

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Second order nonlinear optical effects in centrosymmetric media, as most metals, present peculiar dynamics with respect to conventional non centrosymmetric media, since the electric dipole term in the dipole expansion is vanishing. Moreover, the nonlinear optical susceptibility in metals includes the contribute of conduction electrons, differently to what happens for crystals. Recently, the use of metals for applications in the optical range has been progressively grown together with the interest in their applications in nonlinear optics. Thin metal films, in fact, can be included into multilayer structures in order to get extremely high transmittance in the visible range, despite the strong absorption typical of metals.

We investigated theoretically and experimentally second harmonic generation from metallo-dielectric multilayer structures. Metallo-dielectric samples were realized via magnetron sputtering. Different sets of samples were grown by alternating several periods of a metallic layer, Ag, and a dielectric layer Ta₂O₅, while the linear optical characterization of samples was done by spectrophotometry.

Second-harmonic generation measurements in reflection mode were performed from a fundamental beam consisting of a femtosecond Ti:sapphire laser at $\lambda=800$ nm as a function of incidence angle. The dependence of the generated signal on pumpo beam intensity and polarization was also investigated. The experimental results were reconstructed with calculations based on coupled Maxwell-Drude oscillators under the action of a nonlinear Lorentz force term. According to this model, the multilayer samples were found to exhibit second harmonic generation efficiency which was nearly 20 times higher than that obtained with a single Ag layer, 20 nm thick.

TOPIC: Applications of optical systems and devices

SAFE INFRARED EYE BLINKING DETECTOR

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Eyes blinking detector are often used to monitoring the drowsiness or the fatigue during any activity in the daytime. Usually this monitoring requires long recordings and, therefore, sensors have to be as less intrusive and safe as possible in order to avoid additional annoyance and hazards. According to these two requirements, an infrared eyes blinking detector has been developed. It is formed by an infrared emitter diode coupled to an infrared photodiode embedded in the same device. Thus it can be clipped on the rod of the glasses and placed closed to the eye.

The sensor working principle is based on the difference of the reflectivity between an opened and closed eye. As the infrared radiation hits the cornea, the emitter has been powered according to class 1 specifications of the IEC EN 60825 standard on the safety of laser and led products.

The sensor uses the technique of the modulation of the infrared beam to be less sensitive to the head movements and changes of environmental light. Its frequency, duty cycle and output power have been trimmed to be safe for the eye even if it works for many hours.

Actually the sensor is wire connected to a proper developed acquisition board that sends the eye blink signal to a personal computer in order to be saved or to be processed in real time.

Furthermore, the acquisition board can recognize the eye blink events setting the trigger level by its self, via a calibration, or by the user interaction.

PHTHALOCYANINE-BASED MOLECULARLY IMPRINTED POLYMERS AS NUCLEOSIDE RECEPTORS

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Molecularly imprinted polymers (MIPs) are stable synthetic polymers possessing selective molecular recognition sites, which are obtained by polymerization of cross-linking monomers in the presence of a template molecule¹. Once the template molecule is removed from the polymer, specific sites are left behind which are able to selectively rebind the template or structurally related analytes. Some of these polymers have selectivity and affinity constants comparable with those of naturally occurring recognition systems, such as monoclonal antibodies or receptors, and they can be used in a biosensor format or as solid-phase-extraction (SPE) materials. The objective of the present study is the formation of MIPs having a phthalocyanine-based recognition centre for the molecular recognition of nucleosides. The recognition site is, in this case, a three-dimensional cavity around the phthalocyanine plane in cross-linked polymers to which the nucleoside can be specifically bound through multiple-point interactions (**Fig. 1**)². Organic soluble derivatives of nucleosides, such as tri-O-acetyl adenosine (TOAA), were selected as ligands, since they contain the 2-aminopyridine substructure previously found to be important for polymer imprinting with methacrylic acid as functional monomer³. Tri-O-acetyl uridine (TOAU), not containing the 2-aminopyridine moiety, was also tested as ligand for comparison³. The polymer synthesis was performed by using two different functional monomers which are methacrylic acid (MAA) and phthalocyanine **1** (ad hoc functionalized with methacrylic groups) (**Fig. 1**). Ethylene glycol dimethacrylate (EGDMA) and 2,2'-azobisisobutyronitrile (AIBN) were utilized as cross-linker and initiator, respectively.

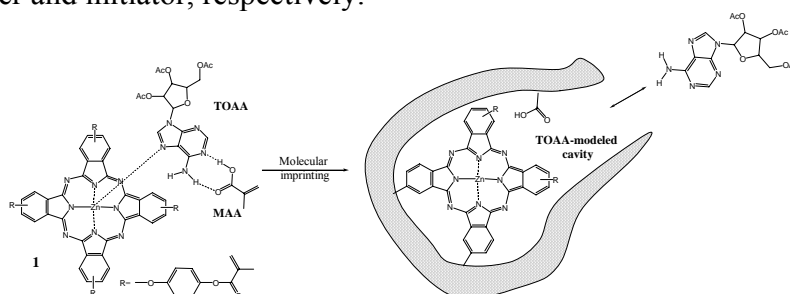


Fig. 1

1. Syu M.J., Deng J.H., Nian Y.M., *Anal. Chim. Acta*, 2004, 504, 167
2. Matsui J., Higashi M., Takeuchi T., *J. Am. Chem. Soc.*, 2000, 122, 5218
3. Spivak D.A., Shea K.L., *Macromolecules*, 1998, 31, 2160

TOPIC: New active and passive devices in optoelectronics.

DESIGN OF SINGLE-MODE VERTICALLY COUPLED MICRORING RESONATORS

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In this work we have studied the possibility to obtain single-mode operating vertically coupled microring resonator that can be obtained by wafer bonding. A single-mode operation regime for these types of the microring resonators is important since the III-V ring waveguides have a highly multimodal behavior which can affect the functionality of the microring resonator based devices. We have found that this problem can be solved by imposing a lateral offset (a misalignment between the ring and the bus waveguide) that allows the radiation carried in the bus waveguide to be coupled predominantly into the ring waveguide's fundamental mode. In our analysis, we have studied various microring resonator configurations. The coupling coefficient variation with the lateral offset is useful for assessing the fabrication tolerance. We have concluded that the use of the offset is effective for obtaining single-mode operating microring resonator devices with desired working characteristics.

TOPIC: Nonlinear optic devices

MID-INFRARED FIBER-BASED OPTICAL COMB

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We demonstrate a mid-IR frequency comb based on a difference-frequency-generation (DFG) process, which takes place in a periodically-poled lithium niobate (PPLN) crystal between a continuous-wave (cw) laser source and a near-IR, fiber-based OFS. The flexible character of our approach allows for a full and direct control of the comb features by simply acting on the parameters of the cw laser. In particular, by tuning its wavelength, the mid-IR comb covers the region from 2.9 to 3.5 μm in 180 nm wide spans. By phase-locking, the pump laser to the near-IR OFS, the mid-IR comb is directly linked to the Cs primary standard via a global positioning system. Then, in order to demonstrate that the generated comb can be properly used as a direct frequency ruler, an external cw DFG source is phase-locked to the closest mid-IR comb tooth and used for high-precision molecular spectroscopy. Moreover, the proposed scheme can be easily implemented in other spectral regions by use of suitable pumping sources and non-linear crystals, thus offering the opportunity of comb-referencing for direct laser sources operating in the mid-IR, such as quantum cascade lasers. This opens new perspectives for absolute frequency measurements on ro-vibrational molecular transitions for determination of molecular constants and frequency grids with improved accuracy. Finally, use of advanced fibre-based devices, which benefit from the continuous progress in telecom technology, will give, in the future, additional advantages for the realization of more and more effective set-ups.

TOPIC: Biosensors.

CARBONARIUS DNA BIOCHIP REAL TIME MONITORING BY SURFACE PLASMON RESONANCE IMAGING (SPRI)

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Nucleic acid-based biochips represent a promising tool for gene sequence analysis, especially for mutation detection. Surface plasmon resonance imaging (SPRI) technique allows kinetic monitoring of molecular interactions, such as DNA–DNA, in real-time and without any prior labeling step.

In this work, SPRI studies, performed on a specially designed system exploiting the Kretschmann configuration, were carried out to develop a DNA sensor for the detection of gene mutations accounting for the analysis of a fungus specie which can be developed especially in cereals producing toxic compounds such as mycotoxins. In this work, a SPRI system has been used in order to study the hybridization process of ssDNA Carbonarius probes immobilized onto a bio-functionalized surface in order to detect in real-time the mutations in a DNA fragment. SPRI system is a proper choice for a real-time monitoring of hybridization dynamics on an array of immobilized oligonucleotide probes because of the high sensitivity in characterization of ultra-thin films adsorbed onto gold or other noble metal surfaces. By this technique, local changes in the reflectivity from a thin metal film describe the hybridization process between the molecules tethered to the surface and those sent in solution in the test chamber.

The increase in the grey-scale levels of the images representing the functionalized gold traps during the hybridization process demonstrated the occurrence of the binding event. The process has been proven to be reversible and specific for the investigated probes, since no signal has been detected in presence of a negative control, that is of a non-complementary target.

TOPIC: Applications of optical systems in health food and agriculture.

MICRO-STRUCTURED LIGHT EMITTING DIODE ARRAYS: APPLICATIONS IN FLUORESCENCE MICROSCOPY

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We describe light emitting diode devices where the device has been micro-structured to produce line or square arrays such that each micro-LED can be individually addressed either in a multiplexed matrix format or by direct drive in a flip-chip format. We then show how these devices can be used as programmable devices in fluorescence microscopy applications.

One particular application is to use the device to project structured illumination patterns onto an object whereby optically sectioned images of only the in-focus parts of the object can be realized. We demonstrate how an array of line LEDs can be used to realize a number of optical sectioning procedures including grid-projection and line-scanning confocal microscopies and we discuss how these may be improved in terms of scanning speed and optical sectioning strength. We also discuss the potential for the devices to be used as patterned sources for photo-uncaging, photo-activation and photo-bleaching in bio-medical applications.

The advantage of this micro-structured LED approach is it allows the projection of programmable patterned illumination onto an object with a single integrated source and with no moving parts. These simple devices have the potential to replace larger, more complex laser scanning systems in bench-top applications as well as providing the potential for miniaturization in endoscopic applications.

TOPIC: New active and passive devices in optoelectronics

MICRO-PIXELLATED FLIP-CHIP InGaN LIGHT EMITTING DIODES INTEGRATED WITH CMOS.

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We report developments in micro-pixelated light-emitting diode arrays ('micro-LEDs') with elements that can be individually addressed via a silicon backplane. These micro-LEDs can be designed to emit spectrally-selective output at any wavelength in the UV to blue and green range.

These versatile micro-structured devices have potential in many areas of optical lab-on-a-chip, including sectioning optical microscopy, time resolved fluorescence imaging or assays and the synthesis or read-out of DNA microarrays.

The devices to be reported are 'flip-chipped', resulting in improved current-spreading, heat dissipation and, hence, output power. This scheme utilises the transparent sapphire substrate as the top surface, thereby protecting the LED elements and offering a stable surface on which to locate e.g. microfluidics and tissue, dye or polymer samples. This geometry allows the integration of microlenses onto the sapphire window, enabling projection of the light from each element.

The current flip-chip devices consist of a 16 x 16 array of elements, each with a 72µm diameter on a 100µm pitch, which can be individually addressed. These have been controlled from a CMOS drive circuit chip, which also contains an array of Single-Photon Avalanche Diode (SPAD) photodetectors.

We have shown this configuration to be capable of addressing individual LEDs in constant drive or nanosecond pulsed regimes, with output pulses as short as 5ns. Given our results we believe this is a promising route to highly-parallel, on-chip single-photon microfluorimetry.

AN INTEGRATED OPTICAL ELECTROMAGNETIC FIELD SENSOR

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Electromagnetic field sensors are widely used in several industrial, scientific and medical applications and can be used for measurements of fields yield by a huge set of communication devices. We propose an integrated optical device for electromagnetic field sensing, instead of standard metallic probes, suitable for electromagnetic field measurements also in the Fresnel region.

The optical probe is based on Mach-Zehnder interferometer and optical transmission lines, therefore the probe is mainly made by non conductive materials making such device suitable to monitor electromagnetic fields radiated by antennas in near field region. Here no simple theory is available in order to evaluate the fields, and mutual coupling between antennas and standard probes strongly affect the measurements. The optical probe avoids the coupling of the fields with metallic structures and the loss of antenna calibration yielding measurement errors, thereby it results dramatically less invasive than standard EMF probes.

A very tiny resistively loaded array antenna with a flat response in a wide band, yields the electric input for an integrated Mach-Zehnder interferometer, then the sensor equivalent model is given. Finally the antenna array and its technological implementation steps are described, then experimental results are discussed.

TOPIC: Optical Microsystems

MICRO-OPTICAL COMPONENTS FOR BEAM SHAPING OF HIGH POWER DIODE LASERS

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Over last twenty years, high power diode lasers have become increasingly important in a number of application areas, like material processing, telecommunications and medicine. Crucial for most applications is the beam shaping of the highly divergent and highly asymmetrical laser beam(s) produced by these devices. In many cases this also involves coupling into an optical fibre. Different micro-optical system solutions designed to achieve this are presented and optical design issues are discussed. The micro-optical components involved in these systems are then presented, with emphasis on their fabrication and characterisation. The most important micro devices in question are the fast-axis collimator, the slow-axis collimator and the beam symmetrisation optics. Finally, the measured performance of these micro-optical components is presented. It is shown that an optical power coupling efficiency of over 70% can be achieved for an optical fibre with a numerical aperture of 0.22 and a core diameter of 200 μm .

TOPIC: Application of optical systems

LIBS SYSTEM FOR SALT DETECTION ON ELECTRICAL INSULATORS IN HIGH VOLTAGE LINES

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High voltage insulators performance strongly depends on the presence of contaminants on their surface. In particular, when a thin layer of salt (NaCl) covers the insulators surface (which is common at the coasts), the insulators flashover resistance capability is strongly reduced by the presence of moisture in the air therefore giving rise to the risk of possible electric power outages under particular weather conditions.

Since no fully reliable and truly remote inspection techniques capable of detecting small amounts of salt on the insulators are at the moment available, we have investigated a new inspection method based on a LIBS system, which in principle could provide a viable solution to this problem. LIBS (Laser Induced Breakdown Spectroscopy) is a noninvasive spectroscopic method for analyzing the chemical composition of solid materials (as well as liquids and gases) based on the generation of a plasma plume via laser irradiation. Multielement real-time detection of the target material can be obtained from the spectral analysis of the light emitted by the excited atoms in the plasma.

Preliminary tests have been carried out on properly prepared salt contaminated glass samples. Experimental results show the possibility of obtaining clear evidence of the presence of sodium atoms in the plasma by using as exciting source a small power and short pulse Nd:YAG laser operating at its fundamental frequency. Interesting features of the recorded spectrum, such as self-reversal of the D lines from sodium and a visible luminescence characterizing very low irradiation regimes, have also been investigated.

APPLIED OPTICAL SYSTEMS IN ANIMAL PRODUCTION

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ABSTRACT – Visual Image Analysis (VIA) has been tested in different domestic species with purposes of morphological evaluation and weight indirect estimation in animal husbandry. A visual image prototype has been developed assembling different hardware and software components. Viable morphological measurements and weight estimations were obtained from a 5 to 10 m distance in milk and meat cattle, buffaloes and sporting horses. VIA linear measurements were compared with traditional instrumental measurements in 210 subjects (50 Friesian cattle, 10 Chianina meat breed, 10 Mediterranean buffaloes and 140 sporting horses). Small differences, ranging from perfect overlapping to 3.0% for each measurement, were observed. Correlation coefficients ranged from $r = 0.86$ to $r = 0.99$. The correlations were highly significant ($P < 0.01$) showing that VIA gives results quite comparable with the traditional measurements but more quickly and without the need of entering in contact with the animals. VIA makes also possible to measure body surfaces which are correlated with weight when specific equations are properly calculated. Simple and multiple correlations are reported. Weight was estimated on a total of 856 subjects (261 Chianina beef cattle; 104 buffaloes and 491 horses) and highly significant correlations were observed ($P < 0.01$), ranging from $r = 0.90$ to $r = 0.99$. The VIA prototype can be considered as an optical system fit to get quick, easy and exact measurements of animal body, suitable to improve data recording for selective purposes of morphological and weight traits.

TOPIC: Polymer-based devices

POLYMER-BASED CHIP FOR SPR SENSORS

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The paper presents design and low cost techniques for polymer-based chips for surface plasmon resonance (SPR) sensors. To obtain the polymer chip with prism, microchannels and chamber at microscale dimensions, the replication techniques in polymers with controlled refractive index have been developed. Photoresist, polydimethylsiloxane (PDMS), polymethylmethacrylate (PMMA) and epoxy resin were used.

The silicon dioxide/silicon-based molds have been obtained by anisotropic etching of silicon and were used to fabricate the microprisms. The photoresist molds were obtained by optical lithography and were used to obtain the microchannels and the chamber. A liquid pre-polymer (PDMS, Sylgard 184) with curing agent at a ratio of 10:1 was used and a special technique was developed in order to fabricate the components of the structure in the same time.

For deposition and direct patterning of the metallic layers onto polymer surface different methods were experimented, including sputtering and thermal evaporation in vacuum.

The materials and the techniques used to achieve SPR sensors are presented and possibilities and limitations of the technology have been discussed.

TOPIC: Optical microsystems and microsensors, MEMS, MOEMS, NEMS

RADIATION PRESSURE COOLING OF A MICRO-MECHANICAL RESONATOR IN A HIGH-FINESSE OPTICAL CAVITY

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We experimentally demonstrate the high-sensitivity optical monitoring of a micro-mechanical resonator and its cooling either by external active control or by intracavity radiation pressure. Coating a low-loss mirror upon the resonator, we have built an optomechanical sensor based on a very high-finesse cavity (30000). We have observed the thermal noise of our resonator over a wide frequency range with a quantum limited sensitivity at the 10^{-19} m/Hz^{1/2} level. According to the high resonance frequency of the resonator (814 kHz) and its very low mass, the sensitivity reached in our experiment opens the way to quantum optics experiments induced by radiation pressure, as well as the experimental observation of the quantum ground state of our macroscopic mechanical oscillator.

This last application requires to reach very low temperature by using both cryogenic operation and active cooling techniques. We have cooled the resonator from 300 K down to 5 K by a cold-damping technique which consists in applying to the resonator an electrostatic viscous force without introducing additional fluctuations. We also demonstrate a new cooling mechanism induced by radiation pressure in a detuned cavity. Depending on the sign of the detuning, the intracavity radiation pressure changes the mirror dynamics and can either cool or heat the resonator. We have observed both cooling for negative detunings and heating for positive detunings, the effective temperature ranging from 20 to 2000 K. We have also observed the emergence of radiation-pressure induced dynamical instabilities for positive detunings.

We will also discuss the possible enhancements of our system in order to experimentally demonstrate the quantum ground state of a mechanical resonator and quantum optics effects such as Standard Quantum Limit.

TOPIC: Optical microsystems and microsensors

FLUORESCENCE DETECTION BY METAL-CLAD OPTICAL LEAKY WAVEGUIDES

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In this work, we study the fluorescence emission of fluorophores emitting close to a multilayer structure, which consists of a glass substrate coated with a thin semi-transparent metal film, followed by a thin dielectric film. The latter has a refractive index lower than the index of the glass substrate, but higher than the external aqueous medium. Hence, light can be partially confined inside of it, because total internal reflection occurs only at the film/water interface. At the bottom interface, light is partially reflected by the semitransparent metal film, so that a fraction of light escapes from the structure at each reflection. Due to the partial optical confinement, the corresponding waveguide is said to be leaky, and propagation can occur only over a short distance (in the μm -range). We theoretically and experimentally study the fluorescence emission of emitting dipoles placed in proximity of a metal clad waveguide. We demonstrate that a high directionality of fluorescence emission into glass can be achieved. Such emission property can be explained in terms of coupling between the emitted fluorescence and the waveguide leaky modes. When this coupling occurs, fluorescence is radiated through the glass at well-defined angles from the normal axis, each corresponding to the de-coupling angle of a mode supported by the waveguide. Additionally, the dielectric film serves as a spacer between the fluorescing molecules and the metal surface, thereby eliminating direct quenching of molecules in close proximity to the metal.

TOPIC: Nonlinear optic devices

DISCRETE DIFFRACTION OF LIGHT WITHIN OPTICALLY INDUCED SUPERLATTICES IN LITHIUM NIOBATE

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The periodic modulation of a refractive index significantly modifies the diffraction behavior of light beams with respect to that when light propagates in homogeneous media. In this work, we investigate experimentally and numerically the linear and nonlinear diffraction of light beams within one-dimensional quasiperiodic waveguide arrays optically induced within photorefractive planar waveguides in lithium niobate.

We form photorefractive planar waveguides in X- and Y- cut lithium niobate wafers using in-diffusion of titanium and iron or iron and copper. Doping of lithium niobate with titanium and iron results in formation of waveguide layers, and copper in-diffusion helps to vary their photorefractive properties within the wide range. The one-dimensional periodic and quasiperiodic waveguide arrays are optically induced in planar waveguides by laser irradiation with wavelength of 532 nm using one-step and two-step holographic methods.

Linear and nonlinear discrete diffraction of light within optically induced waveguide arrays is experimentally investigated using laser irradiation of a microwatt power range with wavelengths of 532 and 633 nm. In the linear regime we observe the strong suppression of discrete diffraction at single-channel excitation scheme for quasiperiodic waveguide arrays formed by two-step holographic method. We also observe for periodic waveguide arrays the development of the discrete gap soliton regime in the same excitation scheme. Numerical modeling of light propagation processes has been performed with a beam propagation method.

TOPIC: Optofluidic Microsystems and devices – Imaging, sorting, circuits

DEVICE FOR STATIC SORTING OF DIELECTRIC MICROPARTICLES AND LIVING CELLS

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The sorting device is based on three laser beams meeting in sample chamber. Two co-propagating beams are interfering and create field of fringes with adjustable thickness. Dielectric microparticles put into this field settle either in minima or maxima of the fringes according to their size. The third beam is counter-propagating and does not interfere – it is used to compensate the radiation pressure of the interference structure. Well adjusted apparatus thus separates particles with respect to their size or optical properties in four ways – they are moved either in minima or maxima of optical intensity and either in the direction of the interfering beams or opposite. The sorting mechanism is static, so it does not require fluid of medium. Experimental results with sorting of polymer beads of units of micrometers in diameter and living cells will be presented, as well as brief analysis of the influence of fringe thickness on the sorting technique.

TOPIC: Fibre-optic sensors

A NEW AREA OF OPTICAL FIBER SENSORS: HYBRID OPTICAL FIBERS BASED ON REDISTRIBUTION OF POWER.

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Sensors build on optical fibers can measure almost all magnitudes in these days. Article describes a new developing area of optical fiber sensors. These sensors use for their function fundamentals of redistribution of power inside a fiber, which is one of the most sensitive effects that appear inside a fiber. This fact allows to constructing a very sensitive optical fiber sensor.

In our research we design new hybrid optical fiber that affords concurrently utilizing of optical fiber for telecommunications and measurement. This fiber is designed to work on two wavelengths. On telecommunications wavelength of 1550 nm this fiber works in single mode regime and on measurement wavelength of 850 nm is working in quasi-single mode regime. Complicated profile of refractive indexes provides four LP modes on 850 nm that are supported by a fiber and that transmitting significant amount of power. First samples of this hybrid fiber are already made thanks to grant cooperation with Czech Academy of Science.

From our first experiments this fiber seems to be really very sensitive for external factors, but these measurements shows some difficulties pair with fabrication of this fiber, stability of measuring equipment and evaluating of external magnitudes.

LITHIUM NIOBATE ELECTRO-OPTIC TUNABLE BRAGG FILTER FOR AMPLITUDE MODULATOR

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A Tunable Bragg Grating integrated in Lithium Niobate is designed and manufactured. The filter tuning is based on electrooptic effect. Optical simulation based on FEM software showing the optical filtering curve and the coupling factor dependence on the manufacturing parameter is reported. The fabrication process is based on micromachining of the crystal realized using deep RIE, the submicron pattern is defined by Electron Beam Lithography. The tunability of the filter is electrooptically controlled and the filter can be used as low loss and low dimensions intensity modulator or as wavelength discriminator for tracking of optical sensors. The sensitivity with temperature is estimated 50 pm/°C.

TOPIC: Physical and chemical sensors.

DESIGN OF INTEGRATED PLANAR WAVEGUIDE OPTICAL SENSORS FOR HYDROCARBON MONITORING

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A realistic design of evanescent field optical sensors is performed. The designed sensors are constituted by different types of planar dielectric waveguides covered by suitable sensing polymeric overlays. Various kind of embedded strip, ridge and hollow waveguides are considered. The sensor operation is simulated, both the optimal waveguide transverse geometry and length are identified, the advantages and drawbacks are shown for each case, too. The simulation results suggest that a selective excitation of the suitable propagation mode can enhance the sensor performance. The waveguide sensor design is performed by taking into account the physical, chemical and optical properties of the materials which will be actually employed in its construction, with reference to specific polluting hydrocarbons. The refractive index dispersion, the shape and the length of the sensors, the wavelength for which the hydrocarbon absorption peak occurs, the polymeric cover characteristics and the modal polarization are taken into account. The hollow waveguide sensor exhibits very intriguing characteristics: the absorbance is quite linear with respect to the contaminant concentration variation, it exhibiting a slope of 2.52×10^{-2} dB/(cm ppm) of toluene in water. As an example, a sensor 2.5 cm long allows to detect a minimum concentration of 40 ppb by using a low cost optical power meter. These results are particularly significant with reference to the investigation of pollutant diffusion in the aquifer. In fact, so compact devices allows the measurement of the point concentration of the contaminant and the modeling of its flow in the water.

TOPIC: Optofluidic microsystems and devices

MICROFLUIDIC DEVICES INTEGRATING FEMTOSECOND-WRITTEN WAVEGUIDES AND MICROCHANNELS

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A lab-on-chip is a device squeezing onto a substrate the functionalities of a biological laboratory. The next challenge is on-chip integration of photonic functionalities, by adding optical waveguides. Femtosecond-laser irradiation is a powerful technique for direct writing of waveguides in glasses and, followed by chemical etching, for manufacturing microfluidic channels. This opens the possibility of using a single laser system for three-dimensional integration of microfluidic channels and optical waveguides.

In this work we fabricate, by femtosecond laser irradiation, high-quality microfluidic channels and optical waveguides on the same glass substrate, in order to demonstrate *in-situ* optical sensing with good spatial selectivity and high signal-to-noise ratio. Both waveguides and microchannels have been fabricated by a regeneratively-amplified Ti:sapphire-laser using the astigmatic beam shaping technique. Microchannels have been obtained by a subsequent etching in an ultrasonic bath with a 20% HF solution in water. Waveguides spaced by 200 μm have been fabricated crossing a 2.2 mm-long microchannel. The microfluidic channel is filled with a solution of rhodamine in ethylene glycol. When coupling green light in the waveguides, yellow fluorescence is visible from the microfluidic channel. The excitation is very selective in space and the signal-to-noise ratio of the fluorescence is very good. Multiple sensing in different positions of the microchannel is thus possible.

In conclusion, we demonstrated the integration of microfluidic channels and optical waveguides both fabricated by femtosecond laser-pulses. This result paves the way to the use of a single production tool addressing a variety of sensing and monitoring functions for biophotonic chips.

INTERFEROMETRIC DIAGNOSTIC OF THERMAL EFFECTS IN A HIGH POWER DIODE PUMPED ND:YAG CERAMIC SLAB LASER

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We report our study on the thermo-mechanical behaviour of a diode-pumped ceramic slab designed for the realization of a compact, high power solid state laser. The polycrystalline YAG ceramic slab, doped with 1% neodymium, was designed to be inserted in a laser scheme based on side pumping and a zig-zag resonator path.

The analysis was performed placing the slab in the object arm of a Mach-Zehnder Interferometer lighted up by a 5mW, HeNe laser. At the interferometer output, a CCD camera, detects the fringes patterns obtained and its change due to the wavefront modification, caused by the induced thermal lens effect when the ceramic slab is pumped. The interferograms are numerically analyzed and the wavefront is fitted referred to a standard set of aberration components (Seidel components).

With this choice an intuitive interpretation of the results is provided, as two of the fitted parameters represent the tilting of the wavefront in the horizontal and vertical direction, with respect to the propagation direction, while a combination of other two represents the focal length of the pump induced thermal lens.

Different configurations were exploited, and higher resolution measurements (every 0.2sec) of the diodes turning-on phases were also performed.

Tilting effect of 7×10^{-4} rad in the vertical direction and of 2.2×10^{-3} rad in the horizontal direction were observed. The resulting thermal lens has a 1000mm focal length in the horizontal plane, while the effect in the vertical plane is negligible.

F.E.M. computer simulations are used to analyze the observed slab distortions enabling us to attribute the onset of optical tilting to a slab bending, and to distinguish between the role of pump radiation and mechanical constraints break of symmetry in the generation of this deformation.

TOPIC: Optical Microsystems and microsensors

GAN AND DIAMOND BASED MSM PHOTODETECTORS IN THE UV RANGE

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Nowadays, the increasing interest in the ultraviolet imaging for scientific instruments and astronomy applications has triggered a research effort to develop radiation sensors based on wide band gap materials, having different detection schemes and improved device performance.

Among suitable devices, MSM detectors based on diamond, GaN and GaN/AlGaN heterojunction with different composition show high sensitivity, extremely low dark current and covers the whole UV spectral range from 200 to 390 nm, with a good UV/visible contrast, which is about two order of magnitude for GaN detector and even higher for the diamond based ones.

Such discrimination values clearly depend on the material properties, since sub bandgap absorption is related to the photoionization of deep centers.

In particular, GaN/AlGaN heterojunctions with different composition can be used for the achievement of spectrally tunable detectors with narrow band pass spectral response. Al/GaN/Ni planar Schottky diodes with ideality factor $n=1.4$ and more than four order of magnitude of rectification have been realized on sapphire substrates.

Owing to the long carrier lifetime, a chopping frequency dependent responsivity and a nonlinear voltage dependence photoresponse is detected. Similar effects of trapping-related persistent photocurrent and long response time are usually observed in diamond based MSM detectors. A direct comparison is performed using Au/hydrogenated diamond/Al Schottky diodes having similar electrical characteristics.

TOPIC: Nonlinear optical devices, materials and phenomena

HIGH RESOLUTION X - RAYS CHARACTERIZATION OF SUB - MICRON PERIODIC DOMAIN STRUCTURES IN LINBO₃

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Owing to the anomalous scattering phenomenon, the crystal polarizability of a periodically poled ferroelectric crystal is modulated by the domain grating, so that from a structural point of view it can be regarded as a superlattice. This opens up the possibility of using the High Resolution X-rays Diffraction (HRXRD) technique to obtain a structural characterization of periodically poled ferroelectric samples with enhanced sensitivity because of the coherent grating diffraction phenomenon.

We report on the realization and characterization of periodic micrometric and sub micrometric domain structures in congruent Lithium Niobate using two different approaches such as the Czochralski off-center technique for bulk micrometric domain structures [1] and the holographic lithography [2] to obtain sub – micron domain patterning realized by electric field poling performed in the overpoling regime. The realized structures have periods from 2 μm down to around 700 nm and depths compatible with conventional waveguide fabrication standards. In the case of sub micrometric structures, the X-rays measurements can be easily performed with a commercial high resolution diffractometer. For micron – sized gratings, a more sophisticated analysis requiring synchrotron radiation sources is necessary. By using the we were able to measure with high accuracy and non destructively the superlattice period, the presence of in - and out – of – plane strains as low as 10^{-5} and the presence of structural defects.

[1] N. B. Ming, J.F. Hong, D. feng, J. Mater. Sci 17, 1663-1670 (1982)

[2] S. Grilli, P. Ferraro, P. De Natale, B. Tiribilli, and M. Vassalli, Appl. Phys. Lett. 87, 233106 – 233108 (2005)

TOPIC: Photonic crystals and metamaterials. Nonlinear response.

PHOTONIC CRYSTALS EMISSION SPECTRA IN THE PHOTONIC FLAME EFFECT

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Experimental investigations of the spectral characteristics of the light emission, arising in the new nonlinear phenomenon - Photonic Flame Effect (PFE) are presented. PFE has been observed in photonic crystals: artificial opal matrices and nanocomposites at the temperature of liquid nitrogen (77 K). Opal matrices have been placed on the Cu plate, which was partly immersed into liquid N₂, and has been illuminated with focused beam of ruby laser light. We observed in these samples few seconds long radiation in blue-green wavelength range under excitation with 20 ns ruby laser pulse. Typical secondary emission temporal distribution had part, close to constant and contained maximum or sometimes few maximums, which were seen by naked eye as light flashes appearing from time to time.

One of the main PFE features is possibility of excitation transfer to other crystals, placed on the same Cu plate at the distance of few cm from illuminated sample. They also began to emit light, though only one crystal was illuminated by the pumping light.

Spectra of the light emission observed in PFE have been registered of mini-spectrometer FSD-8 with fiber waveguide, working in the spectral range 240 - 1000 nm and providing spectral resolution 6 nm. Spectrum consisted of several relatively sharp lines with average distance between them of 1000 cm⁻¹ and had maximum at the wavelength 400 or 500 nm.

TOPIC: Photonic crystals and metamaterials

PERIODIC MODULATION OF THE DIFFRACTED WAVE IN MICROWAVE PHOTONIC CRYSTALS

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At the exit surface of a photonic crystal slab, the intensity of the diffracted wave can be periodically modulated, showing a maximum in the positive (forward diffracted) or in the negative (backward diffracted) direction, depending on the slab thickness. This thickness dependence is a direct result of the so-called Pendellösung phenomenon consisting of the periodic exchange, inside the crystal, of the energy among direct and diffracted beam. We report the experimental observation of the Pendellösung effect in the microwave region by irradiating 2D photonic crystal slabs of different thickness and detecting the intensity distribution of the e.m. field at the exit surface. Measurements are carried out by placing dielectric rods made of alumina (dielectric permittivity $\varepsilon = 8.6$) having radius $r = 0.4$ cm and height $h = 1$ cm in a square geometry (lattice constant $a = 1.54$ cm) sandwiched in an aluminum parallel-plate waveguide terminated with microwave absorbers. The microwave photonic crystal is built in the shape of a slab 40 cm wide, with a thickness that can be varied adding or removing rows. A monopole antenna is used as a microwave source, oriented to produce an electric field parallel to the rods axis. The intensity maps are collected at the exit of the crystal using a HP8720C Vector Network Analyzer and a monopole antenna probe that moves along the x-y waveguide plane. We focused our analysis on structures with a number of rows n ranging from 5 to 10.

TOPIC: Micro-nano engineering of ferroelectric materials.

DOMAIN ENGINEERED DEVICES IN FERROELECTRICS FOR BEAM MANIPULATION

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Ferroelectrics provide a versatile solid-state platform for microphotonics. Domain engineering in ferroelectric single crystals offers the ability to integrate diverse optical functions, such as frequency conversion, dynamic focusing, and beam deflection, seamlessly integrated in a single device.

In this talk, we describe the design, fabrication and performance of an array of electro-optic tunable microphotonic devices on a ferroelectric chip of LiNbO₃ and LiTaO₃ using domain micropatterning. Electric poling methods to create domain structures will be covered including in-situ monitoring techniques. The performance of several novel devices will be described, including a dynamical focusing lens stack of bi-convex parabolic lenses, and various beam deflectors including a cascaded scanner capable of deflection of 25.4 deg, a beamlet scanner capable of deflecting 10 deg a 6.5 mm diameter beam at a wavelength of 1064 microns, and a hybrid two dimensional scanning system incorporating both a piezoelectric and an electro-optic deflector.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

TOPIC: New characterisation methods for materials and devices.

NEW INSIGHTS INTO PIEZORESPONSE FORCE MICROSCOPY

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In the past decade piezoresponse force microscopy (PFM) has become a standard tool for high resolution imaging of ferroelectric domain patterns. Although widely used, there has been a lot of discussions concerning the origin of the domain contrast in PFM, mainly due to a strong frequency dependence of the PFM signal. We explained this frequency-dependence by a system-inherent background, thereby resolving a number of misunderstood features of PFM imaging. Performing background-free measurements, we were able to record quantitatively reliable data on LiNbO₃ single crystals. We used this new possibility to determine, e. g. the dependence of the domain wall width seen by PFM, on the tip radius and we achieved the so far highest lateral resolution measuring of 17 nm for various thick single crystals.

Another focus of our work concerns the origin of the PFM signal on the non-polar faces of single crystals. We therefore used a hexagonally poled LiNbO₃ crystal all surfaces optically polished. Interestingly on both, and the x - and the y -face, the domain structures can be clearly observed. This is of major importance as it can be applied to precisely determine the depth and the evolution of the shape of surface domains. The origin of the domain contrast observed in PFM on the non-polar faces will be discussed in detail.

TOPIC: Application of optical systems in: Automotive, avionics and aerospace

USE OF SHI IRRADIATION IN γ -In₂Se₃ THIN FILMS FOR PV DEVICES IN OUTER SPACE APPLICATION

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The photovoltaic devices used in outer space application show constant degradation in the performance resulting from the radiation damages. This is due to the destruction of minority/photo-generated carriers, by traps/defects that are formed by the prolonged exposure to highly energetic cosmic rays.

In the present study, we irradiated gamma-In₂Se₃ thin films, which can be used as a window layer in CIS/In₂Se₃ solar cells, with swift heavy ions (90 MeV Si and 80 MeV Ni ions) and studied the optical and photoelectrical properties. The study proved that the photoconductivity could be enhanced by irradiation. A particular film, which showed negative photoconductivity, became positively conductive upon irradiation with 90 MeV Si ions. Annealing out of the electron traps might be the reason for the conversion of photoconductivity from negative to positive. Low temperature photoconductivity study showed the effect of traps, which was annihilated upon irradiation. Photo luminescence study depicted an increase in intensity of near band edge emission, which proved general improvement of the material due to irradiation. Optical band gap of the material increased from 1.8eV to 2.8eV due to irradiation and it is attributed to the annihilation of Urbach tail (disorder) in the material. Irradiation study using 80 MeV Ni ions showed an increase in carrier diffusivity (and mobility) as the irradiation dose/fluence increased. This shows an increase in carrier life time.

SHI irradiation causes dense electronic energy deposition to the material via ion-electron interaction, which leads to transient molten track formation and the material gets modified/amorphised. In the analysis of SHI induced modification in materials, it is found that, beyond a threshold fluence/dose the amorphised zone created by the passage of the ions does not get further modified when another ion passes through the same zone, unless the energy of the ion passing through it is having higher energy. Thus by fabricating pre-irradiated PV devices and/or by using thin film materials for PV device fabrication, which can improve its photoelectrical properties via irradiation, one could reduce the degradation of the performance of the device due to the exposure to cosmic irradiation.

TOPIC: Photonic Crystals.

DESIGN OF PHOTONIC CRYSTAL DELAY LINES BASED ON ENHANCED COUPLED CAVITY WAVEGUIDES

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We analyze different two-dimensional photonic crystal (PhC) structures and optimize the cavity geometry to enhance the performance of coupled cavity waveguide (CCW) passive delay lines.

The coupling factor and the group velocity are evaluated within the tight-binding (TB) reference frame, and the CCW structure is analyzed using the plane-wave expansion (PWE) method. From this analysis, we derive the CCW performance as an optical delay line, i.e. we evaluate the corresponding capacity and the stored bit dimension.

A systematic analysis based on numerical simulations demonstrates that the optimal PhC structure is a hexagonal pattern of air holes in a dielectric material, where the group velocity is reduced up to $0.014c$, with c the speed of light in vacuum, and the bit length is about three orders of magnitude smaller than the one corresponding to a fiber delay line. A proper design of the CCW leads to reduce the group velocity to $0.005c$, in both square and hexagonal patterns.

A detailed analysis of the delay line performance, by varying the defect radius and the cavity dimension, allows us to evaluate the optimal geometrical parameters.

To further reduce the group velocity, we enlarge the dielectric material within the point defect, or we increase the Q factor of the cavity. In the last case, the speed of light is reduced to $0.0011c$, that is 192 times smaller than the corresponding parameter of a standard CCW in a square pattern of dielectric rods, where the cavity consists of one rod removed.

TOPIC: Information society technology

AXIALLY AND TRANSVERSALLY SUPER RESOLVED IMAGING

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We present two techniques allowing improving resolution. The first approach is an all optical approach allowing increasing the depth of focus and therefore preserving the spatial information over larger axial range by an all-optical mean in which a birefringent plate is added anywhere between the imaging lens and the detector. The width of the plate is properly designed such that one polarization state contains in-focus near field information while the other polarization state contains in-focus far field details. Both images are superimposed one on top of the other and thus an all-optical spatially sharp imaging is obtained containing both fields in-focus.

The second approach involves totally random aperture coding which obtains both extended depth of focus as well as transversal super resolved imaging overcoming the resolution limits posed by the spatial under sampling of the detection array. This approach involves digital post processing. The inserted random mask generates OTF having random phase which varies for each and every axial plane causing orthogonality between them. By proper decoding, various axial planes can digitally be inserted into focus. This way of increasing the depth of focus results also with the capability of range estimation for objects positioned within the hyper-focal range. The transversal super resolving capability is obtained when the random aperture coding is used in order to have orthogonal coding of various sections of the optical spectrum of a certain in-focus plane such that the aliasing caused due to the under sampling of the detector can be reconstructed.

TOPIC: Silicon based micro-systems

PHOTONIC TRANSISTORS IN SILICON

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We present various techniques for realizing all-optical and electro-optical transistors in silicon. Three main concepts are presented. In the first we show the realization of an all-optical transistor in which the information as well as the control command are optical. The concept includes activation of the plasma effect in silicon in special miniaturized multi-mode interferometer. The transistor is turned ON and OFF by using spatially non uniform illumination that breaks the balancing between the two interferometer arms. The second concept includes realization of an electro-optical transistor where the control is electronic and the information is optical. The operation principle is based upon photons interacting with metal-oxide-semiconductor (MOS) structure while the external electronic command generates population inversion which affects the absorption of the light passing through the silicon waveguide. The third concept is based upon photo-activated transistors in which the information is electronic and the control command is optical. The free carriers are generated in the silicon due to the external illumination and this varies the electronic resistance of the channel through which the information electrons are passing. The photonic transistors that are realized in all these concepts have micro scale dimensions and fast operation rates.

TOPIC: New active and passive devices in optoelectronics.

MICRORACETRACK COUPLED-RESONATOR OPTICAL WAVEGUIDES IN SILICON PHOTONIC WIRES

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Coupled-resonator optical waveguides (CROWs), consisting of a chain of coupled integrated optical resonators, are emerging as very attractive building blocks to be included in optical delay lines, optical buffers, optical add-drop multiplexers and optical non linear devices. Adopting silicon photonic wires with nanometer silicon core, a wide spectrum of ultra-compact photonic devices such as reconfigurable optical add-drop multiplexers (ROADM), microring and microracetrack resonators, arrayed waveguide gratings (AWG), thermo-optic switches, polarization splitter, Raman optical amplifiers and wavelength converters have been fabricated.

To obtain polarization independence, high quality factor and relaxed fabrication tolerances in Silicon-on-Insulator (SOI) microresonators using photonic wire waveguides, racetrack configuration has been demonstrated very attractive because it enables a coupling between guiding structures with precise control.

In this paper we have developed a transfer matrix approach based on accurate formalism to investigate CROW structures realized by coupling microracetrack resonators with silicon wires as guiding structures (see Figure 1). Coupling between adjacent microresonators and between straight waveguides and microresonators has been investigated using a Coupled Mode Theory (CMT) formulation taking into account the coupling coefficient dependence on z coordinate (as in Fig. 1). Then, coupling coefficient has been calculated by an approach based on 2D full-vectorial Finite Element Method (FEM).

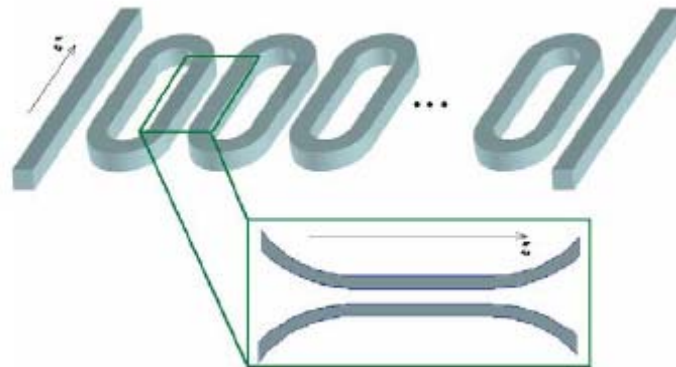


Figure 1. CROW using silicon photonic wires as guiding structures.

TOPIC: Nonlinear Optic Devices (Solitons, soliton waveguides and 3-D circuits).

BRIGTH SPATIAL SOLITON SWITCHING IN A PHOTOREFRACTIVE INTERFACE

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The interface between two different nonlinear media has been the subject of study in nonlinear optics during the last three decades. In this work, we report the bright soliton propagation under reflection and transmission conditions in a photorefractive interface. The interface is formed in a photorefractive crystal divided in a uniform index zone and another zone with transverse modulation of refractive index. This modulation is induced by self-focussing of a diffracted beam from an apertured beam. In our preliminary results, we show important properties of soliton reflection and refraction at the interface with new opportunities for control of beam steering, routing or reflection (switching). We found strong refraction with small incident angles; and guiding channels when the incident soliton is launched almost parallel to the interface. The results between preliminary experimental results and our numerical simulation are in good agreement.

TOPIC: Physical and chemical sensors

THE GAIN AND INDEX LEVER EFFECTS FOR ENHANCED SENSITIVITY CHEMICAL AND BIOLOGICAL SENSORS

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Lasers and other photonics based semiconductor devices can be engineered to be sensitive to numerous physical effects, such as temperature, strain, pressure, magnetic field, or refractive index of the ambient environment. Here, we discuss a new type of on-chip photonic sensor that consists of a multiple section edge emitting laser (EEL) with a lateral surface coating that is functionalized for detection of low levels of chemical or biological stimulants. As molecules adsorb onto the surface, the optical properties of the coating, specifically the complex refractive index, change and this can cause either the laser wavelength or the output power to vary. Compared to conventional optical chemical and biological sensors that use fiber gratings, surface plasmon resonances, or surface reflectance, our sensors offer the advantages of smaller size, monolithic integration of laser source and detector, and 1-D scalability to an array of sensors that can be functionalized to detect different agents.

The gain lever is an effect in multiple section lasers that can be used to enhance the amplitude modulation efficiency by biasing the sections unevenly. The gain-index lever effect describes the corresponding enhancement in the wavelength chirp as the laser is modulated. We will present measurements of the gain lever and gain-index lever effect in our InGaAs double quantum well lasers and show how the minimum detection limit of our sensor can be improved by one to two orders of magnitude by using these effects.

This work was performed under the auspices of the U. S. Department of Energy (DOE) by the

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7405 Eng 48. UCRL-ABS-230338

TOPIC: Applications of optical systems and devices

SAFE INFRARED EYE BLINKING DETECTOR

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Eyes blinking detectors are often used to monitor drowsiness or fatigue during any activity in the daytime. Usually, this monitoring requires long recordings and, therefore, sensors must be as less intrusive and safe as possible to avoid additional annoyance and hazards. According to these two requirements, an infrared eye blinking detector has been developed. It is formed by an infrared emitter diode coupled to an infrared photodiode embedded in the same device. Thus, it can be clipped on the rod of the glasses and placed close to the eye.

The sensor's working principle is based on the difference in reflectivity between an open and closed eye. As infrared radiation hits the cornea, the emitter has been powered according to class 1 specifications of the IEC EN 60825 standard on the safety of laser and LED products.

The sensor uses the technique of modulating the infrared beam to be less sensitive to head movements and changes in environmental light. Its frequency, duty cycle, and output power have been trimmed to be safe for the eye even if it works for many hours.

Actually, the sensor is wire-connected to a properly developed acquisition board that sends the eye blink signal to a personal computer in order to be saved or to be processed in real time.

Furthermore, the acquisition board can recognize eye blink events by setting the trigger level by itself, via a calibration, or by user interaction.

TOPIC: Chemical sensor.

IN-SITU GAS SPECTROSCOPY WITH TUNABLE SEMICONDUCTOR LASERS

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We report on novel uses of MEMS tunable and multi-segmented semiconductor lasers for fieldable, real-time, multiplexed detection and monitoring of gas emissions, critical in identifying drugs, explosives, and chem-bio agents, understanding material aging mechanisms, combustion research, and air pollution studies. Typically, samples are collected in the field and transported to the laboratories for analysis (gas-chromatography mass-spectroscopy). We are combining collection and detection onto a single optical platform. In one inception, we consider MEMS tunable VCSELs designed to scan the spectral features of gas species flowing through the gap created by the sacrificial layer between the active layer and the top Distributed Bragg Reflective (DBR) mirror. The device operation the device could be described as a resonant multipass gas cell with optical gain for in-situ absorption spectroscopy. Having biased the laser above threshold, the gas flowing through the air gap spoils the gain-loss balance necessary for lasing by increasing the absorption loss in the lasers itself, which is detected by the internal light being reflected several times between the bottom and the top suspended DBR mirrors. First estimates show Limit of Detection (LOD) of 10-100 ppms for CH₄, HCl, CO_x, NO, O₂, etc..., and the ability to scan few pms spectral lines on 20-50 nm range with 1 nm tuning. We will discuss our progress and results on MEMS tunable 760nm VCSELS for O₂ sensing and the use of coatings to possibly improve the sensitivity. Initial studies on tunable multi-section edge emitting lasers, laterally coated with palladium, indicated LOD of a few ppms for H₂ detection.

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UCRL-ABS- 230341*

TOPIC: Nonlinear optic devices - Materials and phenomena.

HAFNIUM-DOPED LITHIUM NIOBATE CRYSTALS FOR NONLINEAR OPTICS APPLICATIONS

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In recent years it has been shown that quasi-phase-matched wavelength conversion in periodically-poled lithium-niobate (PPLN) crystals can have important applications in various fields. Unfortunately the presence of the photorefractive effect prevents a wide utilization in guided-wave optics and in high intensity operations. Resistance to photorefractivity can be considerably increased by adding to congruent lithium-niobate (cLN) an appropriate dopant, such as MgO. Recent experiments performed by our group proved that also cLN doped with HfO₂ (Hf:cLN) exhibit a strong resistance to the photorefractive damage.

We present the results of an extensive investigation of the properties of Hf:cLN crystals as a function of dopant concentration (up to 11 mol%), including analysis of crystal birefringence, photorefractivity, nonlinearity (d_{31} -coefficient) and phase-matching temperature.

The obtained data give clear evidence of three different, important aspects:

-The “threshold concentration” of Hf, which should correspond to the minimum amount needed to remove all the Nb-ions in the Li-sites, is about 2mol% a value much lower than that previously observed.

-Photorefractivity, as a function of light intensity, of LN crystals doped “abovethreshold” is different from that of undoped cLN and much more similar to that of stoichiometric-LN.

-Crystal nonlinearity slightly decreases (less than 10%) by increasing Hf concentration. up to 3mol%. Conversely it decreases more significantly for higher dopant concentrations.

We demonstrate that Hf:cLN with dopant-concentration between 2 and 3 mol% exhibits a nonlinear efficiency comparable to cLN, and present an enhanced resistance to photorefractivity, thus representing a very attractive candidate for the development of PPLN-based nonlinear devices.

ALL OPTICAL 3-D TRAPPING THROUGH A FIBER TWEEZER

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In this paper we present a new and miniaturized optical-fiber integrated device for trapping, manipulation and analysis of biological specimens. Optical tweezers represent a powerful tool to manipulate, without physical contact, biological systems characterized by a length scale ranging from tens of nanometers to hundreds of micrometers. Standard tweezers, based on optical microscopes, present several limitations due to their bulky structure that prevents their utilization in several environments. The exploitation of optical fibers, instead of microscope-objectives, for the delivery and proper shaping of the trapping beam, will allow overcoming most of the problems related to the microscope structure, enabling many new applications .

Three dimensional (3D) trapping using a single fiber element, and purely optical forces is extremely difficult; the main limitation comes from the fact that the numerical aperture (NA) of the fiber is usually quite low. The limitations encountered using classical approaches are overcome in our device by using a single structure (fiber or bundle) characterized by an annular distribution of the light-guiding region. By properly shaping the structure-end and exploiting total-internal-reflection at the fiber-biological medium interface, beam convergence with high NA is achieved.

The trapping efficiency of the proposed solution has been numerically verified by calculating the axial optical forces (scattering and gradient) exerted on a polystyrene particle in the Rayleigh scattering regime. Fabrication and testing of the optical fiber tweezers are currently running.

TOPIC: New active and passive devices in optoelectronics.

THERMO-OPTIC EFFECT IN SILICON SLOT WAVEGUIDES

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Nanometer slot optical waveguides realized by using Silicon-on-Insulator (SOI) technological platform enable high optical confinement in a low-index very small region. This kind of guiding structures is emerging as very attractive for active and passive photonic devices fabrication. In last two years, a great variety of optical devices has been realized based on SOI slot waveguides, including micro-ring resonators, optical modulators, electrically pumped light emitting devices, directional couplers, alloptical logic gates and beam splitters. Very recently, slot guiding structures have been demonstrated as very useful for chemical and biochemical optical sensing because they are very sensitive to either refractive index change of cover medium or thickness increase of deposited receptor layer. Silicon possesses a very high thermo-optic coefficient ($1.86 \cdot 10^{-4} \text{ K}^{-1}$ at 1550 nm), so silicon refractive index change produced by thermo-optic effect is a widely used approach for switching, modulation and tuning in a significant number of silicon photonic devices.

In this paper we have carried out a Finite Element Method (FEM)-based static and dynamic thermo-optical analysis of slot waveguides under heating. A model enabling both thermal and electromagnetic simulations in the same calculation environment has been developed. Waveguide effective index sensitivity to temperature changes produced by an heater laying on the top of the guiding slot structure has been investigated (see Fig. 1). Assuming to produce an instantaneous temperature change within the metallic heater, waveguide effective index dynamic behaviour has been calculated. Influence of slot waveguide geometrical features on thermal sensitivity and response time has been studied, taking also into account the effect of cover medium optical and thermal properties.

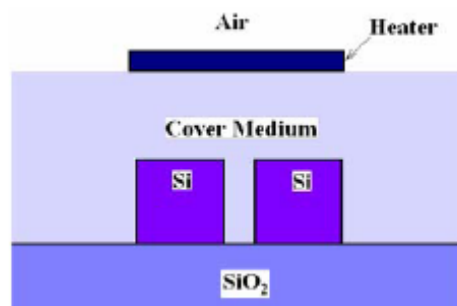


Figure 1. SOI slot waveguide.

TOPIC: Nonlinear optic devices

POLING OF CONGRUENT LITHIUM NIOBATE CRYSTALS WITH SURFACE MODIFICATION

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Ferroelectric lithium niobate (LiNbO_3) crystals have emerged as important materials in nonlinear optical applications such as electro-optics and second-harmonic generation. A critical step in realizing many of these devices is the ability to microengineer 180° domains. Most of the reported switching kinetics in these crystals has been for the congruent composition since it is easy to grow and is available commercially as high quality wafers. But the switching field for congruent LiNbO_3 is found to be more than 20 kV/mm (the risk of dielectric breakdown associated to high poling field makes it quite difficult to get samples thicker than 1 mm), whereas for stoichiometric crystals it could be much lower. At the same time the quality of stoichiometric crystals is not high. Thus for device applications we actually need the quality of congruent crystals and low switching field of stoichiometric one. To solve this problem we suggest surface modification of congruent crystals by Li enrichment.

This paper presents electric field domain switching experiments carried out on congruent lithium niobate crystals with Li enriched surface layer. Li enrichment of congruent lithium niobate surface has been made by sample annealing in Li_3NbO_4 or $\text{LiNbO}_3:\text{Li}_3\text{NbO}_4$ (1:1) powder during 0.5 or 1 h at 800°C . It was found that the Li enrichment of congruent lithium niobate surface layer allows to obtain a composition of surface layer very close to stoichiometry and has enabled domain inversion with the lower electric field than in congruent material.

TOPIC: Nonlinear optic devices

PATTERNED LITHIUM NIOBATE THIN FILMS PREPARATION BY PHOTSENSITIVE SOL-GEL METHOD

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The integrated optical elements prepared on ferroelectric thin films (in particular, lithium niobate films) are the most promising for optoelectronics applications. A key stage in production of the integrated optics devices is forming of microtopography on crystalline films. The current methods generally comprise two separate steps: producing of thin film and creation a topographical pattern on it. Majority of these traditional methods is based on producing patterned films by using photoresist (photolithography with further chemical etching to form the pattern on the crystalline thin film). But use of these traditional methods to form the patterned lithium niobate films is very complicated due to difficulties of lithium niobate etching by mask.

Here we present new approach based on the development of the modified sol-gel technology using the photosensitive gel. This is one of the newest and prospective technologies for obtaining of integrated optical devices. In this case, the photolithography is used on the stage of dried gel whereupon the direct crystallization of patterned film allows to create integrated optical element without subsequent etching of crystalline film.

Presented method of patterned thin film preparation involves synthesis of photo-reactive complex of metal, which undergoes change under the UV light. Pattern on an amorphous (precursor) film can be obtained by exposition of the selected area of the film to UV light. After etching of not exposed part of the film, the subsequent crystallization allows to obtain a crystalline film with the topographical pattern, i.e directly prepare different waveguide devices.

TOPIC: New active and passive devices in optoelectronics.

SHIFT OF APPLICATION POINT OF ANGULAR MOMENTUM IN THE AREA OF ELEMENTARY POLARIZATION SINGULARITY

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The object of report is strictly connected with relatively new optical area, namely, with new type of optical tweezers.

The behavior of the Poynting vector in the area of elementary polarization singularities with one or two C -points, which are bounded by regular shape s -contour is considered. It was shown that C -points are associated with the “vortex” kind singularities of the averaged transversal component of the Poynting vector if the handedness factor and topological charge of C -point are characterized by the different signs. “Passive” Poynting singularities arise in the area, if the signs are the same.

It is shown that such field structures may be obtained by superposition of orthogonally circularly polarized beams. It is established that Poynting singularity shifts relatively C -point position under the definite changes of amplitude or phase on of the superposing beams. Thus, the point of application of the averaged angular momentum shifts also.

The results of the computer simulation are presented. The perspectives of new type optical traps creation are discussed.

TOPIC: Nonlinear optical devices, periodically poled devices

INTEGRATED NONLINEAR DEVICES IN PERIODICALLY POLED LiNbO₃ (PPLN)

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Recent progress achieved with integrated optical devices exploiting quasi-phasematched second order nonlinear interactions in periodically poled LiNbO₃ is reported. Also cascaded combinations of two $\chi^{(2)}$ processes like sum- and difference frequency mixing (cSHG/DFG, cSFG/DFG) are discussed with emphasis on Ti-indiffused waveguide structures.

For future ultrafast reconfigurable all-optical networks key signal processing functionalities like wavelength conversion, parametric amplification, (de-)multiplexing, and switching will be essential. Recent experiments for the simultaneous compensation of chromatic dispersion and nonlinear phase noise using cSHG/DFG for midspan spectral inversion (optical phase conjugation (OPC)) will be presented. Polarization-independent schemes for wavelength conversion have been exploited to allow in-line signal processing. OPC results in a significant increase in transmission distance when compared to a "conventional" transmission system using dispersion compensating fiber for chromatic dispersion compensation. For phase shifted keyed modulation formats (differential phase shifted keyed (DPSK), differential quaternary phase shifted keyed (DQPSK)) nonlinear phase noise can seriously limit the transmission distance. Recent frequency resolved optical gating (FROG-) results together with simulation results confirm the excellent coherence transfer during $\chi^{(2)}$ -based quasi-phase-matched nonlinear optical wavelength conversion.

Besides optical communications integrated sources for tuneable coherent radiation have attracted much interest for applications in optical sensing. Integrated optical parametric oscillators (IOPOs) with Ti:PPLN-waveguide cavities (singly or doubly resonant) are promising as efficient, tuneable, and compact light sources for the mid infrared spectral range ($2700 \text{ nm} < \lambda < 3500 \text{ nm}$), as the fundamental vibrational-rotational absorption "finger prints" of prominent trace gases are located in this range.

In an IOPO the coherence transfer from the pump wave to signal- and idler waves is strongly determined by the dispersion properties of the waveguide material. This facilitates the realization of synchronously pumped IOPOs and the use of broad-band cw-pump waves in a singly resonant IOPO.

TOPIC: Optical Microsystems and microsensors
(New materials and Technologies)

SILICON NANOCRYSTALS EMBEDDED IN SiO₂: OPTICAL AND TRANSPORT PROPERTIES

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Silicon nanocrystals of variable size and density embedded in very thin SiO₂ layers may be fabricated by different techniques, including co-sputtering of Si and SiO₂ [1], low pressure chemical vapor deposition of amorphous Si, followed by high temperature thermal oxidation/annealing [2] and anodic dissolution of Si using short monopulses of current [3]. Their optical characterization by photoluminescence and ultra fast transient photoinduced absorption [4] reveals the importance of both quantum effects and interface states between silicon nanocrystals and the surrounding SiO₂ matrix in the relaxation of photoexcited carriers. Electrical transport in SiO₂ films with embedded Si nanocrystals depends strongly on nanocrystal size and density. Following the transport and photoluminescence above, at and below the percolation threshold, one may conclude on the coupling between electrical and optical properties.

The above properties of Si nanocrystals find important applications in nanoelectronic, photonic and sensor devices.

References

- [1] I. Balberg, E. Savir, J. Jedrzejewski, A. G. Nassiopoulou and S. Gardelis, Phys. Rev. B, 75, 235329 (2007)
- [2] P. Photopoulos and A. G. Nassiopoulou, Appl. Phys. Lett, 77 (12), p. 1816-1818, (2000)
- [3] S. Gardelis and A. G. Nassiopoulou, Phys. Stat. Sol. (c) 4, no. 6, 2165-2169 (2007)
- [4] E. Lioudakis, A. Othonos and A. G. Nassiopoulou, Appl. Phys. Lett. 90, 171103 (2007)

PUTTING FRESNEL OPTICS INTO AN OPTICAL FIBRE

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Fresnel fibres represent a new direction in optical fibre research – they consider for the first time tailoring the phase profile of an optical fibre to achieve specific functionality. Many of the concepts developed in Fresnel lens technology translate directly to Fresnel fibres. Of particular note was the demonstration of far field localisation of light from the end of an optical fibre without any additional optics. Whilst there are certainly a few fabrication challenges to fully exploiting this technology, the potential they offer is enormous. In this presentation I will review the developments and promises of this new technology, including addressing issues of how to combine these fibres with new developments in optical fibre components such as gratings.

OPTICAL IMAGING OF GRATING STRUCTURES AND PHOTONIC CRYSTALS

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Images of three-dimensional objects can be modeled using the scattering function method. The object is considered to be illuminated by an angular spectrum of plane waves. Each of these plane wave components scatters the light, and the image is calculated as an integral over the illuminating and scattered angular spectrum components.¹ The scattering by the object can be calculated by a variety of methods including coupled wave and modal methods.

For a weakly-scattering object, the scattering can be calculated using the Born approximation. For an object structure that is slowly varying in space, the scattering can be calculated using a generalization of the Kirchhoff approximation.^{2, 3} In both cases the scattering function of the object, which is a four-dimensional quantity (two direction cosines each for incidence and scattering), reduces to a three-dimensional function with arguments the three-dimensional spatial frequencies or components of the grating vector.⁴ The optical system can be modeled by a three-dimensional transfer function, allowing the spatial frequency content of the image to be determined.⁵

For very regular objects, however, this method breaks down because of the strong Bragg scattering. This is particularly the case for photonic crystal structures. It is interesting to note that while the name "photonic crystal" was meant to refer to the analogy in the scattering behaviour of electromagnetic waves to that of electrons in a crystal, many of the properties of scattering by a periodic medium were in fact first developed for the electromagnetic case, that of X-rays. Thus the dynamical theory of diffraction is an alternative description for grating scattering.⁶

References

1. C. J. R. Sheppard and J. T. Sheridan, "Micrometrology of thick structures," *Proc. SPIE*, 1139, 32-40 (1989).
2. C. J. R. Sheppard, T. J. Connolly, and M. Gu, "Scattering by a one-dimensional rough surface and surface reconstruction by confocal imaging," *Physics Review Letters* **70**, 1409-1412 (1993).
3. C. J. R. Sheppard, T. J. Connolly, J. Lee, and C. Cogswell, "Confocal imaging of a stratified medium," *App. Opt.* **33**, 631-640 (1994).
4. C. J. R. Sheppard, "Scattering and the spatial frequency representation," in *Light Scattering and Nanoscale Surface Roughness*, A. A. Maradudin, ed. (Springer, New York, 2007), pp. 61-92.
5. C. J. R. Sheppard and M. Gu, "Three-dimensional transfer functions in confocal scanning microscopy," in *Visualization in Biomedical Microscopies*, A. Kriete, ed. (VCH, Weinheim, 1992), pp. 251-282.
6. C. J. R. Sheppard, "The application of the dynamical theory of x-ray diffraction to thick hologram gratings," *Int. J. Electronics* **41**, 365-373 (1976).

INTRACAVITY CW DIFFERENCE-FREQUENCY GENERATION OF TUNABLE AND NARROW-LINEWIDTH IR RADIATION

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A novel set-up is presented for difference-frequency generation of IR radiation in periodically-poled LiNbO₃ (PPLN) using an intracavity scheme. Inside a miniature Ti:Sa ring laser cavity, injection-locked by an external-cavity diode laser (ECDL) for single mode operation, a 2-cm-long PPLN crystal is inserted. This allows nonlinear mixing of fiber-amplified radiation tunable in the 1030-1050 nm range and radiation around 850 nm generated in the Ti:Sa cavity. Such configuration is expected to enhance by several orders of magnitude the power of the generated IR radiation, with respect to single-pass generation [1], while preserving tunability and spectral purity. Preliminary results of our test set-up will be shown and discussed.

The enhanced generated power should also allow to extend the IR spectral coverage well beyond the PPLN cut-off wavelength, still maintaining a useful power for subsequent applications. Moreover, such a set-up also preserves the possibility to directly refer the IR frequency to a visible or near-IR optical frequency comb, as already shown for the single-pass scheme [2]. This opens the possibility of performing absolute frequency measurements for most IR molecular transitions, achieving unique spectral coverage with unmatched sensitivity.

References

- [1] S. Borri et al., *Appl. Phys. B* **76**, 473 (2003).
- [2] D. Mazzotti et al., *Opt. Lett.* **30**, 997 (2005).