Advanced Architectures in Photonics 2014

21st – 24th September 2014, Prague, Czech Republic
Diplomat Hotel**** Prague
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AAP 2014 *covers topics on science, technology and applications of micro- and nano-structured materials used in optics and photonics.*

About Advanced Architectures in Photonics

AAP2014 is the first conference in the AAP series, Advanced Architectures in Photonics, which is held in Prague, Czech Republic. The main AAP objective is to attract attention of international research groups and academic community to photonic and applied optics-oriented research in the Czech Republic.

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The conference will be held in Diplomat**** Hotel Prague, in the centre of the Czech capital Prague.

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Main topics

Preparation of photonic materials and devices

- design, synthesis, purification and processing of optical materials
- self-assembly growth and low-cost fabrication techniques
- thin-film deposition and nano-patterning of material surfaces
- drawing techniques for micro-structured optical fibers, fabrication of waveguides, multilayers, spheres, ...

Light confinement in optical waveguides, micro-structured fibers, spheres, photonic crystals and structured surfaces

- non-linear effects: self-phase modulation, four-wave-mixing, two-photon absorption, Raman and Brillouin scattering, super-continuum generation and laser emission, rare-earth doped devices for photon up- and down-conversion, surface plasmons generation

Characterization and modeling of optical properties of structured photonic materials

- measurements and calculations of the optical properties of structured materials and devices
- design of new functional optical, photonic, plasmonic devices and metamaterials

Applications

- optical sensing in industry, medicine, security and defense
- optical and chemical sensing based on surface-enhanced effects
- enhanced performance of optical devices and elements
- new light sources and non-linear effects
- laser emission from micro- and nano-structured materials
- applications of photonic crystals and metamaterials

Programme scheme

Sunday September 21st	**Monday** September 22nd	**Tuesday** September 23rd	**Wednesday** September 24th
	Openning address 8:30 - 8:40		
	8:40 – 9:25 **PLENARY** - MO1P Y. Ohishi Prospect of mid-infrared...	8:30 – 9:15 **PLENARY** - TO25P S. Matsui Innovative nanoimprint...	9:00 – 9:35 WO39 J.M. Macak Towards functional adv...
	9:25 – 9:40 Coffee break	9:15 – 9:30 Coffee break	9:35 – 9:50 Coffee break
	9:40 – 10:15 **INVITED** - MO2I B. Luther-Davies Chalcogenide waveguides...	9:30 – 10:05 **INVITED** - TO26I Y. Sugimoto Nanofabrication by imprint...	9:50 – 10:15 WO40 T. Sabel Volume and surface...
	10:15 – 10:50 **INVITED** - MO3I J.-L. Adam Chalcogenide glass micro...	10:05 – 10:40 **INVITED** - TO27I J. Nishii Electrical imprint for micro...	10:15 – 10:40 WO41 L. Ondic Improved light extraction..
	10:50 – 11:25 **INVITED** - MO4I M. Schmidt Nanowires in Fibers...	10:40 - 11:15 **INVITED** - TO28I D. Hewak Preparation of chalcogen...	10:40 – 11:05 WO42 O. Mouawad Spectral broadening..
	11:25 – 12:00 **INVITED** - MO5I S. Mizuno Solar-pumped fiber lasers...	11:15 – 11:50 **INVITED** - TO29I S. Kasap Development of Sm-doped...	11:05 – 11:30 WO43 V. T. Mai Te-Ge-Se films: elaborat...
	12:00 – 12:25 MO6 J. Picot- Clemente Supercontinuum generation...	11:50 – 12:25 **INVITED** - TO30I R. Morandotti Nonlinear frequency conv...	11:30 – 11:55 WO44 J. Ren Tunable emission from...
	12:25 – 13:30 Lunch break	12:25 – 13:30 Lunch break	11:55 – 12:05 Closing address
	13:30 – 14:15 **PLENARY** - MO7P C. Lopez Self-assembled structures...	13:30 – 13:55 TO31 S.-H. Oh Engineering metallic nano...	12:05 – 12:20 Take away lunch
	14:15 – 14:50 **INVITED** - MO8I H. Fudouzi Opal photonic crystal films...	13:55 – 14:20 TO32 J. Dostalek Plasmonically amplified...	13:00 – 19:00 CONFERENCE TRIP
	14:50 – 15:25 **INVITED** - MO9I M: Pemble Colloidal photonic crystals...	14:20 – 14:45 TO33 B. Frank Electrochemical route to...	
	15:25 – 15:50 MO10 Y. Takeoka Producing coloured materials...	14:45 – 15:10 TO34 L. Coolen Plasmon excitation...	
16:00 – 19:00 REGISTRATION and WELCOME DRINK	15:50 – 16:15 MO11 C. Schäfer Stimuli-responsive elastome...	15:10 – 15:35 TO35 L. Coolen Determination of the orien...	
	16:15 – 16:30 Coffee break	15:35 – 15:50 Coffee break	
	16:30 - 17:05 **INVITED** - MO12I J. Homola Plasmonic structures for opt...	15:50 – 16:15 TO36 S. Yannopoulos Controlling the morphology...	
	17:05 – 17:30 MO13 J. Valenta Imaging micro-spectroscopy...	16:15 – 16:40 TO37 M. Mensik Sub-picosecond transient...	
	17:30 – 17:55 MO14 T. Mocek Development of kW-class lasers..	16:40 – 17:05 TO38 M. Vala Diketopyrrolopyrroles...	
	16:30 – 18:00 MP15 - 24 POSTER SESSION		
	18:00 – 20:00 CONFERENCE RECEPTION	18:00 – 21:00 CONFERENCE GALA DINNER	

Conference rooms (Diplomat Hotel Prague, 2nd floor)

Prospect of mid-infrared supercontinuum generation using soft glasses

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Many efforts have been devoted to material and waveguide device developments to meet the demands of future photonics applications. There are still strong needs and interests to explore nonlinear fiber glass materials in order to develop various fiber devices including fiber lasers, optical parametric amplifiers, wavelength converters, slow light generation, supercontinuum (SC) generation, quantum effect devices, etc. Especially, SC generation has attracted the large interest in recent years due to its extensive applications such as frequency metrology, optical coherence tomography, pulse compression, microscopy and spectroscopy, telecommunication, and sensing. Silica fibers with engineered dispersion are currently used as major waveguide materials. However, they have two main limitations: low nonlinearity, and poor transmission range in mid-IR. Among non-silica glasses, such as tellurite, fluoride and chalcogenide glasses, are promising materials for photonics device applications, as they combine (i) a wide transmission window, (ii) good glass stability, (iii) high refractive index, and (iv) increased nonlinear optical properties. However, the applications of high nonlinear soft glasses to photonics devices, especially nonlinear devices, have not always been successful up to now. One major issue would be the chromatic dispersion control. We have succeeded in chromatic dispersion engineering of those highly nonlinear soft glass fibers using new microstructured optical fiber structures, such as hybrid structure, and nanowire. Here I present a new prospect of highly nonlinear soft glass microstructured optical fibers for SC generation.

Chalcogenide waveguides and devices for the mid-infrared

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Chalcogenide glasses offer excellent transparency across most of the mid-infrared and are, hence, well suited for sensing and source technologies in this important wavelength range. In this talk I will summarize our program on the development of mid-infrared supercontinuum (SC) sources for the functional group band of the mid infrared and planar waveguide structures for optical sensing.

To generate SC we have developed several designs of dispersion engineered rib waveguides which can be pumped in the 3-4.5μm region with fsec optical pulses. These comprise Ge-As-Se glass cores on a Ge-As-S under-cladding with core area of 7-20μm^2 An example of the typical SC spectrum we produced using a 1cm long waveguide device pumped with 300fs, kW pulses at 4μm is shown in Fig 1a whilst the suitability of this source for spectroscopy was demonstrated by recording the high-resolution spectrum of water vapour shown in Fig 1b. This particular source covers the full functional group band of the mid-IR from 2.5-6.7μm and has an average brightness exceeding that of a typical synchrotron by more than two orders of magnitude. The average power in the SC emitted in a single mode from the waveguide is 10-20mW. Using larger mode are device we expect to improve the average power up to 100mW and extend the wavelength coverage to >10μm thereby producing a compact source very suitable for micro-spectroscopy.

In the area of sensing we have developed air clad rib waveguide designs that can be used as molecular sensors when combined with suitable tunable lasers. The challenge here is to reduce the waveguide loss to an acceptable level across abroad wavelength range. In this context we have successfully demonstrated a waveguide sensor for the full functional group band with average loss of 0.5dB/cm. An important consideration for this device is how to protect the surfaces from contamination from water and adventitious carbon. We show that a very thin plasma deposited fluorocarbon layer is effective for this purpose [1].

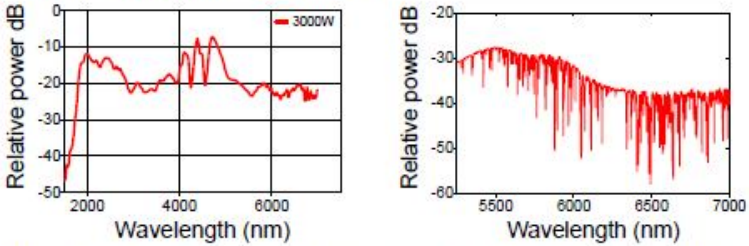

Fig. 1a (LHS). The SC spectrum produced from a 1cm long chalcogenide waveguide pumped by an 300fs 4μm source. **1b** (RHS) this source was used to record a high resolution absorption spectrum of water vapour as a demonstration of its suitability for spectroscopy.

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Chalcogenide glass microstructured optical fibers

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Compared to oxide based glasses, vitreous materials composed of chalcogen elements (S, Se, Te) can present large transparency windows in the infrared. Indeed, chalcogenide glasses can be transparent from the visible up to 12-15 µm, depending on their compositions. In addition, chalcogenide glasses contain large polarisable atoms and external lone electron pairs which induce exceptional non-linear properties. Consequently, the non-linear properties can be 100 or 1000 times as high as the non-linearity of silica [1, 2]. The manufacturing of small-core fibers (diameter smaller than 5 µm) can be of great interest to enhance non-linear optical properties for telecom applications such as signal regeneration [3], generation of supercontinuum, and conversion to the mid infrared using Raman shifting [4-7] . In optical transmission system, non-linear effects in optical fibers can be used to realize all-optical processing such as data regeneration by self-phase modulation (SPM) or wavelength conversion by four wave mixing (FWM).

An original way to obtain single-mode fibers is to design microstructured optical fibers (MOFs). In addition, these fibers present unique optical properties thanks to the high degree of freedom for designing the geometrical structure. With chalcogenide glasses, MOFs are prepared by a newly established casting method [8]. Thanks to this technique, chalcogenide MOFs with low optical losses have been elaborated [6] . The first chalcogenide MOFs exhibited a non-linear parameter γ ($\gamma=2\pi n_2/\lambda A_{eff}$) between 100-1500 W^{-1} km^{-1} and optical losses at the telecom wavelength of 10-15 dB/m [9, 10]. More recently, the non-linear parameters in a chalcogenide MOF reached values from 15000 to 31000 $W^{-1}km^{-1}$ with optical losses less than 5 dB/m [11]. However, despite their very small mode area (5-1 μm^2), they still exhibit a multimode behavior, which is not suitable for telecom applications.

In this paper, the realization of low losses and innovative chalcogenide MOFs such as small core or exposed core fibers will be described. The small core fibers were used for wavelength conversion by non-linear effects (four wavemixing, Raman and Brillouin scattering). Secondly, an exposed core fiber was used for the detection of infrared signatures of organic molecules.

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Nanowires in fibers: a novel base for nanophotonics

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Cylindrical nanophotonic devices in fiber form are a new class of integrated components which can overcome several limitations of state-of-the-art planar devices such as small aspect ratios or significant insertion loss when coupled to single-mode fibers. Our approach to overcome these essential bottlenecks and to implement functionalized fiber waveguide structures is based on nanowires in optical fibers using the pressure-assisted melt filling technology. This method gives fibers new functionalities and opens up new ways for applications in various fields such as plasmonics, material science or nonlinear optics [1].
Using this techniqiue plasmonic nanowires have been successfully integrated into photonic crystal fiber by selectively addressing holes in the holey cladding. We have shown spiralling planar plasmonic modes (Fig. 1a) on single metallic nanowires, coupling between individual plasmons giving rise to superplasmonic modes consisting of more than 100 individual plasmons and ultralow loss hybrid dielectric-plasmonic modes [2].

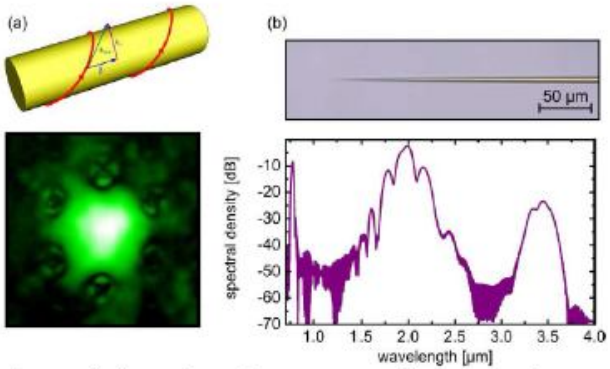

Fig. 1. (a) top: Planar spiraling surface plasmon on metallic nanowire. bottom: measured near field distribution of plasmonic supermode consisting of individual quadrupole plasmons. (b) top: tapered chalcogenide nanowire (nanospike) inside a silica host. Bottom: generated supercontinuum in a 2 mm long nanospike sample when being pumped with a fs laser.

We also used our fabrication approach to create dielectric nanowires made from chalcogenides in silica capillary (Fig. 1b), giving rise to highly nonlinear photonic devices, which cannot be implemented by any fiber drawing technique. In such fibers we have shown high-extinction band gap guidance and mid-infrared supercontinuum generation. We have also implemented a photonic nanospike with dispersion tuned properties, which greatly enhances the incoupling into our waveguide by a factor of 60 [3].

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Solar-pumped fiber lasers and application to photovoltaics

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A solar-pumped laser (SPL) is an optical device that converts incoherent sunlight with a wide spread of spectrum and low areal energy density into a monochromatic coherent light beam. SPLs are expected to be promising core devices in such technologies as satellite communications, space debris management, sunlight energy transmission from space, highly efficient photovoltaic cell and energy cycling by converting sunlight to chemical energy. In particular, optical fiber type SPL, i.e., a solar-pumped fiber laser (SPFL) improves the lasing efficiency and beam quality, as well as solves the cooling issue [1].

Figure 1 (left) shows a schematic set-up of our solar-pumped fiber laser. The sunlight was corrected by an off-axis parabolic mirror and focused on the one end of a double-clad (a single mode designed core/ an inner clad working as an optical waveguide for pumping light/ an outer clad) fiber. ZrF_4-BaF_2-LaF_3-AlF_3-NaF (ZBLAN) fluoride glass doped with Nd^{3+} ions was selected as a fiber medium because of its highly figure of merit of laser, emission quantum efficiency under sunlight, and integrated absorption strength in the 450-900 nm range [2].

Lasing experiments using natural sunlight were performed under a clear sky with occasional drifting clouds. Figure 1 (right) shows the spectra of the sunlight before and after passing through the Nd-doped ZBLAN fiber. The laser line is clearly observed around 1053 nm in wavelength. The full-width-half-maximum of the highest peak centered at 1053.7 nm was approximately 0.01 nm.

One of the applications of an SPL is to illuminate a photovoltaic (PV) cell for highly efficient PV conversion [3, 4]. We recently constructed a prototype of the SPL-PV system consisting of an yttrium aluminum garnet (YAG) micro-solar laser oscillator and a monochromatic PV converter [5].

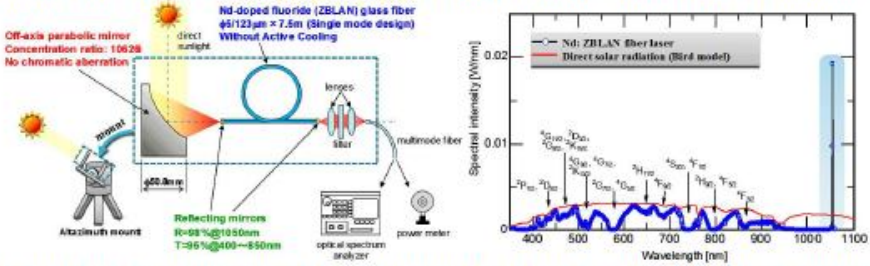

Fig. 1. (left) Schematic set-up of the solar-pumped fiber laser experiment. (right) Solar-pumped fiber laser spectra from the Nd-doped ZBLAN fiber under natural sunlight excitation.

ACKNOWLEDGMENT

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Supercontinuum generation in highly nonlinear tellurite glass microfiber devices: simulations and experiments

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Because of its combined properties of high coherence, large bandwidth, brightness and potential compactness, supercontinuum generation is a topic of high interest in nonlinear optics. Broadband light sources have potential applications in various fields such as spectroscopy, metrology, telecommunication as well as biology. The recent research progresses on tellurite based microstructured optical fibers (MOFs) promote these devices as perfect candidates for the generation of supercontinuum in the near-infrared. The high nonlinearity combined to wide transmission window and convincing chemical durability are serious advantages for tellurite glasses and microstructured optical fibers design allows the control of their dispersion profiles to fit with commercially available pump sources for efficient nonlinear mechanism for SCG [1][2]. It appears that these phenomena could emphasize by additional control of opto-geometric parameters [3]. The taperisation is a technique that involves a reduction of the diameter of the microstructured fiber, which engages a reduction of the core of the fiber. The exceptional modification of the fiber dispersion properties strengthens the nonlinear mechanisms during the signal propagation through the fiber and subsequently enlarges the supercontinuum spectrum. The aim of this talk is principally to present the work realized on tellurite based MOFs, particularly on the generation of supercontinuum in tapered fibers. In a first step, we will show that dispersion simulations have highlighted two zero dispersion wavelengths for small core tellurite MOFs, and in a second step, we will discuss the consequences for the SCG during the propagation in the tapered MOFs (Fig.1). To complete, these simulations will be compared to experimental results.

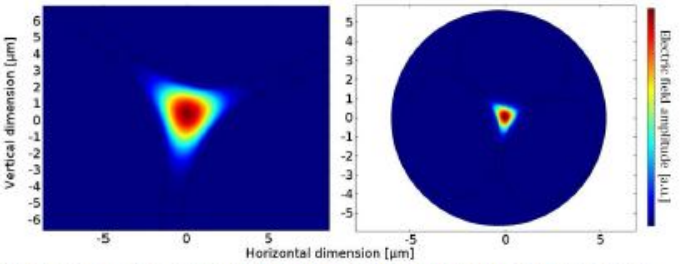

Fig 1. Signal propagation at 1.55 µm in a 3.4 µm (left) and 1 µm (right) core MOFs.

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Self-assembled structures: materials aspects and photonic functionality

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Self assembly has revealed as a powerful technique for the fabrication of photonic crystals. Thus artificial opals have served to test numerous optical properties of photonic crystals and also to create applications ranging from sensing to light harvesting.
Infiltration of opals with guest materials, a technique known as templating, is an excellent tool to provide additional functionality to bare opals that thus profit from the photonic properties of the infiltrated material. The most commonly used techniques involve chemical synthesis in the interior of the pores of opals. They can be combined to produce several morphologies (conformal growth standing out for its quality) of different materials and can be also combined with physical ones where the guest material is introduced rather than synthesized in situ.
When the order inherent to photonic crystals is eliminated from these structures a new category of photonic materials can be conceived that may, by analogy, be dubbed photonic glass. In this new scenario, where diffusion substitutes wave propagation, new phenomena can be expected like random lasing, localization etc. Strict monodispersity and sphericity of the colloidal particles results in a resonant behaviour that shows up in the relevant magnitudes like mean free path and transport velocity. It even allows to design pre-tuned random lasers.
These turn even more uncontrollable when constituted by random shape, random size particles. In such a case resorting to the use of smart pumping designs has proven useful to obtain individual land collective mode phenomena such as mode portation and phase locking.

Opal photonic crystal films as smart materials for sensing applications

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A kind of opal photonic crystal shows response to external stimuli, such as swelling, electric field, magnetic field, thermal change and mechanical strain [1]. From the viewpoint of smart materials, this tunable structural color shows large potential applications as new sensor material and device. Here we will present a soft opal film with tunable structural color by applying external force and its sensing applications.

Figure 1 shows a soft opal film made of arrayed PS colloidal spheres and infilled with PDMS elastomer. Mono dispersed PS spheres are self-assembly forming a face center cubic, fcc, lattice in colloidal crystal, concept image A. The fcc (111) planes play a key role of the structural color. The among of PS colloids are infilled with PDMS elastomer. This elastic material enable to change the spacing of d_{111}, i.e., tuning structural color by an external stimuli. An SEM image B shows the soft opal film with arrayed 200 nm PS colloids at the cross-sectional region. The soft opal films were coated on a black color rubber sheet and PET sheet. Photograph C shows changing structural color of the soft opal film on the rubber sheet by stretching. This color changing is reversible and repeatable. We call this sheet as "Photonic rubber sheet" [2]. In contrast, photography D shows the irreversible color change by plastic deformation of PET sheet. The soft opal film coated PET sheet adhered to the Aluminum plate. Then the Al plate was stretched with a tensile test machine. The structural color of the opal film was changed from red to green. This means that strain of the metal deformation is visualized as a change of the structural color.

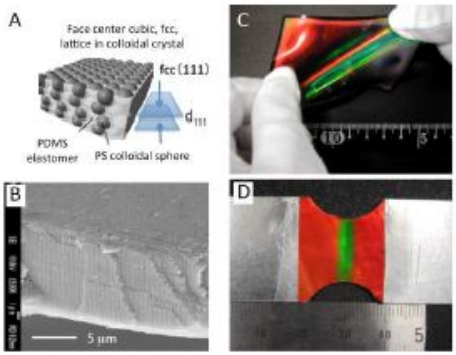

Fig. 1. Soft opal photonic crystal films. A: PS colloidal crystal of fcc (111) planes embedded in PDMS elastomer, B: SEM image of the soft opal film, C: Color changing by stretching a rubber sheet, D: Strain image of deformed Al plate.

Here we demonstrate the soft opal films as smart material for sensing applications. One of sensing applications is to structural health monitoring in civil engineering, such as bridge, building and tunnel. Many developed countries, such as US and Japan, are facing or will face in near future on the serious issues of large number of infrastructures aging. We have been developing an easy, simple and low cost method using opal photonic crystal film with tunable structural color [3].

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Colloidal photonic crystals for advanced light management applications

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Colloidal photonic crystals are materials based loosely on the structure of natural opal gemstones. They may be fabricated cheaply and reliably in the laboratory via the synthesis of colloidal particles of the desired size and functionality followed by the assembly of these particles into regular arrays having periodicity on the order of the wavelength of light in part of the electromagnetic spectrum. This presentation will describe our work at Tyndall, which focuses on the synthesis of particles of SiO_2 or polymer, some of which have metal nanoparticles incorporated into their structure so as to provide access to plasmonic effects, and their assembly using a range of methods with particular emphasis on the use of Langmuir-Blodgett techniques [1] designed to provide a high degree of control over layer assembly and thickness.
In particular, the Langmuir-Blodgett method allows for the fabrication of so-called heterostructured photonic crystals where an 'optical superlattice' can be fabricated using sets of particles having different diameters. An example of one such lattice is shown in Fig. 1 below:

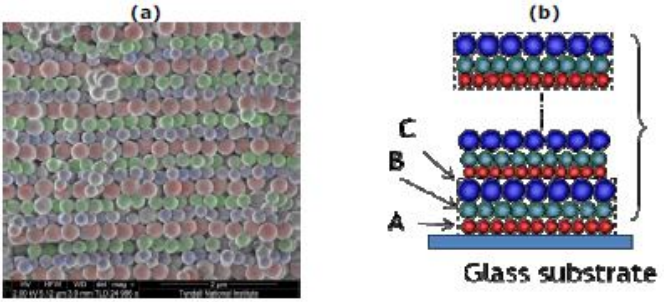

Fig. 1. (a), SEM image of an ABC heterostructured colloidal photonic crystal fabricated using the Langmuir-Blodgett method. (b), a schematic representation of the ABC structure. The different sized spheres shown in (a) have been coloured artificially in the image as a guide to the eye.

A range of such structures will be described and potential applications of such materials in areas such as advanced photovoltaic light trapping or concentrator devices will be outlined. In addition other mixed heterostructures where both size and ordering of the colloidal photonic crystals are varied will be described together with their light-trapping characteristics [2,3]. Finally, some recent work on the synthesis, properties and potential applications of colloidal photonic crystals containing optically active nanoparticles will be outlined [4,5].

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Producing coloured materials with amorphous arrays of black and white colloidal particles

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There are many technical and industrial applications for coloured pigments with anti-fading properties. The development of a low-cost, high-volume production method for anti-fading pigments with low toxicity and minimal environmental impact may promote their widespread use. To accomplish this goal, we need to prepare pigments using abundant and environmentally friendly chemical compounds. Here, I report on the aggregates of various colours formed by fine, submicron spherical white particles. The aggregate microstructure is isotropic with short-range order on a length scale comparable to optical wavelengths and exhibits an angle-independent structural colour due to wavelength-specific constructive interference [1-6]. Interestingly, the colour saturation of these aggregates can be controlled by the incorporation of a small amount of conventional black particles, such as carbon black. I demonstrate that a Japanese-style painting can be successfully drawn with this method and that an interesting effect is obtained that can be applied to steganography.

Fig. 1. Demonstration of a Japanese-style painting drawn by mixing black and white particles.

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Stimuli-responsive elastomeric colloidal crystal films

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Colloidal crystal layers and films belong to the family of photonic crystals [1]. At micro scales such colloidal crystals are composed of monodisperse spheres from 150 to 350 nm in diameter arranged in a face centered cubic (fcc) lattice. As the distance between the packed planes of spheres is on the length scale of visible light, light of a certain wavelength is reflected corresponding to Bragg's Law. In the recent past several techniques were developed and optimized to build up such fascinating structures from simple spheres of various materials. However, the optical properties of such materials strongly depend on the degree of crystallinity and the refractive index contrast between the spheres and the surrounding material. To a first approximation it is expected that the reflected color varies as a function of the incident angle. Therefore brilliant angle-dependent reflection colours can be observed in one material only by tilting the structure (Fig. 1). Furthermore, so-called elastomeric colloidal crystal films attracted a great deal of attention over the last decade because of their reversible colour change during mechanical stimulation due to a controlled lattice deformation [2-5]. These mechanochromic materials are interesting candidates for sensing devices and actuation systems.

Fig. 1. Optical images of elastomeric colloidal crystal film in different angles of view.

Here we present mechano-responsive elastomeric colloidal crystal films for applications as stretch-tunable photonic band gap materials featuring the additional ability to be stimulated by external trigger such as temperature, light, solvents or electrochemistry [2-5,7]. Novel highly functional monodisperse core-interlayer-shell (CIS) particles are synthesized and processed into homogenous large-area elastomeric colloidal crystal films. After extrusion and compression molding these films show an almost perfect order and they can be reversibly mechanically stimulated resulting in tremendous color changes. The emission frequency of an incorporated fluorescent dye locally restricted to the core of the CIS particles interacts with the stop band of the colloidal crystal and shows remarkable angle-dependent fluorescence suppression. Moreover CIS particles with non-cross-linked hard cores were used to prepare films of hexagonally arranged spheroid oblates with an aspect ratio of 2.5 after applying stress. This deformation of the embedded cores provokes a tremendous photonic band gap shift of about 160 nm. Fully reversible shape transition from the spheroid oblates back to the spherical particles and hence full recovery of the original photonic band gap can be achieved. Paper-supported elastomeric colloidal crystal films change their crystalline lattice in contact with various polar and unpolar solvents. Furthermore ferrocene-containing CIS spheres open access to redox-responsive polymer films. Herein described elastomeric colloidal crystal films can be valuable in a wide range of applications such as rewritable 3D optical data storage, tunable laser action and sensing materials.

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Plasmonic structures for optical biosensing

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Surface plasmons are special modes of an electromagnetic field which may propagate along thin metal films (propagating surface plasmons) or exist on metal nanoparticles (localized surface plasmons). Surface plasmons are highly sensitive to changes in the local environment, which make them attractive for the development of (bio)sensors. In the last two decades, numerous sensors based on propagating surface plasmons (sometimes referred to as surface plasmon resonance (SPR) sensors) have been developed. SPR biosensors have become a central tool for characterizing and quantifying biomolecular interactions and have also been increasingly applied to detection of chemical and biological species [1]. In recent years, the sensing potential of surface plasmons supported by various kinds of nanostructures have been intensively studied and various sensor platforms based on localized surface plasmons on metal nanoparticles or their arrays have been developed.

This paper reviews recent advances in the development of plasmonic biosensors. Special attention will be given to plasmonic (nano)structures fabricated by e-beam lithography, multiple-beam interference lithography, and colloidal lithography and their applications in plasmonic sensors [2]. Other topics to be covered will include advances in readout optical systems [3], microfluidics [4], functionalization methods [5] and detection methodologies [6]. Examples of bioanalytical applications illustrating performance and potential of plasmonic biosensors will also be presented. These will include detection of analytes related to medical diagnostics (protein and nucleic acid biomarkers) [7], environmental monitoring (endocrine disrupting compounds), and food safety and security (drug residues, bacterial pathogens and toxins).

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Imaging micro-spectroscopy of the whispering gallery modes of microspheres coated with luminescent silicon quantum dots

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Whispering gallery modes (WGMs) in microspheres containing embedded fluorophores (e.g., organic dyes or quantum dots) may find refractometric sensing or microlasing applications. However, there have been relatively few investigations on the relationship between the intrinsic microsphere resonances and the modes observed in luminescence spectra for emitters coupled to the microsphere. Using our special imaging micro-spectroscopic apparatus [1] (with a broad VIS/NIR detection range and cryogenic equipment) we observed that an apparently simple luminescence WGM-spectrum can mask a much more complicated underlying microcavity mode structure. The observed luminescence spectra are actually controlled by the emitter linewidth (Fig. 1). By examining the cavity structure, we also verify that an effective ensemble emitter linewidth can be extracted from the luminescence data. Finally, spectral diffusion is suggested as a possible origin of the periodic fluorescence WGM spectra observed in many microsphere cavities, without which these resonances might be unobservable [2].

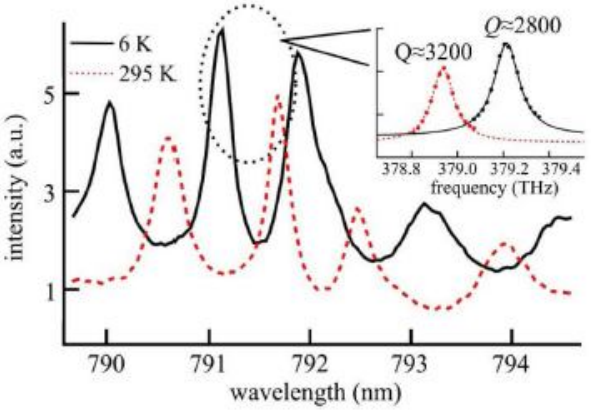

Fig. 1. Photoluminescence spectra of a QD-coated microsphere at 6 K (solid line) and 295 K (dashed line), respectively. The inset shows the Lorentzian fitting of one mode.

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Development of kW-class, ps-ns lasers for photonics applications

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HiLASE (High average power pulsed LASErs, www.hilase.cz) is a new R&D centre focused on strategic development of advanced diode-pumped solid state laser (DPSSL) technologies for high-tech applications in photonics industry and research (Fig. 1). Two key concepts are being explored within HiLASE: picosecond thin-disk laser amplifiers to reach kW average output power, and cryogenically cooled nanosecond multi-slab laser amplifiers to reach 100 J at 10 Hz output. There are three separate thin-disk beamlines under construction with different output parameters: Beamline A (750 mJ, 1.75 kHz, 3 ps), Beamline B (500 mJ, 1 kHz, 2 ps), and Beamline C (5 mJ, 100 kHz, 1 ps). In Beamline B, by changing the pulse duration and the peak intensity of pump pulse at the repetition rate of 1 kHz, we obtained 45 mJ output with 19.3% O-O efficiency and nearly diffraction-limited beam from the Yb:YAG thin-disk regenerative amplifier [1]. In Beamline C, by efficient suppression of nonlinear phonon relaxation in Yb:YAG thin-disk, we generated average output power of 85 W at the repetiton rate of 100 kHz from a compact thin-disk regenerative amplifier. We have also designed and optimized parameters of multi-slab laser amplifier scalable to kJ regime [2-5]. The single-beam 100 J nanosecond laser system based on a gas-cooled cryogenic, diode-pumped Yb:YAG multi-slab architecture with wall-plug efficiency > 12% is under construction at STFC-RAL (U.K.) and will be installed and commissioned in the HiLASE Centre by September 2015. It will be the world's highest pulse energy, fully diode-pumped solid-state laser operating at 10 Hz. DPSSL systems deployed at the HiLASE facility shall be at disposal of external users since 2016 for testing and prototyping of various laser technologies, contract research and development, including laser induced damage testing (LIDT), extreme ultraviolet lithography (EUVL) [6], laser shock peening (LSP), mid-IR generation, micro-nanostructuring [7], etc.

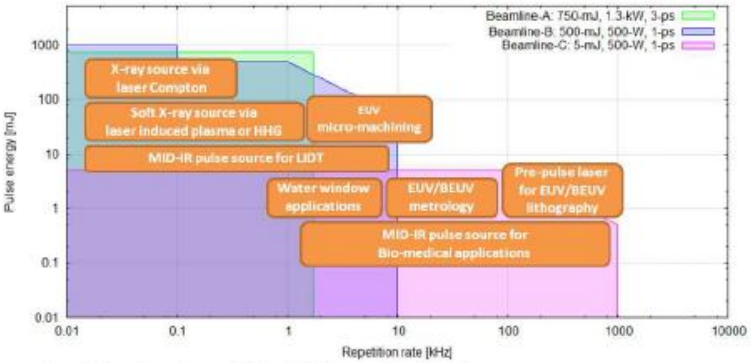

Fig. 1. Examples of applications of thin-disk lasers in the HiLASE Centre.

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Solution processing of As-S chalcogenide glasses

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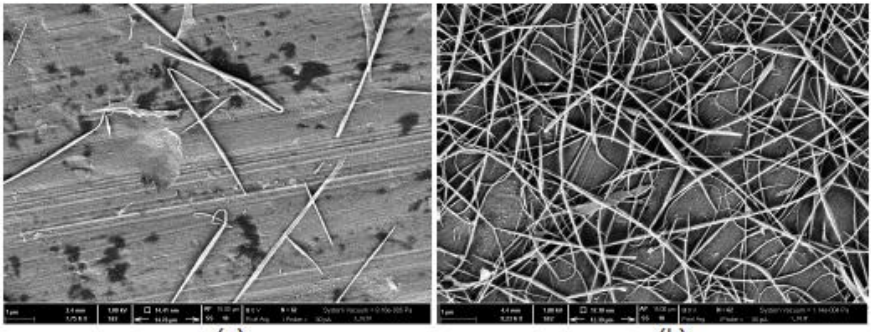
Solution-processed micro- and nano-structured chalcogenide thin films have been already demonstrated in applications such as infrared waveguides [2], ink-printed micro-lens [3], photonic crystals [4], or as a sensitizer increasing a visible light photo-current response of titania nanotube layers [5]. The paper presents examples of the solution-processed optical elements and photonic devices. In addition, we report on electro-spinning deposition [5] as a new method suitable for solution-processing of chalcogenide glass. The electro-spinning of As-S glass from its propylamine solution leads to macrosscopically uniform large area amorphous chalcogenide layers with microscopically unique nanofiber morphology.



(a) (b)

Fig. 1. The electro-spun nanofiber As-S film on Al foil is shown after (a) 1 minute and (b) 10 minutes deposition.

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Ga-Ge-Sb-S: Er^{3+} amorphous chalcogenides: photoluminescence and photon up-conversion

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Er^{3+}-doped Ga-Ge-Sb-S amorphous chalcogenides are promising phosphors in wide-range applications such as optical fiber amplifiers, waveguides, lasers, sensors, LIDAR technology or to enhance the efficiency of silicon solar cells [1-4]. Present study is focused on anti-Stokes (photon up-conversion) as well as Stokes emissions originating from 4f-4f electronic transitions of Er^{3+} ions. Visible or visible and near-infrared photon up-conversion was observed under 802 nm and 1.55 μm laser pumping, respectively. Moreover, the 2.7 μm mid-infrared Stokes emission lying within the absorption band of water was also present which make these materials attractive in surgery lasers or LIDAR technology.

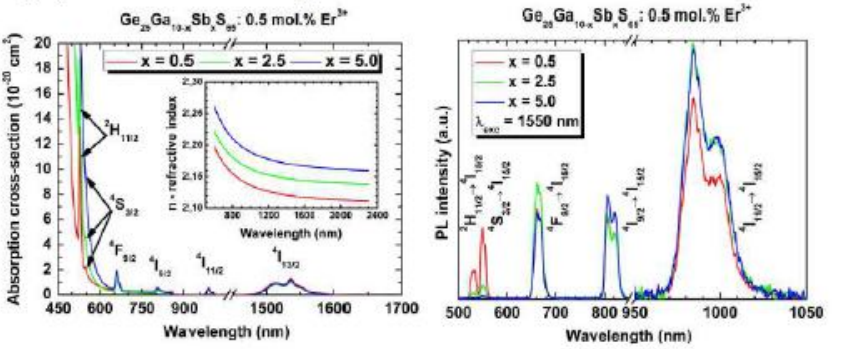

Fig. 1. Absorption cross-section and spectral dispersion of the refractive index in Ge-Ga-Sb-S: 0.5 at.% Er^{3+} glasses containing 0.5, 2.5 and 5 at.% of Sb. The green, red and near-infrared photon up-conversion emissions in the glasses are shown on the right panel under 1550 nm laser pumping.

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Towards functional advanced materials using infilling of ordered anodic oxides supports and templates

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Synthesis of highly-ordered nanostructures of valve metal oxides has recently attracted huge scientific and technological interest motivated by their possible use in many applications. The nanoporous Al_2O_3 – most established member of this group of materials – has been prepared by anodic oxidation of Al under suitable electrochemical conditions nearly two decades ago into perfectly ordered, honeycomb-like porous structures. Owing to the flexibility of the pore diameter/length and the relative ease of the Al_2O_3 dissolution, its porous membranes have been since than widely used as templating material of the choice for a range of materials.
It is the TiO_2 that has received the highest attention after Al_2O_3 motivated by its range of applications, including photocatalysis, water splitting, solar cells and biomedical uses. Very significant research efforts have led to reproducible synthesis of self-organized TiO_2 nanotube layers by means of anodic oxidation, during which the starting Ti substrate is converted into highly-ordered nanotubular layer by anodization in suitable electrolyte.
Although many applications of the nanoporous Al_2O_3 and nanotube TiO_2 nanotube layers have been presented, their potential for the synthesis of advanced functional nanomaterials, in particular when considering all possible shapes and geometries, has not at all been exploited.
In the presentation, we want to focus in detail on various filling routes of anodic templates and supports. We will show examples of various functional devices including some very recent results on chalcogenide-sensitized TiO_2 nanotubes [1] and on the new design of resistive switching of memory switching cells using porous AAO templates [2].

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Soft-mould imprinting of chalcogenide glasses

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Nanoimprint lithography by using a polymeric mould (stamp), such as PDMS (polydimethylsiloxane) [1], is well-established technology for surface replication of micro- and nanometre-sized features into functional materials including low-softening temperature (T_s) chalcogenide thin films [3] and bulk glasses [4,5]. Here, we report on further development of soft-mould patterning of chalcogenide As_2S_7 bulk glass (T_s ~500 K). Transfer of array of pillars, lines and holes, dimension of 0.5 µm, 1 µm, and 2 µm in width respectively, from PDMS mould into the surface of the glass has been succeeded by using defined moulding process with precise temperature profile control. The imprinted motives show good shape reproducibility from the stamp, and the imprinting can be realized over centimetre-square areas.

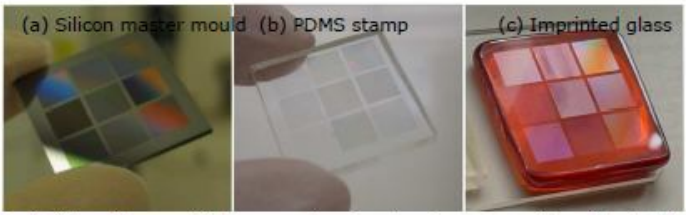

Fig. 1. Arrays of pillars, lines and holes were developed using a conventional photolithographic processes into Si wafer substrate. This was then used as (a) a master mould for creating (b) the PDMS replica (soft stamp). Part (c) shows the individual arrays imprinted into chalcogenide As-S bulk glass.

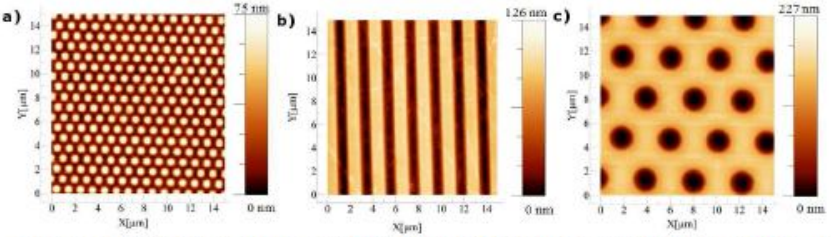

Fig. 2. Atomic-force microscopy images of the imprinted (a) pillars array (0.5 µm in width), (b) lines array (1 µm in width) and (c) holes array (2 µm in diameter) into the chalcogenide As-S bulk glass surface.

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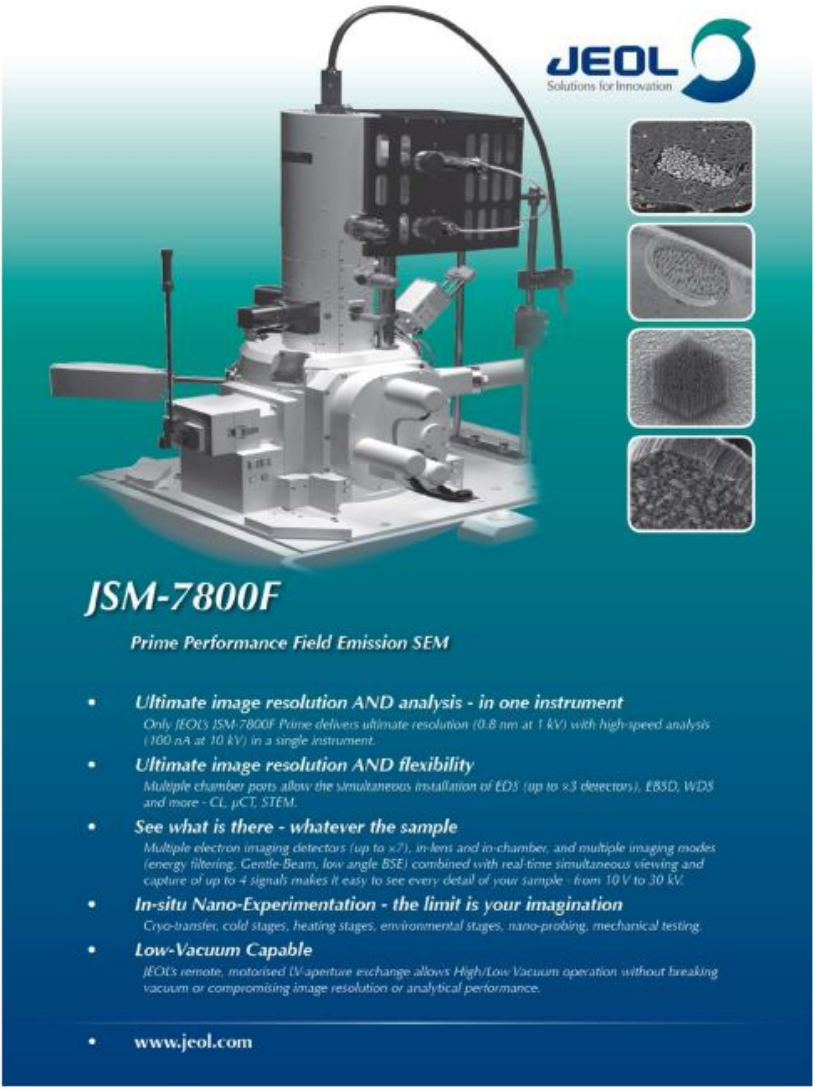

Introduction of new laboratory device 4SPIN® for nanotechnologies

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The 4SPIN® desktop laboratory device has been developed for the deposition of nanomaterials from solutions dedicated not only to medical applications, but also to other fields such as nanoelectronics, optics, filtration, etc. The apparatus integrates various methods to enable the preparation of nanostructured materials according to researching demands.
Nine principally different emitters (most of them are usable in the method called electroblowing) and four different collectors enable to perform various types of experiments. This allowed nanofibrous materials with different microscopic and macroscopic structures to be successfully prepared. Almost twenty different solutions, their blends and composites have been processed so far. It is possible to repeatedly produce nanomaterials with identical properties by implementing precisely regulated process parameters. Its central system simplifies control and also improves productivity and operator safety.
Thanks to its experimental versatility, safety components, easy handling, intuitive device control and other benefits the 4SPIN® apparatus significantly contributes to research progress in the nanofiber application field.

Multi-wavelength and intensity illumination of the GeSbS films

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Amorphous chalcogenide glasses and thin films are known for interesting optical properties including high refractive index, transparency in the infrared spectral region and photo-induced changes of the optical, mechanical and electrical properties [1, 2]. Despite extensive studies of the photo-structural changes (e.g. photo-bleaching or crystallization) only limited number of papers in the open sources is considered to the effects of the thickness, photon energy and intensity on the induced changes together. The main goal of the presented work is summarize the influences of the above mentioned factors during illumination of the GeSbS films by the set of the monochromatic light sources covering spectral region from UV to the IR for intensities ~ 150 mW/cm^2 to 20 W/cm^2. GeSbS glasses were selected for our study because they do not contain dangerous elements such as arsenic and the chemical composition of the films were selected for their high sensitivity ($Ge_{24.9}Sb_{11.6}S_{63.5}$) and stability against illumination ($Ge_{6.5}Sb_{32.1}S_{61.4}$). The results of photo-sensitivity of the virgin $Ge_{24.9}Sb_{11.6}S_{63.5}$ film can be summarized as follows:

- the magnitude of the saturated state (ΔE_g^{opt}) varies from the 2 meV (650 nm) to the 210 meV (535 nm) and the maximal change is reached by the slightly over-band gap photons;
- the magnitude is connected with the penetration depth as well as a part of the absorbed photons or chemical composition;
- light intensity controls the kinetics of the process;
- high intensity illumination may lead to the different processes as crystallization or ablation.

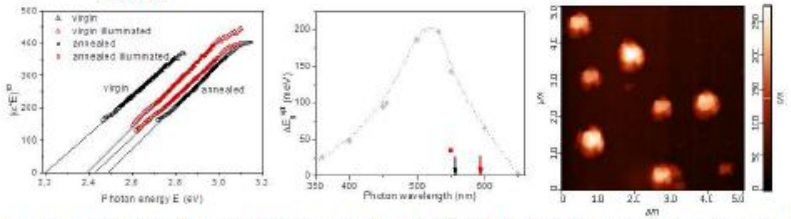

Fig. 1. The spectral dependencies of the $(\alpha E)^{1/2}$ and exposition wavelengths dependence of the magnitude for the photo-bleaching process of the sensitive film $Ge_{24.9}Sb_{11.6}S_{63.5}$, for comparison also the low sensitivity of the $Ge_{6.5}Sb_{32.1}S_{61.4}$ film is illustrated by red dot; the energies of the optical band gap is labeled by the arrow for both films. The topographical scan of the partly crystalline surface of the UV illuminated thin film with the intensity 10 W/cm^2.

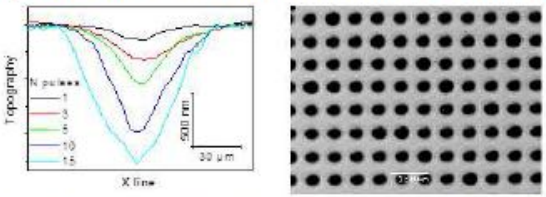

Fig. 2. Topographical profile of the craters created by UV pulsed laser (F=12.9 J/cm^2) for different number of pulses (N) and laser direct writing of the micro-lenses array to the $Ge_{6.5}Sb_{32.1}S_{61.4}$ film.

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High-performance biosensing on random arrays of gold nanoparticles

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Surface plasmon resonance biosensors represent a well-developed tool that is used in affinity biosensing as well as the research of biomolecular interactions. A novel and promising alternative can be found in biosensors based on localized surface plasmons (LSPs) excited on metal nanoparticles (NPs). Both these approaches exploit high sensitivity of surface plasmons to refractive index changes occurring at the proximity of the metal surface. The resolution corresponding to surface RI changes is comparable for both types of sensor. One of the potential benefits expected from LSP-based sensors is a faster response due to the lower foot-print of the sensing area [1].

Here we report on a plasmonic biosensor based on Fano resonance that is excited on an array of randomly distributed gold NPs on a glass slide produced by electron-beam lithography. The structure was illuminated through a prism by a collimated and polarized beam in the attenuated total reflection geometry, and a 4-channel flow-cell was attached to the structure to enable measurements of the sensor response to liquid samples (Figure 1a). Reflection spectra exhibit a pronounced Fano-shaped dip resulting from the interference of interface reflection and LSPs supported by NPs. The shape and position of the resonance dips in the spectrum are dependent on the parameters of the array (i.e. NP surface density and size), the angle of incidence (Figure 1b), and the refractive index of the surrounding medium. Two contributions participate in the sensitivity to refractive index changes: the first is associated with sensitivity of LSP, and the second is associated with the sensitivity of an evanescent wave propagating at the glass/water interface [2].

To evaluate the detection capabilities of the biosensor, a model detection of short oligonucleotides was carried out. Initially, oligonucleotides with a complementary sequence were immobilized on the NP surface. Then a sample containing target oligonucleotides was flowed through the flow cell and the sensor response was recorded. Increase of the binding rate due to the lower foot-print of the sensing area was observed. Figure 1c shows the sensor response to different concentrations of oligonucleotides. There is an evident response for oligonucleotide concentrations higher than 50 pM, which suggests that the biosensor could reach a limit of detection of approximately 10 pM.

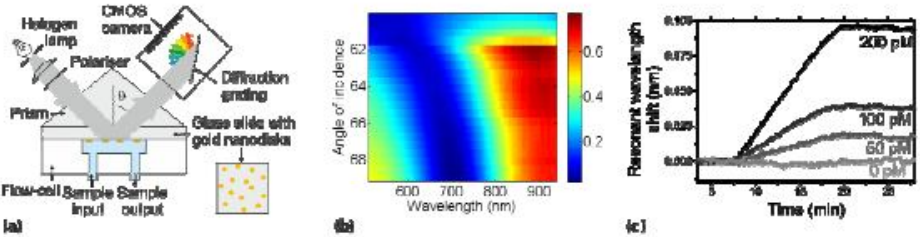

Fig. 1. (a) Optical setup. (b) Reflection spectrum of the Fano resonance excited on the structure in TE polarization. (c) Sensor responce to different concentration.

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Preparation of sparse periodic plasmonic arrays by multiple-beam interference lithography

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Two-dimensional periodic plasmonic nanostructures have been intensively studied in recent years as a promising optical platform for surface enhanced Raman scattering (SERS) or affinity plasmonic sensing [1]. The production of these 2D periodic arrays using interference lithography based on two or more coherent beams is a well-established method. By proper selection of the polarization and orientation of the incident beams, various symmetries of the periodic pattern (e.g. hexagonal or rectangular) and different shapes of nano-features can be obtained [2]. Conversely, it remains difficult to obtain a sparse array of nano-features, which is useful for multiple applications. The typical minimum size of the individual features prepared by interference lithography is limited to about half of the array period. It has been demonstrated that this limitation can be solved by the addition of more coherent beams in order to suppress every second interference maxima of the original pattern, yielding an array with a doubled period yet having the same size of the nano-features [3]. The drawback of such approach is the extreme sensitivity to the adjustment of the mutual positions and orientation of all interfering beams.
In this contribution, we will present a novel approach to a multiple-beam interference lithography that enables production of macroscopic areas of perfectly periodic sparse arrays of nano-features. This method is based on the interference of a large number of coherent beams originating from diffraction of large-diameter collimated beam on a single transmission phase mask (Figure 1a). The geometry (periods and profile depth) of phase mask is designed to provide optimum diffraction efficiencies to all (up to 21) diffracted orders (Figure 1b) to yield an interference pattern with high contrast and narrow maxima (Figure 1c). This approach enables multiple-beam interference lithography without the need of laborious adjustment of individual interfering beams, as their mutual positions and directions are given only by the properties of the phase mask. Moreover, the small ratio of feature size to period of the interference pattern enables the production of more complex shapes of the nano-features (e.g. rods, dimers) via the combination of several consecutive exposures at different positions (or moving the phase mask during the exposure), thus drawing the resulting nano-feature.

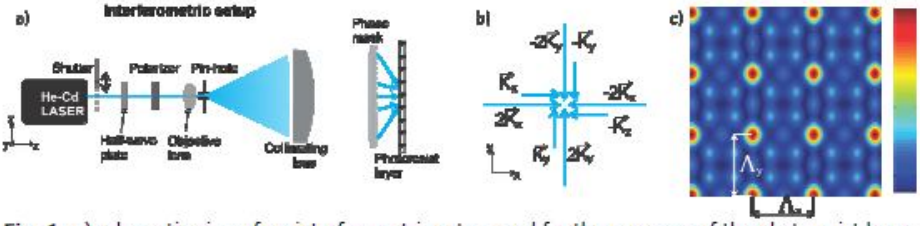

Fig. 1. a) schematic view of an interferometric setup used for the exposure of the photoresist layer by multiple coherent beams; b) projections of the wave vectors of eight interfering beams into the plane perpendicular to the incident beam; c) calculated interference pattern for phase-mask with periods $\Lambda_{PMx}=\Lambda_{PMy}=800$nm ($K=2\pi/\Lambda_{PM}$) and linearly polarized incoming laser beam with 325 nm wavelength. The resulting interference pattern is composed of a sparse array of interference maxima ordered with the same periodicity as the phase mask ($\Lambda_x=\Lambda_y=800$nm).

The design and optimization of the transmission diffractive mask will be discussed and preparation of the periodic arrays of metallic nanostructures with possible applications for affinity plasmonic sensing or SERS will be demonstrated.

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Profile and material characterization of sine-like surface relief Ni gratings by spectroscopic ellipsometry

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Sinusoidally modulated surface relief gratings are of high interest for various optical devices [1]. Their optical response has been widely studied by means of calculations employing many theoretical approaches. Optical experiments on sinusoidal gratings, on the other hand, have mostly been carried out by means of power reflectance measurements and have not received considerable attention by spectroscopic ellipsometry (SE). Nevertheless, SE measured in a wide spectral range can be effectively used to investigate the quality of fabrication by optical lithography combined with material deposition and grating replication.

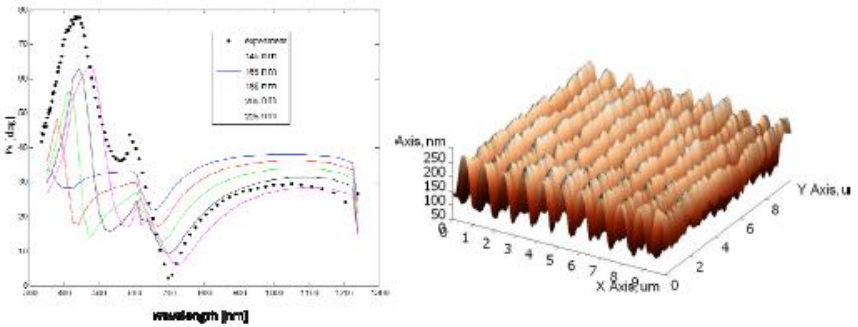

Fig. 1. Experimental and theoretical spectra of ellipsometric parameter psi. Calculated are spectra for various depth of the grating surface profile. (left) AFM picture of studied sinusoidal Ni grating. (right)

We apply SE to analyse geometric and material properties of holographic sinusoidal Ni gratings. Due to various imperfections in the fabrication process, the gratings are not perfectly sinusoidal. For this reason we monitor not only the geometrical dimensions (period and depth), but also the actual sine-like relief shape. Employing measurements in several angles of incidence increases the sensitivity, which helps to determine material properties such as the refractive index and the thickness of the native oxide overlayer. To analyse the SE experimental data, we apply simulations employing the rigorous coupled wave analysis using the correct Fourier factorization rules, which enables fast convergence. As an example, Figure 1 shows the ellipsometric parameter Psi measured and simulated on a sinusoidal Ni relief grating with the period of 892 nm, depth calculated in the range 145-225 nm, thickness of native NiO overlayer of 3.5 nm, and with the angle of incidence being 20 degrees. Obtained results were compared with complementary scanning probe measurements AFM and SEM.

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Innovative nanoimprint lithography

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Nanoimprint lithography (NIL), in which resist patterns are fabricated by deforming the physical shape of the resist by embossing the resist with a mold, has currently attracted a plenty of attention from many industrial fields because of its many capabilities for fabricating various micro- and nano-structure applications with a simple, high-throughput and low cost process. Nanoimprint is a practical nanotechnology which is capable of 10nm pattern delineation [1,2] and the reproducibility is reported from research institutions around the world. Applications of all areas of IT electronics, biotechnology and life sciences, the environment and energy proceeds throughout the world. Nanoimprint industry is being produced rapidly.

Ultraviolet nanoimprint lithography (UV-NIL) [3,4] with precision, high throughput, and low cost has been in the spotlight for its potential for 20 nm level ULSI manufacturing as the next generation lithography. However, the current UV-NIL faces two major issues to be solved for the application; one is throughput and the other is defect density. To solve the above problems, we develop the new processes and materials through the scientific elucidation in the CREST project "Research and Development on Process Science and CD Control in High-Through UV Nanoimprint". One of the adopted core technology is using pentafluoropropane (PFP) in UV-NIL, which we call "Hiroshima method" [5]. The method, UV nanoimprint in PFP exerts good impact. PFP is nonflammable and low toxicity material and has a vapor pressure slightly higher than the atmospheric pressure, or, 0.15 MPa. When UV-NIL is carried out in PFP, the PFP gas is instantly condensed (liquefied) and the trapped PFP hardly obstruct resin intrusion and thus filling process is instantly completed (Fig. 1). It was also found that PFP has a useful side-effect that the release force in mold detachment is reduced. The former effect improves throughput and reduces non-fill defects, and the latter reduces plug defects. We developed new UV –NIL process, simulation, and curable resin adapted to PFP atmosphere and demonstrated 22 nm patterns fabrication. In this talk, recent progress of "UV-NIL in PFP" aimed at application for 20 nm level ULSI manufacturing will be presented.

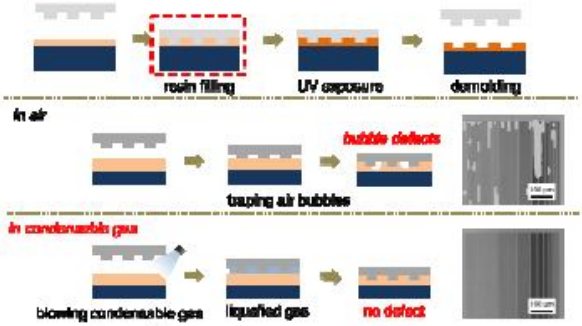

Fig 1. UV-NIL using PFP condensable gas.

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Nanofabrication by imprint lithography process and its application to photonics devices

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Nanoimprint lithography (NIL) technique is currently employed to produce diverse nanostructured devices for electronics and photonics and functional elements. The method using vertical imprinting of molds has an advantage in large-area nano-patterning with high throughput at high precision. Nano-photonic structures/materials such as surface plasmon (SP) and meta material (MM) as well as photonic crystals (PCs) and quantum dots (QDs) are discussed from potentials for new photonic devices and technologies [1]. We fabricated a large area SP-RGB color filter consisting of periodic hole array in an aluminum (Al) film using NIL and reactive ion etching. Figure 1 shows a photograph of 3inch-size SP-RGB color filter based on a quartz substrate. This filter has circular shaped holes, periodically arranged on an Al thin film (150 nm). The diameter of the holes are 210 nm, 165 nm and 130 nm, and the lattice constants are 420 nm, 330 nm and 260 nm, for the red, green, and blue colors, respectively. The maximum size of filter area is 10 mm square. Thus, a full color filter utilizing an SP in the Al film was successfully fabricated by NIL and it was verified that the structure with an Al film has many advantages as a material for the SP-based RGB color filter [2]. We also fabricated large-area stacked complementary plasmonic crystals (SC PlCs) by NIL. The SC PlCs were made on silicon-on-insulator substrates consisting of three layers: the top layer contacting air was a perforated Au film, the bottom layer contacting the buried oxide layer included an Au disk array corresponding to the holes in the top layer, and the middle layer was a Si PC slab. The SC PlCs have prominent resonances in optical wavelengths. It is shown that the fabricated PlCs were precise in structure and uniform in their optical properties. We examined the photoluminescence (PL) enhancement of monolayer dye molecules on the SC PlC substrates in the visible range and found large PL enhancements of up to a 100-fold in comparison with dye molecules on nonprocessed Si wafers [3]. Furthermore, we are exploring high-efficient molecule-sensing substrates by NIL. For the actual application, high-throughput production is essential. To date, we produced plasmonic and non-plasmonic sensing substrates, and obtained large enhancement factor, up to hundreds, of fluorescence (FL) on the nanoimprinted substrates. To make the substrates more practical, it is desirable to be capable of tuning the working wavelength range with resonant enhancement to the range suitable for target molecules. These nanophotonics will pave the road to novel sensing/imaging components as well as new integrated signal processing components/circuits in a next generation photonic system.

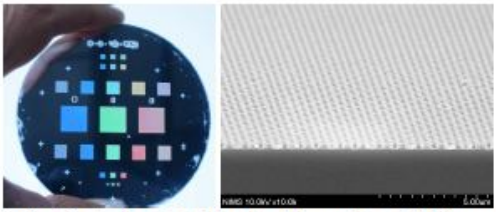

Fig. 1. The photograph of a 3inch-size SP-RGB color filter and an SEM image of sample surface after Al air-holes etching.

ACKNOWLEDGEMENTS

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Electrical imprint for micro- and nano-structure fabrications on glass

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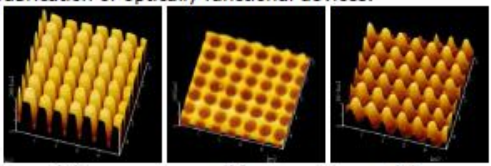
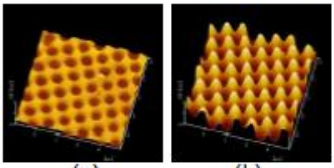
Thermal nanoimprint to glass surfaces was demonstrated using a thermally durable SiC molds [1-3]. However, the life expectancy of mold is limited because the pressing process higher than the softening temperature of the glass is required. On the other hand, the electrical nanoimprint is an attractive process for the alkali containing glasses to reduce the process temperature [4, 5]. The deformation of glass surface proceeds at a temperature lower than the glass transition temperature (T_g). This paper reports the relationships between the fine structure formation and the imprint conditions. A glass molding machine was specially modified in order to apply a DC voltage to the mold using a DC power supply. A soda-lime glass (T_g = 555°C) and a two dimensional SiO_2 grating (700 nm period) coated with carbon were used for the imprint specimen and mold, respectively. Figure 1 shows the mold and the imprinted glass surface observed using an atomic force microscope. The fine pattern appeared after the electrical imprint at 450°C, 3 MPa in pressure, for 180 s. The DC voltage of 200 V was applied for 60 s during the initial pressing stage. The hole depth depended closely on the amount of charge carried by the sodium ions. Chemical etching using a 55 wt% KOH solution (70°C) efficiently enhanced the hole depth of the imprinted surface (see (c) in fig. 1), because the durability of sodium deficient area contacted with the mold is much lower than that of the non-contacted area.

Fine patterns could also be formed under an extremely low pressure. Figure 2 denotes the surface after the imprint at 0.02 MPa in pressure. Other conditions without pressure were identical with those at 3 MPa. The effect of chemical etching was closely similar. One of the origins of fine pattern formation might be the alkali migration from anode side to cathode side. However, some other driving force such as the local temperature increase should exist during the ultra-low pressure electrical imprint. The electrical imprint is a useful process for the micro- and nano-structures on glass at low temperature and pressure. Chemical etching selectively removed the alkali deficient area, accordingly enhanced the structure's aspect ratio. These sequential processes might be useful for the fabrication of optically functional devices.



(a) (b) (c)

Fig.1 Surface profiles of (a) SiO_2 mold, (b) electrically imprinted glass at 3MPa and (c) after chemical etching for 2 h.



(a) (b)

Fig.2 Surfaces of (a) electrically imprinted glass at 0.02 MPa, (b) after chemical etching for 2 h.

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Preparation of chalcogenide materials for next generation optoelectronic devices

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Chalcogenide materials are finding increasing interest as an active material in next generation optical and electronic devices. Their wide range of properties, ranging from photosensitivity, ability to host rare earth ions, electrical conductivity, phase change and exceptional optical non-linearities to name only a few, are fueling this interest. Moreover, the ability to synthesize these materials in numerous forms as diverse as 2D monolayers, microspheres, optical fibres, nanowires, thin films, as well as bulk glass ingots of over a kilogram in size ensures their application space is vast.

We began preparation of chalcogenides, largely based on sulphides, in 1992 and since then have built up an extensive capability for their purification, synthesis and fabrication in various forms. A key aspect of this facility is the ability to process in a flowing atmosphere of hydrogen sulphide which provides the capability of synthesis from elemental, oxide or halide precursors; processing through various chemical vapour deposition reactions, as well as post purification.

In this talk, we describe recent additions to the range of materials we synthesize highlighting transition metal di-chalcogenides for electronic applications, an example of which is shown below, crystalline semiconductors for solar cell applications, ion implantation, which has proven to be an effective method of modifying the electronic and optical properties of chalcogenides thin films, low power phase change memory devices, switchable metamaterial devices as well as traditional chalcogenides glass and optical fibre.

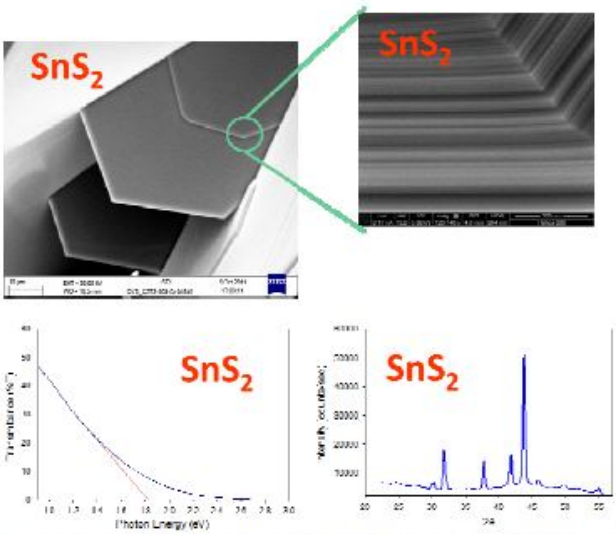

Fig. 1. a) SEM images of chemical vapour deposition (CVD) grown Sn-S thin films (b) UV-VIS-NIR and (c) XRD pattern of CVD grown Sn-S thin films.

Development of Sm-doped glass-ceramics for high-dose, high-resolution dosimetry in microbeam radiation therapy at the Canadian Light Source

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There is a need to develop high-dose, high-resolution dosimetric detectors to characterize the microstructured x-ray beams used in microbeam radiation therapy (MRT). In this paper, we report a technique that is based on the reduction of Sm^{3+} to Sm^{2+} within CaF_2 nanocrystals embedded in an oxyfluoride glass-ceramic (SiO_2-Al_2O_3-CaF_2-CaO-SmF_3) plate. We use the extent of $Sm^{3+} \rightarrow Sm^{2+}$ valence reduction caused by x-ray irradiation as a probe of the x-ray dose delivered. A confocal fluorescence microscope is used to read out the distribution of reduced Sm^{2+}-ions by their characteristic photoluminescence (PL) emission. The PL emission from Sm^{3+} and Sm^{2+} ions have distinctly different PL characteristics and can be distinguished. The technique is similar to that reported for Sm-doped fluorophosphate and fluoroaluminate glasses for MRT where the x-ray induced $Sm^{3+} \rightarrow Sm^{2+}$ valence reduction occurred within the glass matrix [1]. We demonstrate that the $Sm^{3+} \rightarrow Sm^{2+}$ valence reduction takes place in CaF_2 nanocrystals, and not in the glass matrix. The PL emission from the Sm^{2+}-ion is mainly due to the fast $4f_55d^1 \rightarrow {}^7F_0$ transition (in contrast to the *f–f* transitions in Sm^{2+} in a glass host), which allows us to read out the irradiated dosimetric plate at a high scanning speed in confocal fluorescence microscopy. In addition, we show that the dose range that can be detected is several thousands of gray, and x-ray dose distribution is detected at a micrometer scale. Further, the x-ray induced Sm^{2+} signal can be erased by heating the irradiated sample at a suitable high temperature; or by exposing it to UV light. The erased glass-ceramic plate can be used again with very little variation in its response characteristics as a dosimetric detector. The new Sm-doped oxyfluoride glass ceramic containing dispersed CaF_2:Sm^{3+} nanocrystals reported in this work shows potential for practical use in high-dose, high-resolution dosimetry for MRT.

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Nonlinear frequency conversion in glass integrated devices: novel applications

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Frequency conversion is probably one of the most investigated and exploited applications of nonlinear optics. In the last years, research moved towards the miniaturization and integration (especially compatible with the electronics –CMOS– platform) of frequency converters, in order to further increase their performances and diffusion. Several structures and platforms have been investigated, and the quest for defining the optimal solution is still open.
In this paper, we shall review our recent results on nonlinear frequency conversion in high-index doped silica (Hydex) integrated structures. Hydex is a recently developed CMOS-compatible platform combining the low dispersion and low linear losses typical of glasses with the nonlinear properties of semiconductors: high linear and nonlinear index [1,2]. This combination allowed us to observe on chip different third-order nonlinear processes typically exploited for wavelength conversion such as four-wave mixing (FWM) [3], self-phase modulation [4], supercontinuum generation [5], and optical parametric oscillation (OPO) [6]. While wavelength conversion is per se a fundamental application of nonlinear processes, other interesting applications may be envisioned. Exploiting the remarkable properties of our devices, we indeed demonstrated both an all-optical integrator [7] and an oscilloscope on a chip [8]. Further exploiting the capabilities of our device (a microring resonator in particular) we recently worked on applications that not only transfer known nonlinear optical processes to the integrated optics domain, but are truly possible only in this framework. In particular, we recently developed a novel laser scheme delivering sub-ps pulses at a 200 GHz repetition rate and beyond [9]. Such scheme has the peculiarity to automatically lock the pump wavelength to the microring resonance, thus also addressing a typical issue affecting all high Q-factor microresonator-based devices, i.e. the thermal shift of the resonances due to the pump power dissipation.

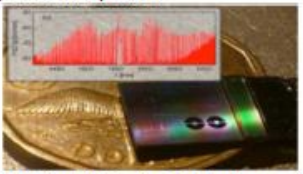

Fig. 1. Picture of the integrated glass photonic chip (on top of a Canadian Dollar). Inset: above threshold OPO spectrum, spanning several hundred nanometers.

While active locking techniques can be exploited to this purpose [10], our pumping scheme automatically eliminates this issue [11]. This scheme is particular effective when pumping the microring resonator well below the threshold for OPO (which is typically the regime of operation for entangled photon pair generation), where active locking schemes are usually inefficient. Exploiting this scheme and the capabilities of our device, we recently reported the generation of multiple and independent photon pairs at different wavelengths matching the standard fiber communication frequency channels, thus paving the way for e.g. high-dimensional, multi-user quantum key distribution.

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Engineering metallic nanoholes, pyramids, and slits for plasmonics and nanophotonics

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Unlike conventional diffractive optical devices, realization of high-performance photonic architectures based on metals presents daunting challenges for both fabrication and modeling. Extreme squeezing of optical energy in metallic nanostructures, such as gaps and tips, is possible via surface plasmon waves, yet they are highly susceptible to defects and nanometric surface roughness [1]. This presentation will focus on two nanofabrication techniques that our team has developed to overcome these challenges, namely, template stripping for making ultra-smooth patterned metals [2] and atomic layer lithography for wafer-scale production of sub-nanometer-wide gaps [3]. Applications of ultra-flat and ultra-small optical structures produced via these methods will be presented, including biosensing [3,4], super-resolution optical microscopy [5], and surface-enhanced spectroscopy.

From a computational modeling perspective, these extremely scaled structures (e.g. 1-nm-wide metallic slits) push the limits of existing modeling techniques because of the enormous mismatch in critical lengths scales. For example, the wavelength of incident THz beams can be up to six orders of magnitude larger than the 1-nm-wide slit, yet experimentalists can now produce such structures and measure their optical properties routinely. Examples of such challenging multi-scale computational problems, awaiting new modeling solutions, will be discussed.

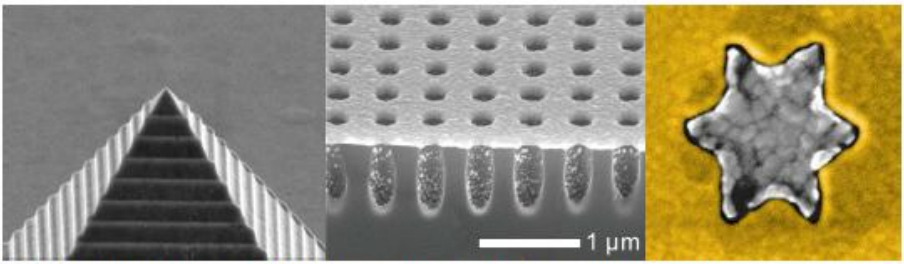

Fig. 1. (Left) Template-stripped silver pyramid with integrated grating couplers; (Center) Periodic nanohole array in a silver film made via template stripping; (Right) Ultra-thin nanogaps are formed alongside the contour of a star-shaped pattern in gold and silver films. These nanogaps can tightly squeeze optical energy via surface plasmons.

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Plasmonically amplified fluorescence for biosensing

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Fluorescence is (arguably) the mostly used optical method for detection of chemical and biological species in important fields of medical diagnostics, food safety, and security. The amplification of fluorescence signal through coupling of fluorophore labels with tightly confined electromagnetic field of localized (LSP) and propagating (SPP) surface plasmons (supported by metallic [nano]structures - see Fig. A) enables improving the sensitivity of fluorescence assays by several orders of magnitude [1]. In particular, this can be achieved through the combination of a) surface plasmon-increased excitation rate at the fluorophore absorption wavelength (λ_{ab}), b) improved efficiency of collecting the fluorescence light at the emission wavelength (λ_{em}) by directional emission, and by the advancing of quantum yield.

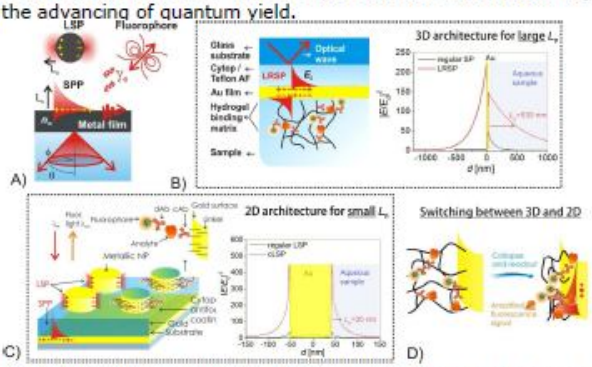

Fig.1 A) Coupling of a fluorophore with metallic structures with a PEF biosensor implementation utilizing B) long range SPPs with 3D biointerface architecture and C) collective LSP with 2D biointerface architecture. D) Schematic of a responsive 3D matrix that can be collapsed to a thin 2D film.

This paper presents two implementations of plasmon-enhanced fluorescence (PEF) for detection of biomarkers that rely on the excitation of surface plasmon modes with tailored characteristics and that employ responsive polymer architectures for capture of target analyte. It discusses advantages of using long range surface plasmons that probe up to micrometer deep into a 3D large binding capacity hydrogel binding matrix (Fig. B) [2, 3]. Compared to this approach, collective localized surface plasmons enable stronger amplification of fluorescence signal but only in small volume at small distances up to L_p~20 nm (Fig.D) [4]. Overcoming of such limitation by using a responsive hydrogel matrix that can capture and subsequently compact analyte at a plasmonic hotspot by a collapse [5] (Fig.D) will be discussed. Preparation of plasmonic and (photocrosslinkable) responsive polymer nanostructures by interference lithography and illustrating their performance by assays for detection of biomarkers such as human auto-antibodies in saliva and interleukin 6 in blood serum will be presented.

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Electrochemical route to large-area mono-crystalline gold platelets for plasmonic applications

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We fabricate high-quality gold platelets for plasmonic applications using an electrochemical approach. This process consists of dissolution of a sacrificial gold electrode by cyclic voltammetry in HCl-water-based electrolytes with a 3-electrode setup. Within a specific negative voltage range the Au ions are reduced back to gold atoms and can rearrange in micrometer-sized monocrystalline hexagons, triangles and truncated triangles. Placed underneath the sacrificial electrode, any kind of substrate collects the high-quality microstructures. The particles can be tailored in size, thickness, and number per area, depending on the electrochemical parameters. Sizes of several tens of micrometers can be reached, and thicknesses are in the 10-100 nm range.

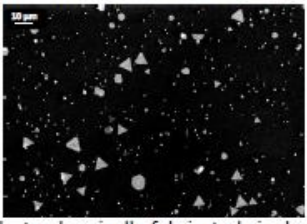

Fig. 1. SEM overview image of electrochemically fabricated single-crystalline gold platelets

To demonstrate single-crystallinity, we perform AFM surface analysis which demonstrates that our structures are extremely flat, down to monoatomic flatness. TEM studies confirm the single-crystallinity via electron diffraction by showing the exact hexagonal arrangement of the gold atoms. Our single-crystalline gold platelets will serve as bulk material for high quality plasmonic structures. Focused-ion-beam (FIB) milling provides a powerful tool to structure the single-crystalline gold platelets with any desired pattern. By applying photoemission electron microscopy (PEEM), we study long-range plasmon propagation on single-crystalline platelets and on FIB-milled structures.

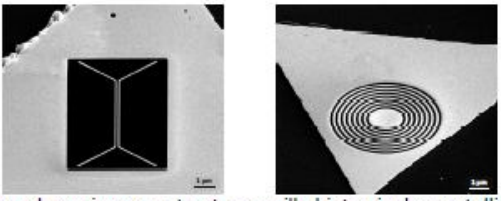

Fig. 2. Single crystalline plasmoinc nanostructures milled into single-crystalline atomically flat gold platelets by focused ion beam milling

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Determination of the orientation of a single nano-emitter by polarisation analysis

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Efficient coupling of nanoemitters to photonic or plasmonic structures requires control of the orientation of the emitting dipoles. Nevertheless control of the dipole orientation remains an experimental challenge. In this paper, we propose to determine the nature and the polarization of nanoemittor by polarization analysis of their emission [1]. A nanoemittor can be considered either by a single radiating dipole (molecule for example), or by the sum of two orthogonal incoherent dipoles (CdSe / ZnS nanocrystal for example)-known as 2D dipole [2]. By analogy, 200 nm spheres filled with a large number of dye molecules, can be modeled of a 3D dipole (sum of three orthogonal incoherent dipoles). The emission of a single nanoemitter coupled to a photonic structure in terms of dynamics, polarization and radiation pattern, depend on the dipole dimensionality of the emitter, and of its orientation with respect to the structure. This dimensionality of a given type of nanoemitter is determined by the experimental study of the emission polarization of a statistical collection of several hundreds of individual emitters randomly oriented [3]. The polarization anisotropy distribution, defined as $(I_x-I_y)/(I_x+I_y)$ where x and y are two orthogonal polarization directions, is limited by extreme values which depends on the dimensionality of the dipole. For an emitter located at glass/air interface, simulations show that anisotropy cannot exceed the value 0.7 for 1D dipole, and 0.4 for 2D dipole. For CdSe/CdS nanocrystals, the polarization anisotropy reveals a clear signature of a 2D dipole.

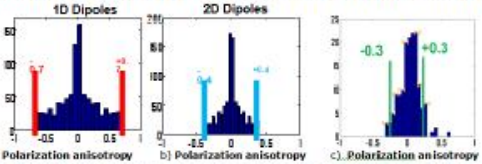

Fig 1. Simulation of the distribution of polarisation anisotropy for a 1D dipole (a) and a 2D dipole(b), experimental distribution of polarization for CdSe/CdS nanocrystals (c).

Once the dimensionality of the emitter is known, at the single scale, an analysis of the emission of a single emitter by turning the polarizer/analyzer gives information on its orientation.

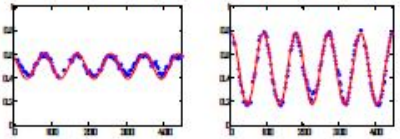

Fig 2. Intensity transmitted by the polarizer for a single nanoemitter as a function of the polarizer rotation angle. red line simulation, blue ponts :experimental points. a) CdSe/CdS nanorod,(1D dipole), b) CdSe/CdS nanocrystals (2D dipole).

The phase of the sinusoidal curve gives the information on the polar orientation and the contrast gives information on the azimuthal orientation of the dipole with respect to the axis (normal to the interface). Thiis determination of dipole orientation by polarization analysis is complementary to defocused microscopy, and can give information even when defocused microscopy is not suited (2D dipole at a metallic interface...).

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Plasmon excitation and induced emission with a plasmonic self-organized crystal

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Metallic surface grating offers the opportunity to absorb light with almost 100% of efficiency and to enhance the fluorescence of nanoemitters close to their surface with applications in fields such as bio-imaging, light-emitting diodes (LED), photovoltaics or single-photon sources. In order to take advantage of surface-plasmon-polariton modes (SPP), which are not coupled to far-field radiative modes in the case of a planar metallic surface, a periodically corrugated metallic surface can be used.
We used self-assembly to fabricate a plasmonic crystal of centimetric size, by evaporating a thick layer of gold on an artificial silica opal used as a periodic template. We performed optical specular reflection spectra and evidenced under p-polarized excitation a dip of almost complete absorption. By comparison with a theoretical model we attributed this absorption to the creation of SPP modes. On the other hand, a dip in s-polarized reflction was attributed to localized plasmon modes. We demonstrated, at a given incidence angle, a broad continuum of coupled wavelengths over the visible spectrum. This opens new possibilities in fields where light-plasmon coupling is required over a broad range of wavelengths and incidence orientations [1]. To study the fluorescence of nanoemitters coupled to the gold surface, we sputtered an intermediate 80 nm silica layer to avoid quenching and then deposited colloidal CdSe/ZnS nanocrystals on silica. We performed angle and polarization-resolved emission spectra. We observed a p-polarized wavelength-dependent anisotropy of emission at angles corresponding to the phase matching condition between the light and SPP wavevectors mediated by the corrugation. As SPP are TM waves, this evidences excitation of plasmon modes by nanocrystals and re-emission of plasmons to far field p-polarized radiation. In order to quantize the extraction and re-emission of SPP, we compared the obtained spectra to the case of nanocrystals on a plane gold surface. We performed lifetime measurements in both cases to check that the corrugation has no influence on the emission rate and so that the two configurations can be compared. We obtained a reliable estimation of the SPP radiation rate (ratio between radiated and excited SPP) which shows a real improvement of the fluorescence intensity. The experimental method developed here can be generalized to other systems and provides an interesting tool for designing light-extracting devices. We used photo-emission electron microscopy (PEEM) in order to further characterize and distinguish the excited SPP or localized modes. PEEM provides a high-resolution mapping of the electric field of the photo-excited plasmonic modes. We demonstrate the coupling of incident light modes to both SPP and localized plasmon modes. The arrangement of the hot spots is discussed as a function of the crystallographic quality of the opal. The wavelength and propagation of the plasmonic modes is analyzed.

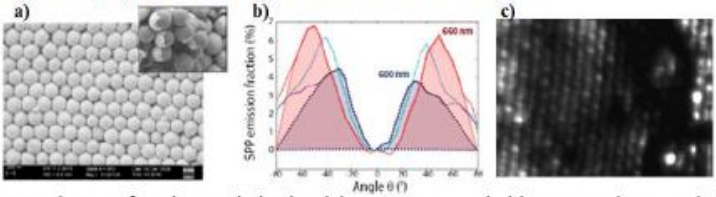

Fig. 1. a) SEM picture of a plasmonic lattice (size 1.4 x 2 µm²). b) Extracted SPP ratio in far field emission. c) PEEM image : periodic and localized plasmonic modes appear.

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Controlling the morphology of ZnO nanostructures grown by Au-catalyzed chemical vapor deposition and chemical bath deposition methods

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Despite systematic research concerning the rational growth of ZnO nanostructures for over a decade, the establishment of an experimental methodology capable of providing specific morphologies of ZnO nanostructures in a reproducible way is still an open question. This is also one of the current research challenges because the resulting morphologies are characterized by different physical properties and are quite sensitive to small changes in experimental conditions. The current work is aimed at providing a systematic study of the role of various growth parameters on the morphological features and the optical properties of ZnO nanostructures. Growth was achieved by catalyst-assisted (Au) vapor transport at high temperature (VLS) and by solution chemistry (CBD). It is important to gain understanding about how certain parameters affect the morphology of the nanostructures, the size distributions of the diameters and their orientation relative to the substrate.

High temperature evaporation methods, such as the vapor-liquid-solid mechanism, have been exploited for the controlled growth of ZnO nanostructures on various substrates. While Au is the most frequently used catalyst for growing ZnO nanowires, its morphological features on the substrate, which determine the size and shape of the nanostructures grown, are not yet methodically explored. Here we investigated the details of thermal dewetting of Au films into nanoparticles on Si substrates. Au films of various thicknesses ranging from 2 to 15 nm, were annealed under slow and fast rates at various temperatures and the morphological details of the nanoparticles formed were investigated. The vapor-liquid-solid method was employed to investigate the role of the Au nanoparticles on the growth details of ZnO nanowires. Efficient and high throughput growth of ZnO nanowires, for a given growth time, is realized in cases of thin Au films, i.e. when the thickness is lower than 10 nm.

In the second case, the influence of a number of parameters such as the thickness of the seed layer, the reactants concentration, the existence of organic compounds, the growth time, etc. on the growth of ZnO nanowires on conducting glass substrates (FTO) was examined. After parameter optimization it was found that ZnO nanowires grown have excellent orientation, perpendicular to the substrate, while their diameter and length were found to be ~30 nm and ~7 μm, respectively.

Sub-picosecond transient dynamics of charge transfer states polyaniline

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Polyaniline is a pi-conjugated polymer with a relatively flexible backbone, which influences the dynamics of excited electronic states. It is known, that the undoped forms of polyaniline support extremely long-lived photoexcitations that are stabilized by out-of-plane rotations of phenyl rings. We observed ultrafast charge transfer exciton localization using the femtosecond pump-probe transient absorption spectroscopy of emeraldine base of polyaniline in dimethyl sulfoxide solution. By modelling of the experimentally obtained evolutions of pump-induced transient absorption with a system of differential equations controlling the population of the excited state manifold we were able to extract the kinetic parameters of the excited state evolution. Namely, our theoretical model could simultaneously explain transient absorption corresponding to four different wavelengths of the probe pulse. In our model, the excited state created by pump pulse (100 fs FWHM; 700 nm central wavelength) in the quinoid absorption band develops by subsequent transition during approximately 20 fs to an intermediate excited state (probed at wavelength of 557 nm). The intermediate state (IS) can be assigned to the excited state with symmetrical charge distribution over the quinoid ring and two benzenoid rings in the nearest neighborhood. Then, during next 20 – 30 fs, the intermediate state relaxes to an asymmetrical charge transfer state (probed at 420 nm) with an electron partially localized on the quinoid ring and a hole on an either of surrounding phenyl rings. The charge transfer state (CT1) is subsequently transformed into a metastable form (CT2) by rotation of phenyl rings, which is confirmed by observation of, at least, bi-exponential decay time. Analyzing simultaneously the time kinetics of charge transfer states probed at 420 nm and ground state bleaching (GSB) probed at 647 nm (Q-band) and 341 nm (B-band) we concluded that the hot charge transfer state partly decays with a time constant ca ~ 0.5 ps and partly relaxes with a time constant of 2.5 ps to the rotated position of phenyl rings with a life-time ca 10 ps.

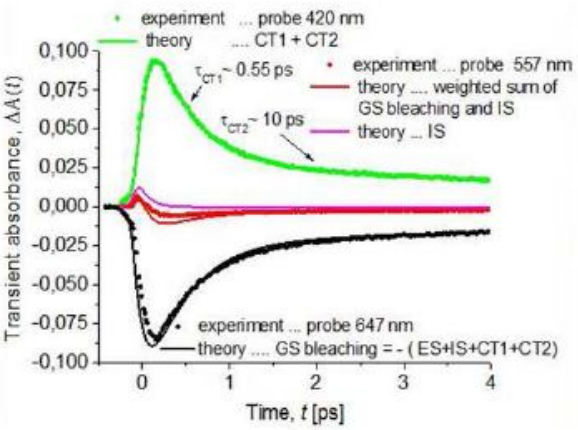

Fig.1. Transient absorption spectra of the emeraldine base. Experiment at three independent probe wavelengths (420, 557 and 647 nm) supplemented by a kinetic model.

Diketopyrrolopyrroles: case study of materials for organic photonics

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The rapidly progressing fields of organic photonics research has led to a renaissance in the chemistry of dye molecules, compelling scientists to revitalize old pigments, transform them into soluble dyes and apply them in the construction of new and complex semiconducting materials. Among other materials (e.g. (iso)indigo, benzodipyrrolidone, benzodifurannone, and others) mainly dyes based on diketo-pyrrolo-pyrrole (DPP) unit becomes to be highly studied nowadays. Derivatives of 3,6-diphenyl-2,5-dihydro-pyrrolo[3,4-c]pyrrole-1,4-dione, commonly referred to as DPPs, constitute recent industrially important class of high-performance pigments. They are endowed with brilliant shades and exhibit exceptional chemical, heat, light, and weather fastness. If we add to this a large conjugated system, they represents attractive basic core for organic photonics. It has been proved that the DPPs can serve as an efficient structure for organic solar cells materials[1] and can exhibit high p-type[2] and n-type[3] mobility.

In this contribution we present the study of the effect of DPP chemical structure on the electrical, optical and optoelectronic properties for photonic applications. We discuss the influence of various substitutions (polar groups, solubilizing groups) on not so often used phenyl-DPPs (contrary to the more common thienyl-DPPs).[4-7] These modifications allow fine-tuning the frontier molecular orbitals, molecular geometries and the resulting properties. We show that these dyes can offer efficient base for optical applications (solid state lasers (see Fig. 1), two-photon absorption) and optoelectrical applications such as photovoltaics and sensors. Model devices were prepared and characterized and the experimental outcomes are compared with theoretical results obtained with the help of quantum chemical calculations.

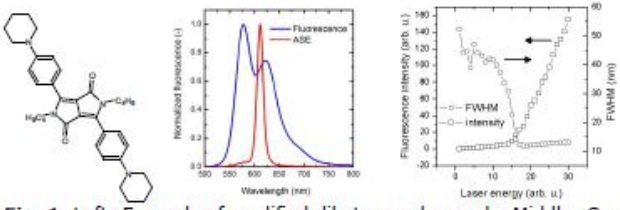

Fig. 1. Left: Example of modified diketopyrrolopyrrole. Middle: Comparison of the normal fluorescence spectrum and spectrum of the amplified spontaneous emission (ASE). Right: The evolution of intensity and full width at half of maximum (FWHM) on pumping energy. See the energy threshold at around 15 arb. u. of the laser pumping energy.

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Towards functional advanced materials using ordered anodic oxides supports and templates

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Synthesis of highly-ordered nanostructures of valve metal oxides has recently attracted huge scientific and technological interest motivated by their possible use in many applications. The nanoporous Al_2O_3 – most established member of this group of materials – has been prepared by anodic oxidation of Al under suitable electrochemical conditions nearly two decades ago into perfectly ordered, honeycomb-like porous structures. Owing to the flexibility of the pore diameter/length and the relative ease of the Al_2O_3 dissolution, its porous membranes have been since than widely used as templating material of the choice for a range of materials.
It is the TiO_2 that has received the highest attention after Al_2O_3 motivated by its range of applications, including photocatalysis, water splitting, solar cells and biomedical uses. Very significant research efforts have led to reproducible synthesis of self-organized TiO_2 nanotube layers by means of anodic oxidation, during which the starting Ti substrate is converted into highly-ordered nanotubular layer by anodization in suitable electrolyte.
Although many applications of the nanoporous Al_2O_3 and nanotube TiO_2 nanotube layers have been presented, their potential for the synthesis of advanced functional nanomaterials, in particular when considering all possible shapes and geometries, has not at all been exploited.
In the presentation, we want to focus in detail on various filling routes of anodic templates and supports. We will show examples of various functional devices including some very recent results on chalcogenide-sensitized TiO_2 nanotubes [1] and on the new design of resistive switching of memory switching cells using porous AAO templates [2].

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Volume and surface - merging optical functionality and specific biointeraction for advanced biomedical materials

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The high flexibility of photosensitive polymers for holographic and photolithographic processing gives rise to many degrees of freedom in the creation of complex structures for micromechanical and photonic devices [1-3] both for integrated optics [4], as well as for potential applications in tissue engineering and medicinal science [5, 6].
Subject of particular interest is the interplay of various structures with complementary functions. This includes multi-dimensional, and/or heterogeneous and hierarchical structures, e.g. with combined optical and mechanical patterns. Thus, for example refractive-diffractive structures, created either separately or within unified processing, can be used as intra-ocular lens (IOL), replacing the human eye lens.
Building on our recent, promising results related to the volume holographic applicability, namely no need for solvent processing, good dimensional stability, variable thickness, high energetic sensitivity, large dynamic range and sharp angular selectivity [4] and elucidation of specific material characteristics [7, 8] we consider further material development by means of targeted surface modifications to open up the field of biomedical applications [6].
This implies, inter alia, to address both optical properties and issues of cytotoxicity and biocompatibility likewise. Appropriately, the characteristics of interest, i.e. optical parameter on the one hand, and protein adsorption plus cell adhesion on the other hand, are determined by the fundamental chemical, physical, and mechanical properties of volume and surface, respectively.
With the specific objective to combine optical patterning by means of volume holographic technique and advanced mechanical structuring of the surface [6] (see figure 1) we want to address the relevant criteria for biomedical applications such as for IOLs.

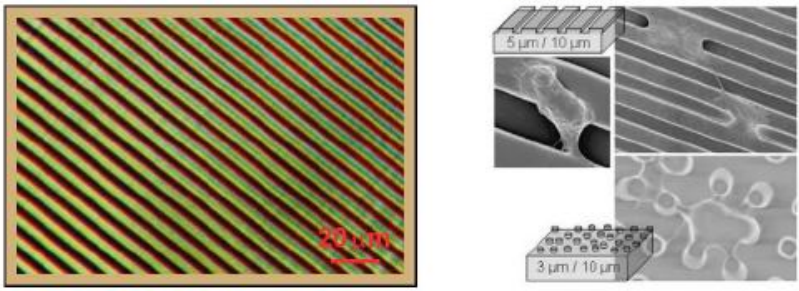

Fig. 1. Volume phase gratings (left side, from [9]) and cellular response to surface patterns (right side, from [6]).

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Improved light extraction from luminescent layers via leaky modes of 2D photonic crystals

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The phenomenon of total internal reflection on a slab-air interface causes that most of radiation generated inside the slab stays trapped in the structure. Several approaches have been developed to overcome this limitation, such as random or periodical patterning of the layer surface. In the latter approach, two-dimensional (2D) photonic crystals (PhCs) with properly-designed dimensions are fabricated on the top of waveguiding layers. Then, the Bragg-diffraction of guided modes, referred to as leaky modes, allows the efficient extraction of light into surroundings [1,2].
In the present study, we employed 2D PhCs with a goal to increase the extraction efficiency of light from silica (SiO_2) layers embedded with nanometer-sized light emitters, silicon nanocrystals (SiNCs). Light emission (luminescence) of the embedded SiNCs is relatively spectrally broad and peaks at around 775 nm. Dimensions of the photonic structures were computed by employing a computer simulation based on Rigorous coupled-wave analysis method such that a spectral overlap of leaky modes of the structure with the emission spectrum of SiNCs was achieved [3]. We have fabricated columns on the top of the silica layer ordered either into square or hexagonal lattices with a typical lattice constant of the order of hundreds of nanometers. For example, for the square lattice, we have measured up to 8-fold enhancement of the luminescence extraction efficiency in the direction normal to the sample plane. For other directions, signal from the PhC was up to 3 times larger than that measured from a planar reference layer. The results of angle-resolved photoluminescence measurements (Fig. 1) followed a theoretically computed leaky modes band diagram which confirms that the extraction enhancement originates dominantly from Bragg-scattering of the guided modes on the periodicity. Even higher extraction efficiencies were obtained for photonic crystals with hexagonal lattices.
In summary, our results seem very promising for optics and optoelectronics as they can be applied to enhance light emission from light emitting diodes (LEDs). In addition to the extraction enhancement, one obtains also a control over the direction of propagation of the extracted light, which is the main advantage of the PhC concept compared to random-scattering surfaces used in conventional LEDs.

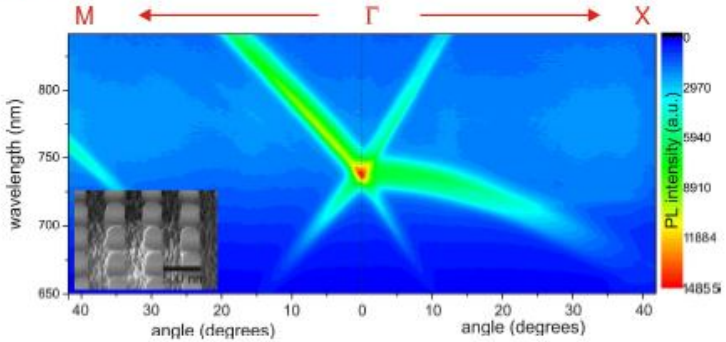

Fig. 1. Angle-resolved photoluminescence of a 2D PhC slab with embedded light emitting SiNCs (inset) measured along the Γ-M and Γ-X crystal directions. Adapted from Ref. [3].

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Spectral broadening and material ageing in As_2S_3 suspended-core microstructured optical fibers

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Demands on infrared technology increasingly grow during the last decade. Providing reliable and stable light sources that cover a broad spectral bandwidth is of major importance. This spectral enlargement can be accomplished through the phenomenon of supercontinuum generation (SCG). Breaking the registered record limits, and spreading further in the infrared, remains needful. For this purpose, a diversity of glass families was extensively explored through these years. Among the variety of investigated glass families, we focus on chalcogenide glasses (ChG) and more precisely on As_2S_3 system. The choice of the vitreous material was based on its wide transparency window, its thermo-chemical stability and its nonlinear optics features responding to the assigned functions: the generation of supercontinuum (SC).
In this work, we report a successful SC spreading over 3500nm in an As_2S_3 microstructured optical fiber (MOF). It extends from near visible (0.6µm) to the mid-infrared (4.2µm), in a 40 dB dynamic range. Spectrum flatness remains under 10 dB from roughly 1.4 to 2.6 µm. The MOF used in these experiements is designed to shift chromatic dispersion around 2.5µm. A 2cm length of low loss MOF is tested. An optical parametric oscillator seeds with Ti-sapphire laser is used as light source. It generates 200fs pulses with 176mW peak power at pump wavelength at a repetition rate of 76MHz. Experimental results are numerically interpreted through the resolution of the nonlinear Schrödinger equation using the split-step Fourier method. Assignment of the nonlinear dynamics taking place in the measured broadening is proposed [1].
Efficiency and durability of SCG could be sufficiently restricted by vibrational absorption bands of impurities and highly pure ChG are required. Thus, a particular ChG glass fabrication process has been developed and glass are routinely produced with convincing optical quality. Nevertheless, experimentally registered SC in MOFs stored under laboratory conditions does not fit with numerical results [1]. To overcome this discrepancy, extra extrinsic losses must be taken into account. This underlines a dynamic evolution of exposed materials, a "glass ageing". Therefore, transmission, extrinsic absorption bands, tomography and surface glass composition have been studied as a function of time spent under laboratory conditions. Evolution of transmission and extrinsic absorption bands were monitored by FTIR technique, surface tomography by Atomic Force Microscopy (AFM) and composition by X-Ray Photoelectron Spectroscopy (XPS). We present here these results. Assignments of the chemicals as well as optical degradation mechanism are proposed.

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Te-Ge-Se films: elaboration by thermal co-evaporation, characterization and use for the manufacture of IR integrated optics components, basic elements of CO_2 optical microsensors

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Films in a wide range of compositions in the Te-Ge-Se ternary system were prepared by thermal co-evaporation. The evolution of optical and thermal properties versus the composition have been used to determine a particular area of composition which is interesting for manufacturing waveguides being able to operate from 1 to about 17 microns.
Straight and curved RIB waveguides as well as Y-junctions based on these compositions were fabricated by using laser lithography and ion beam etching. Propagation losses of straight RIB waveguides were estimated to be around 1 $dB.cm^{-1}$ at λ = 1.55 µm. All the curved RIB waveguides were highlighted to be operational, independently of their curve radius and angle. Finally, the Y-junctions were shown to operate at a satisfying power division.

Tunable emission from novel Mn^{2+}-activated oxide phosphors

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In recently years, great efforts have been made to search for the one-phase and full-color phosphors because there is neither energy loss through reabsorption nor deterioration of color rendering index (CRI) due to different photochemistry in mixed phosphors [1]. A common strategy to realize full-color emission is codoping of different luminescent centers each with its characteristic emission wavelength [2]. Here, we report on novel Mn^{2+} activated zinc gallogermanate phosphors with the composition of $Zn_{1+x}Ga_{2-2x}Ge_xO_4$ (x = 0 ~ 1), where two Ga^{3+} are subsitited by Zn^{2+} and Ge^{4+}. The phosphors can be obtained by conventional solid state reaction in the open air. Our results show that controlling the content of Ge^{4+}, the emission colour can be tuned from pure green at 532 nm (x = 0 and 1) to pure red (x = 0.05 and 0.1) at 680 nm and even coexistence of green and red (x = 0.25 ~ 0.75) (Fig. 1). The green and red emission is attributed to the Mn^{2+} in the tetrahedral and Mn^{4+} in the octohedral coordinations, respectively. The oxidation of the Mn^{2+} to Mn^{4+} is confirmed by the electron spin resonance (EPR) measurement, and is the result of detailed charge balance according to the reaction: $2Ga^{3+} \leftrightarrow Ge^{4+} + Mn^{4+} + O^{2-}$. To understand the mechanism of the tunable emission, the micro structure and the native defects of the host phosphors are also investigated by Raman, positron annihilation lifetime and thermoluminescence spectra. The subsitution greatly influences the content of the oxygen vancancy, which in turn may impact on the luminescence behaviors of Mn ions. Due to the much better thermal and chemical stability than sulfide phosphors, the present Mn^{2+} activated zinc gallogermanate is a promising candidate for the next generation of light conversion materials [3].

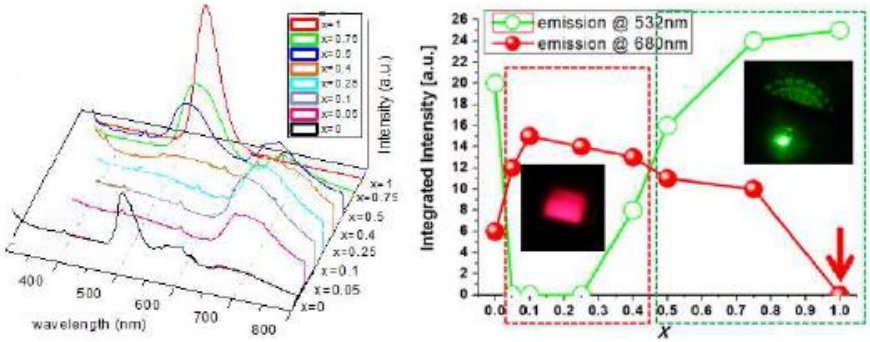

Fig. 1. The emission spectra of the Mn^{2+} activated $Zn_{1+x}Ga_{2-2x}Ge_xO_4$ (x=0-1) phosphors (left), and the plot of the integrated emission intensity @ 532 and 680 nm as a function of the Ge^{4+} content (right). Insets in the right figure show the digital photos of the phosphors when exposed to UV light in the dark.

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