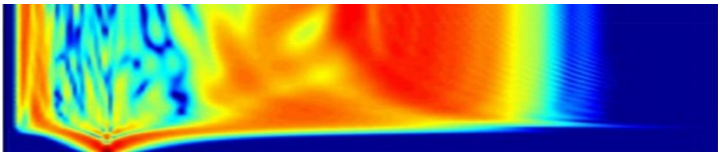
Book of Abstracts

Advanced
Architectures in
Photonics 2016



25th – 29th September 2016, Mykonos, Greece

Saint John Hotel, Villas, Hotel & Spa

www.aap-conference.com

AAP 2016 symposium covers topics on science, technology and applications of micro- and nano-structured materials used in optics, photonics and plasmonic."

About Advanced Architectures in Photonics

AAP2016 is the second in the AAP series, Advanced Architectures in Photonics symposium, held in Mykonos, Greece, following the initial event held in Prague, Czech Republic, in 2014. The main AAP objective is to attract attention of international research groups and academic community to photonic and applied optics-oriented research in the host country.

Both, the Advisory board and the Organizing committee are committed to ensuring an attractive scientific coverage with plenary talks, invited talks, contributed and poster papers with special focus on science, technology, and applications of micro- and nano-structured materials used in optics and photonics.

Venue

The conference will be held in Saint John Hotel, Villas & Spa, Mykonos, Greece.

Address: Agios Ioannis, Mikonos 846 00, Greece,
Tel. +30 22890 28752 / Fax: +30 22890 28751
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Main topics

New light sources
Progress in Light-Emitting-Diods
Progress in laser sources
Super-continuum generation sources
Up- and down conversion sources

Plasmonics
Concepts
Materials
Devices & Applications

Photovoltaics
Enhanced light harvesting
Antireflection architectures
Devices & Applications

Materials and architectures for light manipulation
Metamaterials
Photonic crystals
Devices & Applications

Characterization tools for optical materials
Surface enhanced Raman spectroscopy
Near-field techniques
Non-linear spectroscopy

The AAP2016 symposium is supported by

Involved Ltd. - a technological company with main focus on R&D in applied optics and energy storage, Chrudim, Czech Republic.

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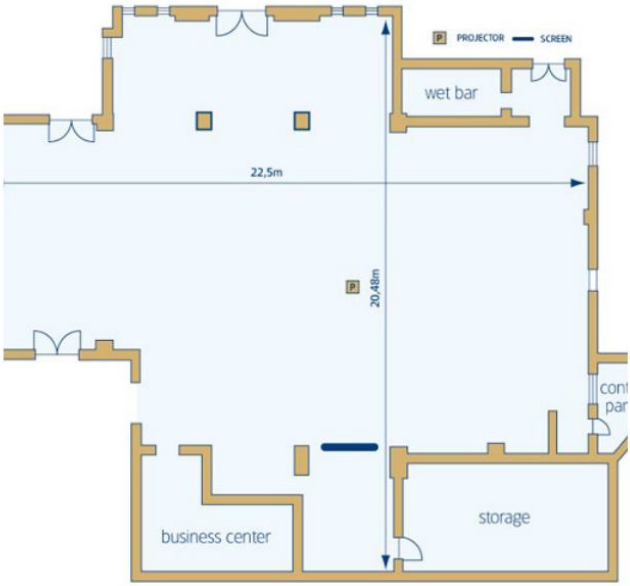
Programme scheme

Sunday Sept. 25th	**Monday** Sept. 26th	**Tuesday** Sept. 27rth	**Wednesday** Sept. 28th	**Thursday** Sept. 29th
	9:00 - 9:15 a.m. Opening address			
	9:15–10:00 a.m. **PLENARY** **C. J. Humphreys** The Amazing Science, Technology and Applications of Gallium Nitride LEDs	9:15–10:00 a.m. **PLENARY** **B. Luther-Davies** Supercontinuum Generation in the Mid Infrared: Challenges and Solutions	9:15–10:00 a.m. **PLENARY** **M. E. Pemble** Recent Advances in the Fabrication and Application of Colloidal Photonic Crystals...	9–12 a.m. Informal Discussion
	10–10:15 a.m. Coffee break	10–10:15 a.m. Coffee Break	10–10:15 a.m. Coffee Break	
	10:15–10:45 a.m. **INVITED** **D. J. Rogers** ZnO-Based Photonics	10:15–10:45 a.m. **INVITED** **E. N. Economou** Toroidal Dipoles in Metamaterials	10:15–10:45 a.m. **INVITED** **R. Carius** Nanostructure Based Light Management in Thin-Film...	
	10:45–11:15 a.m. **INVITED** **M. Farsari** Three-Dimensional Patterning of ZnO Nanostructures	10:45–11:15 a.m. **INVITED** **G. A. Voyiatzis –** Optimizing SERS Conditions, by Noble Metal Film's Thermal Dewetting...	10:45–11:15 a.m. **INVITED** **T. F. Krauss** Photonic Crystals for Biosensing & Imaging	
	11:15–11:45 a.m. **A. Klini** Optical Gas Sensing Based on ZnO-PDMS Nanohybrids	11:30–12 a.m. **INVITED** **J. C. Cuevas** Near-Field Radiative Heat Transfer at the Nanoscale	11:30–12 a.m. **INVITED** **H. Fudouzi** High Quality and Large Colloidal Photonic Crystal Film Coated on Flexible Sheets	
	11:45–12:15 a.m. **D. Anglos** Random Lasing from ZnO Nanostructures	11:45–12:15 a.m. **T. Scopigno** Snapshots of ultrafast processes in biomolecules and condensed matter in the light of Femtosecond		
	12:15–2 p.m. Lunch Break	12:15–2 p.m. Lunch break	12:15–2 p.m. Lunch Break	
	2–2:30 p.m. **INVITED** **F. Rosei** Multifunctional Materials for Electronics and Photonics	2–2:30 p.m. **INVITED** **J.–L. Adam** Advanced Architectures in Chalcogenide Fibers and Micro-Waveguides	2–2:30 p.m. **INVITED** **S. Nakabayashi** Photosensitizer-Conjugated Ultrasmall Carbon Nanodots as Multifunctional Fluorescent Probes for Bioimaging	
	2:30–3 p.m. **J. C. Jarman** Nanoporous Distributed Bragg Reflectors for Non-Polar GaN Microcavities	2:30–3 p.m. **F. Smektala** Mid-IR Supercontinuum Generation in Crystals, Bulk Glasses or Optical Fibers	2:30–3 p.m. **INVITED** **S. Pissadakis** Towards the Optical Fiber-Lab Concept	
	3–3:30 p.m. **M. Vasileiadis** Alternative to Indium Tin Oxide (ITO) Transparent Conductive Films: Need-Driven, EU-Funded Research	3–3:30 p.m. **T. Kohoutek** Solution processing of a chalcogenide glass	3–3:30 p.m. **K. Vlachos** A Single Frequency, Linear Cavity Erbium-Doped Fiber Laser	
	3:30–4 p.m. **Y. Noda** Accumulations of Au and Ag-Coated Au Nanoparticles for Plasmonics	3:30–4 p.m. **I. Zeimpekis** Current and Emerging Applications of Chalcogenides in Optoelectronic Devices	3:30-3:45 p.m. Closing Remarks	
	4–4:15 p.m. Coffee Break	4–4:15 p.m. Coffee break	3:45–4 p.m. Coffee Break	
4-7 p.m. Registration and Welcome Drink	6 p.m. - Dinner	6 p.m. – Greek Style BBQ	6 p.m. Dinner	

Symposium rooms

The symposium is located in Thalata and Zeus rooms

Zeus



M1P

The amazing science, technology and applications of Gallium Nitride LEDs

C. J. Humphreys*
Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, Cambridge CB3 0FS, UK
**Corresponding author: colin.humphreys@msm.cam.ac.uk*

Gallium nitride (GaN) is probably the most important new semiconductor since silicon. GaN LEDs have the potential to save globally 15% of all electricity and 15% of carbon dioxide emissions from power stations. In addition, they could save millions of lives worldwide by purifying water, enable fast visible light communication, stimulate individual neurons in the brain, improve our health, improve productivity at work and school.

The basic science of GaN LEDs is fascinating. The light emission from GaN LEDs comes from quantum wells of InGaN. A long standing mystery is why GaN LEDs (producing blue, green and white light) are so bright when the dislocation density is so high. We have solved this problem by showing that it is because the electron and hole carriers in GaN are localised, so they cannot diffuse to the dislocations, which would prevent the light emission. Remarkably, the electrons and holes are localised by different mechanisms: random In fluctuations in the InGaN alloy localise the holes and monolayer thickness fluctuations in the InGaN quantum wells localise the electrons.

The main problem with obtaining the widespread use of GaN LEDs is cost. We have shown how growing GaN LEDs on large area Si substrates can substantially reduce the cost. This talk will describe some of the problems involved. Our research on low-cost LEDs is being exploited by Plessey which is now manufacturing millions of these GaN-on-Si LEDs in the UK.

This cost reduction will enable the widespread use of GaN LEDs for lighting worldwide, thus saving energy and greenhouse gas emissions. The talk will end by describing the exciting future applications of such LEDs to water purification, LiFi, and improving the health of us all!

M2I

ZnO-Based Photonics

D. J. Rogers[1,*], F. H. Teherani[1], E. V. Sandana[1] and P. Bove[1]
[1]*Nanovation, 8 route de Chevreuse, 78117 France*
[*]*Corresponding author: rogers@nanovation.com*

Zinc oxide (ZnO) is a remarkable, multifunctional semiconducting material with a direct, wide bandgap (Eg ~ 3.4 eV), intrinsically high transparency over the whole visible range, and a resistivity that can be tuned from semi-insulating right through to semi-metallic by doping. It also presents one of the highest piezoelectric responses of any semiconductor and has a relatively high thermoelectric figure of merit. Moreover, it has been judged to be biocompatible and has been approved for human consumption (in products such as vitamin pills) by the U.S. Food and Drug Administration. The figure below shows that ZnO is currently one of the hottest topics in materials science, with almost 8000 publications in 2015:

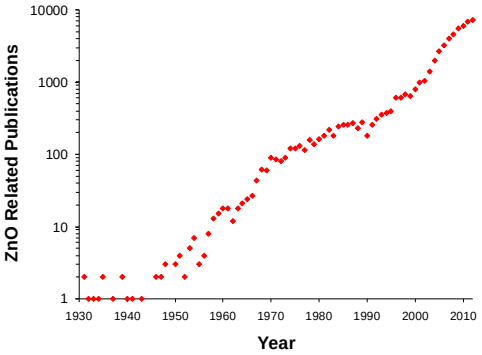


Fig. 1. Number of annual publications vs. year according to a search of the www.scopus.com database for the term "ZnO" in the abstract, title, or keywords**.**

ZnO has become a hot topic because of its' distinctive property set plus a number of recent breakthroughs. Also of note is that a recent Thomson-Reuters study, recorded more publications dedicated to nanostructured ZnO than to carbon nanotubes. This was attributed to the multifunctional nature of ZnO, the ease of fabricating nanostructures by various techniques (including wide-area, low cost chemical growth) and the extremely large family of nanostructure shapes that can be obtained. In this talk, we will give an overview of the advances in the field and present some of the wide range of ZnO-related photonics devices and applications being researched at the moment with illustrations from the work of the French ZnO start-up, Nanovation (www.nanovation.com).

M3I

Three-dimensional patterning of ZnO nanostructures

A. N. Giakoumaki[1,2], G. Kenanakis[1], A. Klini[1], Z. Viskadourakis[3], A. Selimis[1], and M. Farsari[1,*]

[1]IESL-FORTH, N. Plastira 100, 70013, Heraklion, Crete, Greece
[2]Department of Chemistry, University of Crete, 70013, Heraklion, Crete, Greece
[3]Crete Center for Quantum Complexity and Nanotechnology, Physics Department, University of Crete, 70013, Heraklion, Crete, Greece
[*]Corresponding author: mfarsari@iesl.forth.gr

We report on a new method for preparing fully three-dimensional ZnO nanorod-coated structures based on a combination of two laser techniques and low temperature hydrothermal growth. The resulting structures are covered uniformly by nanorods and are electrically conductive. As a proof of principle, we demonstrate the use of the as-grown ZnO nanostructures as photocatalysts against methylene blue decolourization, and we provide evidence that, due to the increase in their active surface area, the photocatalytic efficiency of the samples increases dramatically.

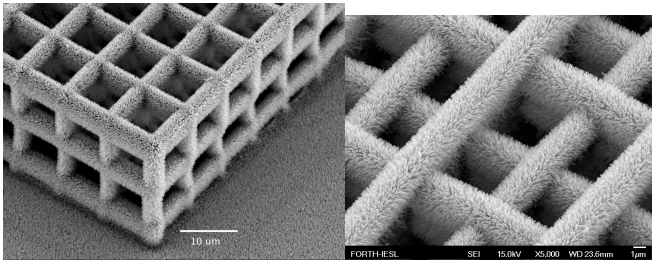


Fig.1. 3D structures covered with ordered ZnO nanorods.

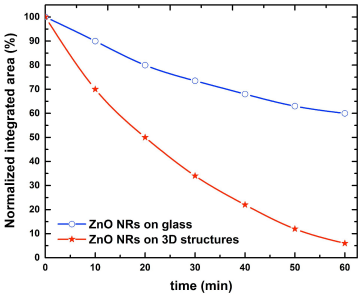


Fig. 2. Normalized absorption of aqueous solution of methylene blue at λ_{max}=665 nm under UV light irradiation for ZnO nanorods grown on glass substrates (blue circles), and ZnO nanorods on 3D structures (red stars), respectively.

M4

Optical gas sensing based on ZnO-PDMS nanohybrids

A. Klini,[1*] S. Pissadakis,[1] R. N. Das,[2,3] E. P. Giannelis,[3] S. H. Anastasiadis,[1,4] and D. Anglos[1,4]

[1]Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas, (IESL-FORTH) P.O. Box 1385, GR 71110 Heraklion, Crete, Greece

[2]Massachusetts Institute of Technology, Lincoln Lab. 244 Wood Street, Lexington, MA, USA 02421, USA

[3]Department of Materials Science and Engineering, Cornell University, Ithaca, New York 14853, USA

[4]Department of Chemistry, University of Crete, P.O. Box 2208, GR 71003 Heraklion, Crete, Greece

[*]Corresponding author: klini@iesl.forth.gr

ZnO-PDMS nanohybrids, composed of luminescent ZnO nanoparticles dispersed in an inert polydimethylsiloxane (PDMS) matrix, exhibit an excellent ability to follow changes of their surrounding atmosphere (e.g. Ethanol, oxygen), through monitoring the modifications of their UV photoluminenscence (PL) emission at room temperature [1]. The performance of this new optical sensing platform as regards its sensitivity, repeatability and response at different excitation parameters (e.g. intensity, wavelength) has been systematically examined and discussed.

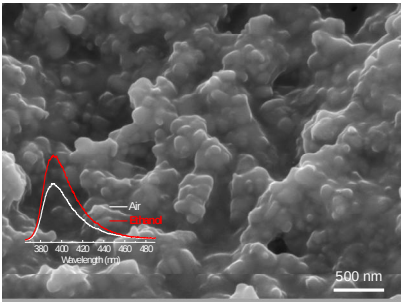


Fig. 1. Morphology of ZnO-PDMS nanohybrids is shown.

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M5

Random Lasing in ZnO Nanostructures

D. Anglos*
Department of Chemistry, University of Crete, 711 03, Heraklion, Crete, Greece
Foundation for Research & Technology–Hellas, Institute of Electronic Structure and Laser, P. O. Box 1385, Heraklion 71110, Greece
**Corresponding author: anglos@iesl.forth.gr*

A variety of ZnO nanostructure architectures neat or embedded in polymer matrices have been studied with emphasis on the investigation of their lasing properties. These structures have been obtained by incorporating zinc oxide nanoparticles in a variety of inert organic polymeric or inorganic sol-gel matrices or by growing nanostructures on various substrates including flexible ones. Common feature of all systems is their high scattering capacity, which combined with the strong photoluminescence emission of ZnO leads to photon localization and lasing. Excitation of the nanohybrids by laser pulses is found to show distinct threshold behavior demonstrated by a dramatic increase in the emitted light intensity and a significant spectral and temporal narrowing. A series of studies that investigate the influence of pump pulse duration and temperature on the random laser efficiency are presented along with coherence length measurements on selected samples and . Nanocomposite fabrication issues and pumping conditions are discussed in the context of performance optimization and potential use of such materials in future light emission or sensing devices.

M6 I

Multifunctional Materials for electronics and photonics

F. Rosei*
Centre for Energy, Materials and Telecommunications, Institut National de la Recherche Scientifique, 1650 Boul. Lionel Boulet, J3X 1S2 Varennes (QC) Canada
**Corresponding author: rosei@emt.inrs.ca*

The bottom–up approach is considered a potential alternative for low cost manufacturing of nanostructured materials [1]. It is based on the concept of self–assembly of nanostructures on a substrate, and is emerging as an alternative paradigm for traditional top down fabrication used in the semiconductor industry. We demonstrate various strategies to control nanostructure assembly (both organic and inorganic) at the nanoscale. We study, in particular, multifunctional materials, namely materials that exhibit more than one functionality, and structure/property relationships in such systems, including for example: (i) control of size and luminescence properties of semiconductor nanostructures, synthesized by reactive laser ablation [2]; (ii) we developed new experimental tools and comparison with simulations are presented to gain atomic scale insight into the surface processes that govern nucleation and growth [3-5]; (iii) we devised new strategies for synthesizing multifunctional nanoscale materials for electronics and photovoltaics [6-11].

References

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M7

Nanoporous Distributed Bragg Reflectors for Non-Polar GaN Microcavities

J. C. Jarman*, T. Zhu, Y. Liu, T. Ding, R. V. Kumar, R. A. Oliver
Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, Cambridge, CB3 0FS, UK.
**Corresponding author: jcj27@cam.ac.uk*

Indium gallium nitride (InGaN) quantum dots grown on non-polar $\{11\bar{2}0\}$ a-plane GaN show promise as efficient, room-temperature single-photon sources emitting at green or blue wavelengths [1]. Purcell enhancement of the single-photon emission can be attained by confining these dots in optical microcavities, which are photonic structures designed to resonate at the emission wavelength of the dot [2]. Several designs of cavity are possible; photonic crystal defect cavities, microdisk resonators, or micropillar cavities. Micropillar cavities use Fabry-Perot modes arising from two distributed Bragg reflectors (DBRs) placed above and below the dot, and the light is confined in three dimensions by etching a pillar into the structure [3]. Realising DBRs in non-polar GaN has presented a significant challenge, as these multi-layered structures traditionally require epitaxial layers of material with substantially different refractive indices. However, development of an etch that is selective for conductivity has allowed nanoporous GaN layers to be used as the low-index component of high-reflectivity DBRs, circumventing many of the challenges associated with creating epitaxial multilayers with high refractive index contrast [4]. We have recently succeeded in creating porous a-plane material, and we have used it to create a highly-reflective DBR structure. This talk will discuss this novel material's properties, and explore the challenges associated with processing this structure into optical and electrical devices.

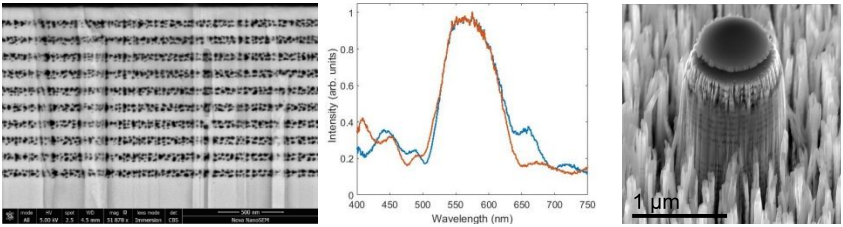

Fig. 1. Left: SEM micrograph of a porous GaN distributed Bragg reflector, fabricated on the non-polar a-plane. Centre: corresponding reflectivity trace, showing a peak reflectivity of 98%. Right: Porous GaN incorporated into an etched micropillar cavity, with roughening of the etched surface due to the porous structure.

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M8

Alternative to Indium Tin Oxide (ITO) transparent conductive films: need-driven, EU-funded research

A. Melitsiotis,[1] K. Hrissagis,[1,2] and M. Vasileiadis[3,*]
[1]Center for Research and Technology Hellas (CERTH), Institute for Research and Technology, Thessaly (IRETETH), Karyes 42100. Trikala, Greece
[2]National Technological University of Athens, school of chemical engineering, Iroon Polytechneiou 9, Zografou 157 80, Athens, Greece
[3]Centre for Technology Research and Innovation (CETRI), K. Paparigopoulou 15, Limassol 3106, Cyprus
[*]Corresponding author: mva@cetri.net

Indium Tin Oxide (ITO) is a transparent conductive oxide (TCO), widely used for manufacturing of displays and photovoltaic. The problem with ITO, however, lies in the fact that it contains indium, a scarce raw material for which its worldwide resources are becoming increasingly limited. Moreover, main indium suppliers are located outside the EU posing a risk for the European industry. Therefore, EU calls for funding include actions for replacement of Critical Raw Materials, such as indium, in the widely adopted technologies.
In this presentation, two routes for the development of indium-free transparent conducting films exhibiting properties similar to or better than ITO will be presented, each one studied under EU-funded projects: AltiTude –Alternative to Indium Tin Oxide materials. AltiTude aims at replacing ITO with transparent conductive oxides containing Ga, Zn and Sn exhibiting good performance. Initially, theoretical modeling has been performed for the evaluation of various composites. After various production methods trials, flame spray pyrolysis has been employed for fabrication of the corresponding materials in powder form. The method involves a liquid feed sprayed with an oxidising gas into a flamezone. The spray is combusted and the precursors are converted into metal oxide particles. The nanoparticles are then sintered to produce compact and dense enough sputtering ceramic targets. Finally, RF-magnetron sputtering has been used for the fabrication of indium-free transparent conducting films, followed by a set of comprehensive characterization methods (including SEM-EDS, XRD, TEM and band-gap measurements). The main challenge of the project is to adopt industrial-friendly only procedures while maintaining all required specifications for the final powders and films such as the purity of the powders and the density and purity, as well as the semiconducting behavior of the targets to be sputtered.
NanoDiGree – Copper-based nanowires for transparent conducting films: NanoDiGree aims at developing cost effective alternative to ITO transparent conducting films using a percolation nanowires network. Percolation theory reveals the need for nanowires of high aspect ratio (length/diameter ratio) and high uniformity of high performance (in terms of high transmittance and low sheet resistivity) nanowires-based transparent conducting films. A number of high efficiency films have been reported in the literature using chemically synthesized silver nanowires exhibiting performance even superior to that of ITO.[1] Silver, however is a high cost material, therefore, effort has been devoted in using copper-based nanowires. Stability of copper nanowires against oxidation issues poses a sever challenge for the competitiveness of the technology. NanoDiGree proposes the use of template-assisted electrodeposition of copper nanowires, a method that allows the fabrication of high uniformity and controlled quality of the nanowires. Following synthesis, copper nanowires are protected against oxidation with suitable ligands and incorporated into printable inks for cost effective, high throughput roll-to-roll spray coating. Finally, a set of steps is used for sintering of the nanowires and further protecting against oxidation.
The work is funded under the following EC-FP7 projects EU-FP7-AltiTude “Alternative to Indium Tin Oxide materials for sustainable growth of displays, solar and automobile industries” (grant agreement no: 606568) and EU-FP7-NanoDiGree “Low-cost, Green, Large Scale Manufacturing of new age conducting nanowires displays”.

REFERENCE

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M9

Accumulations of Au and Ag-coated Au nanoparticles for plasmonics

Y.Noda,[1] T.Tomokatsu,[1*] T.Asaka,[1] and H.Fudouzi[1,2]
[1] *Department of Frontier Materials, Nagoya Institute of Technology, Japan*
[2] *Photonic Materials Unit, National Institute for Materials Science (NIMS), Japan*
[*] *Corresponding author: hayatomo@nitech.ac.jp*

Localized surface plasmon resonance (LSPR) [1] has attracted much interest because of their electric field enhancement effects for improving optical device performances of sensors using surface enhanced Raman scattering (SERS) and energy conversion materials in solar cells [2]. Optical properties of plasmonic nanoparicles are severely varied with their structural situations, especially assembly or metastructures, and so they are promising for deriving new functionalities. We exhibited several types of accumulations of Au and Ag-coated Au (Au@Ag) nanoparticles on a glass substrate. At first, we prepared Au@Ag nanoprisms and immobilized by an oil-coating method [3]. Core shell structures of Au@Ag nanoprisms were analyzed by STEM-EDS. Surface enhanced Raman scattering (SERS) was also examined so that great enhancement of SERS signals was confirmed. Secondly, we manufactured Au and polystyrene (PS) nanospheres composites by making much use of the niches of opal structures of PS nanoshperes to vary their optical properties owing to their periodical structure of Au nanospheres.

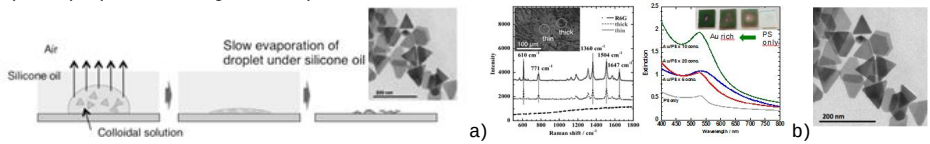

Fig. 1. Formation of Ag shells on Au nanoprisms, SERS spectra of R6G on Au@Ag nanoprisms immobilized by the oil-coating method, and optical absorption spectra of Au/PS opal are shown.

Au nanoprisms were synthesized by a three-step seed mediated growth method [1] and then Ag shell was formed on Au core by Ag-deposition [4]. STEM images of the Au@Ag nanoprisms synthesized were obtained for analyzing the formation of Ag shell on Au nanoprisms, as exemplified in Fig.1a. Insertion is TEM image of Au@Ag nanoprisms [3]. Condensed solutions by centrifugation were dropped on a glass substrate and soaked in 10 cst silicone oil, resulting in the formation of doom-like shape of the colloidal droplet [3]. The samples were dried at 60 ^{o}C until evaporation of the solvent of the colloidal solutions was completed. The Au@Ag nanoprisms films were washed with 0.65 cst silicone oil and ethanol.
Figure 1b shows SERS spectra of R6G (2.65×10^{-5} M) on Au@Ag nanoprisms immobilized by the oil-coating method. The prepared films have uniformity at a glance but micro-scaled non-uniformities were observed, as seen in the insertion of Fig 1b. At 633 nm laser excitation, sharp Raman peaks were successfully observed at 1647, 1504, 1363, 771, and 610 cm^{-1} with a high signal-to-noise (S/N) ratio [3] at both of the parts. Fig 1b shows also the optical absorption spectra and pictures of Au/PS opal films prepared. Absorption peak of opal and LSPR of Au nanospheres also exist around 534 nm. Structure color changes light green to deep green and agglomerates of Au nanospheres were not confirmed. This Au / PS opal structure could be applied for the high-dispersive matrix of Au nanoparticles for plasmonic enhancement applications.Au nanospheres were synthesized by thermal reduction with trisodium citrate acid (Au : Ct-acid = 1 : 2). Prepared nanoparticles were condensed and blended with 202 nm of PS sol (1 : 1). Opal structures were prepared by the oil-coating method.

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T1P

Supercontinuum generation in the mid infrared: challenges and solutions

Y. Yu[1], X. Gai[1], P. Ma[1], Kh. Vu[1], D.-Y. Choi[1], R. Wang[1], S. Madden[1], Zh. Yang[2] and B. Luther-Davies,[1,*]

[1]Centre for Ultrahigh bandwidth Devices for Optical Systems, Laser Physics Centre, RSPE, The Australian National University, Canberra ACT2600, Australia

[2]Jiangsu Key Laboratory of Advanced Laser Materials and Devices, School of Physics and Electronic Engineering, Jiangsu Normal University, Xuzhou, Jiangsu 221116, China

**Corresponding author: barry.luther-davies@anu.edu.au*

Recently, there has been growing interest in producing supercontinuum (SC) sources with high brightness and broad spectral coverage in the mid-infrared (MIR) for applications such as spectroscopy [1]; metrology [2]; and optical coherence tomography [3]. Especially important are sources that emit across the functional group region (2.5 to ~6.6 μm) and the molecular fingerprint band (~6.6 to 20 μm) where almost all molecules can be identified via their characteristic absorption features. Traditional broadband sources for the MIR were based on low brightness thermal emitters of Globars, although these are not capable of sufficient brightness for applications in micro-spectroscopy. Synchrotrons sources have enough brightness but cannot be considered as laboratory instruments, and this has motivated research into MIR SC sources based on nonlinear processes in single mode waveguides whose brightness can exceed that of a synchrotron by 2-3 orders of magnitude.

MIR supercontinuum is generated when a high power, ultra-short laser pulse propagates through a infrared-transparent nonlinear optical waveguide. Only a few materials can be used to fabricate such waveguides the most well established being so-called chalcogenide glasses – heavy-element glasses containing one of the chalcogen elements, S, Se or Te, as a dominant constituent. These can be transparent across most of the mid-infrared and possess high third order optical nonlinearity. It has also been shown that they can be used to fabricate planar waveguides as well as optical fibers. To cover most the MIR, a SC spanning three octaves would be required and this is extremely challenging. This is only likely to be achieved by pumping the waveguide in the MIR itself, since in general SC spectra extend symmetrically around the pump wavelength. Hence sources of fsec MIR pulses become essential.

In this talk I will summarize our work on MIR supercontinuum generation in Chalcogenide fibers [4,5] and waveguides [6] pumped by pulses from a compact fsec optical parametric amplifier in the 3-4.6μm range. We demonstrate that spectra 2.4 octaves wide can be generated extending to around 12μm in Se-based chalcogenides. By using a birefringent waveguide the SC can be emitted in a single polarization state, and if sufficiently short pump pulses (<≈100fs) are used, the SC can be coherent. Both of these properties are desirable for applications in microspectroscopy as they reduce the influence of noise that is characteristic property of SC generation on the recorded spectrum.

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T21

Toroidal Dipoles in Metamaterials

A. C. Tasolamprou, O. Tsilipakos, E. N. Economou*
Institute of Electronic Structure and Lasers, FORTH, 100 Plastira str.
Heraklio 70013, Crete, Greece
**Corresponding author: economou@admin.forth.gr*

The well-known analysis of the electromagnetic radiation in terms of electric and magnetic multipoles is missing another type [1] of contributions: These are the so-called toroidal multipoles, especially the toroidal dipole. Recently [2,3], metamaterials involving metallic elements were proposed where the contribution of the toroidal dipole around a particular resonance frequency was appreciable. Moreover, an almost lossless metamaterial was studied [4] consisting of four polaritonic rods arranged as in Fig. 1(c); this system exhibited significant toroidal contribution.

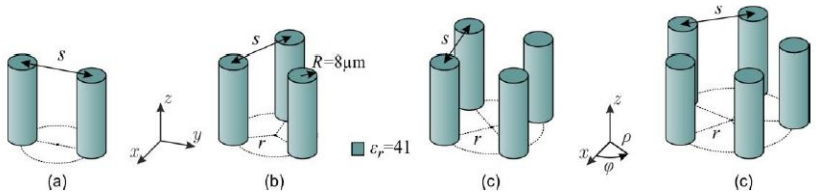

Fig.1. N identical polaritonic rods of radius R=8μm are located at the vertices of regular polygons.

In the present work the optical eigenmodes (both real and imaginary part) of the systems shown in Fig. 1 were studied as a function of the rod separation. One of these modes, usually corresponding to the lowest frequency, is of toroidal nature, while another one is of magnetic dipole nature; a third one resembles a pseudo-magnetic monopole and a fourth one has a frequency (real part) close to that of the toroidal mode. All these eigenmodes, being the result of the various couplings among a single dipole excitation in each of the N rods, can be obtained by an approach analogous to the LCAO method as applied to the electronic molecular orbitals; the results of this LCAO-type scheme are in very good agreement with accurate simulation data.

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T31

Optimizing SERS conditions, by noble metal film's thermal dewetting and chemically assisted processes, for (nano)materials characterization

S. Andrikaki,[1,2] K. Govatsi,[1,3] G. Mathioudakis,[1,3] M. Xirou,[1,3] A. Soto Beobide,[1] G. Bokias,[1,3] K. S. Andrikopoulos,[1] S. N. Yannopoulos[1] and G. A. Voyiatzis[1,*]
[1]FORTH/ICE-HT, Stadiou Str. / P.O. Box 1414, GR 265 04, Rio-Patras, Greece
[2]Department of Materials Science, Univ. of Patras, GR-26500, Rio-Patras, Greece
[3]Department of Chemistry, Univ. of Patras, GR-26500, Rio-Patras, Greece
[*]Corresponding author: gvog@iceht.forth.gr

Raman spectroscopy is a widely used non-invasive technique that provides detailed molecular information. Unfortunately, the Raman Effect is inherently weak; however, it can be significantly enhanced when the probed species are placed on or near nano-rough substrates or nano-structured colloidal clusters of noble metals. When the localized surface plasmons of noble metal substrates exhibiting nanoscale roughness or alternatively nano-colloidal silver or gold clusters are excited by visible or NIR light, strong electromagnetic fields are generated increasing the magnitude of the induced dipoles and the concurrent surface enhanced Raman scattering (SERS) intensity by orders of magnitude. SERS and especially quantitative SERS constitute challenge applications demanding extremely low concentration level analysis. Implementing a surface enhanced Raman scattering excitation/collection configuration bearing an oscillating cell and combined with right angle scattering collection geometry, we introduced a new method to quantitatively monitor the level of active agents at very low concentration range,[1] to probe the initial release of active agents from controlled delivery systems[2] and to characterize functionalized carbon nanotubes at quite low concentration levels in water suspensions.[3] Furthermore, the selective ability of water purification membranes in retaining small molecular weight contaminants may be monitored by the SERS quantitative assessment of these foulants in the permeate at very low concentration levels. Additional intended/ongoing applications refer to SERS monitoring of the release (a) of sensing/barrier (nano)materials from biopolymeric packaging matrices into food simulants and (b) of biocides from antimicrobial polymers into simulated sea-water. Apart from the discrete applications mentioned, an important/basic question that may be posed is whether all types of molecular species can be probed using SERS. "The answer to this question is most of the time `yes', but not always with the maximum level of amplification or the most convenient experimental procedures."[4] If a molecule generates a Raman signal, then it can in principle be amplified by interaction with plasmon resonances on a metallic substrate. Thus, in general the molecule must be attached or at least somehow be brought close to a metallic substrate. In this concept, covalently attached or electrostatically bound biocidal polymers may be utilized as model compounds to chemically assist the approach/attachment of probe molecules to SERS substrates. Considering the plasmonic substrates, the colloidal ones have been already employed offering unique quantification limits. Solid substrates on their turn are ideal for scientific purposes and applications mainly due to their versatility but quantitative results are not straightforwardly obtained. We recently applied thermal dewetting of Au films sputtered onto Si wafers to produce in a controlled manner a variety of plasmonic nano-structures and attain signal enhancement of prototype molecules, which are suitably spin coated on the prepared substrates. The Raman signal enhancement is studied as a function of the nano-structures' optical properties as well as the excitation wavelength. Optimal conditions for the identification and semi-quantification of the probed molecules are established when the morphology of the plasmonic surface is tuned to fulfil surface plasmon resonance conditions for an excitation wavelength that ensures resonance Raman Effects.

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T4I

Near-field radiative heat transfer at the nanoscale

J. C. Cuevas*
Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid, 28049, Spain
**Corresponding author: juancarlos.cuevas@uam.es*

Radiative heat transfer between objects at different temperatures is of fundamental importance in applications such as energy conversion, thermal management, lithography, data storage, and thermal microscopy [1]. It was predicted long ago that when the separation between objects is smaller than the thermal wavelength, which is of the order of 10 · m at room temperature, the radiative heat transfer can be greatly enhanced due to the contribution of evanescent waves (or photon tunneling) [2]. In recent years, different experimental studies have confirmed this long-standing theoretical prediction [1]. However, in spite of this progress, there are still many basic open questions in the context of near-field radiative heat transfer (NFRHT). Thus for instance, recent experiments exploring the radiative thermal transport in nanometric gaps have seriously questioned the validity of fluctuational electrodynamics [3], which is presently the standard theory for the description of NFRHT. In this talk, I will review our recent theoretical and experiment efforts to shed new light on the problem of NFRHT at the nanoscale. In particular, I will discuss the following two fundamental issues: (i) The enhancement of NFRHT in polar dielectric thin films [4] and (ii) the radiative heat transfer in the extreme near-field regime when objects are separated by nanometer-size distances [5].

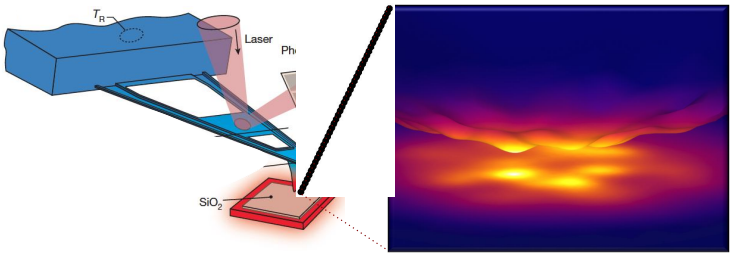

Fig. 1. Radiative thermal radiation between an AFM tip and a surface both made of SiO_2 and separated by a few nanometers.

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T5

Snapshots of ultrafast processes in biomolecules and condensed matter in the light of Femtosecond Stimulated Raman Spectroscopy

T. Scopigno*
Dipartimento di Fisica, Università di Roma "La Sapienza", Roma, I-00185, Italy.
**Corresponding author: tullio.scopigno@roma1.infn.it*

Time Resolved Resonance Raman is a powerful technique to study photo-induced dynamics with structural sensitivity, whose time resolution has been improved over the years from microseconds to a few picoseconds. If a sharp spectral resolution (<15 cm-1) is to be maintained, however, no further improvement of the time resolution (<1 ps) is obtainable with a traditional two beams pump-probe layout, due to the Fourier Transform limit. In recent years, Femtosecond Stimulated Raman Spectroscopy (FSRS) has been proposed as a possible way to "circumvent" the aforementioned time-bandwidth limitation, promising simultaneously high temporal precision and spectral resolution [1].
I will present an account of recent results obtained in our group by developing a broadly tuneable FSRS setup, capable to explore resonance effects in diverse contexts. These include the visualization of energy flow in heme-proteins [2], the ultrafast light-induced modification of the exchange energy in a Heisenberg antiferromagnet [3], the reaction pathway upon photo-excitation of conjugated molecules [4]. Emphasis will be given on how sub-ps snapshots with atomic resolution can be obtained under the constraint imposed by the Heisenberg principle.

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T6 I

Advanced architectures in chalcogenide fibers and micro-waveguides

J. Trolès, V. Nazabal, and J.-L. Adam*
Glasses & Ceramics Team, Institut des Sciences Chimiques de Rennes, UMR CNRS 6226, Université de Rennes 1, Campus de Beaulieu, 35042 Rennes Cedex, France
**Corresponding author: jean-luc.adam@univ-rennes1.fr*

Vitreous materials based on chalcogen elements (S, Se, Te) show large transparency windows that extend from the visible up to 12-15 µm in the infrared, depending on their compositions [1]. This is due to the lower phonon energies of chalcogenides, which are also responsible for enhanced luminescence of rare-earth ions embedded in such matrices [2]. As a result, they possess a high potential for applications as infrared sources, where rare-earth-doped oxide glasses cannot operate.
In addition, chalcogenide glasses contain large polarizable atoms and external lone electron pairs which induce exceptional non-linear properties as compared to oxide glasses. Typically, the non-linear properties of chalcogenide glasses can be 100 or 1000 times as high as the non-linearity of silica [3]. As far as shaping is concerned, specific chalcogenide glass compositions can be obtained in the form of optical fibers, thin films or planar waveguides [4]
The presentation deals with the latest results in the field of chalcogenide glass microstructured optical fibers showing endlessly single mode propagation [5], or supercontinuum generation [6], and in the field of rare-earth-doped sulphide glass optical fibers or micro-waveguides for new integrated optical sensors utilizing mid-infrared luminescence from Pr^{3+} , Er^{3+}, or Dy^{3+} ions [7].

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T7I

Mid-IR supercontinuum generation in crystals, bulk glasses or optical fibers

F. Smektala*, O. Mouawad, C. Strutynski, P. Béjot, F. Billard, P. Mathey, B. Kibler, F. Désévédavy, G. Gadret, J-C Jules, and O. Faucher.
ICB, Laboratoire Interdisciplinaire Carnot de Bourgogne, UMR 6303 CNRS - Université de Bourgogne Franche Comté, 9 Av. Alain Savary, 21078 Dijon, France
**Corresponding author: frederic.smektala@u-bourgogne.fr*

Bright broadband light sources and devices operating in the mid-infrared (mid-IR) region are of considerable interest. This spectral region fits with the molecular fingerprint region (2-20 µm range) and allows applications in civil, medical, astronomy, climatology, military, spectroscopy and sensing areas. For this purpose, studies are devoted to explore supercontinuum generation (SCG) in various crystalline and vitreous materials. We will present the last achievements of our team in the field.
First, we will report a SC spreading from 0.6 to 3.3 µm in a low-OH fluorotellurite suspended core optical fibre. This experimental result doesn't match numerical simulations, which predict a spectral broadening up to 4µm, because of an ageing process of the microstructured optical fibres (MOFs) when exposed to ambient atmosphere. This time dependant phenomenon, already demonstrated by our team on sulphide MOFs, is inherent to the MOFs architecture. Water steam present in the air diffuses inside the holes, inducing a reaction with the fibre core surface, modifying its optical properties. At 2.9 µm, 60% of the initial transmission is lost after 150h of exposition to room conditions. Our attempts in the fabrication of all-solid tellurite-based fibres with a controlled dispersion will be then presented.
We will also present our work related with chalcogenide glasses. Our SC experiments on chalcogenide MOFs have been limited by the ageing process that we have demonstrated in these fibres [1-2]. Recently however, SC generation was reported by Petersen et al. [3] from 1.4 to 13.3 µm in a 8.5-cm-long segment of multimode all-solid step-index chalcogenide fiber by coupling 4.6-µJ femtosecond pulses at 6.3 µm. It is worth mentioning anyway that the specific drawback of the chalcogenide glasses that are actually used in SC experiments is the permanent presence of the highly toxic arsenic element, identified by the World Health Organization among the ten chemicals that present a major public health problem. This could severely limit their prospective applications in the environmental, biological, and medical fields. From this standpoint, we started to develop arsenic-free sustainable chalcogenide glasses. We report here experimental mid-IR SC generation up to 11 µm in a 3.3 mm thick As_2S_3 bulk sample, compared to that obtained in an arsenic-free GeS_3 glass sample (Fig. 1). Mid-IR SC spectra are obtained through the filamentation of µJ-level energy pulses at wavelengths close to the bulk's zero dispersion wavelength, i.e., in both normal and anomalous dispersion regimes. The main features of our results are twofold. On the one hand, a GeS_3 nontoxic As-free glass is successfully conceived and proved suitable for mid-IR SC generation. On the other hand, 3.3-mm-long bulk samples are sufficient to enable the spectral coverage from 2.5 to ~11 µm in a 20-dB dynamic range. The work will be continued towards fiber drawing of these environmentally friendly chalcogenide compositions.
Then we will report on the generation of multiple-octave supercontinuum spanning from 0.5 µm to 11 µm induced by multi-filamentation in a ZnSe crystal. The generated supercontinuum is both spatially and spectrally characterized and is exploited in a proof-of-principle experiment for methane spectroscopy measurements by means of the supercontinuum absorption spectroscopy technique. The entire methane absorption spectrum is successfully recorded within the whole spectral bandwidth of the supercontinuum. Experimental results are in fairly good agreement with the HITRAN database, confirming the reliability and stability over several hours of the generated supercontinuum.

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T8

Solution processing of a chalcogenide glass

T. Kohoutek,*
[1]*InvolvedLtd., Siroka 1, 53701, Chrudim, Czech Republic*
**Corresponding author: tomas.kohoutek@involved.cz*

Chalcogenide glasses are materials with applications in optics and photonics. The devices fabricated from these materials exploit their infrared transparency, high refractive index and extremely high optical nonlinearity. Chalcogenide glass optical components such as lens, prisms and filters can be fabricated by using conventional methods of synthesis and processing similarly to silica glasses. Also, the materials are easily shapable, which allows for their drawing into the optical fibers. Important part in applications of chalcogenide glasses play their thick or thin films, which are suitable for fabrication of optically nonlinear waveguides, active layers for X-ray sensors or active layers used for phase-change recording of information.
Vacuum coating techniques such as thermal evaporation, magnetron sputtering, laser ablation, chemical vapour deposition and others were successfully employed for fabrication of chalcogenide glass films. Beside them, facile fabrication methods for deposition of chalcogenide glass films were investigated. Some chalcogenide glasses are soluble in amines and thus methods like spin-coating were applied for their processing in films. However, the main challenge in these efforts – solvent removal from a glass network - remained unsolved for most of the chalcogenide glass compositions. As the strength of the bond between nitrogen from the amine group and an atom of a chalcogen element (S, Se, Te) is high after the bond is formed, it is uneasy to brake it in a step, when the solvent is forced to evaporate from the material during and after the thin film deposition. To my experience, only As-S and propylamine glass/solvent pair allowed for easy formation of glass solution and later complete solvent removal from As-S film by its vacuum post annealing at moderate conditions without deterioration of film properties and compositions. This was quite disappointing finding after a decade of my study of solution processing of chalcogenide glasses.
However, recent experiments showed the formation of As-S chalcogenide films is possible without any solvent residua in their structure even the process did not include any post annealing step. The method that allowed for obtaining of solvent free chalcogenide glass films is an electrostatic spinning deposition. We used again As-S glass and propylamine solvent to obtain solution of the glass and then spun it into the nanofibers. The resulting chalcogenide glass films then showed surprisingly no contamination from the solvent residua and also a unique nanofibrous morphology, which is unusual for films of inorganic glasses. The questions to be answered by further studies are if the electrospinning film deposition can provide chalcogenide glasses of other compositions as solvent free materials and if we can find suitable applications of these films having nanofibrous morphology. The devices for fabrication of high quality nanofibrous films over large surface areas of substrates including roll-to-roll processing technologies have already reached the market.

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T9

Current and Emerging Applications of Chalcogenides in Optoelectronic Devices

I. Zeimpekis,* and D. W. Hewak
Optoelectronic Research Centre, University of Southampton, Southampton, S017 1BH, UK
**Corresponding author: dh@orc.soton.ac.uk*

Chalcogenide glasses continue to gain momentum as an increasingly important optoelectronic material. Infrared optical fibres and other IR optical components were initially a strong driver for research. These glasses have been extensively studied since 1967, when sulphide based fibres and their potential applications were first proposed. However over the past decade interest has increased significantly as glasses, crystals and alloys find new life in a wide range of devices and geometries beyond the optical fibre. Thin films, microspheres, nanowires and most recently 2D layers are all under active study in our laboratories today. In this talk we provide an overview of our research activities over the last ten years and the applications which motivate our research in these exciting and versatile materials.

W1P

Recent Advances in the Fabrication and Application of Colloidal Photonic Crystals (CPCs): Large Area Roll-to-Roll Assembly of CPCs for OLED and OPV Applications and Waveguide Fabrication for Optical Interconnect Applications

M. E. Pemble,[1, 2*]
[1]*Department of Chemistry, University College Cork, Cork, Ireland*
[2]*Tyndall National Institute, Lee Maltings, Prospect Row, Dyke Parade, Cork, Ireland*
[*]*Corresponding author: martyn.pemble@tyndall.ie*

Colloidal photonic crystals have been studied for decades, yet to date only a handful of real commercial applications of such materials have been demonstrated. Arguably this is because of the lack of fabrication methods that can be applied to the production of large-area samples that are compatible with the high volumes required for manufacturing. In our laboratories we are working to overcome this limitation. In the first part of this paper we describe recent results for the fabrication of high-quality (as determined by packing and optical response) colloidal photonic crystals using a novel roll-to-roll approach suitable for use with flexible substrates. We demonstrate that such methods are also compatible with roll-to-roll methods that may be used to create organic photovoltaic devices (OPVs) and organic light emitting diodes (OLEDs) where the photonic crystal overlayer may provide some degree of light trapping and concentrating while also offering a means of protecting the organic materials from reaction with water of oxygen.

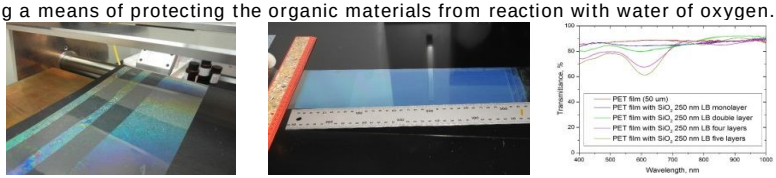

Fig. 1. Left and centre: photographs of our roll-to-roll Langmuir-Blodgett systems showing the results of depositing several layers of colloidal silica spheres of nominal diameter 250 nm onto flexible PET substrates. Right: Transmission spectra of films fabricated with one, two, three and four layers of colloidal spheres, clearly showing the evolution of the Bragg reflection which appears as a dip in transmission.In the second part of this paper we demonstrate the use of colloidal photonic crystals to create novel low reactive index waveguide cores surrounded by a higher refractive index medium, that are designed for use in chip-to-chip and board-to-board optical interconnect technologies. The process that we have developed is shown schematically below:

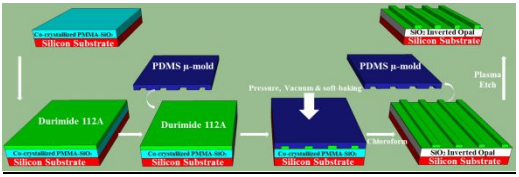

Fig. 2. Waveguide fabrication process.

Firstly a co-crystallized PMMA-SiO_2 film is deposited on a silicon substrate to act as an under-cladding for the polyimide waveguides. The waveguides are made by depositing Durimide 112A and printing a prepared PDMS mold under vacuum. Chloroform is used after soft-baking the Durimide to swell and release the PDMS mold and also remove the PMMA spheres from the underlying co-crystallized film. This results in a low refractive index SiO_2 inverted opal beneath the Durimide waveguides. An oxygen plasma is used to thin the residual layer. The plasma also aids the removal of any retained PMMA spheres. Results of both a theoretical analysis and an experimental analysis of the resulting waveguides will be presented.

The roll-to-roll experiments were performed by group members Dr Mikhail Parchine and Dr Maria Bardosova. The waveguide experiments were performed by group member Dr Joe McGrath in collaboration with Mr Umar Khan and Mr Brian Corbett, also at Tyndall. This work is supported by Science Foundation Ireland Grant Number 11/PI/1117.

W2

Nanostructure based Light Management in Thin-Film Solar Cells

R. Carius*, U. W. Paetzold, A. Hoffmann, M. Ermes, S. Lehnen, K. Bittkau, U. Rau
IEK5 – Photovoltaik, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany
**Corresponding author: r.carius@fz-juelich.de*

Light-trapping is essential for high performance solar cells. This holds in particular for most of the thin film solar cells where light trapping can boost their efficiency significantly. Advanced cell concepts consist of stacked multilayer systems and/or textured interfaces with feature sizes in the range of the wavelength or even smaller. Consequently the characterization has to be done with a very high spatial resolution over a broad spectral range as they originate from small structural features. Periodic or random nanostructures implemented into thin-film solar cells at the front, rear and as interlayer have been demonstrated to enhance solar cell efficiencies. For optimization and the development of new light trapping concepts a deep understanding of the underlying effects, such as dielectric or plasmonic light scattering is indispensable. E.g. the influence of material properties and structure size on the gain and loss mechanisms is one of the key issues for the success of a new light trapping concept.

Here we address this issue by a combination of experiment and simulation applying local (near field optical microscopy, local photoconductivity) and global (angular resolved scattering, quantum efficiency) measurements with finite element method (FEM) and finite difference time domain (FDTD) simulations on silicon thin film solar cells as a model system to gain understanding on the relevant optical processes involved.

W3I

Photonic Crystals for Biosensing & Imaging

T. F. Krauss*, G. J. Triggs, Y. Wang, C. P. Reardon, J. J. Colas, S. D. Johnson
Department of Physics, University of York, York, YO24 4BD, UK
**Corresponding author: thomas.krauss@york.ac.uk*

Photonic Crystals are the culmination of many fascinating developments in Physics, such as Bragg mirrors, Bloch modes, and bandstructures. Their ability to control the flow of light has given rise to many applications, ranging from light emission to optical switching and light trapping in photovoltaics [1]. Here, we discuss a novel sensing & imaging architecture, whereby the localised guided mode resonances of the photonic crystal can be considered the pixel of an image [2]. This combination adds an exciting new imaging modality to the biophotonics toolkit, which allows us to image both cells and the biomarkers they secret in real time. Thinking of each resonance as an imaging pixel also provides a very simple readout mechanism, where we have now demonstrated nanomolar sensitivities with a device that, in principle, can be made for £10 (fig. 1) [3]. Furthermore, we note that silicon photonic biosensors do not tend to exploit silicon's obvious ability to conduct electricity, and we demonstrate the first hybrid silicon photonic - electrochemical biosensor [4].

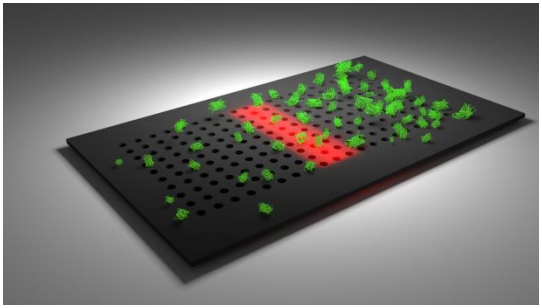

Fig. 1. Artist's impression of a photonic crystal biosensor that affords a simple camera readout, as the resonance is localised in a certain part of the photonic crystal depending on the local refractive index; as the index changes due to, e.g. the attachment of biomolecules, the resonanace moves to a different position on the chip.

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W4I

High quality and large colloidal photonic crystal film coated on flexible sheets

H. Fudouzi*

National Institute for Materials Science, 1-2-1 Sengen, Tsukuba, 3050047, Japan
**Corresponding author: Fudouzi.hiroshi@nims.go.jp*

Colloidal photonic crystals show response to external stimuli, such as swelling, electric field, magnetic field, thermal change and mechanical strain [1,2]. We have been investigating colloidal crystal materials with tunable structural color shown in Fig.1. These materials have potential applications as new sensor material and device. In this symposium, we will present a colloidal photonic crystal film with tunable structural color by applying external force and its mechanical sensing applications. Colloidal photonic crystal films made of 3D arrayed polystyrene, PS, colloidal particles were infilled with Polydimethylsiloxane, PDMS, elastomer. The colloidal photonic crystal films were coated on a black color rubber sheet and PET sheet [3]. Change of structural color of an opal by stretching the rubber sheet is reversible and repeatable. In contrast, the irreversible color change is done by plastic deformation of PET sheet. The colloidal photonic crystal film coated PET sheet adhered to a metal plate. Then the plate was stretched with a tensile test machine. The structural color of the colloidal photonic crystal film was changed from red to green [4]. This means that strain of the metal deformation is visualized as a change of the structural color. Here we demonstrate the soft opal films as smart material for sensing applications. One of sensing applications is for structural health monitoring in civil engineering, such as bridge, building and tunnel. Many developed countries, US, EU and Japan, will face in near future on the serious issues of large number of infrastructures aging. We have been developing easy, simple and low cost method using colloidal photonic crystal film with tunable structural color [5].

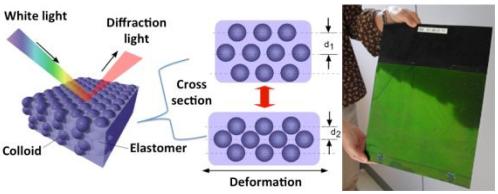

Fig. 1. Colloidal photonic crystal film with tunable structural color. Left: Tuning periodic structure by mechanical deformation. Right: High quality colloidal photonic crystal films coated over 1000cm^2 on a black color PET sheet.

In AAP2014 meeting, we have reported the high quality and large colloidal photonic crystal film with 200 cm^2 size. Now we have developed the new coating equipment for A3 size (300 mm by 450 mm) as shown the right photo in Fig. 1. For mass production of high quality colloidal photonic crystal film in industry sector, we have been investigating Roll-to-Roll coating process.

This work was supported by JSPS KAKENSHI grant Numbers 23360313, 24120004, 26289139, 16K14408, and by Council for Science, Technology and Innovation, “Cross-ministerial Strategic Innovation Promotion Program (SIP), Infrastructure Maintenance, Renovation, and Management”. (funding agency: JST).

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W5I

Photosensitizer-conjugated ultrasmall carbon nanodots as multifunctional fluorescent probes for bioimaging

A. Loukanov and S. Nakabayashi*
Graduate School of Science and Engineering, Saitama University, Shimo–Ohkubo 255, Sakura – Ku, Saitama 338-8570, Japan
**Corresponding author: Sei@chem.saitama-u.ac.jp*

Highly luminescent ultrasmall carbon nanodots (CDs) have been prepared by one step microwave-assisted pyrolysis and functionalized with fluorescein photosensitizer by diazo-bond. The absorption edge of such prepared Fluorescein–N=N–CDs was red shifted in comparison with the bare one. Nevertheless, the emission signal induced by the nanoparticle quantum-sized graphite structure was quenched due to photo-isomerization of the diazo group at photoexcited state. In order to restrict the photo–isomerization, i.e. rotation around nitrogen – nitrogen bond, the diazo group was fixed by metal cation to form complex compound or chelate. The obtained metal–complex of Fluorescein–N=N–CDs show absorbance maximum same as bare CDs, but recovered emission signal from nanoparticle moiety, which was bathochromic – shifted. They exhibit lower quantum yield in comparison with the bare CDs but better photostability toward emission quenching in nutrition cell culture. The formed photosensitizer-conjugates nanoprobes were proposed as multifunctional fluorophores for intracellular *in vivo* imaging due to their attractive photophysical attributes, tunable and excitation-dependent emission. The bio-application of photosensitizer–conjugated CDs was demonstrated as fluorescent tracers for endocytosis pathways in cultured Tobacco cells. Their successful staining and lower toxicity to the plant cells were compared with conventional quantum dots (CdSe/ZnS core – shell type, which caused acute toxicological *in vivo* effect).

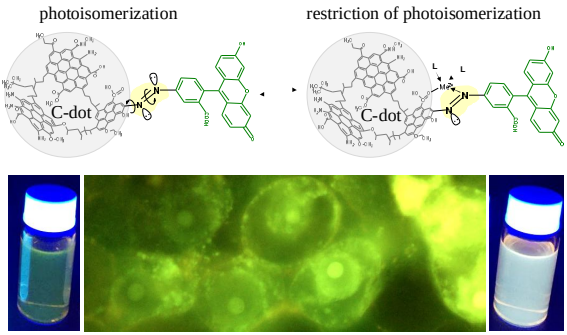

Fig. 1. The formation of photosensitizer-conjugates.

W6I

Towards the Optical Fiber-Lab concept

S. Pissadakis*
[1]*Institute of Electronic Structure and Laser (IESL), Foundation for Research and Technology - Hellas (FORTH), Greece*
**Corresponding author: pissas@iesl.forth.gr*

Recently, the field of Optical Fibre Devices is conceptually re-directed towards the investigation of smart materials, versatile guiding platforms and novel functionalities for targeting diverse applications in a "disruptive" approach. Different optical designs, processing and material science technologies fuse together for constituting the "Optical Fiber-Lab" concept, where benchtop operations are now scaled down and implemented into the robust optical fibre geometry. The device and processing examples which will be presented, refer to configurations realised in standard, tapered and microstructured optical fibres, whereas their development blends mature and emerging photonic and material technologies, driving research beyond the state-of-the-art.

Specifically, results will be presented on light localization designs in optical fibres, utilizing whispering gallery mode resonation [1], combination of periodic and scattering media [2], and structural gratings inscribed in photonic crystal fibres [3]. Then, experimental demonstrations in optofluidic [4] and magnetofluidic [5] operations inside microstructured optical fibres will be shown and perspective device examples will be presented [6, 7]. The applicability of the above sensing, light routing and actuating devices in specific applications fields will be discussed.

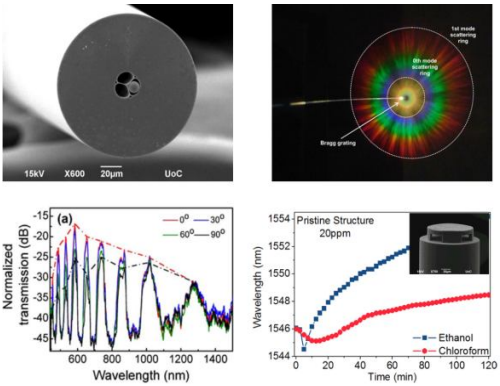

Fig. 1. (top left) microspherical resonator encapsulated inside a microstructured optical fibre; (top right) out-scattering light from a relief Bragg gratings reflector inscribed inside a photonic crystal fibre; (bottom left) transmission bands from an all-solid photonic band gap fibre, exhibiting plasmonic properties; (bottom right) sensing behavior for ethanol and chloroform of a fibre endface Fabry-Perot sensor fabricated using multi-photon polymerisation.

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W7

A single frequency, linear cavity erbium-doped fiber laser

K. Vlachos,[1,2,*]
[1]*Computer Engineering and Informatics Dept., University of Patras*
[2]*Institute of Chemical Engineering Sciences (ICE-HT/FORTH)*
[*]*Corresponding author: kvlachos@ceid.upatras.gr*

Highly stable, single frequency fiber lasers are key components for a variety of applications, such as high-resolution spectroscopy, gas sensing, combustion engine analysis as well as coherent optical communication systems. Conventionally, Fabry Perot (FP) filters with a high finesse have been used to lock output wavelength and obtain single frequency operation. However, FP filters cannot be used to completely stabilize laser operation (output power and frequency). To this end, other more complex techniques have been exploited as for example the use of multiple-ring cavities, the integration of multiple FP filters with different free-spectral range, the use of tunable fiber Bragg grating (FBG) Fabry-Perot etalons or a saturable absorber with a tunable FBG, [0]. Another technique, involves the use of an unpumped EDF, [0], together with an optical reflector. The EDF acts as a saturable absorber in which, two counter-propagating waves form a standing wave and induce spatial-hole-burning (SHB). The refraction index of the unpumped EDF changes spatially due to SHB and this results in an ultra-narrow bandwidth, auto-tracking filter. The technique has been exploited in different configurations, i.e. Sagnac loop, linear cavity outside a ring cavity etc. In this paper, we employ such a narrowband filter directly inside the laser cavity, in a linear cavity configuration. For this purpose, a specially designed low noise, low input power EDFA was incorporated. In this way, cavity length is significantly minimized, using less components, yielding extra stability and single frequency operation at the cost however of no wavelength tunability. Fig.1 displays the experimental setup of the single frequency laser. The unpumped erbium doped fiber consists of 3.2-meter of a commercially available HE980 fiber. The EDFA of the laser cavity consists of a specially designed low input power EDFA, pumped by a 980nm laser diode (LD) through a 1550nm / 980 nm wavelength division multiplexer (WDM) coupler. A 70:30 coupler was used for obtaining the laser output, placed at the opposite direction of the unpumped EDF to increase output power, without affecting spatial-hole-burning (SHB) effect that induce the narrow band filtering. Finally, two optical reflector mirrors (ORM) were used to form the laser cavity. The total ring cavity was measured to be approximately 13.5 m, which corresponds to a longitudinal mode space of 14.8 MHz. To verify single-frequency operation, the rf spectrum of the laser output was measured, using the conventional delayed self-homodyne technique. Fig. 2(a) displays the self-homodyne spectra, exhibiting stable operation with no rf spikes, while Fig.2(b) the spectrum without the unpumped EDF, illustrating an unstable spectra with ~15 MHz mode spacing peaks.

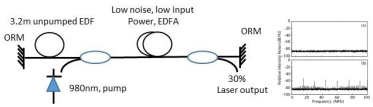

Fig.1: Left: Experimental setup of the single frequency EDF laser. Right: Experimental setup of the single frequency EDF laser

For laser operation and for inducing the SHB effect, the maximum intra-cavity power was limited to 18 mW. The estimated refraction index change is $\Delta n < 2.93 \times 10^{-7}$, while the FWHM of the self-induced FBG <5.5 MHz, [0]. To this end, single mode operation with cavities less than 36 m can be achieved. Output from the laser was measured to be 5.4 mW, while signal-to-noise ratio >41dB, with no significant variation in the spectrum shape and power at different time scales. The wavelength fluctuation was less than 0.05 nm, while power fluctuations less than 5μW. These can be attributed to thermal drifts and can be further reduced with conventional stabilization techniques. The authors acknowledge support from the Greek NSRF Program (MariBrain) with Grant No. 11SYN_6_288.

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P1

Amplified spontaneous emission in self-written waveguide containing $KY_3F_{10}:Er^{3+}/Yb^{3+}$ nanocrystals

X. Xue, T. Suzuki, and Y. Ohishi*
Research Center for Advanced Photon Technology, Toyota Technological Institute, 2-12-1 Hisakata, Tempaku-ku, Nagoya, 468-8511, Japan
**Corresponding author: ohishi@toyota-ti.ac.jp*

Er^{3+}-doped nanocrystals have attracted much interest not only for potential applications in bio-imaging due to green visible upconversion emissions but also for the intense emissions in the C-band. The polymer containing Er^{3+}-doped nanocrystals has been demonstrated as novel gain medium for the optical amplification in the C-band [1]. However, light is launched into waveguides via the coupling of lens or glass fiber. It is difficult to integrate conventional waveguides and glass fiber. Laser-induced self-written technique is a promising method to integrate glass fiber and polymer waveguides [2]. The waveguides fabricated by this method are grown on the edge of the surface of glass fiber by a self-written process. Connection with glass fiber on both sides have been successfully demonstrated with a low insertion loss. Here, we present the amplified spontaneous emission (ASE) in the laser-induced self-written waveguide containing KY_3F_{10}:0.5%Er^{3+}/5%Yb^{3+} nanocrystals.

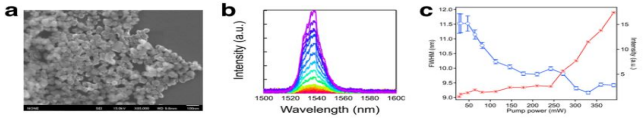

Fig. 1. (a) SEM image of the as-prepared KY_3F_{10}:0.5%Er^{3+}/5%Yb^{3+} nanocrystals. (b) Emission spectra from the polymer waveguide containing $KY_3F_{10}:Er^{3+}/Yb^{3+}$ nanocrystals and (c) Dependence of FWHM of the emission band centered at 1539 nm and peak intensity at 1539 nm on the pump power of 976 nm laser.

Since Er^{3+}-doped nanocrystals are the only gain media in the waveguide, quantum efficiency of nanocrystals will affect the optical gain of the waveguide. Thus, Er^{3+}-doped nanocrystals with high quantum efficiency are desired. We synthesized KY_3F_{10} nanocrystals doped with various concentrations of Er^{3+} (0.2, 0.5, 1, 2, and 5 mol%) and Yb^{3+} (0, 5, 10, 20, and 40 mol%) via a facile hydrothermal method. The analysis of X-ray diffraction patterns indicates that all the as-prepared $KY_3F_{10}:Er^{3+}/Yb^{3+}$ nanocrystals were cubic phase KY_3F_{10}. The averaged particle size was about 40 nm. Figure 1(a) shows the SEM image of KY_3F_{10}:0.5%Er^{3+}/5%Yb^{3+} nanocrystals. All these samples showed visible upconversion emissions and near-infrared emissions centered at 1539 nm under excitation by a 976 nm laser. The KY_3F_{10}:0.5%Er^{3+}/5%Yb^{3+} sample has the highest quantum efficiency, about 14%, including upconversion emissions ~4% and emissions at 1539 nm ~10%. We selected this sample to embed in self-written waveguides as gain media. Citric acid was utilized as surfactant of synthesizing nanocrystals. As a result, the as-prepared sample can be dispersed in some polar solvents, such as ethanol and chloroform forming a colloidal sample. The colloidal sample was further mixed with monomer, bisphenol A ethoxylate diacrylates (BPAEDA), which contained photoinitiator and sensitiser.

Two pieces of single mode fiber (SMF) were well aligned and the gap between them was filled with the monomer mixture. A 488 nm laser was launched through the SMF and radiated the monomer. After several minutes the self-written waveguide was grown along the direction of light propagation. The length of the obtained waveguide was about 7 mm. Then a 980 nm laser was launched into the waveguide through the connected SMF and an optical spectrum analyzer was used to record the output spectra. Figure 1(b) shows the spectra with various pump power. The full width at half maximum (FWHM) and the peak intensity of emission at 1539 nm were shown in Fig. 1(c). The decreasing FWHM and dramatically increasing intensity show the generation of ASE. It implies the nanocrystals doped self-written waveguides could be used as optical amplifiers in the C-band.

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P2

Chalcogenide hybrid microstructured optical fibers with dispersive characteristic invariant to fiber structure fluctuation

T. H. Tuan, K. Nagasaka, T. Suzuki and Y. Ohishi*.
Research Center for Advanced Photon Technology, Toyota Technological Institute, 2-12-1 Hisakata, Tempaku-ku, Nagoya, 468-8511, Japan
**Corresponding author: ohishi@toyota-ti.ac.jp*

Highly nonlinear optical fibers based on chalcogenide glasses are well-known for their wide transmission ranges, high nonlinear refractive indices and high nonlinear coefficients than those of silica fibers [1, 2]. They are favorable for several nonlinear processes such as supercontinuum generation (SC) and fiber-based optical parametric amplification (FOPA) in the mid-infrared window where many novel applications in biology, medicine and sensing can be realized. The key to obtain high performances of SC and FOPA is to tailor the fiber chromatic dispersion profile to satisfy their phase-matching conditions over a wide wavelength range.
Additionally, it was reported for silica step-index fibers that the chromatic dispersion variation due to fabrication fluctuation resulted in a very large change of FOPA gain spectra [3]. A new structure for silica step-index fibers was proposed to obtain dispersive characteristic invariant to fiber structure fluctuation [3]. However, to the best of our knowledge, it has never been realized for chalcogenide step-index fibers, especially for hybrid microstructured optical fibers (HMOFs) [4].
In this work, we propose novel chalcogenide HMOFs which can provide flattened and near-zero chromatic dispersion profiles in the mid-infrared window. By adding a buffer layer with appropriate refractive index and diameter around the core, the variation of chromatic dispersion profiles due to fiber structure fluctuation can be greatly suppressed. This feature is very meaningful to maintain high performances of SC and FOPA in chalcogenide highly nonlinear optical fibers.

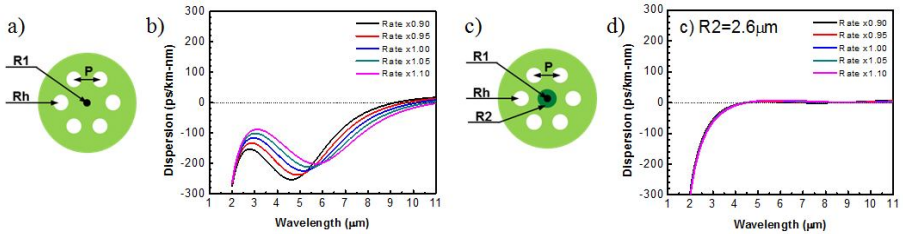

Fig. 1. (a) Conventional structure of chalcogenide HMOFs and (b) the calculated chromatic dispersion with ±10% fiber structure fluctuation. (c) New structure of chalcogenide HMOFs and (d) the calculated chromatic dispersion with ±10% fiber structure fluctuation. The core diameter, buffer diameter and air-hole diameter are R1, R2 and Rh, respectively. The distance between the two air holes is depicted by P.

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P3

Quantum dot based 3D photonic devices

I. Sakellari[1,*] E. Kabouraki[2] D. Gray[2] M. Vamvakaki[2] and M. Farsari[2]
[1]*4th Physics Institute, University of Stuttgart, Building 57, 70569, Germany*
[2]*Institute of Electronic Structure and Laser, Foundation for Research and Technology, N. Plastira 100, 70013, Greece*
[*]*Corresponding author: i.sakellari@pi4.uni-stuttgart.de*

Direct fs Laser Writing (DLW) by two-photon polymerization (TPP) is a versatile technique for the creation of solid three-dimensional polymer nanostructures for photonics, biomedical and microfluidic applications. The polymerization process is initiated by a tightly focused ultrafast laser beam due to nonlinear absorption within the focal volume. By employing laser intensities that are only slightly above the nonlinear polymerization threshold, structures with resolution of 100nm can be fabricated.
In this work, we present our most recent results on the fabrication of 3D high-resolution woodpile photonic crystals containing an organic-inorganic silicon-zirconium (Si-Zr) composite and Cadmium Sulfide (CdS) quantum dots (QDs) exhibiting $\chi(3)$ nonlinearity and photonic band-gaps at visible wavelengths. The material used in this work is a photo-structurable hybrid silicon-zirconium (Si-Zr) composite synthesized by means of the sol-gel method, where we have incorporated quencher molecules allowing for the fabrication of structures with features sizes well below the diffraction limit [1], and quantum dot precursors enabling the in situ synthesis of CdS QDs. The incorporation of CdS QDs in the polymer matrix results in a novel CdS-Zr-Si composite material that exhibits a high nonlinear refractive index value measured by means of Z-scan method. Employing DLW and in situ synthesis of CdS QDs, we have successfully fabricated 3D woodpile photonic structures with varying inlayer periodicity from 600nm to 500 nm that show clear photonic stop bands in the wavelength region between 1000nm to 450 nm measured by means of FTIR spectroscopy.

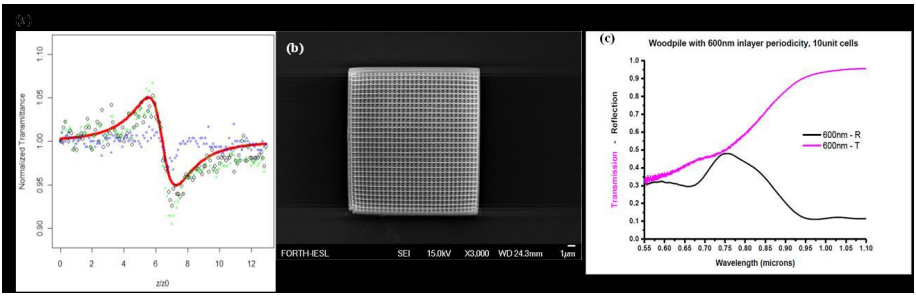

Fig. 1. a) Z-scan graph of the CdS containing hybrid material, b) SEM image and, c) Transmission-Reflection spectra of a woodpile photonic crystal with 600nm inlayer periodicity.

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