COST Action MP1205: Advances in Optofluidics

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Abstract Booklet

Keynote Lectures

Photons and fluids

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The realm of optofluidics is experiencing remarkable growth through the deployment of newly developed forms of structuring light. By a variety of methods, it is already well proven that it is possible by such non-contact means to engage highly localised, and sometimes unusually strong, dynamical response in microscale components. Attention is now increasingly being focused on pursuing similar principles down into the nanoscale regime, with large molecules now in prospect. For example, severe recent studies have entertained the possibility of selectively steering individual molecules in a fluid, with a view to separating molecules of opposite chiral form. The challenges of building theory to represent mechanisms for such interactions are considerable, as both the matter and the light itself demand casting in forms that can fully account for their intrinsic quantum features. This presentation aims to identify how these difficulties may be addressed through an explicitly quantum formulation of the driving electrodynamics. Symmetry and tensorial aspects of the key interactions are automatically taken into account, and key differences between parametric and non-parametric forms of coupling can be readily identified. Thermal diffusion and viscous drag constraints on nanoscale optomechanical motion are also discussed with due regard to the constitution and form of individual molecules and nanoparticles.

Optical and microfluidic tools for great optofluidic discovery

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Advanced in sciences needs many things: a network of great brains, the time money and freedom to go far in a project and also good instrument. Through the microfluidic valley, Elvesys tries to gather it all and to boost research by creating costumed tools especially designed for microfluidics and optofluidic. At the border of academia and industry, this company runs its own research projects with university all around the world. This presentation will show some of the research projects Elvesys is involved in, some of the powerful tools it develops to fasten research and the presentation will share some research projects Elvesys forecast for the future.

Integrated Microfluidic Systems with Multiple Actuators

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The increasing availability of microfluidic devices recently opened the door to new biological applications. In this scenario, the development of microfluidic devices for biomedical applications exploiting optical, acoustic or electric forces is currently attracting great attention. As amatter of fact, the integration of different stages on a single substrate chip is a key point for promoting new insights into many applications that need portable devices to speed up the analysis and allow the investigation of new phenomena. In my presentation I will illustrate recent results involving optical and acoustics actuation mechanisms and I'll show how their combined use may be relevant for the creation of new devices and for the generation of new knowledge.

Oral Presentations

Monitoring antimicrobial photodynamic inactivation at the single-cell level

A. Barroso, M. Grüner, T. Forbes, C. A. Strassert, and C. Denz

Antimicrobial Photodynamic Inactivation (PDI) represents an attractive alternative in the treatment of infections by antibiotic-resistant pathogenic bacteria. In PDI a photosensitizer (PS) is administered to the site of the biological target in order to generate cytotoxic singlet oxygen ($^1O_2$) which reacts with the biological membrane upon application of harmless visible light. Established methods for testing the photoinduced cytotoxicity of PSs rely on the observation of the whole bacterial ensemble providing only a population-averaged information about the overall produced toxicity. However, for a deeper understanding of the processes that take place in PDI, new methods are required that provide simultaneous regulation of the ROS production, monitoring the subsequent damage induced in the bacteria cells, and full control of the distance between the bacteria and the center of the $^1O_2$ production. Herein we present a novel method that enables the quantitative spatio-time-resolved analysis at the single cell level of the photoinduced damage produced by transparent microspheres functionalized with PSs. For this purpose, a methodology was introduced to monitor phototriggered changes with spatiotemporal resolution employing holographic optical tweezers and functional fluorescence microscopy. The defined distance between the photoactive particles and individual bacteria can be fixed under the microscope before the photosensitization process, and the photoinduced damage is monitored by tracing the fluorescence turn-on of a suitable marker. Our methodology constitutes a new tool for the in vitro design and analysis of photosensitizers, as it enables a quantitative response evaluation of living systems towards oxidative stress.

Compact nonlinear photonic crystal fiber systems infiltrated with liquids

R. Buczynski, R. Kasztelanic, J. Pniewski, A. Filipkowski, T. Stefaniuk, D. Pysz, R. Stepien, M. Klimczak

PCFs allow for an efficient dispersion control through the proper design of the internal structure. Usually air-glass or all-glass structures are considered. However it is usually difficult to modulate its optical properties to make it a tuneable optical device. The possibility to infiltrate PCFs with liquids gives an additional degree of freedom during the design. Liquids have relatively high nonlinear refractive index in comparison with solids, which makes them attractive as core medium in fibers. Only few papers discussing SG in liquid-infiltrated PCFs for optofluidics were published. However, in general, these works do not take into account the attenuation neither the material dispersion of a real liquid. Until now publications on dispersion engineering focused mostly on fused silica PCFs. In this paper we propose a PCF based on soft glass, infiltrated with different liquids. We study the possibility to engineer the dispersion of a real fiber through an infiltration by using organic liquids, where the attenuation of real liquids is taken into account. We present also a compact coupling system based on nanostructured gradient index microlens integrated with photonic crystal fibers. Since the diameter of the lens module matches the diameter of the optical fiber the system is well suited for optofluidic systems. The GRIN lens were fabricated using the stack-and-draw optical fiber technology. A photonic crystal fibers is infiltrated with liquids though microchannels. The microchannels are developed using femtosecond laser ablation. This work was supported by the National Centre for Research and Development grant TANGO1/269956/NCBIR/2015, National Science Centre grant Harmonia No DEC2012/06/M/ST2/ 00479, and (c) COST Action MP1205

On the NLO response of two 2D-materials: Graphene(s) versus some PAHs

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The recent discovery of graphene has driven decidedly the research on two-dimensional (2D) materials. So, during the last few years, very important research efforts have been devoted in the detailed study of the properties of the already known 2D materials and also to the search, preparation and functionalization of novel ones. In fact, the two-dimensional (2D) materials have become currently one of the most active areas of research in nanomaterials, and offer a huge opportunity for both fundamental studies and practical applications, including superfast, low-power, flexible and wearable electronics, sensors, photonics and electrochemical energy storage devices that can have an immense impact on our society. Among the various properties of the 2D materials, their nonlinear optical properties are of particular interest in view of their potential applications in opto-electronics and photonics. The aim of this talk is to present briefly some new results obtained recently from our group, concerning the nonlinear optical properties of two different families of 2D materials, namely some graphene(s) and some O-doped polycyclic aromatic hydrocarbons (PAHs). Both of these 2D materials exhibit significant NLO response, which can be largely tuned in order to meet the specific needs of particular applications. Moreover, the similarities and differences of their structures and their impact on their NLO responses will be presented and discussed. [1-7]

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An optofluidic diaphragm pump

O. Emile, J. Emile

Most of the vibrating mechanisms of optofluidic systems reported up to now are mainly based on a local heating of membrane that then induces a flow. We demonstrate here a new type of diaphragm pump in a thin liquid film based on the optical radiation pressure force. We modulate a low power laser that induces, at resonance, a counter gravity flow in a vertical free standing draining soap film. The thickness of the soap film is then higher in the upper region than in the lower region of the film. Moreover, the lifetime of the film is dramatically increased by a factor of 2. As the laser power is increased, the resonance turns into an anti resonance. Since the laser beam only acts mechanically on the film interfaces, such a pump could be easily implemented on delicate micro-equipment on chips where temperature variations are detrimental and even in biological systems.

Towards Bioinspired MicroSystems

L. Florea, W. Francis, A. Dunne, A. Tudor, D. Diamond

The continuing interest in stimuli-responsive materials has yielded quite an expansive variety of smart materials that respond to a wide range of stimuli such as electrical current, pH and light, among others [1], and are opening up new concepts in so-called 4D-materials science, in which the 4th dimension is the ability to change materials characteristics over time in a controlled manner using external stimuli. A subclass of this family is comprised of stimuli-responsive hydrogels that are three-dimensional, hydrophilic, polymer networks capable of large water intake. These characteristics make them a potential candidate for the fabrication of biocompatible systems, which can be used for tailored drug delivery and regenerative medicine within the body. Incorporation of responsive units in such polymeric networks allows for their use as micro-machines capable of doing mechanical work in response to the chosen stimulus. The application of smart materials offers tangible solutions in the field of actuators for microfluidic valves, artificial muscles and biomimetic robots [2-5]. Moreover, new capabilities such as motility, switchable selective uptake and release of molecular agents, sensing, signalling and seeking, will enable microstructures and micro-vehicles to manifest many of the features of biological entities. In this talk I will explore several bioinspired microstructures and micro-vehicles including smart droplets and 3D stimuli-responsive microstructures, focusing in particular on the important role of light as a means to enable and control stimuli-responsive materials, and discuss how these might provide initial building blocks for creating futuristic microsystems.

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Smart, hybrid liquid crystal modulators

M. Kaczmarek, G. D’Alessandro, V. Fedotov, O. Buchnev, E. Mavrona, L. de Sio, N. Tabiryan

Future photonic and optofluidic devices require smart micro- or nano-components, active and tuneable, with dynamically controlled optical properties. In order to achieve such adaptive, flexible and tailor-made devices we exploit liquid crystals integrated with inorganic nanoparticles, photoactive polymers as well as metamaterials. One promising example includes photoresponsive, azobenzene materials assembled with liquid crystals and photoconductive polymers for new optical light valves and modulators. Efficient spectral tuning of metamaterials infiltrated with liquid crystals is also demonstrated specially designed nano-structured, plasmonic membranes using electric field.

All-optical phase shifter with photovoltaic liquid crystal cell

L. Lucchetti, K. Kushnir, A. Zaltron, G. Bettella, G. Pozza, C. Sada, V. Reshetnyak, F. Simoni

Liquid crystal cells with LiNbO3:Fe crystals as substrates, are described. The photovoltaic field generated by the substrates is able to reorient the liquid crystal director thus giving rise to a phase shift on the light propagating through the cell, as in liquid crystal light valves. The process does not require the application of an external electric field, thus being potentially useful for applications requiring a high degree of compactness. A detailed characterization of several cells based on lithium niobate crystals with different iron concentration and/or reduction degree has been carried out. An example of possible application, is also proposed and described.

Fabrication of optofluidic devices by femtosecond laser direct writing

P. Marques, J. Maia, V. Amorim and D. Alexandre

Lab-on-chip systems integrate microfluidic channels to transport, mix, make react and analyze small volumes of samples. These devices are usually manufactured by soft lithography, however femtosecond laser direct writing adds new advantadges such as three-dimensional fabrication and on-chip optical detection. In this technique, the interaction between laser irradiation and a glass sample alters the material properties around the focal volume by increasing the refractive index and etching selectivity in hydrofluoric acid. The first effect allows fabrication of low-loss waveguides, Bragg grating waveguides and directional couplers, among others, which are demonstrated in this work. Irradiation of the sample also promotes an anisotropic etching reaction thus allowing fabrication of channels inside the glass with varrible geometry while maintaing smooth sidewalls and uniform aspect ratio. By placing the microfluidic channels next to optical layers (Bragg gratings or interferometers) we can analyze the fluid properties either by evanescent coupling or by crossing the waveguide with the channel. Some results exploring these interrogation schemes are presented.

In-vivo flow profiling for improved tissue engineering of blood vessels

R. Meissner, P. Sprick; C. Denz

In all higher developed organisms complex structures of arteries, veins and capillaries make up the cardiovascular systems supplying nutrients, gas and waste exchange. Diseases of these systems are the number one reason for death worldwide. General treatment in humans is done by bypassing damaged vessels or introducing donor vessels. An ever increasing demand is placed on artificial, biomimetic vessels produced in the lab, though. Little research has been done so far on quantifying the requirements of shear stress, flow speeds and pressure, such vessels have to endure during development. Here, we obtain real in vivo data from zebrafish organisms through Particle Image Velocimetry. Zebrafish are used around the world to investigate human diseases, their causes and treatments. Simplified models of zebrafish cardiovasculature in Polydimethylsiloxane (PDMS) are produced in a highly flexible PDMS work station.

Since PDMS is a low cost, bio-compatible, comparably soft and transparent polymer, it is well suited for such biomimetic applications. Through particle tracking we show proof-of-principle biomimetic blood flow. We address limitations with respect to suitability of the proposed model as well as discuss important aspects of modelling, fabrication and factors degrading the quality of these biomimetic vessels.

Optically manipulated microtools optimised for different biological applications with appropriate fuctionalization

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The capabilities of optical manipulation can be vastly enhanced by the application of microtools of complex structure actuated by holographic optical traps. The microtools are fabricated by direct laser writing based on two photon photopolymerization (TPP). The shape of the microtools is designed for the specific application. These polymerized structures are designed to have two functional parts separated even by micrometers: the handle part that interacts with the optical field and the probe part that performs the main function of the tool. The great advantage of TPP is that tailor-made probes can be prepared practically in one step with on-demand handle arrangement and probe shape. However, in order to use trapped microstructures effectively for biological tasks, they need to be functionalized. In this process the desired functionality is added to the microtools, completing the micromanipulation system. We show typical examples: The microtools are used for localized spectroscopy, where covering the tools (1) – or just the active parts of the tools (2) – with metal nanoparticles enables local fluorescence (3) or Raman (2) excitation. The microtools can also realize high precision 6D manipulation of live cells (4), where tailor made surface coating is applied to establish sufficiently strong bonding ofbetween the manipulator and the target object. The examples illustrate the power of the method, where the applications presented with the new approach offer previously not available important experimental possibilities.

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Thermo-optical tweezers for individual nanoparticle manipulation

N. Osterman, J. Stergar

Laser tweezers, a standard tool for micro-manipulation, cannot be used in an aqueous environment to trap particles smaller than a few hundred nanometers as the optical trapping force scales with the volume of the particle. A feasible alternative to trap smaller particles and individual biomolecules is the use of temperature gradients and resulting thermophoretic force. We induced the temperature gradients in a sample by the absorption of a focused laser beam. Measurement of particle trajectories and comparison to the temperature profile confirmed that the thermally-induced particle motion is the direct result of thermophoresis. By real-time particle tracking and control of the laser focus position, we were able to trap and manipulate individual nanoparticles.

Tunable WGM microresonators from optically trapped liquid crystal emulsion droplets

Z. Pilat, J. Jezek, P. Zemanek

We developed multiple types of tunable WGM microresonators from optically trapped liquid crystal emulsion droplets. The tuning of the laser emission was achieved by heating, optical forces or electric field. The excitation was provided by a pulsed laser. We observed lasing from the droplets and the tunability range was from units to tens of nanometers, depending on the mode of tuning.

Two-wave energy exchange in hybrid photorefractive cell with bent-core cholesteric liquid crystal

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In hybrid cells a liquid crystal (LC) is sandwiched between two photorefractive substrates. The interfering incident light beams induce a periodic space-charge field in the photorefractive substrates. Space-charge electric field penetrates into the adjacent LC, causing director modulation, and hence the diffraction grating. Each light beam diffracts from the induced grating, leading to energy gain and loss within each beam. The combination of organic-inorganic materials results in gain coefficient two orders of magnitude larger than in pure photorefractive materials. We developed a theoretical model describing two-beam energy exchange in the hybrid LC cells and show that flexoelectricity is the main physical mechanism governing the two-beam coupling in these cells [1]. New liquid crystalline materials, so-called bent-core LCs were synthesized recently and are intensively studied [2]. Important properties of these materials are increased values of flexoelectric coefficients, the lower bend or twist elastic constants compared to the conventional LCs. Having the lower elastic constants and increased flexoelectric coefficients one may expect a much stronger director deformation in bent-core LCs subjected to the space-charge field. Following the paradigm of paper [1] we develop a theory for beams coupling in hybrid bent-core cholesteric LC cells. We numerically solve equations for the LC director profile together with the Maxwell's equations for electric field and calculate the gain coefficient in the hybrid cell. We show that the bent-core cholesteric liquid crystalline structures/mixtures exhibit a higher response to the space-charge field, which results in a higher photorefractive gain.

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Optofluidic dye laser based on a Fabry-Perot cavity fully embedded in a glass chip

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Recently the demonstration of monolithic nanofabrication of an optofluidic ring resonator by femtosecond laser writing has been reported [1] being a milestone in the investigation of robust and flexible optofluidic microlaser for sensing applications. In this way a reliable ring microlaser has been realized achieving a threshold of about 15 µJ/mm2, with characteristic multi-peaks emission due to Whispering Gallery Modes (WGM). By coupling the femtosecond laser micromachining with the inkjet printing technology we were able to realize for the first time an optofluidic Fabry-Perot resonator fully embedded in a glass chip. [2]. Using Rhodamine 6G in ethanol at concentration of 5·10−3 mol/l as gain medium, laser emission was detected at a threshold energy density of 1.8 µJ/mm2 with linewidth below 0.6 nm, achieving a quality factor Q~103. The previously reported optofluidic lasers, based on Fabry-Perot cavity, have been realized by coating mirrors either on top of optical fibers used to collect the signal or on side of a microfluidic channel usually in contact with the laser dye. In all these cases emission linewidth was broader than 3-4 nm with threshold in the range of tens of µJ/mm2. The threshold achieved in our device is about one order of magnitude lower than state-of-the-art optofluidic lasers. These performances and its robustness make it an excellent candidate for biosensing, security and environment monitoring applications.

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Investigation of the influence of velocity and temperature on the dynamics of capillary assisted particles deposition yield

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Nano and microparticles, sized at 1 nm to 100 µm, have found their applications in a wide range of scientific areas: medicine, biochemistry, colloid chemistry, aerosol research, optics and photonics, food industry, etc. An area receiving much interest is particle self-assembly, where their shape, size and material as well as the pattern of substrate surface can all influence the geometry and physical properties of the final assembly. When particles are in a specific order in space, interesting optical properties can be achieved, such as negative refractive index and Fano resonance; employing localized surface plasmon resonance, a significant amplification of electrical field can be achieved [1]. One of the more effective methods for submicron positioning of particles is capillary force assisted assembly [2]. Capillary force assisted assembly arises among others as a method offering great efficiency and scalability. It exploits long ranging capillary interactions, which are used to overcome the Brownian motion of particles in a colloidal suspension. Bringing a droplet of the suspension in contact with a patterned surface as well as controlling its evaporation allows to master the localization and the organization of particles into predefined patterns. Although much work has already been done to characterize and find optimal parameters for successful large area assemblies [2, 3], the fundamental principles of particle behavior during the assembly are not quite fully understood. In this work we report our findings on the behavior of the assembly yield (most often described as a ratio of trapped particles to the number of traps) during the very start of the assembly. We performed experiments of 270 nm green fluorescent polystyrene beads deposition on two differently patterned polydimethylsiloxane substrates: densely packed holes (300 nm in diameter) and sparse, square shaped holes (2x2 µm) were formed on their surfaces. The assemblies were observed and characterized using SEM and optical fluorescence microscopy. Custom algorithm was developed to calculate and plot the assembly yield with respect to a spatial dimension. The experimental points were fitted using a logistic function, it's slope being the defining factor of the assembly yield behavior. The results showed a certain dependence of the slope to the most important deposition parameters – template temperature and translation velocity. In the case of the substrate with sparse traps we found that the temperature was the key factor defining accumulation zone formation whereas in the case of substrate with high density traps, velocity was found to be the limiting factor. This research was funded by COST Action MP1205 and Research Council of Lithuania Lithuanian–Japan bilateral cooperation partnership program, project no. LJB-1/2015.

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Fabrication of photonic microscopic surface structures for copper2+ ions detection in fresh water by incorporation of LTL-type zeolites nanoparticles

V. Toal, Sabad-e-Gul, A. Khartchenko, M. Zawadzka, S. Martin, J. Cassidy, S. Mintova, I. Naydenova

The fabrication of photonic microscopic surface structures by holographic recording in a self-processing acrylamide-based photopolymer, for application in sensing, is reported. The structures were functionalized by incorporation of porous nanoparticles (nanosized zeolites). Interrogation of these structures by light allows indirect measurements of chemical analyte concentration in real time by determination of the diffraction efficiency of the photonic structure. In this paper we present the procedure for fabrication of the microstructures by initial exposure to light followed by thermal treatment. Recording conditions such as light intensity and exposure time were optimised. The structures were characterised by white light interferometry and AFM. The structures were then functionalised by incorporation of LTL- type zeolite nanoparticles. The performance of the sensors in detection of copper (II) in water was characterised. The current detection limits are 1-4 mM.

Isotropic contractive scaling of microstructures: A new microtechnology principle demonstrated in laser processed vitrified aerogels

N.A. Vainos

A novel method and a generic microfabrication principle based on the isotropic contraction of micropatterns are demonstrated. The approach enables to surpass fundamental physical resolution limits and yield two- and three-dimensional patterns unavailable by any other means. A first realization utilizes vitrification of highly porous silica aerogel monoliths, which are microstructured by laser ablative methods. Surface relief and inner void micropatterns inscribed in the monolith undergo isotropic contraction. Feature minimization beyond the spatial resolution of their original recording is achieved in the produced dense solid. Stereometric contraction depends on the aerogel structural properties and a 3:1 ratio is achieved here. However, the clear experimental evidence of much high contraction ratios in embedded void

structures demonstrates the potential of this generic principle in micro- and nano-fabrication, with specific applications in photonic, fluidic and lab-on-chip technologies.

Multi-modal natural user interface for holographic Raman tweezers

P. Zemanek, Z. Tomori, P. Kesa, M. Nikorovic, J. Kanka, P. Jakl, M. Sery, S. Bernatova, E. Valusova, M. Antalik

Holographic optical tweezers provide a contactless way how to trap and manipulate several microobjects independently in space using focused laser beams. Although the methods of fast and efficient generation of optical traps are well developed, their user friendly control still lags behind. Even though several attempts have appeared recently to exploit touch tablets, 2D cameras or Kinect game console, they have not reached the level of natural human interface yet. Here we demonstrate a multimodal "Natural User Interface" approach which combines fingers and gaze tracking with gestures and speech recognition to select objects with an operator's gaze and voice, to trap the objects and control their positions via tracking of fingers movement in space and to run semiautomatic procedures such as acquisition of Raman spectra from preselected objects. This approach takes advantage of the unbeatable human processing of images together with smooth control of human fingertips and downscales these skills to control remotely the motion of microobjects at microscale in a natural way for the human operator.

Poster Presentations

A versatile lab-on-a-chip tool for modeling the blood-brain barrier

A. Dér, F.R. Walter, S. Valkai, A. Kincses, S. Veszelka, P. Ormos, M.A. Deli

Models of biological barriers are important to study physiological functions, transport mechanisms, drug delivery and pathologies. However there are only a few integrated biochips which are able to monitor several of the crucial parameters of cell-culture-based barrier models. The aim of this study was to design and manufacture a simple but versatile device, which allows a complex investigation of barrier functions. The following functions and measurements are enabled simultaneously: co-culture of 2 or 3 types of cells; flow of culture medium; visualization of the entire cell layer by microscopy; real-time transcellular electrical resistance monitoring; permeability measurements. The chip was applied to monitor and characterize blood-brain barrier (BBB) function, using the hCMEC/D3 human brain endothelial cell line and primary rat brain endothelial cells co-cultured with primary astrocytes and brain pericytes. This triple primary co-culture blood-brain barrier model was assembled on a lab-on-a-chip device and investigated under fluid flow for the first time. Such a versatile tool is expected to facilitate the kinetic investigation of BBB and various other biological barriers.

Rotation of millimetre-size objects using ordinary light

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Because no direct contact is required, the ability to optically rotate bodies offers new degrees of control of micro-object with applications in various domains including micro-electromechanical-systems (MEMS), biomanipulation or optofluidics. Two major schemes have successfully enabled such rotations, based either on the linear or on the angular momentum of light. The first scheme takes advantages of specially shaped three-dimensional objects, whereas, the latter, relies either on the spin or on the orbital angular momentum of light from dedicated sources. Here we demonstrate the optically induced rotation of simple asymmetric two-dimensional objects using plane waves originating from ordinary light sources. The objects are floating on an air/water interface. The light originates either from ordinary laser sources or from black body radiation and impinges perpendicular to the interface. We observe a steady state rotation that we interpret in terms of light diffraction by the edges of the object. Such systems could be easily implemented in optofluidic devices to induce liquid flow without the need for special light sources.

Cholesteric microparticles: chiral resolution of spin angular momentum in linearly polarized and unpolarized light

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Linearly and unpolarized light are racemic entities since they can be described as superposition of opposite circularly polarized components of equal amplitude. i.e. they do not carry spin angular momentum. Chiral resolution of a racemate is usually performed via asymmetric interaction with a chiral entity. We report an experimental evidence of the chiral resolution of linearly and unpolarized Gaussian beams through the transfer of spin angular momentum to cholesteric microparticles dispersed in water. Due to the interplay between linear and angular momentum exchange, basic manipulation tasks as trapping, spinning or orbiting of microparticles can be performed by light with zero helicity.

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Microfluidic assisted preparation of polymer microgels and microparticles

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In this communication we show the results obtained in our group regarding the preparation and characterization of polymer microgels and microparticles by means of microfluidic techniques in the framework of action COST 1205. Microfluidics has been demonstrated to be a successful technique for the preparation of polymer microparticles and microgels by employing T-junction and flow focusing geometries and different device designs. It is important to highlight the versatility of MF technique as it allows to easily change the geometry configuration and to control several experimental parameters, such as the flow rates of the aqueous and the organic phase at the same time[1, 2]. Chitosan, a cationic polysaccharide obtained by the thermo-alkaline N-deacetylation of chitin, is the second-most abundant naturally occurring amino polysaccharide offering high biocompatibility. Chitosan microgels can be obtained through ionic gelation of chitosan with tripolyphosphate salts using a simple nanoprecipitation method based on controlled adition of TPP salts onto an aqueous solution of chitosan subjected to high stirring to promote the formation of chitosan microgels [3]. However this method cannot provide narrow size distribution of biocompatible particles, yielding instead particles with a wide size distribution. Microfluidics is a successful technique for the preparation of chitosan droplets and for its transformation into microgels. As an example, we have reported on the setting up of a four-inlet microfluidic device for on-chip crosslinking of chitosan with TPP as an alternative to off-chip crosslinking which does not assure homogeneous crosslinking. The obtained chitosan microgels present particle sizes of ~10 microns and CV ~13%. [4]

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Fabrication of static microfluidic mixer in alumina ceramics for precise fluid mixing employing ultra-short pulse ablation

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With the ever advancing field of nanotechnology, the research in microfluidics has brought a wide array of improvements over techniques involving the manipulation of miniscule amounts of fluids, often in the range of femtoliters. Applications of microfluidic devices are revolutionizing areas of clinical diagnostics, genetics, biology, etc., since the very low consumption of reagents, fast response, low cost and disposability are all very important aspects in practical science. Furthermore, as the field of microfluidics is advancing, more and more complicated structures as well as manufacturing strategies are requested for sophisticated applications in life sciences. Until recently, the only widely used techniques for manufacturing of microfluidic devices were well established lithography methods: optical, nanoimprint, very often followed by soft lithography for fast replication or injection molding for a more industrial approach. Although these methods are well-known and reliable, they involve several steps, which are time and resource consuming. Over the recent years, micromachining using femtosecond laser impulses has evolved to a point where the quality of structures, time consumption and cost are on par or even better than the conventional methods. What is more, femtosecond laser-assisted etching and water-assisted femtosecond laser drilling are relatively new techniques, offering the fabrication of 3D microchannels within the bulk of material, bringing a huge advantage over the surface constrained traditional methods [1, 2]. In this work we present an implementation of laser ablation of microchannels on the surface of alumina, which is our first step towards femtosecond laser assisted manufacturing of microfluidic devices. A microfluidic device for mixing of fluids was successfully fabricated using femtosecond laser ablation on the surface of alumina slide. The microfluidic device was designed for precise dosing and dilution of colloidal solutions applied in capillary assisted particle deposition experiments. It contained three inlet channels, a Tesla valve based passive mixer and branching outlets with holes drilled through the slide. Linear dimensions as well as depth of the channels were investigated using optical and scanning acoustic microscopes. The performance of the device was experimentally investigated. Furthermore, numerical simulations demonstrated close conformity with the experimental results, i.e. the geometry of laminar flows within the channel as well as mixing behavior, indicating that the suggested microfluidic device prototyping technology can be employed as an alternative for conventional methods especially when hard materials are in use. This research was funded by COST Action MP1205 and Kaunas University of Technology interdisciplinary, project no. PP35/161: 3DSonic.

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Optical and electrical manipulation of nanoparticles in topological defects

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Soft templates are a promising approach to assemble and manipulate nanoparticles structures. Due to the high sensitivity of soft matter systems to external stimuli, such composite materials can exploit the soft surrounding medium to move or to reconfigure nano-structures or nano-objects as well as to tune their own properties. We report strategies to assemble and manipulate nanoparticles arrays. The first approach is based on the use of topological defects, namely disclination lines, created in chiral liquid crystals. The control of nanoparticle-loaded topological defects by low power light is demonstrated. Large-scale rotation, translation and deformation of quantum dots light-emitting chains is achieved by homogeneous LED illumination[1]. In the second appraoch, using an external voltage, displacements and deformation of disclination arrays lines rich of nanoparticles have been observed. Full reconfigurability and time stability make this approach attractive for future developments and applications. Moreover, the results support the good opportunities offered by soft templating of nanoparticles via topological defects in the creation and manipulation of soft matter based nanomaterials.

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Observation of Algae Cell Division by Digital Holographic Microscopy

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Imaging of microscopic objects is an essential need in techniques and in life sciences. The rapid progress in electronic detection and control, digital imaging, image processing, and numerical computation has been crucial in advancing modern microscopy. Digital holographic microscopy is a new imaging technology in the field of optical microscopy. In conventional holography, invented by Gabor [1], the holograms are photographically recorded and optically reconstructed. Much more conveniently in digital holography the holograms are recorded digitally and the reconstruction is performed numerically. The digital holographic microscopy has also one more clear advantage over conventional holography as it yields a 3D volume image from a single image capture. A digital in-line holographic microscope (DIHM) was developed at the Agricultural University of Plovdiv. DIHM was applied to visualise the division of live algae Pseudokirchneriella subcapitata without any preliminary preparation. Digital reconstruction of the recorded interference patterns was performed using the “HoloVision 2.2” software [2]. The reconstructed images illustrate the possibility of observation of the structure and morphology of live algae cells obtained from a digital hologram. These experiments illustrate the capability of DHM for non-invasively visualizing and quantifying biological cells and tissues. That’s why DHM can be successfully used for: visualising morphology of live cells, cell counting, measuring cell viability directly in the cell culture etc. DIHM is capable of visualizing of live cells with dimensions 1 – 10 microns without any preliminary preparation. It can be applied to dynamic quantitative visualization of live cell deformations to study their interactions with other particles as well as the surrounding environment. This makes the DIHM a valuable technique for many life science applications. It is shown that DIHM can be used for biological studies of live algae cell division without any preliminary preparation.

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In Depth Structure Investigation of TGS by Digital Holographic Microscopy

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In conventional holography, invented by Gabor [1], the holograms are photographically recorded and optically reconstructed. Much more conveniently in digital holography the holograms are recorded digitally and the reconstruction is performed numerically. The digital holographic microscopy has also one more clear advantage over conventional holography as it yields a 3D volume image from a single image capture. A digital in-line holographic microscope (DIHM) was developed at the Agricultural University of Plovdiv. DIHM was applied to visualise the domain structure of triglycine sulfate (TGS) single crystals without any preliminary preparation. Digital reconstruction of the recorded interference pattern is performed using the "HoloVision 2.2" software [2]. TGS single crystals doped with different concentrations of Nd were grown by the dynamical method in the ferroelectric phase [3]. All samples used in these experiments were grown from aqueous solution. The monocrystals of TGS doped with Nd show a clear cleavage plane perpendicular to its ferroelectric axis. The samples for the present investigations were plates, cleaved perpendicular to the polar axis [010] from clear regions far from the seeding area. The principal optical axis X coincides with the polar crystal axis. According to the notation of Damen et al. [4] our experiments were performed in the geometry . The domain structure of doped TGS crystal was visualised by digital in-line holographic microscopy (DIHM) for the first time. DIHM was employed without any preliminary preparation of the TGS samples. It was established that the diameters of the single domains (cross sections) in TGS crystals doped with Nd vary between 2 μm 15 μm. It was established that the size of the domains increase with increasing the concentration of the dopant.

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Light induced rotation of chiral birefringent microparticles

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We report the rotational dynamics of solid chiral and birefringent microparticles induced by elliptically polarized laser light in optical tweezers. We find that both reflection of left circularly polarized light and residual linear retardance affect the particle dynamics. The degree of ellipticity of laser light needed to induce rotations is found. The experimental results are compared with analytical calculations of the transfer of angular moment from elliptically polarized light to chiral birefringent particles.

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Light-induced rotations of chiral birefringent microparticles in optical tweezers SCIENTIFIC REPORT (2016) 6:31977 | DOI: 10.1038/srep31977

Laser radiation interaction with microvolumetric droplets

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Results about the emission spectra of microvolumetric droplets containing Rh6G solutions in ultrapure water impurified/doped with TiO_2 nanoparticles are reported. The excitation is made by lateral optical pumping using the second harmonic of a pulsed Nd:YAG laser emitted in green at 532 nm, pulse duration at half maximum 6ns, pulse repetition rate 10 pps and energy modified between 6 mJ and 10 mJ. The laser induced emission spectra are analyzed function of the TiO_2 concentration and of the pumping laser energy. Comparison between fluorescence dispersed spectra emitted by pendant droplets containing TiO_2 nanoparticles with respect to Rh6G water solutions droplets pumped in the same conditions and using the same scheme is made. Correlation of spectral data with surface tension data measured on the same droplets is made.

Topological defects and electro-convective flows in anisotropic fluids: a microfluidic platform for nano-objects tunable structuring

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Anisotropic fluids are a class of soft materials that offer wide possibilities for engineering a small scale laboratory; their physical properties can be manipulated on short length scale by appropriate confining conditions and external stimuli leading the systems across fascinating phenomena. In this work two of these phenomena are combined to create a microfluidic platform for reconfigurable nanoparticles (NPs) patterning: the formation of topological defects (TDs) and the electrically controlled convective flows. Here the nanoscopic environments created by defects within liquid crystals (LCs) have been used as linear nano-reservoirs of NPs. Afterwards, virtual channel flows that connect the linear reservoirs have been created by means of electro-convective rolls[1]. The results reveal a strategy for managing nanometric objects based on anisotropic fluids and connected phenomena, proposing an unconventional microfluidic device characterized by switchable and contactless micro-channels.

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Beam Coupling in Photorefractive Hybrid Cell with Bent-Core Liquid Crystal

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Recently new liquid crystalline materials, so-called bent-core LCs were synthesized. Important properties of these materials compared to the conventional LCs are higher values of the flexoelectric coefficients and lower bend or twist elastic constants. Having the lower elastic constants and increased flexoelectric coefficients one may expect a much stronger director deformation in bent-core LCs subjected to the space-charge field. We develop a theory for the optical gain characteristics of hybrid bent-core cells. We first numerically solve equations for the LC director profile togeth

er with the Maxwell's equations for electric field in LC cell and then calculate the gain coefficient in the hybrid cell. We show that the bent-core liquid LCs may exhibit a higher response to the space-charge field which results in a higher photorefractive gain.

Additive Manufacturing of Metallic Nanoparticles Structures by Two-Photons Direct Laser Writing

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Additive Manufacturing refers to a group of technologies that build physical objects directly from 3D Computer-Aided Design (CAD) data. In the field of nanotechnologies a the 2-photons Direct Laser Writing is the most advanced optical technique for creating arbitrarily complex 3D materials featuring details well below the diffraction limit, in organic resists. The possibility to include metallic details or even to create metallic structures would pave the way for the realisation of metallic/polymeric nanocomposites for advanced optics. Here we report about the study on the physical features of gold nano-particles created by 2-photons photo-reduction Direct Laser Writing in a polymeric or hydrogel matrix, doped with a suitable metallic precursor. Our experiments are performed in a free surface drop cast or cell segregated thin film onto a glass substrate, in which we create 1D gratings made by stripes of GNPs with single or multiple laser sweep. We also analyse the influence of the exposure time over the created nano-particles size distribution and density and we show that by suitably adjusting the exposure time it is possible to maximize the frequency of a given diameter. Finally, we report about preliminary experimental results aimed to elucidate the involved physical phenomena, beyond the optical absorption. In particular, we point out the key-role of thermal and diffusive processes

Opto-electronic trapping on Iron-doped Lithium Niobate crystals

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Optoelectronic tweezers (OET) are a promising technique for the realization of reconfigurable systems suitable to trap and manipulate micro-particles. In particular dielectrophoretic (DEP) forces produced by OET represent a valid alternative to micro-fabricated metal electrodes, as strong and spatially reconfigurable electrical fields can be induced in a photoconductive layer by means of light-driven phenomena. Results obtained by analyzing the spatial configurations of the DEP-forces produced by a 532-nm laser beam, with Gaussian intensity distribution, impinging on a Fe-doped Lithium Niobate substrate will be presented with perspectives towards biological samples manipulation by way of droplets trapping.

Development of Lanthanide ions doped Glass Substrate Material for Microfluidic Application

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The aim of this work is devoted to the detection of contamination by dioxins [1], which are very toxic agents. This is achieved using a new lab-on-a-chip device functioning with lanthanide doped glasses. There are two principal aspects presented in relation to this: (i) the material science and engineering aspect concerning the fabrication of lanthanide doped glassy phases and their complete characterization [2]; (ii) the fabrication of the lab-on-a-chip platform [3] and the analytical procedure for the photo-detection of dioxins. It is important to understand these aspects and for their practical usage they must lead to an improvement in public health and to a reduction in the cost of dioxin detection. Therefore, in this preliminary study, we will contribute the development of Ln3+ glasses and their luminescence performance. In order to verify the response of the Ln3+ emission properties time-resolved studies were performed. The dependency of emission spectra, steady-state luminescence spectroscopy (SSLS) and time-resolved emission spectral (TRES) studies were investigated. By making use of TRES measurements the decay associated spectra were obtained allowing the decay time for the different emission bands to be elucidated. This is important in ascertaining information about the Ln3+ microenvironment and its ability to provide a detectable signal that can noticeably alter in the presence of dioxin.

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