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(Conference)

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Conference program

Sunday, March 13th

Chairman: Pavle Andjus

16.00 – 16.30	**Registration & Opening**
16.30 - 16.50	**Ivana Drvenica** *Characterizing red blood cells deformability by ektacytometry*
16.50 - 17.10	**Drenka Trivanovic** *Monitoring of bone marrow stem cell niches by two-photon microscopy*
17.10 – 17.30	**Danica Pavlović** *Synergy of interference, scattering and pigmentation for structural coloration of Jordanita globulariae moth*
17.30 – 17.45	**Tanja Pajić** *Label-Free Third Harmonic Generation Imaging and Quantification of Lipid Droplets in Live Filamentous Fungi*
17.45 – 18.00	**Marta Bukumira** *Determination of spatial resolution limits of nonlinear laser scanning microscopy*
18.00 – 18.15	**Danka Stojanović** *Tunable graphene based metamaterials in terahertz frequency range*
18.15 – 18.30	**Marija Ćurčić** *Experimental and theoretical study of two-mode squeezing by FWM in potassium vapor and its applications*

Monday, March 14th

Chairman: Zoran Grujić

16.00 - 16.30	***Refreshment***
16.30 - 17.00	**Ferucio Renzoni** *Quantum Sensors for Electromagnetic Induction Imaging: from Atomic Vapors to Bose-Einstein Condensates*
17.00 - 17.20	**Vladimir Đoković** *Tryptophan functionalized silver nanoparticles: environmentally sensitive probe for fluorescent imaging*
17.20 – 17.35	**Bratislav Marinković** *Photonic, electronic and ionic collisional data represented in Belgrade database for inner-shell excitation and ionization of atoms*
17.35 – 17.50	**Marija Radmilović Rađenović** *The thermal effect during microwave ablation treatment of Hepatocellular Carcinoma*
17.50 – 18.05	**Vladimir Damljanović** *Full classification of linear dispersions in two-dimensional materials*
18.05 – 18.20	**Dragan Lukić** *Prospective of Solar Pumped Lasers for Space Propulsion*
18.20– 18.35	**Mihajlo Radmilović** *Two - photon microscopy as a tool for the studying erythrocyte morphology in a Diabetes mellitus type 1 patients*

Chairman: Bratislav Marinković

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20.20 - 20.40	**Goran Gligorić** *Topological Charge Switch in Active Multi-Core Fibers*
20.40 - 20.55	**Stanko Tomić** *Quantum Information Processes: Single Photon Sources on InGaN QD*
20.55 - 21.10	**Mirjana Stojanović** *Dynamics of nonlinear Aharonov-Bohm caged compact localized modes in Dice lattice*
21.10 - 21.25	***Mini break***
21.25 – 21.40	**Edi Bon** *Exploring The Active Galactic Nuclei Through Photometric Variability*
21.40 – 21.55	**Dragutin Šević** *Using artificial neural networks to make temperature sensing calibration curve*
21.55 – 22.25	**Louissa Reissig**

Thuesday, March 15th

Chairman: Branislav Jelenković

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16.50 - 17.10	**Caterina Credi** *Engineering versatile optical sensors for highly sensitive SERS analysis of liquid biopsies*
17.10 – 17.30	**Sara Nocentini** *Light responsive polymeric microstructures for robotics and photonics applications*
17.30 – 17.50	**Suzana Petrović** *Laser surface texturing of Ti-based multilayers for biomedical application*
17.50 – 18.05	**Aleksander Kovačević** *Laser beam waveguiding capabilities of the suspension of Chlorella sorokiniana in water*
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18.20 – 18.35	**Duška Popović** *Dynamic interference of photoelectrons in two-photon ionization of hydrogen by intense short laser pulses*

Neurophotonics on the Top

BRAIN AWARENESS WEEK Dana Foundation

Chairman: Dejan Pantelić

20.00 - 20.30	**Srdjan Antic** *Photonics Experiments in the Mouse Model of Alzheimer's Disease*
20.30 - 21.00	**David Lutz** *The cell signalling molecules reelin, ghrelin, pedin, pedibin and L1CAM stimulate neuroplasticity*
21.00 - 21.15	***Mini break***
21.15 - 21.35	**Irina Stoyanova** *Grafted and chemically-guided regeneration of injured peripheral nerves with modern tools*
21.35 – 21.55	**Pavle Andjus** *Imaging the molecular markers of neurodegeneration in the ALS rat oligodendrocytes and microglia*
21.55 – 22.15	**Nina Milosavljavic** *A platform for tracing single neurons in 3D from multi-colour labelled populations*
22.15 – 22.30	**Ana Jakovljević** *Investigation of structural synaptic plasticity in the hippocampus of tenascin-C deficient mice*

Wednesday, March 16th

Chairman: Aleksander Kovačević

16.00 - 16.30	***Refreshment***
16.30 - 16.50	**Ljupco Hadžievski** *Optical vortices in waveguides with discrete and continuous rotational symmetry*
16.50 - 17.10	**Jovana Petrovic** *Multi-SENSor SysteM and ARTificial intelligence in service of heart failure diagnosis (SensSmart)*
17.10 – 17.30	**Branko Matović** *Synthesis of doped ceria nanopowders by cations with different valence state*
17.30 – 17.50	**Uros Ralevic** *Nanoscopy of transition metal dichalcogenide based van der Waals heterostructures fabricated by the wet and dry transfer methods*
17.50 – 18.05	**Goran Isic** *Analysis of the ellipsometric spectra of nanometer thick polyelectrolyte layers on silicon wafers with thermally grown silicon dioxide*
18.05 – 18.20	**Stanko Nedic** *Characterization of ultrathin dielectric films prepared via layer-by-layer polyelectrolyte deposition on thermally oxidized silicon wafers*
18.20 – 18.35	**Yasemin Demirhan** *Design and Deposition of Anti Reflective Coating for Solar Cell Applications*

Chairman: Ljupco Hadžievski

20.00 - 20.20	**Theo Scholtes** *Optically pumped magnetometers for unshielded applications*
20.20 - 20.40	**Zoran Grujić** *Why do we need accurate magnetometers and how to realize them*
20.40 - 20.55	**Jonas Hinkel** *Optically pumped magnetometers in high background fields*
20.55 - 21.10	**Aaron Jaufenthaler** *Low dead time, wide bandwidth optically pumped magnetometer for unshielded magnetorelaxometry of magnetic nanoparticles*
21.10 – 21.25	***Mini break***
21.25 – 21.40	**Saša Topić** *New bounds on ultralight bosonic ALP matter mass and SM fermion coupling strengths from Science run 5 of GNOME OPM network*
21.40 – 21.55	**Aleksandar Atić** *Numerical modeling of new oxide-based heterostructures for use in QCL devices*
21.55 – 22.10	**Nikola Vuković** *Anisotropy of dielectric permittivity in optical gain modelling of MIR quantum cascade lasers*

Content

Abstracts

Dynamics of nonlinear Aharonov-Bohm caged compact localized modes in Dice lattice

Mirjana G. Stojanović[1], Ana Mančić[2], Milutin Stepić[1], Aleksandra Maluckov[1]

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Contact: M. G. Stojanović (mirjana.stojanovic@vin.bg.ac.rs)

Abstract. Photonic lattices are an ideal platform for creating flatband (FB) spectrums because they are easy for manipulation. Possibility to design artificial gauge field effects equivalent to the magnetic field flux and the spin-orbit interaction in atomic systems, originates from their geometry [1]. An example is the two-dimensional (2D) dice lattice which hosts fully FB spectrum [2,3,4] owing it the Aharonov-Bohm (AB) caging effect.

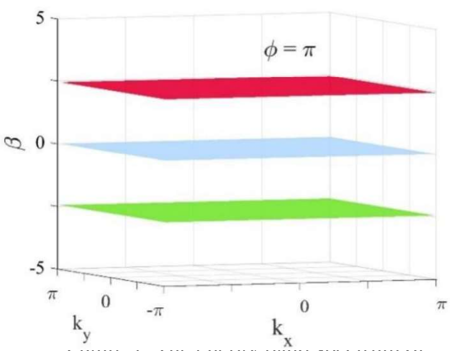

Figure 1. The energy band spectrum of linear 2D dice lattice for value of flux ϕ=π.

Here, we study the compact localized modes in 2D dice lattice dressed by artificial flux [5,6] in the presence of nonlinearity. The idea is to confront the AB to nonlinearity effect for the purpose of finding the favorable conditions for choosing the localized modes with user-friendly properties.

The primitive cell of dice lattice consists of six sites, which are linearly coupled by complex hopping $te^{i?/2}$, where t is the hopping parameter and ? is the artificial flux. Two sites are 6-fold coordinated (hub-sublattices) and four sites are 3-fold coordinated (rim-sublattices). For ?=?, this lattice spectrum is described by three momentum independent, fully degenerated FBs, as shown in Fig. 1. The FB eigenmodes are compact snowflake-like structures shared by a few unit cells [5].

The dynamics of compact localized modes in flux-dressed nonlinear 2D dice lattice has been analyzed numerically adopting the Runge-Kutta procedure of the 6th order. By calculating the participation ratio, mode overlapping and distribution of mode intensity we succeeded to distinguish between two types of dynamically compact localized patterns: the snowflake-like steady compact modes which showed high robustness in both linear and weakly nonlinear lattice, and localized breathing complexes robust to the presence of weak nonlinearity.

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Photonics Experiments in the Mouse Model of Alzheimer's Disease

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Abstract. In Alzheimer's disease (AD), synaptic dysfunction is thought to occur many years before the onset of cognitive decline. Detecting synaptic dysfunctions at the earliest stage of AD would be desirable in both clinic and research settings. Population voltage imaging allows monitoring of synaptic depolarizations, to which calcium imaging is relatively blind. We developed an AD mouse model (APPswe/PS1dE9 background) expressing a genetically-encoded voltage indicator (GEVI) in the neocortex. GEVI was restricted to the excitatory pyramidal neurons (unlike the voltage-sensitive dyes that bind all membranes indiscriminately). The expression of GEVI was stable in both AD model mice and Control (healthy) littermates (CTRL) over 247 days postnatal. Around postnatal age 150 days (P150) and especially at P200, synaptically-evoked voltage signals were weaker in the AD groups vs. the age- and sex-matched CTRL groups, suggesting an AD-mediated synaptic weakening that coincides with the accumulation of amyloid plaques. However, at the youngest ages examined, P40 and P80, the AD groups showed differentially stronger signals, suggesting "hyperexcitability" prior to the formation of plaques. From the evoked voltage waveforms, we extracted several parameters for comparison AD vs CTRL. Some parameters (e.g. temporal summation, refractoriness, and peak latency) were weak predictors, while other parameters (e.g. signal amplitude, attenuation with distance, and duration (half-width) of the evoked transients) were stronger predictors of the AD condition. Together, our results indicate subtle alterations in cortical physiology in AD model mice, occurring both prior (P40-80) and after (P150-200) the amyloid deposition. Supported by: *National Institute on Aging* & *The Cure Alzheimer's Fund*.

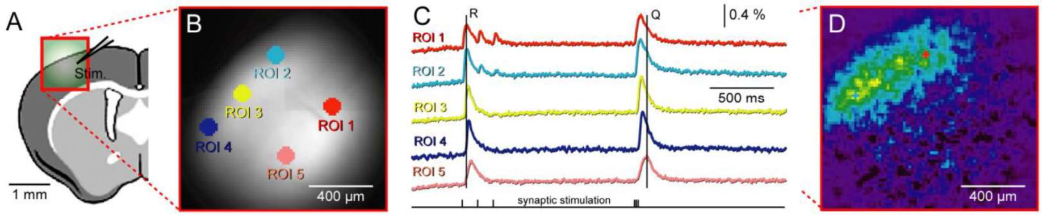

Figure 1. Optical Imaging of Synaptically Evoked Neuronal Depolarizations. (A) Coronal section through mouse brain with position of synaptic stimulation electrode inside neocortical layer 2/3. Scale, 1 mm. (B) A fluorescence microphotograph of a brain section of transgenic animal expressing a fluorescent voltage inadicator protein in pyramidal neurons, only. Surface of brain slice with 5 regions of interest (ROIs) selected for spatial averaging. (C) The black trace at the bottom marks the timing of two triplets of synaptic shocks, with 120 ms interspike interval (first), and with 12 ms interspike interval (second triplet). Vertical line R marks the peak of voltage depolarization in ROI-1. Vertical line Q marks the peak of voltage depolarization in ROI-5. (D) Same area as in B, except optical signals amplitudes are coded by color, where dark purple is the minimum and bright red is the maximum of the optical signal amplitude. The spatial and temporal aspects of a biological response (i.e. synaptically-evoked depolarization) were succesfully recorded using the GEVI imaging methodology in mouse model of Alzheimer's Disease (AD Group) and in healthy littermates (Control Group).

Quantum Sensors for Electromagnetic Induction Imaging: from Atomic Vapors to Bose-Einstein Condensates

Ferruccio Renzoni

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Abstract. Electromagnetic induction imaging (EMI) allows mapping of the conductivity of target objects and, when combined with appropriate algorithms, the generation of full 3D tomographic images. Despite its tremendous potential, and the wealth of possible applications, for a long time the use of EMI was hampered by the lack of suitable sensors, with high sensitivity at low frequency. The use of atomic magnetometers (AMs) was shown to overcome such a limitation and, in conjunction with machine learning techniques, opened the path to new applications of EMI. Most of the EMI-AMs demonstrations reported thus far rely on atomic vapors as sensing media. This talk reviews the state-of-the-art of EMI with atomic magnetometers and discusses recent results obtained with ultra-cold atoms and Bose-Einstein condensates, highlighting the potential extreme resolution obtainable.

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Design and Deposition of Anti Reflective Coating for Solar Cell Applications

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Abstract. Anti-reflective coatings (ARC) are used in a wide range of applications for various optical and opto-electrical equipments [1]. Extensive research in the field of minimizing biological and optical reflection has contributed to the development of ARC in different optic types of equipment. Increasing surface reflectivity due to the high refractive index mismatch at the interface seriously affects the efficiency of optical devices. In solar panels, the photon flux into the cell approximately reduces to ~4.22% owing to the effect of reflection. ARC is the commonly used way to increase the efficiency of photovoltaic technologies. ARC are widely used to increase the efficiency of optoelectronic devices such as light emitting diodes, bolometers and solar cells. Especially for solar panels, adequate absorption of light is crucial to increase the short-circuit current, which implies an increase in the solar cell efficiency. Usually, the AR layers on silicon solar cells are made of SiO_2 and TiO_2 [2-3], but some practical problems may be encountered, such as optical compatibility, surface passivation, or angle-dependent anti-reflection. The most suitable candidates as next-generation AR coatings for solar panels are surface-coated nanostructured materials, which can provide versatile antireflection, short diffusion length of minority charge carriers, and potential self-cleaning properties, in addition to being cost-effective. In this study, single-layer and double-layer antireflection coatings with a low refractive index were deposited by using a computer controlled CNC system and investigated in terms of performance and continuity. The transmission and reflectance measurements were performed by Perkin Elmer Lambda 950 UV/VIS/NIR spectrophotometer. SEM images of AR surface were taken to observe the distribution of nanoparticles on the surface of the AR coatings. The photocatalytic performance of (SiO_2) thin films was performed with methylene blue dye solution (20 mL) under UV source. The AR coated glasses mounted on a solar panel and the I-V characteristics curves and P-V curves were obtained. The efficiency of the solar panels was determined and 2% increase in efficiency was observed in AR coated glass mounted solar panels. Adhesion tests was utilized by tape tests on substrates of glass to investigate the durability of AR coatings. As a conclusion, the field tests of ARC mounted solar panels were accomplished, the low reflectance and high efficiency were established.

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Numerical modeling of new oxide-based heterostructures for use in QCL devices

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Abstract. Semiconductor devices operating in the terahertz (THz) and near/mid infrared (IR) parts of the optical spectrum have been continuously explored and improved during the previous two decades [1-3]. Multiple new material platforms are being experimentally and theoretically investigated as candidates for room temperature operation of THz devices. One of the materials under recent consideration is ZnO due to its wide direct bandgap and high exciton binding energy. In this contribution we illustrate the use of a modified version of the Newton-Raphson method to numerically and self-consistently solve a system of Schrödinger-Poisson equations for a structure consisting of coupled ZnO–based quantum wells. The results obtained are compared with the experimental data available in the literature, after which the influence of layers' thickness and doping profile on the bound states energies is analyzed. Additionally, the impact of the external electric field applied to the structure is assessed in order to determine the doping profile and well/barrier thicknesses that would be most promising for quantum cascade laser applications. Finally, we evaluate the absorption due to intersubband transitions between the bound states.

Acknowledgments

The authors acknowledge support from Ministry of Education, Science and Technological Development (Republic of Serbia), "Multi-Scale Modeling of Terahertz Quantum Cascade Laser Active Regions", Multilateral scientific and technological cooperation in the Danube region 2020-2021, and "DEMETRA: Development of high-performance mid-IR / THz quantum cascade lasers for advanced applications", Science Fund of the Republic of Serbia, Serbian Science and Diaspora Collaboration Programme: Knowledge Exchange Vouchers.

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Analysis of the ellipsometric spectra of nanometer thick polyelectrolyte layers on silicon wafers with thermally grown silicon dioxide

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Abstract. The layer-by-layer deposition method involves a successive deposition of polyanions and polycations onto a desired surface, usually by repeated immersion in aqueous solutions of the polyelectrolytes. Since its advancement in the early 1990s, it has become widespread as a cheap and versatile means for ultrathin polymer film preparation [1].

Here we consider multilayers of cationic poly(allylamine hydrochloride) (PAH) and anionic poly(sodium 4-styrenesulfonate) (PSS) molecules deposited on top of commercially produced dry thermal silicon dioxide layers (target thickness of 285 nm) grown over a lightly Boron-doped crystalline silicon wafer, which serve as well-known substrates for the accurate optical characterization of PAH/PSS multilayers. The bare substrate, substrate after base piranha functionalization and, finally, substrate with the number of PAH/PSS bilayers ranging from 1 to 4, were carefully measured by variable-angle spectroscopic ellipsometry (VASE) [2, 3].

In this work, we analyze the obtained VASE spectra to determine the dielectric function of the polyelectrolyte films of different thicknesses. First, the spectra of bare substrates are fitted to several models with different parameters, involving the Sellmeier function for the silicon dioxide permittivity, the interfacial layer between silicon and silicon dioxide and the layer thicknesses, in order to determine the minimal value of the test (error) function that can be achieved for a given model [4, 5]. The fitting involved the least squares minimization of the vector of residuals (difference between measured and model spectra) achieved using 3 different algorithms, (i) Trust Region Reflective, (ii) dogleg and (iii) Levenberg-Marquardt, implemented in the scipy.optimize package of the SciPy Python library [6]. In the second step, the VASE spectra of samples with various number of polyelectrolyte bilayers are fitted to several models involving the Cauchy's function for the refractive index of the polyelectrolyte layers and their thicknesses, assuming the dielectric functions and layer thicknesses of the underlying substrate are known. The layer thicknesses inferred from VASE spectra are then compared with thicknesses directly measured by atomic force microscopy.

This research was supported by the Science Fund of the Republic of Serbia, PROMIS, 6062710, PV-Waals, and by NPRP11S-1126-170033 project of the Qatar National Research Fund.

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Characterizing red blood cells deformability by ektacytometry

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Abstract. The erythrocytes have remarkable physico-elastic properties with an elastic modulus softer than the softest latex rubber [1]. Such feature allows them to deform from its diameter of approximately 8 µm to diameters as small as 1.5 µm in the narrowest capillaries, and consequently to perform oxygenation of the tissue [1] and help proper adhesion of white blood cells in blood flow [2] or platelets marginalization [3]. Decreased red blood cell deformability is a well-known characteristic of several disorders, such as sickle cell anemia, Plasmodium infection, iron deficiency, and hemolytic anemias, and can be conveniently measured by ektacytometry. This technique uses laser light diffraction to measure red blood cells deformability and cellular heterogeneity [4]. Since human erythrocytes possess a life span of 120 days and are under the constant influence of oxidative stress, metabolic depletion, and loss of ion gradients [1], deformability could be a biomechanical biomarker indicating presence of subtle chronic pathological states or an early sign of a disease. This study has analyzed the effects of several *in vitro* parameters on erythrocyte deformability by using RheoScan D 300 (RheoMeditech. Inc., Korea, Fig. 1). The parameters were chosen in such a way to simulate some pathological conditions and included treatment of erythrocytes by oxidative agents, changes of osmotic gradient, and erythrocytes storage and isolation from whole blood. Relevant outputs of red cells deformability include the maximum elongation index (EI Max), a quantity of the maximum deformability of erythrocytes as reaction to increasing shear stress, and shear stress ½ (SS ½), the shear stress needed for half maximal deformability.

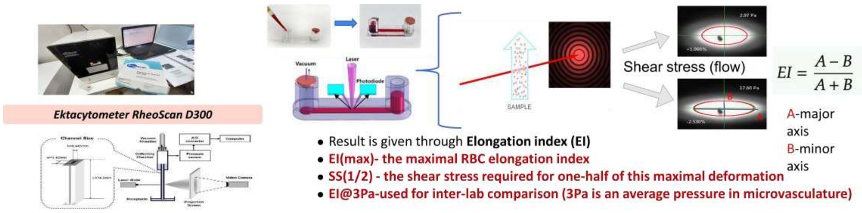

Figure 1. Schematic presentation of ektacytometer RheoScan D300 set-up and diffraction measurement of red blood cells (RBC) deformability indices-elongation index (EI) at specific shear stress (SS)

By variation of *in vitro* parameters, ektacytometry enables us to detect even those subtle differences in deformability of erythrocytes of healthy human donors induced by changes due to age, osmolarity, and type of applied oxidative stress. Since the diffraction measurement by ektacytometry is an average of all cells present in the measured sample [5], the actual usefulness of the technique for monitoring disease onset or progression through the determination of erythrocytes population deformability merits further examinations and parameters optimization.

Funding: This study was funded by Science Fund of Republic of Serbia through HEMMAGINERO project

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Experimental and theoretical study of two-mode squeezing by FWM in potassium vapor and its applications

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Abstract. We present experimental results that show intensity difference squeezing (IDS) from a pair of quantum correlated (twin) beams generated by the four-wave mixing (FWM) process in dense potassium vapor. Quantum squeezing was observed by measuring noise power spectrum of the signal difference of twin beams. We search for the highest IDS by the analyzes of effects of important FWM parameters that can be changed in the experiment – one-photon pump and two-photon probe detuning, pump and probe powers, matching angle between the pump and probe, potassium density, and size and shape of potassium cells.

The experimental results are compared to theoretical ones. In our calculations, we use two different models – analytical distributed gain-loss model and microscopic model based on Heisenberg-Langevin formalism. We emphasis the importance of using an adequate model in the study of intensity difference squeezing in potassium vapor. The agreement between results of the models and of the experiment will be discussed. Our results are among of only a few that investigated the IDS in potassium, and will be compared to squeezing obtained in other alkali vapors, notably Rb and Cs.

We will also discuss the changes in the set-up in order to improve the level of squeezing, and do experimental studies in multi-spatial-mode regime. At the end, we present possible applications of twin beams generated in out experiment for quantum enhanced imaging and sensing.

Anisotropy of dielectric permittivity in optical gain modelling of MIR quantum cascade lasers

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Abstract. An enhanced numerical model for calculation of population densities and optical gain in quantum cascade laser (QCL) [1] that takes into account anisotropy of dielectric permittivity [2] of the layered quantum-well based structure is presented. Our results indicate that the layering induced anisotropy leads to significant changes in electron-longitudinal (LO) phonon scattering rates [3] on account of the existence of additional resonant frequencies for LO phonons, each altering the total scattering rate between the relevant subbands. Namely, instead of taking LO phonon frequency as a constant [4], we have included dependence on phonon wavevector in the vicinity of the LO phonon modes: one dependence originates from the material system that is used and the others on the transition energies of the structure's active region. Subsequently, carrier distribution between the subbands and the degree of population inversion in the mid-infrared QCL active region are substantially changed in comparison to the predictions of an isotropic permittivity model widely used in the literature [5]. Numerical calculations presented in this contribution are based on solving the system of rate-equations iteratively and then evaluating carrier densities, scattering rates, and optical gain.

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The authors acknowledge support from Ministry of Education, Science and Technological Development (Republic of Serbia), "Multi-Scale Modeling of Terahertz Quantum Cascade Laser Active Regions", Multilateral scientific and technological cooperation in the Danube region 2020-2021, and "DEMETRA: Development of high-performance mid-IR / THz quantum cascade lasers for advanced applications", Science Fund of the Republic of Serbia, Serbian Science and Diaspora Collaboration Programme: Knowledge Exchange Vouchers.

Tryptophan functionalized silver nanoparticles: environmentally sensitive probe for fluorescent imaging

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Abstract. Fluorescent nanostructures were prepared by a functionalization of silver nanoparticles with the amino acid tryptophan. The obtained silver-tryptophan (AgTrp) particles were investigated by transmission electron microscopy (TEM) and various spectroscopy methods (XPS, FTIR, UV–vis and photoluminescence). The interaction of the AgTrp nanoparticles with microbial cells (*Escherichia coli*, *Candida albicans*) and synthetic polymers was followed by means of fluorescent microscopy. The AgTrp nanoprobes proved to be environmentally sensitive, due to the fact that the tryptophan emission is sensitive to the polarity of the environment. For this reason, it was possible to get the additional information about the particular sites in the cell where the accumulation of the nanoprobes takes place. Deep ultra violet (DUV) imaging measurements were performed at SOLEIL synchrotron (Paris) by using excitation of λ_{exc}=280 nm. The images were collected on the TELEMOS endstation of DISCO beamline by acquiring the luminescence signals in the [327 nm-353 nm] and [370 nm-410 nm] spectral ranges, which correspond to the tryptophan emission in non-polar (hydrophobic) and polar (hydrophilic) environments, respectively. In the case of *Escherichia coli bacteria*, it was found that upon incubation the AgTrp nanostructures were situated in a hydrophobic environment i.e. cell membrane. In contrast, the AgTrp particles introduced in polyvinyl alcohol (PVA) polymer matrix emit only in [370-410 nm] spectral range, due to polarity of the matrix chains. It was also found that, nanoparticles induce profound effects on morphology of the host PVA polymer.

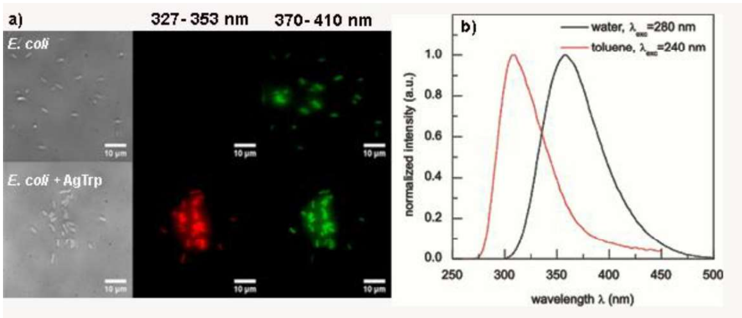

Figure 1. a) Bright field and fluorescence images of control *E. coli* cells and *E. coli* cells incubated with AgTrp nanoparticles (λ_{exc} = 280 nm, Filter I: 327–353 nm, Filter II: 370-410 nm). b) Normalized photoluminescence spectra of AgTrp colloids in water (black line) and toluene (red line).

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Full classification of linear dispersions in two-dimensional materials

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Abstract. We present group-theoretical classification [1] of all possible dispersions, which are linear in all directions, in the vicinity of high-symmetry Brillouin zone points, in non-magnetic layered materials. Both spinless and spinfull cases in the presence and in the absence of time-reversal symmetry are covered. We found that only three types of such dispersions are possible: Dirac, fortune teller and poppy flower. Low energy effective Hamiltonians are also presented. Special attention will be given to some recently published results not supported by our theory [2-5].

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Photonic crystal behavior of biosilica – influence of frustule's morphology on SERS sensitivity

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Abstract. Hybrid substrates for Surface Enhanced Raman Spectroscopy (SERS) based on diatom biosilica frustules covered with thin uniform gold films have been investigated. The observed increased sensitivity has been linked to the resemblance of diatom frustules to 2D photonic crystals and associated unique optical properties, such as guided mode resonance (GMR) [1, 2]. In this work the enhancement of three structurally distinct diatom biosilica species were compared – *Aulacosira sp.*, *Coscinodiscus sp.* and *Gomphonema Parvulum*. Uniform and well controlled thin layers of gold could be deposited onto the biosilica utilizing physical vapour deposition and a self-assembled (SAM) monolayer adhesion layer leading to accurate and reproducible SERS enhancement factors without creating artificial hot-spots. Those could hamper interpretation regarding the contribution of the frustules intrinsic photonic structure and lead to unsatisfactory reproducibility. The in the samples occurring distinct structural parameters, obtained from scanning electron microscope (SEM) analysis, such as pore size, spacing and other lattice parameters, allow us to study the influence of chosen laser excitation lines on coupling of GMR and Surface Plasmon Resonance (SPR), theoretically (using COMSOL multiphysics) as well as experimentally. We demonstrate that SERS enhancement strongly depends on the frustule's morphology, and thus its photonic properties. The greatest SERS enhancement factor (of more then 3, compared to gold on flat glass) of Rhodamine 6G was obtained on frustules from *Coscinodiscus sp.*, with dominant structural parameters in the range of the excitation line. The reproducibility of the measurements was verified with Raman mapping. The results suggest that high emphasis should be given to the detailed analysis of lattice parameters of the several 100k diatom species and increasing our understanding of the structural relationship of the enhancement, for selecting best target materials for future bio-sensor application.

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Fast Preparation and Detection of a Rydberg Qubit Using Atomic Ensembles

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Abstract: Arrays of neutral atoms have recently emerged as a competitive platform for quantum simulation and computation with many properties favorable for scaling. Rydberg states of atoms are often used because the strong Rydberg-Rydberg interactions can facilitate two-qubit gate operations and simulate many-body systems. However, for most schemes, readout of a Rydberg qubit is a destructive process that precludes its reuse and the application of many error-correcting codes. To address this challenge, we demonstrate a nondestructive implementation of preparation, manipulation, and readout of a single Rydberg qubit embedded in an atomic ensemble with high fidelity. By harnessing the collective optical response of the atomic ensemble, we detect the state of a qubit ~1000x faster than single-atom fluorescence imaging. This method determines the state of the Rydberg qubit without affecting the other atoms in the ensemble to first order, which can then be reused for further operations. With this developed technique, we are making progress towards realizing a quantum computer based on arrays of atomic ensembles, which can significantly improve the computation speed.

Synthesis of doped ceria nanopowders by cations with different valence state

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Abstract. Great attention has been devoted to the development of new technologies for the synthesis of nanoparticles and nanostructured materials, which are profitable for industrial production and are environmentally safe. Such materials have new and specific physical properties and find application in almost all spheres of human life. In nanoparticle materials there are significant changes in physical characteristics compared to microcrystalline ones, which in some cases can differ to several orders of magnitude. These specific changes in properties of the nanomaterial are observed in the change of magnetic, mechanical and optical characteristics, phase relations, the conductivity, etc.

In this presentation, self-propagating room temperature synthesis has been applied for controllable synthesis of nanostructured CeO_2 powders with fluorite-type structure as well as single Me-ceria solid solutions (Me: cations with different valence state; monovalent (Ag^{+}), divalent (Sr^{2+}) and trivalent (Bi^{3+})). The solid solubility of Me into ceria lattice was the topmost reported so far. Powder properties such as, crystallite and particle size, its thermal stability as well as lattice parameters have been studied. Crystal structure of fluorites, point defects, specific features and properties connected to it, this innovative method of nanopowders synthesis, and properties of ceria based materials will be discussed through: crystal structure and defect chemistry, synthesis of nanostructured solid solutions, hot consolidation of ceria nanopowders, some key properties of nanostructured ceria.

Laser surface texturing of Ti-based multilayers for biomedical application

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Abstract. Ultrafast laser processing with the formation of periodic surface nanostructures on the Ti-based multilayers is studied in order to the improve cell response. A novel nanocomposite structure in the form of 15x(Ti/Zr)/Si, 15x(Ti/Cr)/Si, Ti/Zr/Ti/Si and Ti/Cu/Ti/Si multilayer thin films, with satisfying mechanical properties and moderate biocompatibility, was deposited by ion sputtering on an Si substrate. All chosen multilayer thin films were modified by femtosecond laser pulses in air to induce the following modifications: (i) mixing of components inside of the multilayer structures, (ii) the formation of an ultrathin oxide layer at the surfaces, and (iii) surface nano-texturing with the creation of laser-induced periodic surface structure (LIPSS). The dynamic multi-pulse irradiation was observed via the production of lines with laser-induced periodic surface structures (LIPSS) at different laser parameters (scan velocities and laser polarization) [1]. Based on this experimental observation, it can be established that the spatial periodicity of the formed LIPSS is quite sensitive to changes in laser parameters (the effective number of pulses and laser polarization), as well as the nature of the material. The spatial periods varied in a wide range, which depended on the number of generated carriers in the conduction band of the laser excited materials, and the applied laser pulses.

The focus of this study was an examination of the novel Ti-based multilayer thin films in order to create a surface texture with suitable composition and structure for cell integration. Using the SEM and confocal microscopies of the laser-modified surfaces with seeded cell culture (NIH 3T3 fibroblasts), it was found that cell adhesion and growth depend on the surface composition and morphological patterns [2,3]. These results indicated a good proliferation of cells after one and up to four days with some tendency of the cell orientation along the LIPSSs.

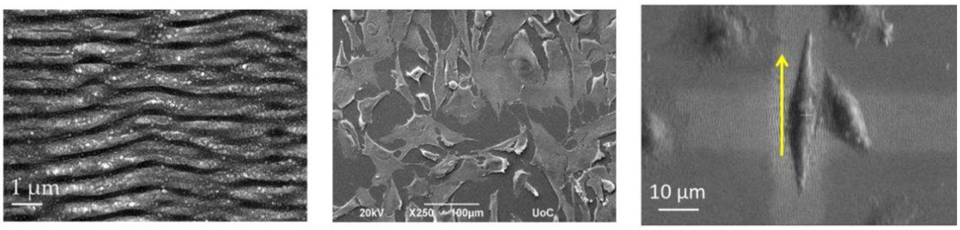

Figure 1. SEM images laser surface structured 15×(Ti/Zr)/Si multilayer thin film with cultivated of NIH 3T3 fibroblasts on the as-deposited and laser-processed surfaces

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The cell signalling molecules reelin, ghrelin, pedin, pedibin and L1CAM stimulate neuroplasticity

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Abstract. The accurate visualisation of dynamic changes in the fine ultrastructure of the developing and regenerating nervous system opens up exciting possibilities to draw conclusions on the mechanisms underlying development and disease. Cutting-edge *in vivo* and *ex vivo* techniques such as two-photon imaging on cells and organotypic slices, small-animal magnetic resonance imaging in combination with electron microscopy, and calcium imaging of different cellular entities were used to study and understand how neuroprotective molecules, such as reelin [1], ghrelin [2], pedin [3], pedibin [3] and L1CAM [4-6], modulate morphogenic processes in the scenario of neurodevelopment, neurodegeneration and regeneration after injury. By dint of modern bioimaging, we uncovered novel roles of these molecules not only in nervous system development but also in the aetiology of neurodegeneration. Moreover, these molecules hold within a promising potential to stimulate recovery of the nervous system after injury, thus translating their reputation as molecules of development into neuroprotective therapeutic agents.

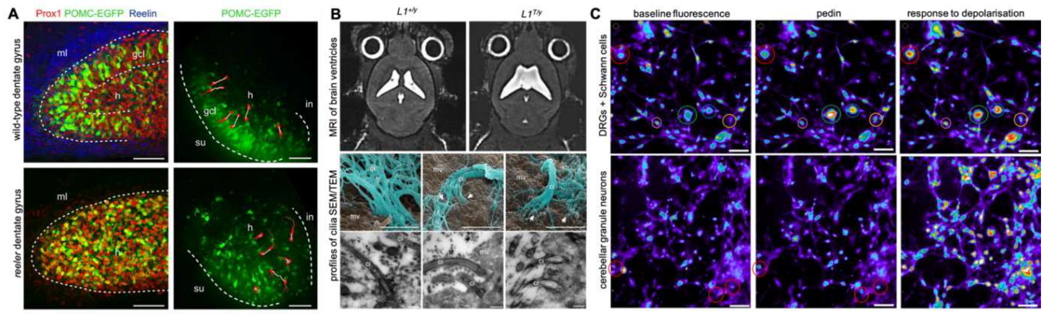

Figure 1. State-of-the-art bioimaging techniques applied to understand different mechanisms of neurodegeneration. (A) Two-photon imaging of murine dentate gyrus slices and trajectory analysis of newborn dentate granule cells, which migrate towards the reelin-enriched molecular layer in wild-type vs. reelin-deficient (*reeler*) mice. (B) Magnetic resonance imaging (MRI) showing enlarged ventricles in mice with a neuropathological mutation in the L1CAM gene ($L1^{T/y}$) vs. healthy littermates ($L1^{+/+}$). Lower panels: scanning and transmission electron microscopy showing aberrant profiles of the ependymal cilia in $L1^{T/y}$ and L1-deficient mice vs. healthy littermates ($L1^{+/+}$). (C) Calcium imaging of dorsal root ganglion neurons cocultured with Schwann cells (upper panels) and cerebellar granule neurons (lower panels) in different states: untreated, responding to the cnidarian peptide pedin, and during depolarisation.

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Grafted and chemically-guided regeneration of injured peripheral nerves with modern tools

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Abstract. Nervous system injury affects the integrity of the blood vessels and blood-brain-barrier as well as the cell metabolism within and around the area of damage, thus resulting in apoptosis and activation of immune and glial cells. The injured nervous system attempts to regenerate, yet the process of repair occurs in a stochastic and hardly controllable manner due to the lack of guiding tools that enable precise axonal outgrowth and pathfinding as well as the presence of inhibitory molecules that create a surrounding less permissive for newly formed axonal sprouts. Advanced grafting technologies in combination with special/suitable biomaterials facilitate the process of neuroregeneration towards a better functional outcome. One modern approach is the establishment of a bidirectional, highly selective neuro-electronic interface between a prosthetic device and a severed nerve. We implanted three-dimensional bifurcating guidance microchannels with gradually diminished widths (80, 40 and 20 μm) in the dissected sciatic nerve of rats to test if such a design could facilitate separation pattern of ingrowth *in vivo*. We achieved 91% of successful separation of the axonal bundles and re-growth of the axons, which suggested that the 3D-bifurcating scaffold might provide a much more precise motor control and sensory feedback to users of prosthetic devices in comparison to other standard grafting approaches. In another set-up, we applied the neuropeptide and hormone ghrelin locally at the grafting site of the dissected femoral nerve. Ghrelin, which is well-known to act neuroprotectively, stimulated sprouting and re-myelination of the severed axons. Both methodological approaches resulted in functional improvement of the injured peripheral nervous system. These findings encourage us to continuously look out for novel strategies employing modern bioimaging in combination with advanced biografting and neuroprotective molecules on the traumatized nervous system, seeking for a better recovery.

Investigation of structural synaptic plasticity in the hippocampus of tenascin-C deficient mice

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Abstract. Neuronal structural plasticity implies a reorganization and formation of new synapses, as well as remodeling the extracellular matrix that surrounds neurons. Among the main regulators of this synaptic plasticity are perineuronal nets (PNNs), condensed forms of extracellular matrix (ECM) that enwraps mostly inhibitory neurons. Tenascin-C (TnC) belongs to a family of ECM glycoproteins, that was demonstrated to modulate synaptic plasticity in the CA1 region of the hippocampus. The aim of this still ongoing study is to show if TnC deficiency affects structural plasticity of inhibitory synapses with regards to PNN in the dentate gyrus region of the hippocampus.

TnC-deficient (TnC -/-) and wild type mice were reared in an enriched environment (EE), to induce neuronal plasticity, compared to standard environment (SE) for 8 weeks. Immunohistochemistry was used to label brain sections for the presynaptic vesicular GABA transporter (VGAT), the postsynaptic marker protein gephyrin, and using *Wisteria floribunda* agglutinin (WFA) as the PNN marker. The dentate gyrus has been imaged using confocal laser scanning microscope (LSM 510, Zeiss) equipped with an argon multiline laser (457, 478, 488 and 514 nm) for excitation of Alexa Fluor 488, and helium–neon lasers (543 and 633 nm), for excitation of Alexa Fluor 555 and Alexa Fluor 647, respectively. Plan-Apochromat 63/1.4 Oil DIC was used as objective, and images were obtained with additional 1,5 digital zoom, folowed by analysis of synaptic parameters using SynapticCounter software.

Preliminary results show that the number of inhibitory VGAT and gephyrin markers as well as the number of their colocalising puncta decreased in the dentate gyrus of TnC -/- mice housed in EE, compared to wild type mice housed in the same environment, and to TnC -/- mice housed in SE, all negatively correlated with the WFA signal intensity.

Deficiency of TnC with EE, could have caused PNN condensation leading to a decrease in the number of impinging inhibitory synapses. These findings thus suggest the important role of TnC in hippocampal structural synaptic plasticity, mediated by PNN as the plasticity restrictor.

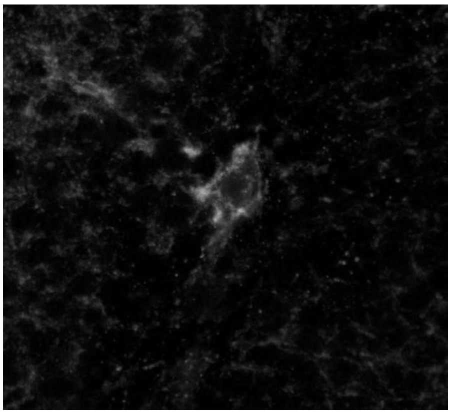

Figure 1. Perineuronal net in the dentate gyrus labeled with WFA.

Tunable graphene based metamaterials in terahertz frequency range

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Abstract. The development of metamaterials that respond resonantly in interaction with the terahertz (THz) electromagnetic waves is an important task for the achievement of diverse optical functionalities in this spectral range. Active metamaterials in THz range [1] have potential applications for active components such as tunable filters, switches and modulators which allow manipulation of THz waves in a dynamically controllable fashion. Graphene, a two-dimensional atomic system, can be used as active material by modification of the Fermi level and the corresponding charge carrier density is usually achieved by simple electric gating [2].

On the other hand, there are other ways of changing the Fermi level of graphene, such as optical pumping. As graphene monolayer weakly interacts with pumping radiation in IR frequency range, graphene/semiconductor hybrid structures are used in order to enhance optical response. Until now, as a semiconductor materials Si or Ge were used [3]. Photo-generated carriers Si or Ge convey into graphene layer and result in variation of graphene's conductivity. However, it is hard to grow Si and Ge layers which complicates experimental realization of the whole metamaterial, so we propose a structure which consists of graphene/Sb_2Se_3 resonators [4].

In this study, we investigate graphene based structures by preforming numerical simulations using finite element method applied in Comsol Multiphysics software. Unit cell of the metamaterial is composed of gammadion shaped graphene/ Sb_2Se_3 layers separated with the sapphire substrate. We investigated how geometrical parameters influence on reflection and transmission coefficients. Furthermore, we analyzed chiral features of the metamaterial, circular dichroism and optical activity, which were not enough investigated until now for the case of tunable THz structures [5].

This work is supported by the bilateral project Serbia-Turkey: „Tunable Graphene Based Chiral Metamaterial for Terahertz Wave Polarization Modulation" and by TUBITAK project number 220N350. The research was funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

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Characterization of ultrathin dielectric films prepared via layer-by-layer polyelectrolyte deposition on thermally oxidized silicon wafers

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Abstract. Seminal work by Decher et al. in the 1990s introduced the layer-by-layer deposition of oppositely charged polyelectrolytes [1-3]. This versatile deposition technique has since attracted considerable interest owing to its ability to modulate polyelectrolyte multilayer film properties at the nanoscale [4].

In this work, we study layer-by-layer polyelectrolyte deposition by alternately immersing thermally oxidized silicon wafer substrates into successive aqueous solutions of cationic poly(allylamine hydrochloride) (PAH) and anionic poly(sodium 4-styrenesulfonate) (PSS) polyelectrolytes with intermediate rinsing steps [5]. The surface functionalization (SF) of the substrates was performed by dipping them into the NH_4OH/H_2O_2 base piranha mix for 2 hours at 50°C, thus creating an OH^- terminated surface prior to exposing the samples to the positively charged PAH.

Due to the polyelectrolyte multilayer film thickness at the nanometer scale, their characterization requires highly sensitive techniques such as atomic force microscopy (AFM) and variable-angle spectroscopic ellipsometry (VASE). Both techniques verified the presence of polyelectrolyte multilayer films. Particularly, the SF and PAH/PSS bilayer thicknesses were established by AFM scratching, whereas VASE measurements demonstrated consistent shifts in the most prominent tanΨ peak resulting in an increase in the peak's wavelength shift with the increasing number of PAH/PSS bilayers.

Finally, the refractive indices of polyelectrolyte multilayer films of different thicknesses (consisting of 1-4 PAH/PSS bilayers) in the wavelength range of 200-800 nm are determined from the obtained VASE spectra for bare substrates, substrates after surface functionalization, and substrates with one to four polyelectrolyte bilayers.

This research was supported by the Science Fund of the Republic of Serbia, PROMIS, 6062710, PV-Waals, and by the NPRP11S-1126-170033 project of the Qatar National Research Fund.

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Prospective of Solar Pumped Lasers for Space Propulsion

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Abstract. We will present an overview of the recent progress in main technologies for solar-pumped laser and discuss several potential designs for laser driven light-sail powering. The history of laser technologies for space starts with the first laser echoes reflected off the Moon in 1962. We will examine the possibilities for application for the Interstellar Heliopause Probe mission. We present an overview of the technologies for solar pumped lasers from solar light collectors to the composition of active material. We will debate several problems with space basing of such system.

Femtosecond laser spectroscopy for Exploration of Space

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Abstract. The Time-Domain Spectroscopy group (TLS - ZS) in the department of Terahertz and Laser Spectroscopy (TLS) is introducing new topic of time domain spectroscopies to space exploration. Group has a long track record in instrumentation development and has in recent years pioneered terahertz time-domain set-ups demonstrating world-wide unique sensitivity levels [1,2]. We're currently working on developing compact laser-based spectroscopy techniques based on short-pulse lasers for future applications in e. g. robotic missions to extraterrestrial objects in our solar system. Scientific applications range from planetary research to nonlinear spectroscopy of novel quantum materials with applications in space instruments [3]. The group is contributing its expertise in laser spectroscopy, optic design, detector development and qualification of spectroscopy components to different cross-sectoral projects within TLS. In this work we're presenting first results on coherent phonon spectroscopy on space relevant minerals.

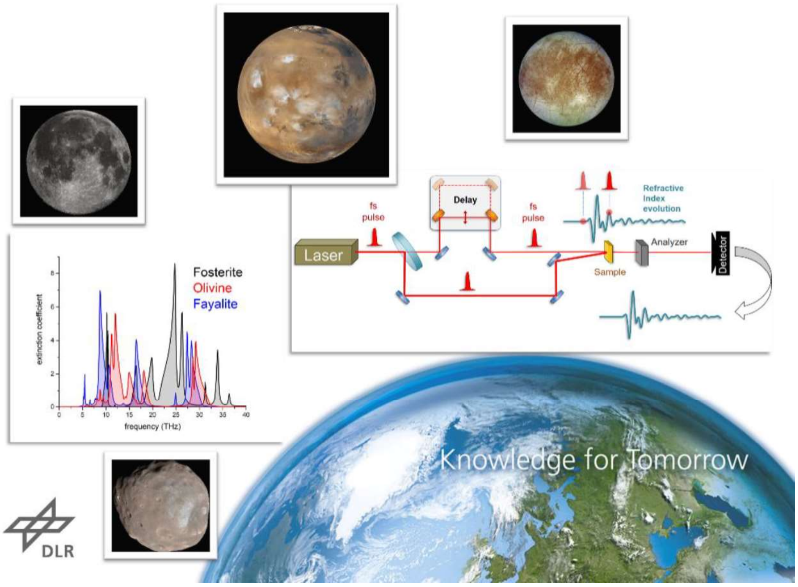

Figure 1. Towards new research enabled by space ready ultrafast lasers: Coherent phonon spectroscopy on space relevant mineral material.

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A platform for tracing single neurons in 3D from multi-colour labelled populations

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A fundamental aim in biology is to describe the morphology and connections of individual cells within tissue ensembles. Multi-reporter labelling technologies, such as Brainbow, apply stochastic expression of several fluorescent proteins to allow visualization of cell populations with single-cell resolution. However, extending this approach to generating objective quantification of anatomical features is more difficult and has to a large extent awaited the development of analysis platforms capable of extracting images of single cells in 3D. I will present a computational platform we developed - BRIAN (BraInbow Analysis of individual Neurons) allowing objective identification of voxels clusters, and their subsequent extraction to produce 3D images of single neurons. I will show that BRIAN allows multi-reporter samples to be analysed using existing tracing technology, to efficiently recreate single neurons from densely labelled tissue with sufficient anatomical resolution for sub-type classification, and describe dendritic projections over large brain volumes including with cleared tissue. The application of BRIAN here will be presented on melanopsin-expressing retinal ganglion cells, which are playing important roles in non-image-forming responses such as circadian entrainment, pupillary light reflex, and mood regulation as well as in visual perception.

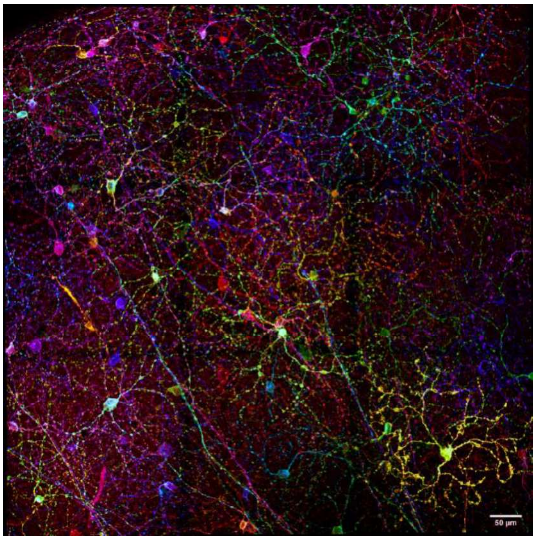

Figure 1. A retinal wholemount from an *Opn4Cre* mouse model with Cre recombinase expressed in melanopsin-retinal ganglion cells labelled using Brainbow and imaged using a confocal microscopy

Imaging the molecular markers of neurodegeneration in the ALS rat oligodendrocytes and microglia

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Amyotrophic lateral sclerosis (ALS) is a fatal neurodegenerative disease caused by death of motor neurons in the spinal cord and brain. Non-neuronal cells particularly of glial origin play an essential role in disease onset and progression. The aim of our study was to examine functional properties of two glial species of the spinal cord, oligodendrocytes and microglia in the ALS $SOD1^{G93A}$ rat with a particular focus on the expression and functional significance of the inwardly rectifying potassium channel Kir4.1 that is abundantly expressed in these glial cells.

We demonstrate that the expression of Kir4.1 is markedly diminished in oligodendrocytes of the $SOD1^{G93A}$ rat. Moreover, our data show an elevated number of dysmorphic oligodendrocytes, indicative of a degenerative phenotype. To assess physiological properties of oligodendrocytes, we prepared cell cultures from the rat spinal cord. The cells isolated from the $SOD1^{G93A}$ spinal cord displayed similar processes ramification as the control, but expressed a lower level of Kir4.1. Whole-cell patch-clamp recordings revealed compromised membrane biophysical properties and diminished inward currents in ALS oligodendrocytes, while the Ba^{2+}-sensitive Kir current was decreased in ALS oligodendrocytes [1].

The microglia in the ALS rat spinal chords shows remarkable clustering in ventral horns, already starting in presymptomatic animals. Colocalization of Kir4.1 and microglial Iba1 staining was 2-3 times more abudant in presymptomatic as well as in symptomatic animals compared to individual cells The morphology of micorglia also changes in ALS where the number and length of processes dicreases almost the same in pre- and symptomatic animals. It was also shown that these clusters bare a higher accumulation and colocalization with Kir4.1 and Iba1 of mutated SOD1 compared to individual cells. Similarly, the transmembrane marker of microglial fagocitosis, CD68 was also augmented in these clusters.

The spinal chord micorglial cells were cultured and explored with patch-clamp electrophysiology by using an innovative movable microscope stage [2] to facilitate the gigaseal formation of the cell membrane and patch pipette. These measurements demonstrated a decrease of Kir Ba^{2+}-sensitive currents.

Altogether, our findings provide the evidence of impaired Kir4.1 expression and function in $SOD1^{G93A}$ spinal cord oligodendrocytes and microglia with this channel's particular abundance in clusters typical of ALS pathology and its progression.

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High stability Graphene/c-Si Schottky junction solar cells for indoor application

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Abstract. As the global energy demands increase on a yearly basis, simultaneously with technology development and connectivity uptrend, there is a clearly defined need for compact and reliable clean energy sources. In particular, small-scale photovoltaic devices for **indoor** usage iPV (indoor Photovoltaic) are particularly attractive options to these demands. From the market perspective, if we look in only one segment of autonomous devices, like Internet of Things, IoT (with P=μ-mW), iPV has very bright future. Market increase forecast for produced smart sensors systems and wireless communication devices started from 43 billion in 2023 and ended on 1 trillion in 2035 [1,2] with market values of 1.6 billion of US$ till 2025.[5]. Today iPV devices has power of about 3–100 μWcm^{-2} [1]. The main focus of this paper is to propose facile, low-cost fabrication approach towards efficient indoor light harvesters based on highly stabile graphene/n-Si Schottky junction solar cells. Furthermore, we validate operational stability of such devices and identify critical structural points responsible for performance degradation during the ageing process. Finally, we suggest ways to mitigate these negative effects by adjusting trade-off between device design and fabrication cost. The cells exhibit the efficiency of 6% and only 0.2% in indoor and outdoor conditions, respectively; demonstrating a 30 times increase in efficiency indoors [3]. With Raman spectroscopy, Thermovision (Fig. 1) and LBIC (Fig. 2) we validate the operational stability of such devices over a period up to 60 months. The high efficiency under indoor light is caused by large shunt (parallel) and serial resistances and intense fast three body recombination. The Ag contact degradation mostly impacts the cell performance. The cells are produced from liquid phase exfoliated graphene made by Langmuir-Schaefer assembly [4]. In addition, cells were annealed (A cells) and then functionalized for 5 min by UV/ozone (AO cells). We found that AO cells exhibit a better performance than A cells even though they have a lower EQE. We assume that our cells are better in dark than light conditions because of intense recombination owing to the very highly doped Si ($Nd \sim 10^{19} cm^{-3}$). Those cells have high concentrations of carriers leading to efficient photo conversion, but more light results in more carriers and a higher recombination rate, consequently reducing the efficiency of the cells. A good performance at low light intensities could significantly extend the usage of Si solar cells in indoor light conditions.

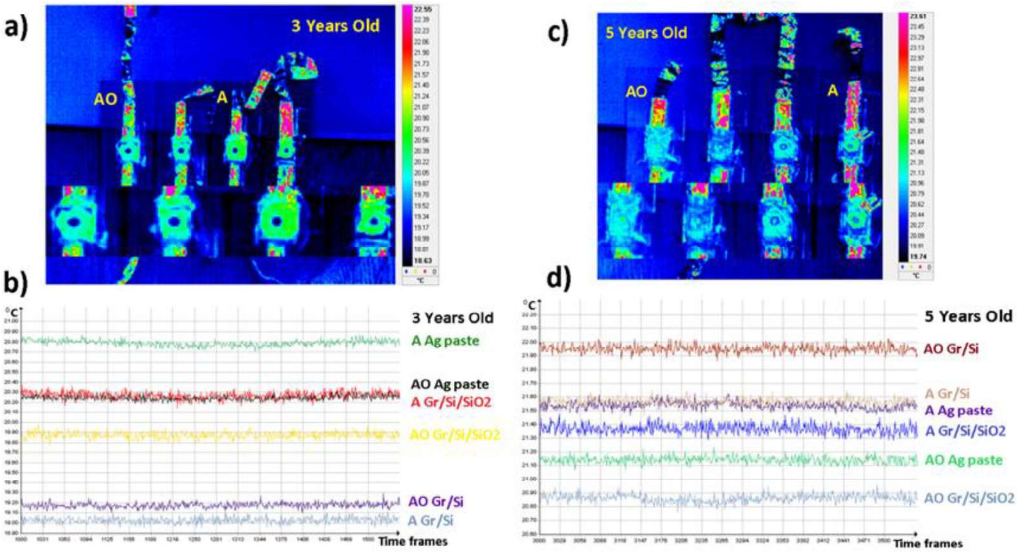

Fig. 1. Thermovision FLIR IR stability maps of A and AO solar cells, 3 and 5 years old. From the homogeneity of the effective temperature distribution on the materials we can't see defective (hot/cold) shunt places in cells in both a) 3 or c) 5 years old samples. Time diagram of b) 3 and d) 5 years old samples show particularly uniform effective radiance distribution from separated area of materials (Gr/Si, Gr/Si/SiO2 and Ag paste) during time.

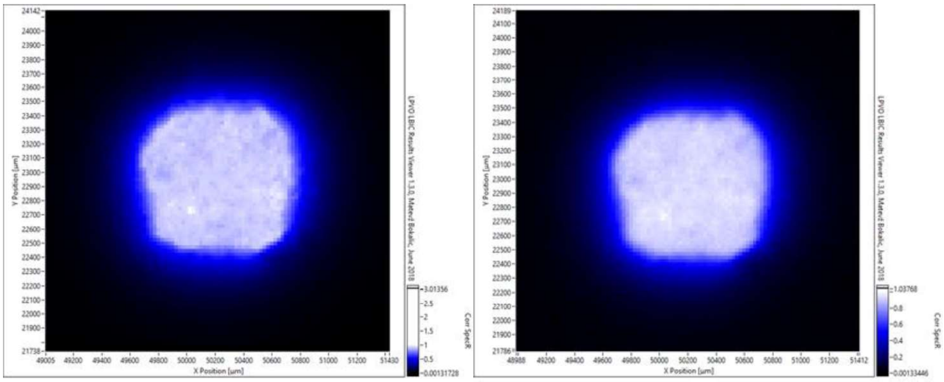

Fig. 2. LBIC measurements of AO solar cells 3 years old for left) 642nm, right) 1060nm laser light.There is no visible spatial degradation; however this gives no answer on overall degradation. We can notice slightly more spatial inhomogeneity's at 642nm, which may arise due to inhomogeneity of the top contact layer, which is a graphene layer.

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Light responsive polymeric microstructures for robotics and photonics applications

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Abstract. Responsive polymers patterned ad the nanoscale in 3D designs allow for functional microstructures with a wide range of applications. The reversible shape change and refractive index variation of smart polymer such as liquid crystalline networks (LCNs) open for a dynamic operation encoded in the material properties and design. LCNs, also defined as "artificial muscles", offer the possibility to perform different movements depending on their molecular alignment and, by optically controlling their elastic deformation, a wireless activation of microstructures is attained. The light driven elastic deformation of the LC polymeric nanostructures is characterized by a sub-millisecond dynamics that rules the robot evolution and the timescale of the photonic property change.[1] To reach such temporal response, light has been used not only as energy source for activating the but also for patterning microstructures in 3D with nanoscale precision. While most of the available lithographic techniques give access to 2D geometries, a truly 3D shaping can be achieved by Two photon Direct Laser Writing (TP-DLW).[2] By manufacturing LCNs with TP-DLW, untethered microrobot operation and tunable integrated photonic structures will be described in this contribute. We will present as a micro walker is able to advance on different substrates;[3] and a micro hand can catch micro objects by an external light control and even autonomously, depending on the target optical properties.[4] In the field of polymer photonics, tunable devices such as a 2D grating structure with sub-millisecond time response has been demonstrated for optical beam steering exploiting an optically induced reversible shape-change.[5] Further optical functionalities can be addresses through integrated photonic circuits where single mode waveguides coupled to whispering gallery mode resonators (WGMR) enable dynamic signal manipulation and filtering.[6] The versatility of TP-DLW and responsive shape-changing materials has demonstrated its great potential in these applications, promising novel intelligent microstructures able to sense and react both for micro robotic applications and light manipulation in tunable photonic devices.

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Engineering versatile optical sensors for highly sensitive SERS analysis of liquid biopsies

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Abstract. Liquid biopsies represent a minimally invasive tool for the early diagnosis of widespread diseases as well as for routinely patients monitoring by tracking selective biomarkers. Owing to its high sensitivity, optical detection techniques based on surface enhanced Raman spectroscopy (SERS) are capable of providing information on the molecular content of analyzed samples thus constituting the most promising analytical method in clinical research, as alternative to traditional bioassays.[1,2] With the attempt to develop point-of-impact diagnostic devices, we successfully combine 3D printing and soft-lithography processes with plasmonic nanoparticles (NPs) synthesis for the development of multifunctional lab-on-chips (LOCs) platforms integrating SERS-based sensors for molecular liquid probing. As a matter of fact, LOCs enable to easily handle very small volumes (micro- to nanoliters) of biological samples as well as to perform multifunctional analyses on the same restricted volumes while avoiding cross-contaminations.[3] This is crucial for pathologies whose diagnosis relies on the ratio of more than one biomarker (e.g. neurodegenerative Alzheimer's Disease - AD). LOCs versatility is guaranteed by 3D printing process enabling rapid prototyping of devices with networks of channels and detection chambers of varied size and shape.[4] Then, high-resolution direct laser writing (DLW) is explored to direct embed stimuli-responsive micro-structures in the microfluidic networks, working as valves and actuators to load and control liquid sample within the device. SERS functionality is achieved with gold NPs with tunable resonant properties (from 500 nm to 800 nm).[5] Finally, NPs surface chemistry is engineered to increase their affinity towards target specific molecules recognized as pathological biomarkers.[6] The resulting devices, collecting multiple functions and detection configurations, will provide high sensitivity, speed of analysis, low sample and reagent consumption, measurement automation and standardization on a highly integrated dynamic platform that will revolutionize liquid biopsy making it costless, on-chip, handy and easy to use.

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The thermal effect during microwave ablation treatment of Hepatocellular Carcinoma

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Abstract. Hepatocellular Carcinoma (HCC) accounts for more than 75% of all liver cancers representing the fourth major cause of cancer-related death [1]. One of the most persuasive treatments for HCC is microwave ablation (MWA) particularly recommended for COVID-19 patients with liver tumors as a minimally invasive procedure with a short recovery time. For this study, calculations were performed using the COMSOL Multiphysics software package based on the finite element method [2]. Simulation conditions include a 10-slots antenna operating at microwave frequency of 2.45 GHz, the input power of 10 W, and parameters corresponding to the liver tissue (healthy and tumoral) taken from ref. [3]. The antenna immersed into the tissue radiates energy that is converted into the heat invading the tissue (Fig. 1a). The absorbed energy converted into thermal energy leads to an increase in the tissue temperature (Fig.1b). The region where $\Delta T = T - T_b \geq 15$ ◦C (T_b is the blood temperature) is mainly located inside the tumor indicating a small risk of damaging healthy tissue (Fig. 1c). The damage zone is concentrated around the tip and slots of the antenna, while the backward heating effect is smaller as depicted in Fig. 1d.

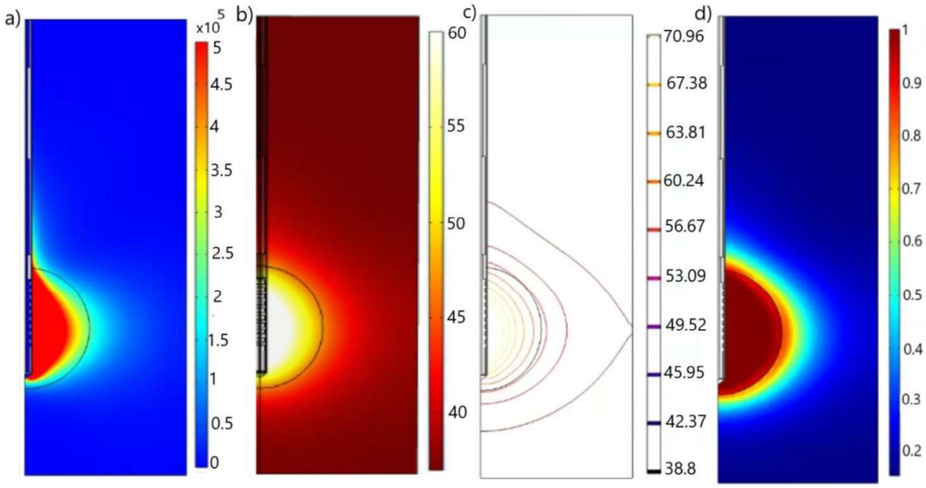

Figure 1. a) The total power dissipation density (expressed in W/m^3). b) The temperature (expressed in °C) distributions in the liver tissue after 600 s of microwave ablation. c) Spatial distribution of ($\Delta T = T - T_b$). d) Fraction of necrotic tissue after 600 s of microwave ablation.

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Nanoscopy of transition metal dichalcogenide based van der Waals heterostructures fabricated by the wet and dry transfer methods

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Abstract. The research of two-dimensional (2D) crystals beyond graphene has led to a new idea of stacking these atomically thin layers one on top of the other into the so-called van der Waals heterostructures (VdWhs) [1]. The combination of different 2D crystals into a VdWh gives rise to new electronic and optical properties, while preserving the intrinsic properties of the constituent crystals [2]. This paired with the vast choice of currently available 2D crystals, renders VdWhs as an interesting prospect for various applications in the fields of electronics to optoelectronics [2].

In this work we investigate VdWhs produced from 2D transition metal dichalcogenides (WS_2, WSe_2, MoS_2 and $MoSe_2$), which are considered to be strong candidates for applications in the field of optoelectronics [2]. The fabrication of VdWhs was done by using the wet and dry variants of the transfer method [3]. The structural and optical properties of the VdWhs fabricated by these methods were thoroughly investigated by atomic force microscopy, Raman spectroscopy and photoluminescence spectroscopy. The analysis of the results obtained from the afore mentioned characterization techniques shows that VdWhs have low amount of surface contaminants, unmodified crystal structure, high and uniform photoluminescence intensity. The VdWhs are found to have interlayer contaminants which are accumulated in pockets of different shapes. In fact, achieving clean interfaces is one of the main challenges of the transfer methods.

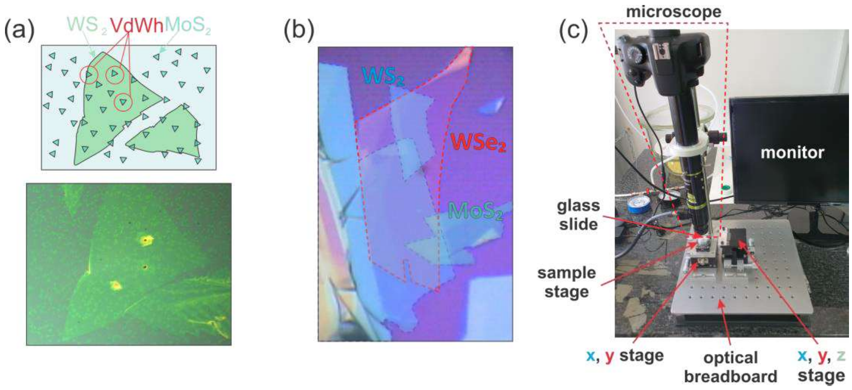

Figure 1. (a) MoS2 / WS2 VdWh. (b) WSe2 / WS2 / MoS2 VdWh. (c) Dry transfer setup

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Quantum Information Processes: Single Photon Sources on InGaN QD

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Abstract. Proof-of-principle demonstrations with InAs/GaAs,[i] GaN/AlN[ii] and phosphide-compatible material systems have shown that solid-state quantum dots (QDs) can be near-ideal sources of quantum light, albeit covering narrow wavelength ranges. Radiative recombination from exciton (X) and biexciton (XX) states, confined in InGaN/GaN wurtzite quantum dots (QD), could potentially provide useful sources of visible quantum-light, targeting applications in the nascent field of quantum information, amongst others. To assess their potential, a theoretical methodology with which to calculate single-particle states was established, based on both symmetry exact strain-dependent envelope function Hamiltonian, with contributions from the spin-orbit interaction, crystal-field splitting, piezoelectric and spontaneous polarization all included. Excitonic states were found using the configuration interaction method that takes quantum mechanics effects of charge correlations and exchange explicitly,[iii] whilst taking into account the important second-order effect of piezoelectricity in this III-N material system.[iv] The influence of mirror changes was eliminated with a Makov-Payne correction, adapted to wurtzite lattices. The optimal QD morphology for use in quantum light sources was determined by varying the aspect ratio, based on the optimization of the target function, which depends on the biexcitonic shift and optical dipole matrix element of the excitonic transition. The model established in this work is validated against experimental results on existing single GaN QD sources.[2] Further to this the model predicts that, with suitable variation of the In concentration within the QD, from 20 to 70%, it is possible to find morphologies that emit throughout the entire visible spectrum, i.e., from ~3 to 1.6 eV.[v] Within this range of In-concentrations conditions can be found for the formation bound biexcitons.[5] The competition between strong confinement in InGaN QDs and the internal electric field, generally reported in wurtzite III-N, was also investigated, as well as its effect on existence of bound biexcitons and a vanishing fine-structure spitting. The latter is a prerequisite for the on-demand generation of the entangled-photon pairs from InGaN-QD's.

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Topological Charge Switch in Active Multi-Core Fibers

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Abstract. The multi-core fiber (MCF) is a physical system of high practical importance. In addition to standard exploitation, the MCFs may support discrete vortices that carry orbital angular momentum suitable for spatial-division-multiplexing in high capacity fiber-optic communication systems which may also be attractive for applications in high power lasers. The main concern of our study has been related to optimization of the conditions capable to ensure transfer of high coherent light through the MCFs. Regarding this we firstly proved the possibility of nonlinearity managed propagation of highly coherent vortices carrying huge power through the passive circular MCFs, which consist of small number of periphery cores. The central core has been shown to play the role of optional switch/gate of coherent light transfer [1]. In addition, the effects of the presence of central core and material loss/gain of all cores on the linear MCF system eigenvalue commensurability conditions have shown significant impact on the coherent planar and vortex mode dynamics [2]. All these findings stimulated the investigation of possibility to amplify the power transferred through the MCF via vortex carriers by inducing effects of the saturable gain and non-saturable loss in the periphery and/or central cores [3].

We numerically consider three cases of active circular MCFs. In the first case active were only periphery cores. Secondly we investigated response of the system with only central core active, while last case included all cores to be active. The light propagation is modeled by the generalized nonlinear difference-differential Schrödinger equations with saturable nonlinear pumping and non-saturable loss [3]. The results for MCF with 4, 5 and 6 periphery cores have shown that the active periphery is the most promising candidate for purposes we such as high power transfer or topological charge switch. The central core appears to play role of mode dynamics moderator. Being the 'singular phase' point of vortex, the central core which only passively takes part in tunneling energy towards the periphery cores, can support the coherent light amplification through the MCF. Briefly, we obtained the total power saturation via vortices to the values which can extend the initial power for one or two orders of magnitude. The last can be managed by suitable tailoring of loss and gain ratio in fiber cores. Interestingly, the previous can be followed with the change of the vortex topological charge value, i.e. transition between different vortex states [4].

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Monitoring of bone marrow stem cell niches by two-photon microscopy

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Abstract. Bone marrow represents the most investigated and complex multipotent stem cell niche in adult human body. Intravital imaging can provide reliable insights into dynamic bone marrow stem cell behavior and response to different physiological and pathological cues. Two-photon microscopy (TPM) allows us to probe previously inaccessible stem cell dynamics. Thus, two-photon-excited fluorescence and visualization of bone through second harmonic generation from collagen in even long bones can be applied for tracking of hematopoietic stem cell divisions, their mobility upon administration [1] and competition for bone marrow space with leukemic cells [2, Figure 1].

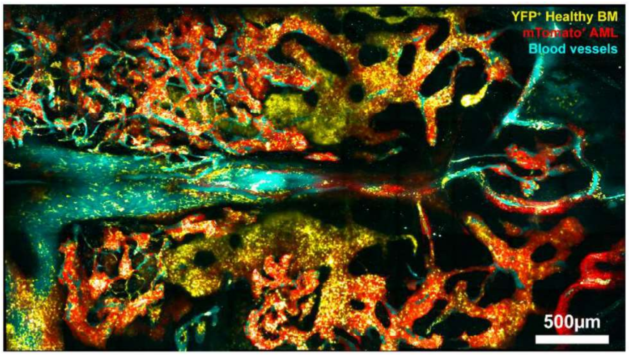

Figure 1. Intravital microscopy image showing communication of leukemic cells (mTomato+; red), non-malignant hematopoietic cells (YFP+; yellow) and the blood vessels in bone marrow (Cy5-dextran+; cyan) [2].

Due to deep tissue penetration and relatively minor light-induced thermal and chemical damages, TPM can improve the lineage tracing approaches for imaging of bone marrow stem cells at a single-cell level. Recent findings suggested that TPM can be used for reliable monitoring of stem cell mitochondrial bioenergetics within complex 3D environments [3] and single stem cell tracking of very small-size subsets within heterogenic cell populations [4]. Application of TPM for studying of healthy and neoplastic bone marrow stem cell positions and spatial relocation in aging and diseases can reveal novel biomarkers and potential targets relevant for medicine. Thus, in the near future, it is meaningful to expect further increase of imaging resolution quality and access to yet unrevealed stem cell niches, such as bone marrow adipose tissue, as well as subcellular compartments in native-like form.

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Exploring The Active Galactic Nuclei Through Photometric Variability

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Abstract. Active galactic nuclei (AGN) are located in the cores of galaxies and surround their central supermassive black holes (SMBHs). AGN have been studied for over seven decades. Monitoring of these objects helped us to reveal many interesting things about them. Some of them have been monitored much earlier, before being classified as AGN, so their photometric light curves can span for over a century. Here we explore the photometric variability time scales of a sample of well studied AGN. We discuss mechanisms that can produce the observed variability time scales, as well as implications of such scenarios.

Two - photon microscopy as a tool for the studying erythrocyte morphology in a Diabetes mellitus type 1 patients

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Abstract. Fluorescence emission was detected during the interaction of ultrashort laser pulses with hemoglobin (Hb) and red blood cells (RBC) [1,2]. The formation of fluorescent photoproduct was associated with the interaction of ultrashort laser pulses with Hb [3]. Here we want to present some photophysical properties of (Hb) photoproduct and to apply that knowledge for studying erythrocytes morphology in a patient with type 1 diabetes (T1DM). Diabetes mellitus (DM) represents a group of metabolic disorders characterized by hyperglycemia and insulin secretion defects [4]. Erythrocytes as a glucose-consuming cells are affected by the glucose level variation so that their morphology and function are altered [4,5]. Spatial distribution of photoproduct was measured as the change of two-photon emission signal (2PE) and reflects the position of Hb in the single RBC [6]. Our preliminary results suggest differences between healthy donor RBC Fig 1 a) and T1DM RBC Fig 1 b) in a shape and Hb distribution. Although preliminary data on T1DM RBC deformability determined by ektacytometry did not reveal any disturbance compared to normal RBC, we still assume that observed alteration in the distribution of Hb can have consequences to the RBC physiology in T1DM patients. However, further investigations are needed.

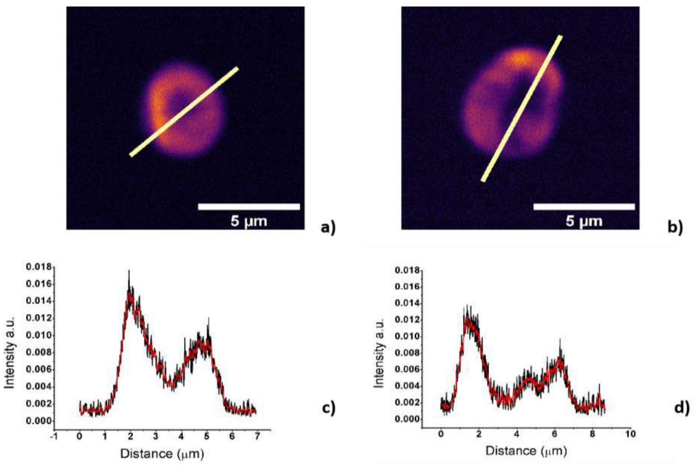

Figure 1. a) Two - photon microscopy image of RBC from a healthy donor and b) T1DM patient c) Spatial distribution of photoproduct as a change of 2PE signal through the cell diameter in a healthy donor RBC and in the d) T1DM patient. Black curve represents raw data plot and red curve are obtained using adjacent point averaging by the usage of percentile filter.

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Valence Band Electronic Structure of Hybrid Nanoparticles Studied by Synchrotron Radiation Aerosol Photoemission Spectroscopy

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Abstract. Aerosol photoemission spectroscopy is an important method for studying the electronic structure of submicrometer particles, free from the influence of substrate or solvent [1-4]. This technique relies on the interaction of focused beam of particles (typically ~100 nm in size) with ionizing radiation under high vacuum conditions. In this approach the aerosol particles can be directly produced from a solution or a colloidal dispersion, which opens a possibility for investigations of a variety of hybrid nanosystems that can be produced by conventional wet chemistry methods. In addition, by using tunable synchrotron radiation as an excitation source one can obtain high-resolution photoelectron spectra in the investigated kinetic energy range. In this report, we describe the methodology and present the results of the aerosol photoemission spectroscopy studies of different hybrid nanostructures, including hybrid perovskites and biomolecule-functionalized nanoparticles.

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Optical vortices in waveguides with discrete and continuous rotational symmetry

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Abstract. Coherent vortex structures are fascinating physical objects that are widespread in nature: from large scale atmospheric phenomena, such as tornadoes and the Great Red Spot of Jupiter to microscopic size topological defects in quantum physics and optics. Unlike classical vortex dynamics in fluids, optical vortices feature new interesting properties. For instance, novel discrete optical vortices can be generated in photonic lattices, leading to new physics. In nonlinear optical media, vortices can be treated as solitons with nontrivial characteristics currently studied under the emerging field of topological photonics. Parallel to theoretical advances, new areas of the engineering applications based on light vortices have emerged. Examples include the possibility of carrying information coded in the vortex orbital angular momentum, understood as a spatial-division-multiplexing scheme, to the creation of optical tweezers for efficient manipulation of small objects. This report presents an overview highlighting some of the recent advances in the field of optical vortices with special attention on discrete vortex systems and related numerical methods for modeling propagation in multi-core fibers.

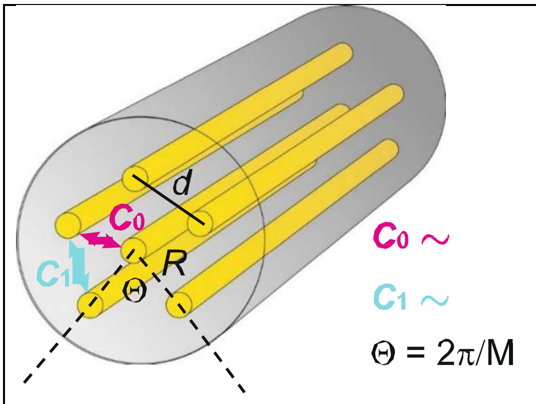

Fig. 1 Schematic of an MCF with M = 5 periphery cores and the central core. Geometric parameters that dominantly determine coupling coefficients C0 and C1 , are the distance between the central and each of periphery cores R and the distance between two neighboring periphery cores d = 2R sin(π/M). Coupling coefficients depend on the geometry and refractive index of cores. Here, all periphery cores are assumed to be identical, while the central core can be different

The light vortices – ring shaped modes guided by the MCF with linearly coupled circular array of cores - are shown to be promising candidates for applications in high-capacity communication systems and high-power fibre lasers. They are dynamically stable structures characterized by invariant orbital angular momentum and energy capable to carry huge power over long distances without significant losses by properly arranging the system geometry and structural parameters of the cores and cladding.

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Using artificial neural networks to make temperature sensing calibration curve

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Abstract. In this study we analyze possibilities of determining the temperature sensing calibration curve of thermophosphors using artificial neural networks (ANN). For machine learning analysis of data we have used Solo+Mia software package (Version 9.0, Eigenvector Research Inc, USA). Experimental results were obtained using experimental setup presented in detail in [1,2]. Upconverting material was excited at 980 nm by using pulsed laser diode. Usual, conventional way is to use intensity ratios of spectral lines for determining the calibration curves for remote temperature sensing [3-5]. Based on thus obtained data we have trained the neural network to recognize temperature of sample based on its luminescence spectrum. For training we have used 69 measured spectral points between 525 nm and 560 nm, so the neural network has 69 input nodes. Although training of neural network took some time (in minutes, on i7 processor based laptop), the neural network provides quick and strait answer when questioned with data of samples heated to unknown temperatures. Predicted values of two unknown temperatures provided by the neural network in Fig. 1. are about 401 K and 572 K. This kind of approach is very versatile, and, if needed, improved by deep learning.

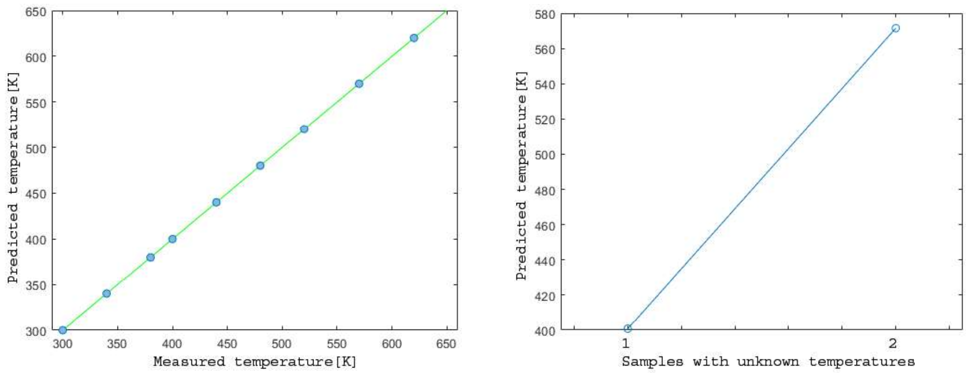

Figure 1. Temperature sensing calibration curve obtained by ANN, simulated by SOLO software (left), predicted temperatures of samples heated to unknown temperatures (right).

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Multi-SENSor SysteM and ARTificial intelligence in service of heart failure diagnosis (SensSmart)

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Abstract. The presentation will introduce SensSmart project recently funded within the Programme IDEAS, Science Fund, Serbia. The ambition of the project is to provide proof-of-principle of the new heart failure (HF) diagnostic methodology combining multiparameter measurements with artificial intelligence.

HF, inability of heart to pump sufficient amount of blood or impaired relaxation, is a serious condition associated with morbidity, mortality and high healthcare expenditures. When diagnosed in an early phase the condition can be arrested or even reversed, while a late diagnosis inevitably leads to the fatal outcome. However, HF is difficult to diagnose in primary care, thus leaving many patients undiagnosed and untreated.

SensSmart project focuses on development of the multi-sensor technology for timely HF diagnoses, which uses non-invasive measurements of the electro-mechanical processes in a cardiovascular system, such as the electrocardiogram, heart sounds, heart movement and arterial pulsations. The new technology is deeply rooted in our preliminary work on the photonics-assisted polycardiographic and other physiological measurements [1, 2]. The new sensing techniques and AI-assisted signal analysis [3,4] will enable much needed operator-independence and speed, while maintaining the test simplicity, accuracy and low cost. An important criterion for the HF features' selection will be their relation to the underlying physiological processes, which will ensure interpretability and transparency of the decision-making model.

Finally, presented will be the preliminary results and challenges of the proposed multiparameter measurement approach [5] with accent on the photonic sensors used.

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Photonic, electronic and ionic collisional data represented in Belgrade database for inner-shell excitation and ionization of atoms

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Abstract. The inner-shell excitation and ionization of atoms have been extensively studied during past 60 years, primaraly owing to the development of spectroscopic methods used by synchrotron radiation and in less extent by electron impact. Different kind of photonic, electronic and ionic data have been covered by VAMDC and RADAM [1] consortia. Our aim is to develop a possibility of storing ejected electron spectra obtained either by photoelectron or electron spectroscopy methods in which recorded electron intensities are shown versus incident photon/electron energy or kinetic energy of ejected/scattered electrons. A specific database designed for the curation of such spectra is BeamDB – Belgrade Electron Atom/Molecule DataBase [2] with the example of the spectrum given in Fig.1.

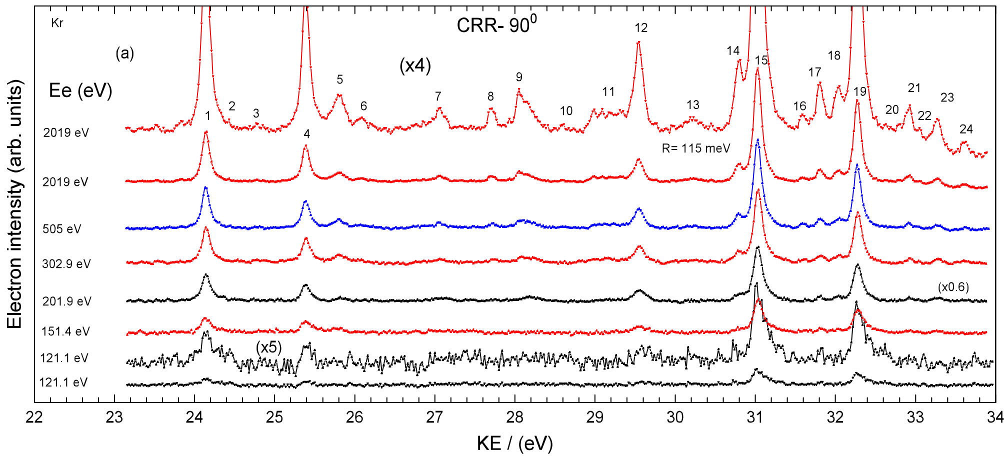

Figure 1. An example of the ejected-electron spectrum of Kr in the 22-34 eV range obtained at electron impact energies from 121.1 to 2019 eV [3].

The interpretation of spectra is complicated not only by configuration interaction in the initial states but also by the fact that often the binding energies of neither the initial nor final states are known accurately. De-excitation pathways due to Auger transitions may lead to multiple ionized atomic species (for Xe atom they have been investigated up to Xe^{6+}) [4].

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Label-Free Third Harmonic Generation Imaging and Quantification of Lipid Droplets in Live Filamentous Fungi

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Abstract. Lipids in oleaginous filamentous fungi are considered to be a valuable alternative resource for various biotechnological applications. *In vivo* label-free imaging enables monitoring of fungi lipid droplets (LD) accumulation with the minimal unwanted effects on the metabolism. LDs are the main source of contrast [1] in the Third Harmonic Generation (THG) microscopy method [2] due to their optical properties (high refractive index). The THG phenomenon is utilized in nonlinear laser scanning microscopy that employs ultra-short laser pulses for imaging. We present *in vivo* and label-free THG imaging of the individual hyphae of *Phycomyces blakesleeanus* (Figure 1), an oleaginous filamentous fungus with very rapid growth rate. The THG signal was detected in the forward direction (transmission arm) by PMT through Hoya glass UV filter with peak transmission at 340 nm. The Yb KGW laser, wavelength 1040 nm, pulse duration 200 fs, and repetition rate 83 MHz, has been the source of the infrared femtosecond pulses. The LDs from THG images were quantified by two image analysis techniques: Image Correlation Spectroscopy (ICS) and software particle counting – Particle Size Analysis (PSA). We used hyphae that undergo nitrogen starvation, which is known to cause alterations in lipid metabolism and increase of cellular lipid reserve. The two analysis methods gave similar results. The applicability of the described procedure can be easily extended to other unicellular organisms for the *in vivo* quantification of LDs since there is no need for sample labeling, fixation or any other specific preparation. In addition, we demonstrate that the ICA is suitable for THG images, although it is primarily developed and have been mostly used for fluorescence signals so far.

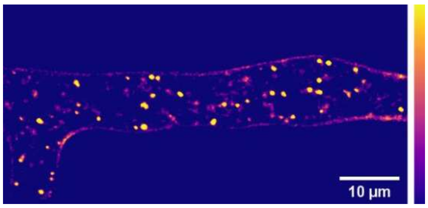

Figure 1. Label-free THG image of live *Phycomyces blakesleeanus* hyphae (4.5h nitrogen-depleted conditions). The bright structures are lipid droplets. The image was taken with Zeiss 40x 1.3 oil objective lens. The average laser power: 20 mW. Color intensity bar: deep blue – the lowest, yellow - the highest THG signal.

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Determination of spatial resolution limits of nonlinear laser scanning microscopy

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Each microscopic set-up is characterised by its own point spread function (PSF), which describes how points from the object are abberated in the image. We determined the axial and the lateral resolution of a nonlinear laser scanning microscope by measuring its PSF. Two – photon excited fluorescence method was used to obtain signal from sub-resolution fluorescent beads. Beads were of the following diameters: 4µm, 0.2µm and 0.1µm (ThermoFisher SCIENTIFIC) and were excited with wavelengths of 730nm and 980nm. We used two different objectives, Zeiss 20x 0.8 and Zeiss 40x 1.3. The laser beam was also expanded in order to fill the entrance pupil of the objectives. The PSF values were calculated by deconvoluting experimentally obtained profiles (Fig 1) with simulated theoretical functions of the bead. For lateral measurements we obtained the following values with wavelength of 980nm: 0.640µm for 20x 0.8 objective and 0.400µm for 40x 1.3 objective; and with wavelength of 730nm: 0.450µm for 20x 0.8 objective and 0.280µm for 40x 1.3 objective. These PSF width values are in compliance to the theoretical values set by the diffraction limit and can be further used to deconvolve images obtained on this microscope.

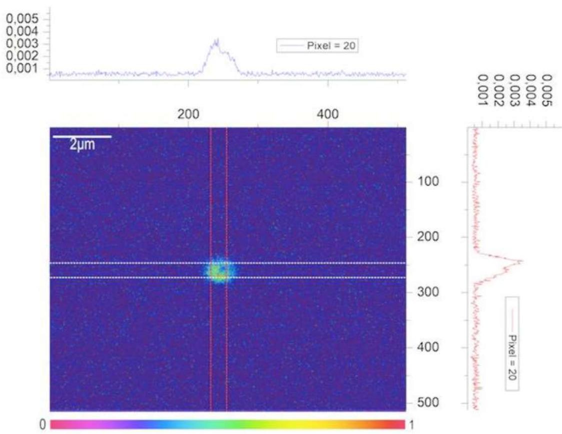

Figure 1. TPEF image of a fluorescent bead with corresponding intensity profiles. To reduce noise, the values are averaged to 20 pixels each. Marked profiles are also drawn in the figure. The 40x 1.3 lens and excitation wavelength of 730nm was used.

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Synergy of interference, scattering and pigmentation for structural coloration of *Jordanita globulariae* moth

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Abstract. Structural coloration has attracted a lot of attention due to its significance in biophotonics and biomimetics. Structural and pigment colorations are omnipresent in insects, producing a range of colors for camouflage, warning, mimicry and other strategies necessary for survival. The coupling of structural and pigment colorations has been largely unnoticed. Herein we show how pigments, scattering and interference work together in two-dimensional waveguiding structures to produce the coloration of *Jordanita globulariae* (Huebner, 1793), a moth whose forewings sparkle with slightly iridescent green scales. we reveal the structure and function of the scales of the *Jordanita globulariae* moth through morphological characterization, spectral measurement and numerical simulation. The synergistic operation of structure and pigments is analyzed. We also discuss the role of this particular coloration in the moth's lifestyle.

Laser beam waveguiding capabilities of the suspension of Chlorella sorokiniana in water

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Abstract. Controlled light guiding to target regions in biological and biomedical systems is important for applications like sensing and diagnosis. The penetration depth in tissues, limited due to scattering, is increased by using conventional optical waveguides, built on materials like silica glass and hard plastics. More potential for formation of biophotonic waveguides having higher biocompatibility and biodegradability have natural biomaterials, like living cells.

Strong scattering and absorption loss in cells is overcome by nonlinear effects arising during laser light propagation through suspensions of living cells, like marine bacteria [1]. Microalga *Chlorella* shows more attractiveness due to robustness, simple structure, high growth rate and ability to grow in various conditions, and its species *Chlorela sorokiniana* is most robust and most resistive to heat and intense light [2, 3].

We examined the propagation of the 532 nm CW laser beam of various powers through the suspension of freshwater green microalga *C. sorokiniana* of various concentrations. Due to nonlinear effects, like thermo-optical, scattering, optical gradient forces, the beam modified. Self-guiding and the changing of cross-section occurred for chosen parameters of power and concentration. Some of the outcomes might be of interest for applications in biophotonics and biomedicine: waveguiding, medical imaging and optimal propagation of laser beam in biological suspensions.

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Dynamic interference of photoelectrons in two-photon ionization of hydrogen by intense short laser pulses

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Abstract. We studied sequential two-photon ionization of hydrogen atom whose ground (1s) and excited 2p states are coupled resonantly by an intense short laser pulse. The populations of states, as well as the photoelectron energy spectrum (PES), are calculated numerically using the wave-packet propagation method. The obtained PES shows an intensity dependent splitting of the resonant peak and associated modulations. The numerical results are analyzed using a three-level model (1s, 2p, continuum) [1]. It is shown that the splitting can be attributed to the existence of two dressed states whose quasi-energies repel each other by the field-induced coupling. On the other hand the modulations can be explained by the dynamic interference of the electron wave packets emitted with the same energy, but with a time delay at the rising and falling sides of the pulse.

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Joint event: Free Alignment precession optically pumped magnetometer

Low dead time, wide bandwidth optically pumped magnetometer for unshielded magnetorelaxometry of magnetic nanoparticles

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Abstract. Magnetic nanoparticles (MNP) offer a large variety of promising applications in medicine, e.g., magnetic hyperthermia and magnetic drug targeting. Quantitative imaging of the MNP distributions is crucial for planning and monitoring of these treatments. A promising method is magnetorelaxometry imaging (MRXI), where the MNP's response to multiple spatially different pulsed magnetic fields is recorded and an ill posed inverse problem is solved. Superconducting quantum interference devices (SQUID) are the state of the art magnetometers for measuring the MNP's relaxation signals. With optically pumped magnetometers (OPM) reaching similar sensitivities in the fT/rtHz region, they are a prominent alternative, offering flexible sensor positioning and the omission of cryogenic cooling. In OPM, an alkali metal vapor is spin-polarized using optical pumping. The interaction with the magnetic field to be measured is probed optically. Current OPM-MRX(I) is limited by the OPM bandwidth and by the OPM dead time after pulsing the magnetic field for MNP orientation. We will present and discuss on how to overcome these limitations by exploiting a pulsed OPM (OMG from Twinleaf). With microsecond, 1 W optical pumping, the 87Rb can be rapidly polarized after magnetic field switching, reducing the system dead time from tens of ms to 28 µs. The magnetic field is measured by analyzing the free spin precession of Rb. By extracting the instantaneous frequency and therefore the instantaneous magnetic field using Hilbert transform, the magnetometer bandwidth can be selected arbitrarily, e.g. 80 kHz (with caveats). Notably, the magnetometer noise is flat up to 1 kHz (the pump repetition rate), while above the noise increases linearly. Further, we will present how these findings were extended to a tabletop setup (Figure 1) for unshielded quantification of fast relaxing MNP. We will give an outlook on currently running experiments towards (unshielded) OPM-MRXI.

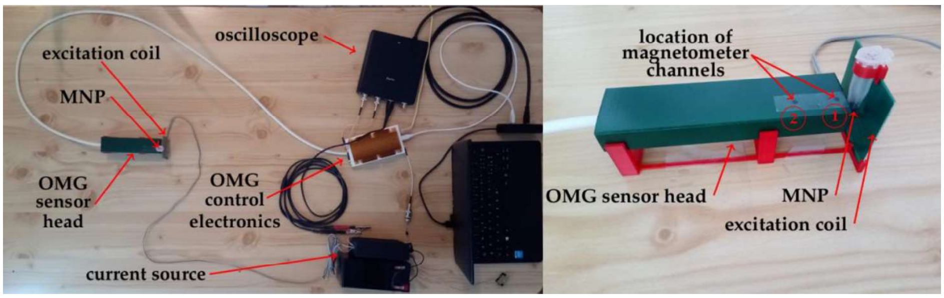

Figure 1. Portable tabletop OPM-MRX setup in unshielded laboratory environment (figure from [1]).

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Optically pumped magnetometers for unshielded applications

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Optically pumped magnetometers (OPMs) are the most sensitive sensors for low-frequency magnetic fields available today without the need for cryogenic operation [1,2]. Using advanced methods of laser optical spectroscopy of an alkali vapor they can detect changes in the magnetic field as small as femtotesla within a magnetically well-shielded environment. In unshielded geophysical applications such as mineral exploration or archaeological prospection, the main challenge is the handling of the large background geomagnetic field (20 - 70 microtesla). As this magnetic field is multiple orders of magnitude larger than the anomalous magnetic field changes of interest, a very high sensor dynamic range is required. Moreover, especially when aiming at mobile sensing applications, systematic effects connected to sensor rotations or vibrations within the background field can give rise to false-readings which again can easily outrange the intrinsic noise level of today's ultrasensitive OPMs by orders of magnitude [3,4,5]. We will review the phenomena important in this respect, show their implications for sensor characteristics, discuss ways for their elimination or correction, and compare approaches towards OPM sensors laid out for highly performant operation within the Earth's magnetic field.

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Algorithms for Estimating Frequency from Dumped Sinusoidal Signal

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Abstract. Output from Optically Pumped Magnetometer (OPM) is sinusoidal exponentially decaying signal at Larmor frequency ω_L (or $2\omega_L$) on top of an also decaying DC offset. From ω_L we can deduce the intensity of the magnetic field. The signal frequency, in our case, is in range from few kHz up to 100 kHz. The signal is digitized at 3 MSPS and can long up to t_s = 100 ms. Important requirement is that all the computation time t_c should be shorter than $t_s > t_c$. For such task, we found that few methods have been used in literature: FFT, Prony method and least-squares curve fitting [1]. In [1], FFT and fit methods reach fundamental Cramer-Rao limit in accuracy and precision, with FFT being faster, while Prony method lack such accuracy and precision. For signal estimated in this paper FFT is not precise enough, so we attempted zooming DFT method, where amplitude is calculated just in range around frequency of interest, with zooming to narrower range yielding better precision. As predicted, due to frequency shift by exponentially decaying DC offset the DFT is not accurate as presented on Fig. 1.

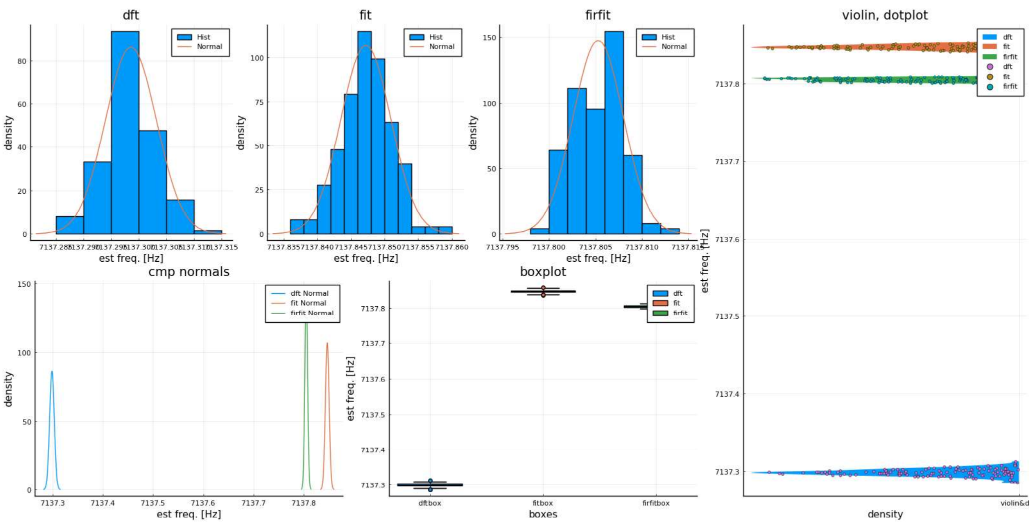

Figure 1. Comparison of few algoritms on measured data.

We also attempted to fit signal filtered with FIR filter, decimation approach is also tested but with limited success in accuracy and with limitation on estimating higher frequencies. Fit method is implemented in 4 steps [2] and in 1 step, where with good selection of initial parameters 1 step approach is slightly faster, with computation time around 3 s, but much simpler. In further work, acceleration of fit algorithm will be implemented in FPGA and integrated with the rest of the DAQ system.

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Optically pumped magnetometers in high background fields

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Abstract. In recent decades, the demand for ultrasensitive magnetometers has increased in a number of fields of science and industry. Various measuring methods and devices have been developed to provide magnetometers for the low-frequency, almost static signal range with sensitivities down to a few femtoteslas [1]. Based on the Zeeman resonance in alkali atoms, optically pumped magnetometers (OPMs) have shown spectral noise levels of a few $\mathrm{fT}/\sqrt{\mathrm{Hz}}$ in small magnetic background fields [2,3]. This exceptional sensitivity strongly degrades in unshielded environment within Earth's magnetic field as a consequence of the nonlinear Zeeman effect [4]. However, important applications (e.g. in geophysics, NMR research or methodologies for imaging of magnetic nanoparticles) would profit from high-performance operation of OPMs in high magnetic background fields. For example, by placing an OPM within a strong bias magnetic field, the sensors' sensitive axis can be predefined, enabling measurements of vectorial character [5]. For applications within Earth's magnetic field this would mean, that the sensor would need to operate in a magnetic field > 500 µT.

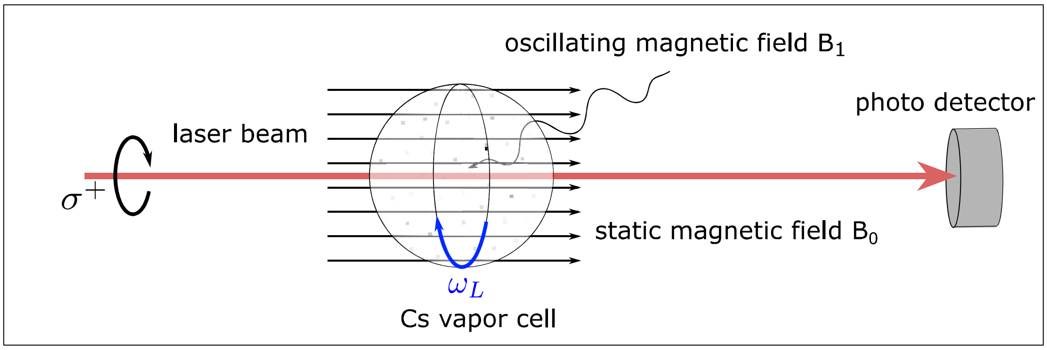

Figure 1. Sketch of the Mz OPM working principle, exploiting the double resonance consisting of an optical and a magnetic resonance of the cesium atoms driven by a resonantly tuned radio frequency field B_1 to measure the spin precession frequency ω_L, thus the static magnetic field magnitude B_0.

I will present work performed in context of my master thesis which aims to study the sensitivity of such a sensor configuration operating in the magnetic field range an order of magnitude above the Earth's magnetic field strength. The experimental setup design, simply sketched in Figure 1, as well as the observed nonlinear Zeeman splitting, the sensor performance, and ideas for further improvement will be discussed.

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DC Transverse Magnetic Field Scan in True Scalar Cs Magnetometers

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Abstract. We present a true scalar magnetometer (TSM) consisting of a paraffin-coated glass cell filled with Cs vapor with the $\overrightarrow{B_{rf}} \parallel \vec{k}$ geometry where $\vec{k}$ is the light propagation direction for the optical pumping and $\overrightarrow{B_{rf}}$ is a magnetic field oscillating at Larmor frequency [1]. Spin dynamics of this system are described by the Bloch equations in Cartesian spin components:

$$\frac{d\vec{S}}{dt} = \vec{S} \times \vec{\omega} - \gamma\vec{S} + \gamma_p\vec{k}.$$

The measurement of a DC magnetic field transverse to the main magnetic field in the system produced unexpected signal shapes in different transverse directions. Specifically, with the RF field in the YZ plane, the DC field in the x-direction produces unfavorable signal when modulated at sufficiently high frequencies. This difference in the dynamic RF projection phase is investigated by solving the above equation both analytically and numerically with different transverse field geometries. The theoretical calculations produce results that are in good agreement with the observed systematic effects during measurement.

We will present the measurements in both described geometries and discuss the differences between the obtained signals. We will also present the details of both calculation processes and discuss how the results compare to the measurements.

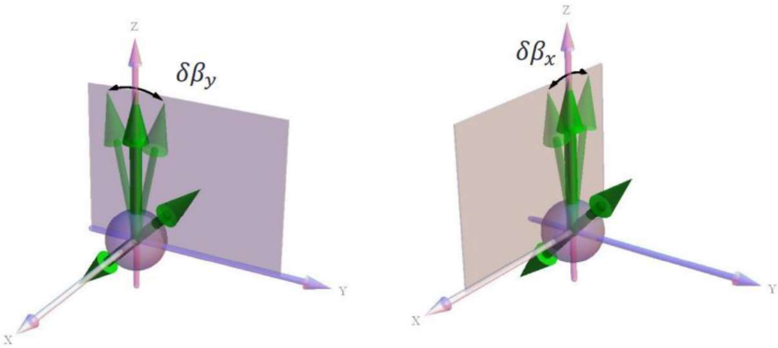

Figure 1. Two different field geometries considered for the DC transverse magnetic field scans. The additional magnetic DC field manifests as a small "rotation" of the main field in the appropriate direction.

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Why do we need accurate magnetometers and how to realize them

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Abstract. In most cases magnetometers have been developed with accent on sensitivity in order to detect very small changes of magnetic fields like brain waves, magnetic field of beating hart or variations of geomagnetic field. For such applications exist wide range of devices like fluxgates, GMR, SQUID, OPM (Optically Pumped Magnetometer), etc. [1]. Our goal is to improve accuracy or precision of OPMs based on vapors of alkali metals while retaining most of their sensitivity. Alkali metals are very well studied, their properties are measured and theoretically calculated to high precision. It is to expect that a sensor, based on, for example cesium, should be easy to deploy and understand in various schemes. It turned out this is not the case and future research is required in order to overcome heading errors of cesium based OPMs.

Accurate OPMs would have broad range of applications like precision experiments in fundamental research (like measurement of nEDM – neutron Electrical Dipole Moment), metrology, space explorations and for mapping of geomagnetic fields. The latter would benefit in archaeology, mining operations and from improved quality in tracking changes in global distribution and intensity of the Earth's magnetic field.

In my talk I will present the old nEDM experiment at PSI [2] and its improvements towards its next generation – n2EDM [3]. The last part of the talk will be dedicated to accurate magnetometry with Free Spin Precession (FSP) [4] and Free Alignment Precession (FAP) magnetometers. If time permits, prospects of a ^{4}He magnetometer will be discussed.

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New bounds on ultralight bosonic ALP matter mass and coupling strengths form Science run 5 of GNOME optical magnetometers network

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Abstract. In this work we present newest results from the science Run 5 of Global Network of Optical Magnetometers for Exotic physics (GNOME). Long uninterrupted time series and novel preprocessing methods provide more stringent bounds that are used to estimate exclusion domain of mass and interaction strength of hypothetical axionic or axion like dark matter in form of topological defects. Hypothetical axions or Axion Like Particles (ALP's) are form of ultralight bosonic matter that are postulated in order to solve strong CP problem and matter-antimatter imbalance in the Universe. This type od Dark Matter (DM) has a number of detectable signatures, one being in form of axionic field coupling to fermions that results in formation of pseudo-magnetic fields during passage through topological defect. The GNOME experiment is designed as GPS referenced worldwide distributed network of quantum cross-correlated sensors that increases its sensitivity reach and excludes false positives. Science Run 5 lasted from 24. August to 26. October of 2022 and included, at the highest extent, 11 stations and is characterized by lowest amount of noise, optimal station placement and highest quality of data. Novel scheme for measuring bandwidth of each station and its frequency response was devised along with pulse sequences that made possible re-scaling in order of site-specific coupling of Optically pumped magnetometers (OPM) to magnetic perturbation as presented (Fig. 1). We present various sensors in the GNOME network and will quantify some of then in terms of bandwidth, test pulse regularity and Allen plots. Special accent will be given to still unofficial exclusion domain that is extrapolated from GNOME Science Run 2 processing with the Run 5 data and preprocessing methods.

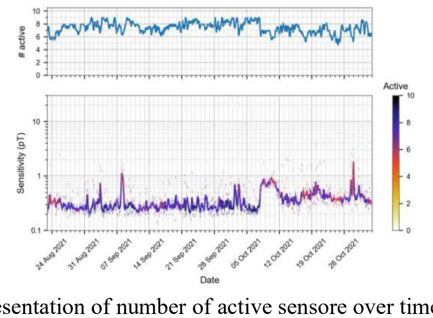

Figure 1: Representation of number of active sensore over time (upper frame); representation of rescaled magnetic field sensitivity of entire network (lower frame).

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All-optical Cs magnetometer based on free alignment precession

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Abstract. Since their first demonstration, in 1960s [1], optically pumped atomic-based magnetometers (OPM) [2] have been in the focus of many scientific studies. Recently, they have been of special interest due to their wide range of application, including measurements of magnetic fields in bio-medical science, environmental and geo-science.

Our focus is on the development of a compact, portable magnetometer for geophysical field measurements. We present the design and operating principle of a novel kind of OPMs, optically-pumped Cs magnetometer based on a free alignment precession (FAP). This type of magnetometer is free of some limitations of conventional OPMs, such as frequency shifts and systematic displacements. We use a paraffin-coated Cs vapor cell. Magnetometer operates at room temperature. The atomic medium is pumped with linearly polarized amplitude-modulated light at a double Larmor frequency, $2\omega_L$. This process generates spin alignment. After the optical pumping, the decay of the spin polarization can be detected in the weaker probe beam passing through the cell. The information on the magnetic field and Larmor frequency can be gathered via further signal processing.

We will discuss the influence of various parameters on the performance of our magnetometer – state of polarization of the probe and pump beam, angle between the probe and the external magnetic field, probe and pump powers and lengths. We will present our set-up and first test measurements. Finally, we will give an outlook for the further work.

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