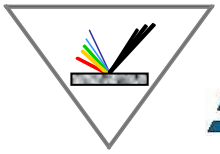
XXI International Conference and School on Quantum Electronics

LASER PHYSICS AND APPLICATIONS

Book of abstracts

21-24 September 2020

VIRTUAL FORUM



XXI INTERNATIONAL CONFERENCE AND SCHOOL ON QUANTUM ELECTRONICS

"LASER PHYSICS AND APPLICATIONS"

VIRTUAL FORUM

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BOOK OF ABSTRACTS

ABOUT THE ACADEMICIAN EMIL DJAKOV INSTITUTE OF ELECTRONICS

72 Tzarigradsko Chaussee Blvd., 1784 Sofia, Bulgaria
http://www.ie-bas.org/

The Institute of Electronics at the Bulgarian Academy of Sciences was established in 1963 as a non-profit state organization conducting research, education and dissemination of scientific knowledge in the fields of Physical Electronics, Photonics and Quantum Electronics and Radio Sciences.

The research efforts in physical electronics are concentrated on studying and solving the problems of generating and controlling electron and ion beams and their interaction with materials. This includes theoretical modeling, modern techniques, research and industrial equipment for micro- and nano-structuring, thin films deposition and study, modification of surfaces, vacuum melting and welding of metals by intense electron beams. The physical basis is being formed of creating nanostructures, nanomaterials and nanoelements by using electron and ion beams. Furthermore, fundamental properties are being investigated of gasses and gas plasma, plasma arcs and plasma torches in view of developing diagnostic techniques and applications in thin films deposition and plasma chemistry.

The research in photonics and quantum electronics comprises theoretical and experimental studies on the interaction of short and ultrashort lasers pulses with matter; development of novel nanostructuring technologies; laser thin-films deposition and treatment; light-induced absorption and transmission in alkaline vapors; development of complex laser systems for analysis and modification of semiconducting and superconducting materials; theoretical and experimental investigation of non-linear optical phenomena; biomedical photonics.

The research efforts in radiophysics are directed to clarifying the processes of interaction of optical and microwave electromagnetic radiation with the atmosphere and the Earth's surface; developing experimental systems for laser remote sensing and monitoring of the atmosphere; microwave remote radiometric measurement of soil moisture content; developing algorithms and techniques for signals and information processing; constructing microwave units and systems for radar and communication applications; studying non-linear processes in optical communication media. New ferrite devices with micrometric dimensions were developed with possibility for a higher degree of integration. Active research on gyro-magnetic materials is underway, in view of reaching higher frequency ranges, especially mm-waves for wireless communications and protection from powerful microwave radiation.

The Academician Emil Djakov Institute of Electronics was where the first Bulgarian laser, lidar, plasma torch, ultrahigh vacuum pump, micro-channel electron-optical converter, parametric microwave amplifier, Josephson junctions and SQUID, portable microwave moisture meter, magnetometer, installations for electron lithography, electron beam melting, refining, and welding were built, followed by the development of several advanced e-beam technologies, novel types of optical gas sensors, pioneering achievements in nanostructuring and nanoparticle formation, laser and plasma high technologies.

XXI INTERNATIONAL CONFERENCE AND SCHOOL ON QUANTUM ELECTRONICS "LASER PHYSICS AND APPLICATIONS"

ORGANIZED BY

The Institute of Electronics, Bulgarian Academy of sciences

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Project No. KP-06-MNF/6

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INVITED LECTURES

LASER - MATTER INTERACTIONS

IL.A1

FEMTOSECOND LASER-INDUCED MODIFICATION OF ELASTOMERS TO CONDUCTIVE MATERIALS

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Laser irradiation induces localized photo-thermal and/or photo-chemical effects near the focal spot, degrading the polymer material and causing permanent changes in its properties including electrical conductivity. Polydimethylsiloxane (PDMS) has been widely utilized in optical and electrical applications including flexible devices owing to its optical transparency, elasticity, and biocompatibility. In this presentation, our study on the modification of PDMS by using femtosecond laser will be reviewed and recent progress in micro- and nanometer-scale analyses as well as its application to strain sensing will be discussed. By irradiation to femtosecond laser pulses, the surface of a native PDMS was modified to black-colored structure, which exhibit electrical conductivity. FTIR, XRD, SEM, and TEM results show that the black structure was composed of SiC nanocrystals as well as graphitic carbon. The features of the formed materials varied depending on the distance from the focal spot. Graphitic carbon formed closer to the focal spot contained significantly less defects, and higher crystallinity. SiC nanoparticles with different grain sizes ranging from 50 nm to less than 10 nm were observed as well. The state of the formed material differed depending on the distance from the focal spot, suggesting photo-thermal effects contributed to the degradation of PDMS into conductive material. Raman spectra of the structures indicated a decrease in disorder of the graphitic carbon, with the increase in number of scans, indicating the effect of the graphitic carbon, in particular the amount of disorder in the carbon lattice, on the electrical conductivity. Additionally, the fabricated structures showed changes in electrical conductance when bent. The change in electrical conductance deferred depending on the laser scanning direction, used for the fabrication procedure, showing directional sensitivity to applied strain. The results indicate that the structures fabricated by femtosecond-laser-based modification of PDMS could be applied for flexible device applications such as strain sensing.

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IL.A2

BUILDING THE PHOTONIC BLOCKS OF LIGHTWAVE CIRCUITS BY PULSED LASER DEPOSITION

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The successful migration from electronic to photonic devices relies on the fabrication and integration of multiple building photonic blocks, including active devices, such as lasers and amplifiers, on a common planar substrate to reduce their size, cost and power consumption, while maintaining their compatibility with current fiber technology. The excellent optical properties and ease of preparation of glasses makes them promising materials to achieve that goal at a reasonable cost. Yet, their application requires first the fabrication of high quality thin films a few microns thick with good light emission performance.

Pulsed laser deposition is very attractive for this purpose since it allows the synthesis of metastable phases of complex oxides in thin film configuration. First we will show that a fine tuning of the deposition parameters allows the synthesis of good quality transparent heavy metal oxide film glasses with unconventional structure, a composition well outside the bulk glass formation region and high refractive index that allows the building of waveguides with high light confinement. Then, we will present an overview of the capability of alternate-PLD for the nanostructuration of film glasses through the incorporation of rare earth (RE) ions and metal nanoparticles as functionalizing elements to achieve active light emitting components. The optimization of the films is achieved by controlling the dopant concentration and by using a pre-designed in-depth distribution, which is critical to enhance their photoluminescent response.

This opens a broad range of material function and design possibilities, since the optical and photoluminescent properties of the produced nanostructures can be tailored at the nanoscale.

Acknowledgements: Work partially funded by the Spanish Ministry for Science and Innovation and CSIC (Projects RTI2018-096498-B-I00 and PIE-202050E195).

LASER SPECTROSCOPY AND METROLOGY

IL.B1

FROM BLACKBODY RADIATION TO NEAR-FIELD THERMAL EMISSION: SPECTROSCOPY OF THE ATOM-SURFACE INTERACTION AS A PROBE OF SURFACE POLARITON MODE

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Blackbody radiation, with its universal spectrum, has been at the origin of quantization. Nevertheless, the concept of "blackbody" applies only as a far-field limit. At short distances relatively to the wavelength of thermal emission (T = 300 K, λ = 10 μm for the thermal energy, or λ = 50 μm for most probable photons), the thermal emission is material-dependent, with the spectral properties of the material appearing in the surface boundary conditions. Hence, at sub-micrometric distances, thermal exchanges are considerably enhanced, and mostly determined by the properties of spectrally narrow surface polariton modes, governed by a surface response $S(\omega) = [\varepsilon(\omega)-1]/[\varepsilon(\omega)+1]$, originating in the boundary conditions with vacuum.

We have a long experience in atom-surface interaction, and notably in the measurement of the van der Waals (vW) electrostatic limit of the Casimir-Polder interaction, through selective reflection spectroscopy. This had already enabled us [1] to measure the temperature-dependence of the vW dipole-dipole interaction, governed by a $-C_3(T).z^{-3}$ potential (with z the atom-surface distance). The C_3 coefficient itself is the signature of the coupling between atom-dipole fluctuations, and the vacuum electromagnetic fluctuations as modified by the boundary conditions. Thermal fluctuations, as an additional contribution to the vacuum fluctuations, modify the C_3 coefficient; when the atom dipole fluctuations coincide with the surface polariton mode, rapid variations with T are expected.

We have explored this situation [2] by comparing the doublet of second Cs resonance levels: $Cs(7P_{1/2})$ is resonantly coupled (through connection to 6 $D_{3/2}$) to the sapphire surface polariton at 24.6 THz, while $Cs(7P_{3/2})$ is only loosely coupled to the polariton mode. As expected, a strong temperature- dependence appears, and for $Cs(7P_{1/2})$ only. The growth is nevertheless well below the exponential one promised by the relevant Bose-Einstein statistics. Indeed, the surface response resonance itself, found around $\varepsilon(\omega) \approx -1$ [with $\varepsilon(\omega)$ the permittivity of the material], broadens and shifts with temperature. This led us to conduct also a detailed study to determine $\varepsilon(\omega,T)$ on an identical sapphire window through far-field thermal emittance, improving previous results derived by optics of solids [3]. Extrapolation to the surface response remains a serious challenge, because surface and bulk resonances strongly differ.

Our comparison between two radically different methods allows an in-depth discussion of the limits of each technique. The sapphire birefringence adds to the complexity of the situation. It is worth noting that the ability to obtain good knowledge of the near-field thermal response is essential for fancy thermal rectification (*i.e.* "thermal diodes") [4]. It is also crucial to predict the transfer of thermal energy from surface to an atom, or to a molecular vibration. This would open the possibility of a specific thermal equilibrium for a gas-wall system.

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IL.B2

OPTICAL MAGNETOMETRY. *MAGNETIC DRESSING* APPLICATION IN MAGNETOMETRY, AND MAGNETOMETRIC INVESTIGATION OF *DRESSING*

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The precession of a dipole in a static uniform field is a well known process studied as a basic phenomenon both in classical and quantum mechanics. The precession of atomic magnetic momentum in a homogeneous magnetic field is at the basis of atomic magnetometry. In particular, the so called Bell and Bloom optical magnetometers detect the precession of atomic spins that are prepared in a non-stationary quantum state by a pumping radiation propagating transversely to a static field. In the Bell and Bloom scheme, a resonance occurs, provided that the pumping radiation is modulated at the Larmor frequency (or at an integer sub-harmonics). The atomic precession can be detected by a probe-radiation that must be transverse to the static field, for instance collinear to the pump one.

Having introduced general features of an atomic magnetometer in Bell and Bloom configuration, we will present results of its application to detect tiny signals and to study a phenomenon named *magnetic dressing.* The presence of a strong alternating field oscillating perpendicularly to the static field at a frequency much larger than the Larmor frequency *dress* the atoms. The consequence is a freezing of the evolution of the magnetization component along that dressing field.

Nuclear spins behave quite similarly to atoms, but precess much more slowly. Atomic magnetometers may detect the magnetic signal produced by precessing nuclei. This is at the basis of non-inductive detection of NMR, and enables the study of NMR in the ultra-low-field regime. NMR based imaging (MRI) requires a strong gradient of the magnetic field to encode the position of nuclei into their precession frequency. Such large gradients would smash the atomic magnetic resonance, preventing atomic magnetometry. Dressing the atoms with an opportunely inhomogenous field may restore the smashed atomic resonance, as to enable MRI signal detection by in-situ magnetometry.

Beside this application of the dressing phenomenon, we will present another feature of the dressing mechanisms, which was recently foretold theoretically and verified experimentally by our group. Unexpected features are discovered when a secondary (weak) alternating field is added to the static+dressing ones, and oscillates at a harmonic frequency of the dressing field. This secondary field may tune the dressing phenomenon, modifying the effective Lar- mor frequency by large amounts and with freezing or enhancing signs, with perfect accordance between experimental evidence and theoretical prediction.

Keywords: Optical magnetometry, Bell and Bloom, magnetic dressing, ultra-low-field NMR, ultra-low-field MRI, tuning-dressing phenomenon.

IL.B3

GENERALIZED RAMSEY METHODS IN HIGH-PRECISION SPECTROSCOPY OF CLOCK TRANSITIONS

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This report provides a detailed overview of methods for suppressing field shifts in atomic clocks and interferometers using various generalized Ramsey schemes.

Atomic clocks are based on high-precision spectroscopy of isolated quantum systems and are currently the most precise scientific instruments. Fractional frequency instabilities and accuracies at the level of 10^{-18} have already been achieved, with the goal of 10^{-19} on the horizon [1]. Frequency measurements at such a level could enable new tests of quantum electrodynamics and cosmological models, searches for drifts of fundamental constants, and new types of chronometric geodesy [2].

For many atomic and ionic systems promising for development of high-accuracy optical clocks, a key limitation is the field shifts due to the probe field itself, whose frequency is stabilized and is a reference point for atomic clocks. In particular, for ultra-narrow transitions (for example, for electro-octupole [3] and two-photon [4] transitions), the non-resonant Stark shift can be so large that achieving high accuracy and stability is almost impossible. For magnetically induced spectroscopy [5,6], field shifts (Stark and quadratic Zeeman shifts) can ultimately limit the

attainable metrological characteristics. A similar restriction also exists for atomic clocks based on the direct use of the "frequency comb" (direct frequency-comb spectroscopy) [7,8], due to Stark shifts induced by a huge number of non-resonant laser modes. In addition to optical frequency standards, the problem of field shifts is also critical for radio frequency clocks based on the effect of coherent population trapping (CPT).

Over the past decade, significant progress has been made in solving these problems with the use of Ramsey spectroscopy methods [9]. Unlike continuous-wave spectroscopy, the pulsed Ramsey spectroscopy has a large number of additional and well-controlled parameters (such as the durations of Ramsey pulses τ_1 and τ_2, the time of free evolution T, the "phase composition" of Ramsey pulses, etc.), by manipulating these parameters it is possible to solve various spectroscopic problems. The development of Ramsey field-suppression schemes in optical frequency standards began in [10], where the hyper-Ramsey spectroscopy method was proposed using so-called composite pulses. Soon this method was successful experimentally confirmed [11,12].

This report provides a detailed overview of methods for suppressing field shifts in atomic clocks using various generalized Ramsey schemes (see original papers [13-18] and review [19]). It turns out, that some methods [16-18, 20-22] are so universal that they can be successfully used both in optical clocks and in radio frequency clocks based on the CPT effect, as well as in atom interferometers.

Acknowledgments: This work was supported by the Russian Science Foundation (Grant No. 20-12-00081).

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IL.B4

NONLINEAR RESONANCES OF ENHANCED ABSORPTION IN ALKALI-VAPOR CELLS FOR DEVELOPMENT OF COMPACT ATOMIC MAGNETOMETERS, MICROWAVE AND OPTICAL ATOMIC CLOCKS

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We review several novel laser spectroscopy schemes for observing high-quality nonlinear resonances in cesium vapor cells that have been recently proposed. These schemes have three common features: a light field is composed of counterpropagating beams, optical transitions within the D_1 line are used, and a nonlinear resonance of enhanced absorption can be observed in the light transmission.

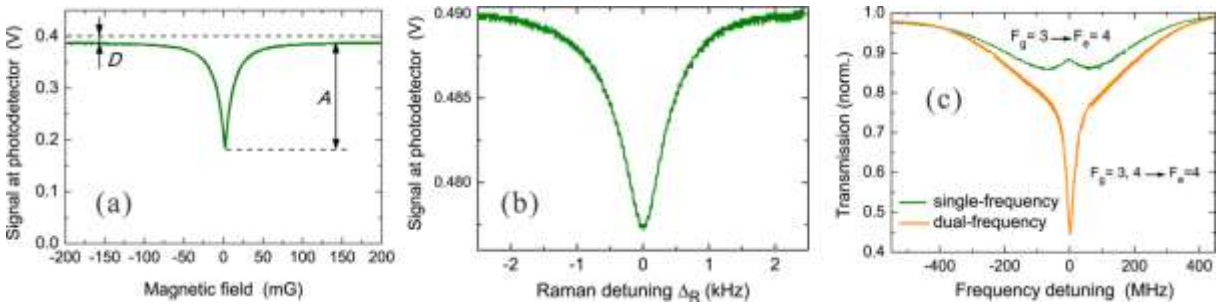

Figure 1. (a) Subnatural-linewidth magneto-optical resonance for development of a three-axis Hanle magnetometer. (b) Subnatural-linewidth resonance in two-color light field for a microwave atomic clock. (c) Sub-Doppler natural-linewidth resonance for development of a miniature optical clock (orange curve).

Fig.1a shows an electromagnetically induced absorption (EIA) resonance that can be observed under counterpropagating light waves with orthogonal linear polarizations. The waves have equal optical frequencies and should be in resonance with an optical transition $F_g=4 \rightarrow F_e=3$ in the D_1 line. The 2 cm long vapor cell contains a neon buffer gas (20 Torr). The resonance can achieve an extremely high contrast-to-width ratio. In particular, "D" in the figure denotes height of a wide Doppler profile that, as seen, is much smaller than the EIA resonance height ("A"). The scheme can be used for development of a high-sensitivity three-axis magnetometer based

on the so-called magnetic-field compensation technique. Fig.1b shows EIA resonance under counterpropagating two-color light beams of equal circular polarizations. The scheme has been applied to create a microwave atomic clock with a short-term frequency stability of 5.8×10^{-12} at 1 s integration. To the best our knowledge, this is the first implementation of a microwave atomic clock based on the EIA-type resonance. Fig.1c demonstrates a high-contrast sub-Doppler resonance (orange curve) under two-color counterpropagating light beams with orthogonal linear polarizations when laser frequency is being scanned around the middle frequency of two optical transitions $F_g=3\rightarrow F_e=4$ and $F_g=4\rightarrow F_e=4$. The scheme has been tested in various vapor cells, including a microcell ($V \approx 5$ mm^3), and has great prospects for creation of a miniaturized optical clock. The recent measurements have shown a short-term optical frequency stability of 2×10^{-12} at 1 s.

Acknowledgments: The Russian part of the team appreciates the support of RFBR (grant nos. 20-02-00075, 20-32-90029) and RSF (grant no. 17-72-20089).

LASER REMOTE SENSING AND ECOLOGY

IL.C1

LIDAR MEASUREMENTS OF AEROSOLS IN THE FREE TROPOSPHERE AND STRATOSPHERE

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The Raman lidar at Capel Dewi, near Aberystwyth in the UK, often measures aerosols in the free troposphere and stratosphere, particularly in the summer months. These are usually associated with three kinds of events: Saharan dust, forest fires and volcanic eruptions. Saharan dust is usually confined to the lower free troposphere, but the latter two events can extend to the tropopause and beyond. In this talk I will describe the lidar system, and present examples of the kind of events we measure.

The first event resulted from pyrocumulus convection over Canada in May 2016, which resulted in a cloud of forest fire smoke crossing the Atlantic and being detected by the lidar. On this occasion the UK Met Office was operating a network of Raman lidars and we were able to track the passage of the smoke across the country. This event was associated with an atmospheric blocking event which meant that smoke was detectable for around a week from one pyrocumulus event.

The second event was the 'Red Sun' day on 16 October 2017. On this day a plume of Saharan dust was drawn northwards on the flanks of hurricane Ophelia. This airstream picked up smoke from forest fires in Portugal, giving the highly unusual conditions of very dark skies and a faint, red Sun. Raman lidar measurements were not possible during this event. Instead we used a network of other lidars to follow the passage of this airstream over the UK.

Finally, the Raikoke volcano in the Kuril Islands (48.29N 153.25E) erupted on 21 June 2019, sending a plume of SO_2 and ash into the stratosphere. Lidar measurements of the evolution of the volcanic aerosol cloud as it passed over the site show that its optical depth decreased from 0.05 in summer 2019 to 0.01 in spring 2020.

IL.C2

SPECTROSCOPIC LIDARS IN ATMOSPHERIC AND ENVIRONMENTAL RESEARCH

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Lidar is the only remote measurement method that allows for spatially (vertically) and temporally highly-resolved observations of atmospheric state parameters, trace gases and particulate pollution. The combination of various lidar techniques (nitrogen Raman and high spectral resolution lidar) with mathematical inversion algorithms nowadays allows for temporally and vertically resolved observations of aerosol optical and microphysical properties. Differential absorption lidar is a different concept in lidar applications. This method allows for quantitative range-resolved measurements of the concentration of chemical components in the atmosphere.

Lidar and passive remote sensing instruments currently cannot provide us with vertically-resolved information on the chemical composition of aerosols under ambient atmospheric conditions. We are exploring the potential of a multi-channel high-resolution spectrometric lidar for the vertically-resolved chemical characterization of aerosols and reactive gases by measuring range-resolved Raman and fluorescence/photoluminescence spectra. For that purpose, we have been developing a new remote sensing facility, called **L**idar **I**nnovations for **T**echnologies and **E**nvironmental **S**ciences (LITES). The facility combines a unique **Li**dar **S**pectro**s**copy **I**nstrument (LiSsI) with in-situ instruments such as Raman and fluorescence microscope, gas and aerosol chambers.

In this lecture we will present: i) a short historical overview of the development of spectroscopic lidars, including advantages and disadvantages of the method and particular lidar systems, ii) the potential of spectroscopic lidars for the vertical profiling of trace gases, chemical components in particles, and bio-aerosols through combining different non-linear spectroscopy techniques (photoluminescence, fluorescence, Raman and coherent anti-Stokes Raman spectroscopy) on a single measurement platform, and iii) the setup and measurement examples of **LITES** that has been developed at the University of Hertfordshire.

LASERS IN BIOLOGY AND MEDICINE

IL.D1

RECENT RESULTS OF RIGA GROUP ON LASER APPLICATIONS FOR SKIN DIAGNOSTICS

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A brief review about the Biophotonics Laboratory activities on lasers for skin assessment following the previous *ICSQE-20* conference will be presented. The main current projects under implementation are:

- *Laserlab-Europe*, the Integrated Initiative of European Laser Research Infrastructures, H2020 # 871124 (PI Vanesa Lukinsone).
- *Multimodal imaging technology for in-vivo diagnostics of skin malformations*, ERDF #1.1.1.1/18/A/132 (PI Janis Spigulis).
- *Development of prototype devices for nonivasive assessment of skin condition*, ERDF #1.1.1.2/VIAA/1/16/070 (PI Edgars Kviesis-Kipge).
- *Advanced spectral imaging technology for skin diagnostics*, Latvian Science Council # lzp-2018/2-0006 (PI Janis Spigulis).

The first two projects aim at developing picosecond laser applications for skin autofluorescence lifetime studies and for experimental determination of skin-remited photon path lengths at different spectral intervals. Single-line (405 nm, 473 nm, 510 nm) and broadband lasers equipped with a set of interference filters are used. Measurements are taken using specific optical fiber contact probes from agar-based skin phantoms and from *in-vivo* skin, both healthy and pathologic. Besides, Raman spectra and Raman spectral band images are taken from ex-*vivo* skin samples in the framework of the ERDF project.

In the last two projects, different concepts of snapshot multi-spectral-line imaging are implemented in new prototype devices for skin chromophore mapping and autofluorescence imaging. One design comprises an illumination ring of laser diodes around the image capturing camera. Another one employs a silica-core side emitting fiber loop as simultaneous four spectral line illumination source combined with double-camera setup or with a VIS-NIR four-band camera. Skin autofluorescence is excited by violet 405 nm laser diodes and detected in the camera G-band. Clinical validation phase of the prototypes is somewhat delayed due to current restrictions caused by the global Covid-19 pandemic.

IL.D2

LASER SCANNING CONFOCAL MICROSCOPY AND ITS BIOMEDICAL APPLICATIONS

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Imaging is an integral part of cell biology, which allows the observation of intracellular structures and cellular processes. Decoding the cellular structure, function, and associated dynamic processes in real-time is a critical aspect in cell biology and may provide valuable insight into the normal and pathophysiological conditions. The introduction of the laser scanning confocal microscope (LSCM) has aided in obtaining the 3D structure of the cell by increasing resolution, higher contrast, and greater depth of field of microscopes. The application of LSCM in biomedical fields includes spatial-temporal distribution of molecules, acquisition of 3D data, understanding the biological interaction between macromolecules, multiple wavelength imaging, and measuring physiological events in either live or fixed condition. The practical aspects of sample preparation, imaging (acquisition and processing), and image presentation for biomedical applications will be discussed.

IL.D3

BREAKTHROUGH OPTICAL TECHNOLOGIES OF CLEARANCE OF TOXINS FROM THE SKEEPING BRAIN VIA THE LYMPHATICS

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There is an intensively growing body of evidence that sleep and the lymphatics play a crucial role in keeping the health of the central nervous system (CNS) via the night activation of drainage of CNS tissues and clearance of metabolites and neurotoxins. The ability to stimulate the brain drainage and clearing function during sleep might be a promising strategy in developing innovative methods in neurorehabilitation therapy. However, the current concept about the absence of the lymphatic vessels directly in the brain hinders the understanding of how toxic waste products are removed from its tissues and mechanisms of drainage of the CNS. This significantly slows down the progress in the appearance of technologies in therapeutic modulation of drainage and clearing functions of the CNS. We discuss the presence of lymphatic structures in the brain and we demonstrate breakthrough optical technologies of night stimulation of lymphatic clearance of macromolecules and toxin from the brain. Our animal

results reveal a transcranial photo-stimulation (PS, 1268 nm, 9 J/cm^2) of meningeal clearing and drainage functions, as well as PS effects on the permeability of the lymphatic endothelium to macrophages. These findings open new strategies for alternative nonpharmacological therapy of brain diseases via PS modulation of lymphatic mechanisms of the central nervous system homeostasis.

Acknowledgments: This work was supported by grants RBRF 19-515-55016-China_a, RSF — 20-15-00090, RF Government Grant 075-15-2019-1885.

IL.D4

POLARIZATION-RESOLVED SECOND HARMONIC GENERATION MICROSCOPY AND ITS APPLICATIONS

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Second harmonic generation (SHG) microscopy is an effective analytical tool for detailed investigation of microscopic structure of non-centrosymmetric molecules. We developed a four-channel photon counting based Stokes polarimeter integrated to an SHG microscope for spatial characterization of polarization effects in SH signal. In general, polarization measurement can be carried out using either Jones calculus or Stokes algebra. Jones calculus is, however, only suitable for describing perfectly polarized light, whereas Stokes algebra is more applicable for characterizing all states of polarization, partially or completely unpolarized. We implemented Stokes vector based polarization-resolved SHG imaging in order to perform quantitative polarimetry, with a view to applications in biomedicine, which can measure the full polarization state of SH light. The technique is used to visualize the structural distribution in highly ordered samples (KDP crystal) including biological samples (collagen and starch) through inspection of various polarization properties. Conventional polarization-resolved SH microscopy is unable to measure the full output polarization states of SH light, although it is applied for examining the linear birefringence and anisotropy of samples. In this work, we describe the application of a Stokes vector based four-channel photon counting SHG microscope to determine the molecular interpretation of SH light from collagen type I, skeletal muscle fiber, and starch granules. The principle of Stokes vector-based SHG microscopy were described in detail for mapping of the orientation of SH active biological structures.

Keywords: optical scanning microscopy, second harmonic, Stokes vector, polarization.

Acknowledgements: We acknowledge Prof. K. Satyamoorthy, Director, Manipal School of Life Sciences for his encouragement and Manipal Academy of Higher Education, Manipal, India for providing the infrastructure facilities. This work is supported by Department of Science and Technology (DST) - Science and Engineering Research Board (SERB) (Project No.: ECR/2016/001944) and DST (Project No.: DST/INT//BLG/P-03/2019), Government of India.

LASER SYSTEMS AND NONLINEAR OPTICS

IL.E1

QUANTUM ROUGHNESS OF LIGHT

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Quantum electrodynamics postulates that photons, the quanta constituents of the electromagnetic radiation, do not interact with each other in vacuum. This brings up the unique property of photons in a laser light beam to be independent and as a consequence their arrival times and positions at a detector to be random. The macroscopic photon flux in a laser beam, in this case, is said to be irregular, in both space and time. Whereas the randomness in time manifests itself with the famous temporal light "shot noise," the randomness in space results in the so-called "quantum roughness" or a spatial "shot noise" of laser beams.
In optical sensing and imaging these two shot noise types pose a fundamental limit to the achievable signal-to-noise ratio (SNR), provided the laser power cannot be increased arbitrarily. In these cases where the optical illumination in sensing cannot be increased due to heating or irreversible changes in the inspected specimen, a more appropriate course of action is to reduce the shot noise.

In this context, we employ a nonlinear four-wave-mixing (FWM) optical process in hot rubidium vapor, to induce interaction between photons in a light beam whereby generating quantum correlations in space and time between them [1]. These correlations help us to reduce both the temporal shot noise and "smooth" the quantum roughness in the laser beam. In the quantum optical sense this method of reducing the shot-noise is called "squeezing" and the generated light is termed squeezed in temporal and spatial modes.
We analyze the properties of the squeezed light by evaluating the degree of shot noise reduction and the number of squeezed spatial modes generated by the FWM process [2]. Next, we present recent results on applications of the squeezed light in beam position measurement, which is a prerequisite to implementation of the technique in atomic-force microscopy, and show that the SNR of the measurement improves over the coherent light result with a factor equivalent to the achievable degree of squeezing.

The employment of spatially multimode squeezed light to improve the SNR in optical sensing and imaging techniques is commonly termed as quantum enhanced optical sensing and quantum imaging. Our proof-of-principle experiments can be used as a starting point in the development of quantum sensing technologies for industrial applications, which are at the heart of UK National Quantum Technology Program and the EU Quantum Technologies Flagship Program.

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IL.E2

PROGRESS TOWARDS HIGH INTENSITY LASER-BASED X-RAY MACHINE FOR COHERENT X-RAY IMAGING AND SPECTROSCOPY

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We present a review of INRS program on the development of intense X-ray sources, based on laser-wake-field acceleration, for high throughput coherent X-ray imaging and time-resolved X-ray spectroscopy. Application of this technology to various sectors including global food security, inertial confinement fusion and warm dense plasmas will be discussed.

The general goal of our project is to design a practical LWFA-based X-ray machine presenting the best compromise between complexity and performance. From the user prospective, the most important parameters are i) a high X-ray conversion efficiency, ii) a high duty cycle with the possibility to operate during a long period in order to capture a very large number of shots and data with a very high stability and iii) a reasonable foot-print and cost. We will discuss the key technical points that defined our roadmap and framed our design responding to those constraints.

1. X-ray yield scaling.

We experimentally measured the conversion efficiency and the scaling of the betatron X-ray emission with a wide range of laser parameters on target [1]. The physical processes affecting the generation of very intense and stable X-ray beam during the propagation of a high intensity ultrashort pulse in a gas jet, filamentation instability, self-focusing/defocusing and pulse guiding, have been measured and controlled. We have successfully generated stable propagation in gas jets through self-guiding on length well larger than the classical (blowout regime) dephasing and depletion lengths, generating very intense beams of hard X-rays [2]. With a laser energy of 4J, 20fs pulse and an intensity on target of $3x10^{19}W/cm^2$, we have currently an X-ray beam with 20µJ in the 10-20keV band, a divergence of 50mradx50mrad (1.7µm FWHM source size) and an average power of 50µW (2.5Hz). The scaling law provides useful guiding for experiments at higher intensity or laser peak power [1-3].

2. Duty cycle

The second important parameter is the duty cycle required by users (very large number of successive shots). We defined this constraint by studying the variation of the damage threshold of all our optics (including gold gratings and mirrors with dielectric coating) as a function of the shot number. Our experiments have been realized with a 10 cm beam diameter and a 20fs pulse. We will present and discuss our results which define the right fluences to be used for a machine operating with a high duty cycle.

3. Technical roadmap

The third aspect is related to the compromise between complexity and performance. To increase further the X-ray Yield, a first route is to increase the laser energy and a few systems start to be available in the PW range. However, increasing the laser energy requires an increase of the laser beam diameter and of the foot-print and complexity of the laser system. We started to explore a different route which consists in increasing the intensity and peak power of the laser by decreasing the pulse duration. We will present and discuss our experiments demonstrating the compression of our 4J beam with a 24fs pulse (10 cm beam diameter) to a 13fs pulse with an energy of 4J [4].

4. Applications

Our system has been used to demonstrate phase contrast high throughput imaging with an in-line geometry and time resolved X-ray absorption spectroscopy. We will discuss the application of our X-ray source in several fields including i) the global food security for the rapid identification of phenotypes in a plant production setting [3, 5], ii) Inertial Confinement Fusion (ICF) for enabling real-time examination of the ICF laser driver interaction with the target especially during the acceleration phase of the imploding shell where deleterious hydrodynamical instabilities can take place [6] and iii) Warm Dense Plasmas (WDM) for benchmarking ionization models [7].

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IL.E3

TRAPPING, DETECTION AND MANIPULATION OF SINGLE Rb ATOMS IN AN OPTICAL DIPOLE TRAP USING A LONG-FOCUS OBJECTIVE LENS

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Single alkali-metal atoms, being loaded in arrays of optical dipole traps, represent a quantum register that can be used for quantum computation and simulation based on short-term Rydberg excitations that switch the interactions between qubits [1-3]. To load single atoms into optical dipole traps and then detect them by the resonance fluorescence, lenses with a large numerical aperture (NA > 0.5) are commonly used. Such lenses provide focusing of a Gaussian laser beam into a spot of small radius (~1 μm), which ensures localization of trapped atoms and provides conditions for collision blockade [4], when loading of more than one atom into a dipole trap becomes impossible. In addition, the use of lenses with a large numerical aperture increases the efficiency of collecting scattered photons when detecting atoms by the resonance fluorescence. In experiments on trapping single atoms, short-focus aspherical lenses are typically installed inside a vacuum chamber, while the low-intense fluorescence of single atoms is typically detected by highly-sensitive EMCCD cameras.

Despite the obvious advantages of optical schemes that employ lenses or objective lenses with a large numerical aperture, their principal feature is the placement of optical surfaces at a relatively short distance from a cloud of cold atoms. For lenses placed inside a vacuum chamber, this distance usually does not exceed 5-10 mm, which leads to the potential occurrence of spurious electric fields in depositing alkali-metal atoms on dielectric surfaces. The uncontrolled electric fields arising in this case significantly affect interactions of Rydberg atoms and reduce the fidelity of quantum gates. In addition, EMCCD cameras are expensive devices that are not always available in laboratories.

In this talk we present our recent experimental results [5] on demonstrating the trapping of single Rb atoms using a long-focus objective lens with a numerical aperture NA=0.172, placed outside the vacuum chamber, and detecting single atoms with a lower-cost sCMOS camera at a short exposure time (50-300 ms). We estimated the error in measuring the number of trapped atoms and measured the probability of re-recording of single atoms as a function of exposure time. We also present our current results on implementing a single-qubit gate based on optical pumping and subsequent microwave or Raman transitions between two hyperfine sublevels of ^{87}Rb atoms, as well as supplementary results on observing such transitions in a Rb vapor cell using the Hanle resonances in a scanned magnetic field.

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Acknowledgements: This work was supported by the RFBR Grant No. 19-52-15010 (for theoretical analysis), the Russian Science Foundation Grant No. 18-12-00313 (for experiments), the Siberian Branch of RAS, and the Novosibirsk State University.

ALTERNATIVE TECHNIQUES FOR MATERIAL SYNTHESIS AND PROCESSING

IL.F1

FABRICATION OF NANOCOLUMNAR FILMS BY USING GLANCING ANGLE DEPOSITION WITH MAGNETRON SPUTTERING

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In this lecture, I will show how nanocolumnar coatings are manufactured by glancing angle deposition with magnetron sputtering. This technique is environmentally friendly, since it is carried out at room temperature in a single step and does not involve chemical products (therefore, without recycling problems). It will be seen that the formation of nanocolumns is the result of the atomic shadowing when the atoms reach the surface along an inclined direction and possible hyperthermal processes associated to a highly directed momentum distribution and the relatively high kinetic energy of the sputtered atoms. Depending on various parameters (such as gas pressure, the angle of inclination of the substrate and its possible rotation), the nanocolumnar structure can be controlled, giving rise to different properties [1-6]. Moreover, we have shown that this methodology can be scaled up to large surfaces, representing a valid approach for the industrial production of nanostructured coatings [7]. Actually, in the final part of the talk I will show several applications we have recently demonstrated: as antibacterial coatings for orthopedic implants [8,9]; as black metal coatings in the visible range [5]; as substrates for surface enhanced Raman spectroscopy, SERS [10]; as nanostructured electrodes for advanced perovskite solar cells [11]; as anti-multipactor coatings for the space industry [12].

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ORAL SESSIONS

PRESENTED CONTRIBUTIONS

ORAL PRESENTATIONS – Session I

O.D3

TECHNOLOGICAL PARAMETERS OPTIMIZATION IN PICOSECOND LASER TEXTURING OF TITANIUM SURFACES

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The paper presents investigation of the surface morphology of commercially pure (cp) Ti Gr-2 and the Ti6Al4V alloy treated by a pico-second laser and defines the optimal technological regimes for manufacturing holes with definite sizes. Round samples with a diameter of 22 mm and a thickness of 3 mm were used. Their surfaces were treated by a commercial picosecond laser with λ = 1064 nm, a frequency of 100 Hz and a pulse width of 500 ps. Two irradiation parameters were varied: the average power (1 W, 0.5 W, 0.2 W) and the number of pulses (1000 – 20 000). The samples surface was investigated by OM, SEM, EDX and a contactless 3D surface profile-meter. In view of minimizing the length and height of the affected zone and achieving maximal width and depth of about 10 μm, the technological parameters were optimized by regression analysis using the QStatLab software.

It was established that the laser treatment of cp Ti Gr-2 changes only the surface roughness when the lowest parameters values are used (0.2 W and 1000 pulses); in the case of the Ti6Al4V alloy, an affected zone of 5.5-μm depth is formed. Raising the laser power and number of pulses leads to morphological changes in the affected zone in cp Ti Gr-2, while the morphology of the affected zone in Ti6Al4V changes mostly with the increase of number of pulses. In both materials, the affected zone has a layered in-depth morphology and its dimensions increase with increasing the values of the variable parameters. The optimal technological parameters found were 0.42 W and 4050 pulses for the cp Ti Gr-2, and 0.21 W and 7890 pulses for the Ti6Al4V alloy. The results obtained could be used for texturing titanium surfaces using linear or other types of patterns by the picosecond laser used.

Keywords: cp Ti, Ti6Al4V, picosecond laser, surface texturing, parameters optimization

O.E1

PROCESSES OF ENERGY EXCHANGE DURING THIRD HARMONIC GENERATION

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The paper presents a study on the processes of energy exchange between two optical waves, the fundamental one and the third harmonic, in multi-mode optical fibers. We investigated two cases. In the first one, short-cut equations are solved describing the parametric processes. In the second one, the influences are included of self-phase modulation and cross-phase modulation, which are important during the evolution of laser oscillations in a CW mode. These additional processes significantly change the period of energy transfer between the waves.

Keywords: Parametric four-photon mixing, third harmonic generation, self-phase modulation, cross-phase modulation, elliptical Jacobi functions

O.E2

SOLITON REGIME OF PROPAGATION OF OPTICAL PULSES IN ISOTROPIC MEDIUM UNDER THE INFLUENCE OF THIRD-ORDER LINEAR DISPERSION AND NONLINEARITY DISPERSION. DARK SOLITONS

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The propagation of ultrashort broadband optical pulses in nonlinear dispersive media has attracted considerable attention in the last few decades. The nonlinear Schrödinger equation (NSE) is well known and is one of the most commonly used tools in the field of nonlinear optics. Pulses of picosecond and femtosecond duration are very well described by the NSE, but for attosecond and phase-modulated femtosecond laser pulses, where the condition $\Delta\omega \approx \omega_0$ is satisfied, the equation does not work. In this case, it is more convenient to use the general nonlinear amplitude equation (NAE).

During the propagation of ultrashort pulses in single-mode optical fibers, the effects of the third-order linear dispersion and the nonlinearity dispersion become significant and have to be taken into account. In this case it is necessary to include additional terms in the NAE, which show how the third-order linear dispersion and the nonlinearity dispersion of affect the pulse propagation. In a medium with normal dispersion, one can observe the so-called dark solitons that result from the dynamic balance between the effects of higher order of dispersion and nonlinearity.

We investigated analytically the influence of the third-order linear dispersion and the nonlinearity dispersion on the evolution of ultrashort optical pulses and the possibility of formation of dark soliton under such conditions in a medium with normal dispersion. The results obtained are important as contributing to a better understanding of the behavior of ultrashort broadband optical pulses in nonlinear dispersive media.

ORAL PRESENTATIONS – Session II

O.B1

INTEGRATED INTERFERENCE WEDGED STRUCTURES AS A BASIS FOR COMPACT LIGHT-BEAM SPLITTERS WITH IMPROVED PARAMETERS

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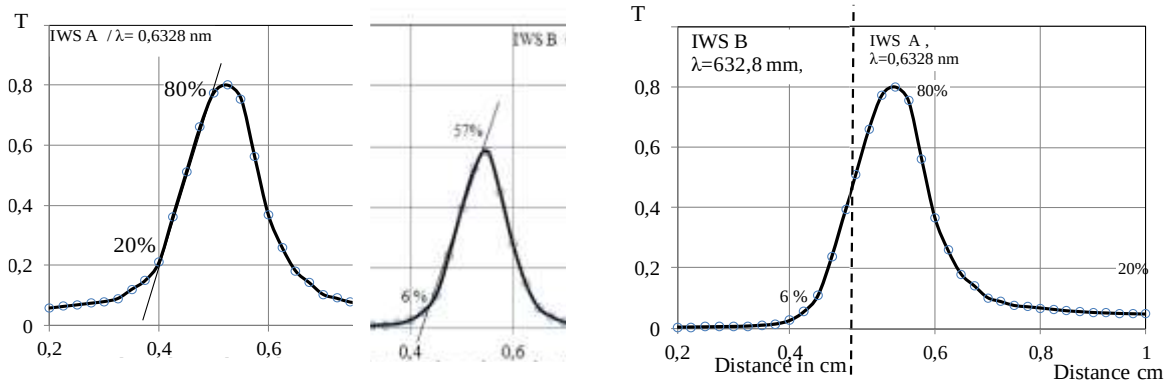
Based on the idea of combining in one plane and in a puzzle type of properly designed parts of planar sheet-like interference wedged structures (IWS) [1-4] realized as beam splitters, we show the possibility of implementing novel integrated light-beam splitters (essentially for laser beams) that possess useful properties. The proposed integrated splitters are plane sheet-like structures (e.g. with dimensions 5×3×0.1cm). Using our theoretical approach for analysis of IWS [3, 4], simulations and test experiments, we show the useful properties of the proposed splitters. As other splitters of IWS type [4] they ensure a variable, smooth linear separation of the beam by simple sliding in their planes, conserving the propagation direction of the formed beams. As additional advantages, the splitting is with linear variation of the transmission T and the reflection (R = 1-T) from ~ 80-95% to 5% that is difficult to obtain by traditional splitters, and with a large working range (translation of the splitter for linear splitting to ~ 6-10 mm and more), the latter providing the required low slope for the splitting and, respectively, splitting of large (to ~ 3-5 mm and with focalization ~10 mm and more) beams. No polarization requirements exist, and operation is possible at relatively high powers (~ W/cm^2 CW and more, and ~ MW/cm^2 for ~ns pulses). An example of a simple variant of such a splitter formed by combining the suitable front parts of two suitable IWS splitters (A, B) is shown below (the calculation graphs and combination of selected parts with the experimental points). A convenient practical realization can be using a mask technology for integrated circuits for a sequential deposition of layers of the corresponding elements on a substrate.



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Acknowledgements: The work is supported by the Bulgarian National Science Fund Contr. DN 17/7 (2017).

O.B2

EXTREMELY HIGH RESOLUTION LASER SPECTROSCOPY OF HOT CESIUM DIMERS IN A BUFFER GAS OF HOT CESIUM ATOMS CONFINED IN AN OPTICAL CELL OF SUB-MILLIMETER LONGITUDINAL DIMENSION

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In this communication, we discuss the application of a micrometric-width, high-quality optical cell with a sidearm containing a small amount of pure Cs metal that intrinsically contains a very small impurity of Rb. When the sidearm is heated to a temperature around 300 ^{o}C, an alkali vapor mixture is formed that consists of Cs atoms, Cs dimers and a small number of Rb atoms. The internal sides of the cell windows are very close to parallel. This particular confinement of the alkali vapor allowed us to achieve a high hot-vapor density and an optically-thin alkali vapor

layer that was used to produce diatomic Cs molecules together with a high concentration of Cs atoms (used as a buffer gas), as well as to perform linear spectroscopy of the molecular ensemble.

An optical cell with a strongly reduced longitudinal dimension (L = 700 μm)) is irradiated by a narrow-band (2 MHz) distributed feedback diode laser (DFBDL) with a maximum power of 150 mW, 1 mW being sufficient for the study. The laser frequency was scanned over a 50-GHz spectral interval in order to cover the Rb atom reference spectrum and a large interval of the spectrum of Cs dimers. We studied experimentally the spectral profiles and frequency positions of the spectral lines of Cs_2 molecules within the $B^1\Pi_u \leftarrow X^1\sum_g^+$ absorption band, which lies in the spectral region around the D_2 resonance line of Rb with wavelength λ = 780.24 nm.

We showed experimentally that due to the dramatically smaller longitudinal dimension of the optical cell a significant narrowing of the Cs_2 dimer optical transitions can be realized experimentally. Moreover, our theoretical analysis showed that the second derivative of the experimental spectrums not only provides a significant additional enhancement of the spectral resolution, but also yields additional information related to the physical processes involved in the dimer spectrum formation.

Acknowledgements: This work was supported by the National Science Fund of Bulgaria under contract DO08-19/2016 "New coherent and cooperative effects in hot alkali vapor".

O.B3

EFFICIENT LIGHT BEAM SPLITTERS BASED ON COMPLEX INTERFERENCE WEDGED STRUCTURES THAT USE LOW-REFLECTIVITY COMPONENTS (FRESNEL REFLECTION)

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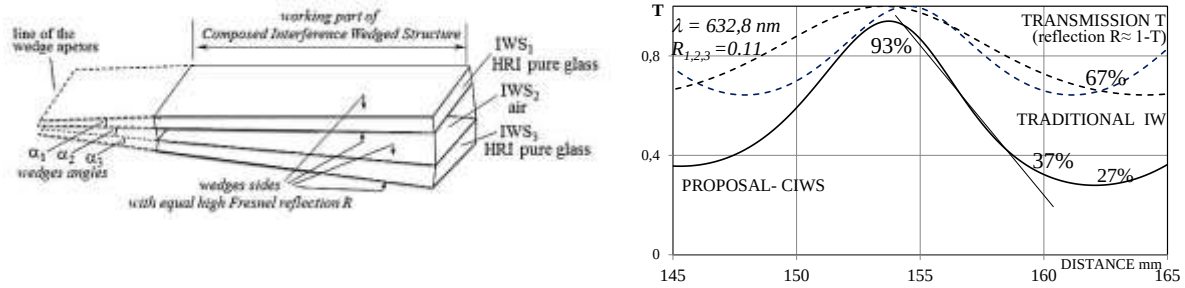
Based on our long-time experience in the field of development and use of interference wedged structures [1-4], we found and demonstrated that low-reflection optics (elements mainly using only Fresnel reflection) can be effectively employed in realization of efficient light beam splitters (especially for laser beams). It is well known that the traditional use of low-reflection elements cannot ensure the depth of transmission and reflection needed for the discussed purpose. We demonstrated by theoretical analysis, simulation and experimental testing that a low reflectivity mirror (e.g., with Fresnel reflection) in a suitably designed interference complex of thin wedged structures can overcome this problem and can serve as a basis for efficient light-beam splitters. The splitters use only purely high refractive index (HRI) glass or some other type of HRI transparent material and do not need dielectric and metallic mirrors. Such kind of splitters are very compact sheet-like elements (e.g., 5×3×0.2 cm) and split the beam only by sliding in their plane. Such natural for the splitter beam separation assures unchangeable directions of the split beam propagation. Due to the use of only glass building elements, high-power beams can be split in a wide range of wavelengths (IR, visible) at angles of incidence up

to 15-20^o without polarization requirements. Below, as an example, is shown one design of such a splitter that uses HRI glass (R = 11%, losses of less than 5%). As a comparison, the computed curves of the proposed splitter transmission (solid line) and of a traditional interference wedge used as a splitter (dotted line) are also given. (Right-hand panel – proposed CIWS-composed interference wedged structure; left-hand panel – transmission curves of the proposed and the traditional IW (dotted lines).



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3. Nenchev M., Stoykova E., Deneva M., Composite wavelength tunable wedged interference structures with increased free spectral range, *Optical and Quantum Electronics* **50**(12) DOI: 10.1007/s11082-018-1668-9 (2018).
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Acknowledgements: The work is supported by Bulgarian National Science Fund Contr. DN 17/7.

O.F1

IMPACT OF BASE PRESSURE, POST ANNEALING TEMPERATURE AND AGEING ON THE ELECTRICAL PROPERTIES OF CHROMIUM NANOFILMS

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Pressure is one of the important deposition parameters, which considerably affect the purity and texture of the deposited films. It has been observed that the resistivity increases as the pressure

is raised because of the incorporation of defects during the film growth. Ultimately, this leads to a large resistivity for chromium films grown at higher pressures and a decrease in the mean free path of conduction electrons. The mobility and immobility of large particles can be a proof of the pressures at which the films have been grown. Film deposition by evaporation usually gives rise to a large number of defects unless great care is taken to avoid them. It is possible to remove these defects by annealing, which generally results in a decrease of the film resistivity. A reduction of (20-50)% of resistance of 24 elements has been reported by Belser. In some cases, heat treatment may also increase the resistivity due to oxidation, agglomeration and the difference in the thermal expansion of the substrate and the grown film. Especially, in cases of films grown from high melting point materials, such as Cr, a randomly oriented structure is found and an increase in the film resistance is seen. For titanium oxide thin films, similar effects on the resistance have been observed after annealing. We obtained an increase in the resistivity of 10% for Cr after annealing at 100 ^{o}C for two hours in vacuum (6-7)×10^{-6} Torr. Another possible reason for this may be that these films exhibit a negative TCR in the temperature range (77-450) K; with the increase in substrate temperature (T_s), the film resistivity also increases and the thermal expansion of the glass substrate exceeds that of bulk Cr metal. Ageing is nothing but annealing the films at room temperature and, consequently, the film resistance changes as a function of the time. It is noticed that the resistance (R) of films increases considerably more in very thin films with time up to 15 hours (for Cr) and remains more or less constant afterwards. This kind of resistance behavior suggests that oxygen is first chemisorbed on the Cr metal surface and then reacts to form oxide. After a certain thickness of oxide layer is formed on the metal surface, the diffusion of oxygen through the oxide layer becomes difficult at room temperature and thus prevents further oxidation. The oxide film, thus, acts as a protective layer on the metal surface.

Keywords: Chromium films, pressure, annealing, ageing, electrical resistivity.

ORAL PRESENTATIONS – Session III

O.D1

LOW-LEVEL LASER THERAPY IN CASES OF DENTIN HYPERSENSITIVITY

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Dentin hypersensitivity (DHS) is characterized by short, sharp pain in response to a stimulus – thermal, drying, tactile, osmotic or chemical; the stimuli cause an unpleasant sensation lasting from seconds to minutes after provocation. Various treatment methods have been introduced, one option being the use of low-level laser therapy (LLLT), whose effect is based on increasing the excitability threshold of the free nerve endings thus causing an analgesic effect, as well as on stimulating the pulp mesenchymal cells to differentiate into odontoblasts and produce reparative dentin.

We report on studies of the efficacy of low-level laser therapy in treatment of dentin hypersensitivity. We selected a group of patients complaining of sensitivity at the cervical area of teeth provoked by such stimuli as air, touch and cold spray. The patients were with good oral hygiene and with intact teeth or small non-carious cervical lesions. They declared the absence of serious systematic and psychological diseases; but some admitted smoking electronic cigarettes, which may aggravate the pain.

Patients were submitted to six sessions of treatment of DHS with intervals from 48 to 72 hours, as indicated by the manufacturer of the low-intensity laser device. The painful sensation was measured before each of the six sessions and immediately after treatment. The results were evaluated by using a four-point scale. The assessment of the answers showed good results, namely, a decrease of the pain sensation from level 3-4 to level 1-2. Yet, we have to interpret this carefully, because pain evaluation is subjective and some of the smokers have stopped smoking electronic cigarettes during the treatment.

To conclude, the LLLT method of curing DHS shows a good treatment efficacy, but needs a more detailed long-term follow up.

O.D2

LOW-LEVEL LASER THERAPY IN CASES OF BURNING MOUTH SYNDROME

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Burning mouth syndrome (BMS) is an intraoral burning sensation, which develops in the absence of mucosal changes. It is a chronic condition and in most of the cases is idiopathic – no cause or mechanism can be identified, and no effective treatment can be prescribed. This leads to anxiety, altered pain perception, and, therefore, reduced quality of life of the affected patients. A variety of therapeutic approaches are being applied – cognitive-behavioral therapy, different drugs and supplements, acupuncture, lasers, none of them achieving a definitive solution of the problem.

The aim of the study is to present the low-level laser therapy as a pain control option in patients with burning mouth syndrome.

We show the potential of diode laser treatment in reducing the unpleasant burning sensation. We also applied laser therapy on patients with a primary burning mouth syndrome. The affected sites on the oral mucosa in the selected cases were various – tongue, lower lip, upper lip, palate, cheeks. They were irradiated 10 times (two or three times a week) by an infrared laser (λ = 904 nm) and a red laser (λ = 658 nm). The probe was kept in contact with the tissue and the mucosal surface was scanned during the irradiation. The burning intensity was evaluated through a visual analog scale before and after the treatment.

We thus found that the low-level laser irradiation reduces the burning sensation significantly for a long period. In conclusion, the low-level laser therapy is a valuable alternative for BMS treatment and can be combined with other treatment methods.

O.F2

PULP VITALITY OF TEETH WITH PERIODONTAL DISEASE

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The periodontal disease is associated with a damage of the supporting structures of the tooth – bone and periodontium. This may affect the teeth, because their innervation and blood supply originate partially from the periodontium.

The aim of the study was to determine the levels of pulp saturation and innervation status in teeth with periodontal disease. To achieve this goal, 192 teeth of 32 patients (17 male and 15 female) were examined. The pulp vitality was examined by a pulse oximeter to determine the pulp saturation, and by an electric pulp test (EPT) to determine the pulp electro-excitation. Teeth with a probing depth (PD) > 4 mm were examined. They were divided into two groups – PD = 4-6 mm and PD > 6 mm. As a control group, we examined teeth without periodontal disease. The results were analyzed statistically using SPSS v.19.

The results are summarized as follows:

Teeth with PD = 4-6 mm: pulp saturation 81 ± 3%, EPT 7 μA ± 3 μA.
Teeth with PD > 6 mm: pulp saturation 79 ± 4%, EPT 10 μA ± 4 μA.
Control group: pulp saturation: 84 ± 3%; EPT 5 ± 3 μA.

To conclude, as the periodontal disease progresses, changes in the dental pulp are observed leading to decreased blood circulation and nervous excitability.

Keywords: pulp vitality, periodontal disease, electric pulp test, pulse oximetry, diagnosis

POSTER SESSIONS

PRESENTED CONTRIBUTIONS

POSTER SESSION I

P.A1

LASER REMOVAL OF MARKER TAGS FROM A CONTEMPORARY GRAFFITI PAINTING

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The application of lasers in the field of art restoration has a long history of scientific study, development, and improvement, which has led to an established and reliable cleaning method for the majority of cases. However, considering the large variety of contemporary art materials, the laser-matter interaction has not been comprehensively studied in this respect. Given the challenge of the scarce knowledge of these newly emerged materials, the efficiency of the laser cleaning of unwanted surface contaminations from contemporary painted artworks is a topic of high interest for heritage science.

This report presents a study on the laser removal of black marker tags from a polychrome contemporary graffiti painting. The cleaning tests are performed with a Q-switched Nd:YAG laser operating at its fundamental (1064 nm) and second harmonic (532 nm) wavelengths, with a pulse duration of 8 ns and a pulse repetition rate of 10 Hz and 20 Hz, while varying the pulse energy. The characterization of the marker inks and the graffiti spray paints is performed by Fourier-transform infrared spectroscopy (FTIR), X-ray fluorescence spectroscopy (XRF), and laser-induced breakdown spectroscopy (LIBS). The evaluation of the cleaning performance is done using optical microscopy and colorimetric measurements.

Keywords: laser cleaning, contemporary graffiti painting, black marker tags, FTIR, XRF, LIBS, optical microscopy, colorimetry.

P.A2

MARKING AND ENGRAVING OF ALUMINUM USING CuBr LASER SYSTEM

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Marking and engraving of aluminum were carried out by a CuBr (copper bromide) laser operating at a wavelength of 511 nm with a pulse duration of 30 ns. The reflectance of the laser ablated aluminum surface was investigated depending on the laser beam scanning speed and

laser pulse frequency and the distance between laser traces. The changes of the aluminum surface were observed before and after laser processing by an optical microscope. The laser marking quality was estimated by measuring the reflectance of the irradiated aluminum surface by an optical spectrometer.

Lasers emitting short pulses, such as CuBr lasers, have shown potential in achieving quality marking and engraving due to their high pulse power, high repetition rate and good focussing capability.

Acknowledgements: The authors acknowledge the financial support by the European Regional Development Fund, Postdoctoral Research Aid No. 1.1.1.2/16/I/001, research application "Analysis of the parameters of the process of laser marking of new industrial materials for high-tech applications, No. 1.1.1.2/VIAA/3/19/474".

P.A3

ANALYSIS OF THE DIFFRACTION EFFICIENCY OF SURFACE RELIEF GRATINGS WITH VARYING SPATIAL FREQUENCIES

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An important goal in the development of diffractive optical elements is achieving a high diffraction efficiency. One class of these elements comprises surface relief gratings recorded by polarization holography in azopolymers, for example (poly[1-[4-(3-carboxy-4-hydroxyphenylazo) benzenesulfonamido]-1,2-ethanediyl, sodium salt]), shortly denoted as PAZO. The aim of the present work is to simulate a highly efficient surface relief grating formed in the PAZO azopolymer; the model is based on experimental results obtained previously by our group. The research tasks are related to the diffraction efficiency analysis in the spectral range from 300 nm to 800 nm for: 1) a range of the grating' spatial frequencies from 300 to 1500 lines/mm, 2) a surface relief height varying from 100 to 500 nm and 3) different shapes of the relief formed.

Acknowledgements: This work was financially supported by contract H38/15 with the National Science Fund of Bulgaria. Equipment of INFRAMAT (Research Infrastructure from National Roadmap of Bulgaria) supported by Contract D01-284/17.12.2019 with the Bulgarian Ministry of Education and Science was used in the present investigations.

P.A4

LASER TREATMENT OF CHITOSAN BIOPOLYMER MATERIALS OF DIFFERENT MOLECULAR WEIGHT COATED WITH ZnO FOR DEVELOPMENT OF ANTIMICROBIAL SURFACES

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Tissue engineering is emerging as a possible solution for regeneration of irreversible bone tissue defects, its main "tools" being artificially created cellular matrices. Chitosan is a natural polysaccharide characterized by a high mechanical strength, biocompatibility, biodegradability and antimicrobial activity (Kumar, 2000). Its linear structure and high molecular weight make it an ideal fibrous matrix that can be blended with other bactericidal metal compounds, such as ZnO, Ti, TiN, TiO to form composite material with even superior antimicrobial properties. Such blending gives rise to cell scaffolds that possess the combined natural potent antimicrobial and photo-catalytic degradation properties of both components (Li, 2010; Haldorai, 2013). For effective tissue engineering integration, the biopolymer-based scaffolds still need additional modification in order to impart biological cues that drive diverse cellular functions, such as adhesion, migration, survival, proliferation, differentiation, and communication. The "ideal" 3D-multicomponent scaffolds mimic the porous native environment of the cells – interconnected pores with well-defined sizes providing the normal functioning of the seeded cells. This porous structure could be achieved by femtosecond laser modification – a non-contact technique ensuring hierarchical porosity and high levels of geometric complexity of the blended scaffolds and thus, an innovative solution for development of customized, antibacterial implants surface mimicking the natural body environment.

In this study, a femtosecond-laser-based method for surface modification was applied to improving the morphological properties of chitosan-based magnetron-sputtered ZnO blends and of chitosan matrices of different molecular weight, thus achieving different levels of morphology to create enhanced antibacterial cell surface environment. The microstructured scaffolds were investigated by SEM, EDX and FTIR. Wettability measurements were performed in order to elucidate the hydrophilicity of the treated surface. Changes in the contact angle values were monitored in the range from 120° to 70° by introducing various laser patterning conditions. Topography/morphology modifications of the biopolymer sputtered blends can essentially improve their bioactivity properties; moreover, creating hierarchical porosity will affect their antibacterial features, which will enable successful applications in tissue engineering.

Keywords: Biomaterials, femtosecond laser processing, antimicrobial coatings, bone tissue engineering.

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Acknowledgements: The authors acknowledge project KP-06-H 38/5 (2019-2022), "Functionalization of 3D printed fibrous scaffolds via femtosecond laser patterning" and project NASU-BAS "Synthesis of calcium phosphate and chitosan composites followed by femtosecond laser treatment for bioactivity improvement of bone scaffolds" 2019-2021 for the support of this study.

P.A5

NANOSTRUCTURES BASED ON ZnO AND TiO_2 OXIDES PRODUCED BY PLD IN OPEN AIR

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Due to their remarkable physical and chemical properties, semiconductor oxides are among the most widely studied materials in view of various applications, such as gas sensors, transparent electrodes, catalysts, etc. One novel approach to modifying and improving the performance of a semiconductor oxide is forming a compound or composite with other oxides. Another approach to improving the functionality of these materials is producing a nanostructured morphology.

In this work, we report fabrication of highly porous metal oxide nanostructures by pulsed laser deposition performed in air at atmospheric pressure. The attention was focused on the structure, morphology, composition, optical and photocatalytic properties of ZnO-TiO_2 metal oxides. The depositions were performed by ablation of ZnO, TiO_2 and a mixed target of ZnO and TiO_2 as initial materials. The materials obtained were characterized by XRD, SEM and UV-Vis analyses. The photocatalytic activity was investigated by degradation of a model aqueous solution of Rhodamine B (RhB) upon UV-light irradiation. The technology applied leads to the formation of nanostructures composed of nanoparticles. The samples possess high transmittance in the visible region, which indicates that they are suitable for photocatalysts for degradation of organic dyes.

Acknowledgements: This work is financially supported in part by the Bulgarian National Science Fund under Project KP-06-N37/20.

P.A6

Nd:YAG LASER ABLATION OF MICRO-CRYSTALLINE GRAPHITE IN WATER SUSPENSION

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The aim of our work was to obtain graphene-like phases (defected graphene, graphene oxide and reduced graphene oxide) as fine suspensions by applying pulsed laser ablation (PLA) to microcrystalline graphite suspension in a water medium. The third (λ_{FHG} = 355 nm) and fourth (λ_{FHG} = 266 nm) harmonics were used of a Nd:YAG laser system with a 15-ns pulse duration at a 10-Hz pulse repetition rate. The morphology of the particles was studied by scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Their phase composition and structure were explored by Raman and X-ray photoelectron spectroscopies, grazing incidence X-ray diffractometry (GIXRD) and TEM. The specimens were prepared by drop casting on a glass substrate (for the Raman and GIXRD studies) and on a standard TEM copper mesh for the SEM and TEM examinations.

Acknowledgements: The authors acknowledge the financial support of the National Science Fund of Bulgaria under grant DN18/9-11.12.2017.

P.A9

RELATIONSHIP BETWEEN TUNABLE OPTICAL ABSORPTION AND SERS ACTIVITY OF Ag/ZnO NANOCOMPOSITES

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We report an experimental and theoretical study of the optical characteristics of Ag/ZnO composite nanostructures. The work is focused on the synthesis and properties of Ag/ZnO nanocomposites and demonstrates their application as SERS active substrates for detection of pesticides. The samples were synthesized by pulsed laser deposition (PLD) of ZnO thin films, followed by implantation of Ag^+ ions in the ZnO matrix and laser annealing of the heterostructures produced. The morphology and properties of the samples were studied with respect to the processing parameters. The optical absorption studies revealed a tunable surface plasmon resonance of the silver nanoparticles in the ZnO matrix. The theoretical calculations of the optical properties, namely, extinction, absorption and scattering efficiencies, were performed on the basis of a generalized multi-particle Mie (GMM) approach. The simulated system adopted in this comparative study consisted of a surface embedded ensemble of silver nanoparticles in a ZnO surrounding medium and in air. The simulated structures were reproduced from the corresponding SEM images after laser annealing at 355 nm and 532 nm.

Acknowledgements: This work is financially supported in part by the Bulgarian National Science Fund under the bilateral project DNTS/Russia 02/3; and by the Russian government – RFBR grant No. 18-58-18001.

P.E2

SPIKES MINIMIZATION BY PULSE DOUBLING PUMP IN Q-CW OPERATION OF A Nd:YAG LASER WITH FLASH LAMP PUMPING

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In this paper, we examine the factors which we can control to minimize the transient spikes in the evolution of a laser pulse.

Our study is based on a simulation model of the overall laser implemented on Matlab Simulink. The proposed model is applicable in the cases of single- or multiple-mesh pulse forming networks (PFN). The technique that can be considered to substantially reduce the spikes is Pulse Doubling Pump.

Keywords: Solid-state laser, pulse forming network PFN, rate equations, Q-CW mode, spikes.

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P.E3

SPATIAL DISTRIBUTION OF THE ELECTRIC FIELD FOR LASER PULSES IN OPTICAL FIBERS WITH A REFRACTIVE INDEX GRADIENT PROFILE – LINEAR CASE

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In recent years, the evolution of one-dimensional and three-dimensional optical pulses in isotropic dispersive linear and nonlinear media has been actively studied. They are used in telecommunications, in optical methods for encoding and recording information, in modern medical laser systems for precision cutting and ablation of tissues. The advances in waveguide technologies are due to the modernization of the equipment and the progress in the scientific knowledge in the field of fiber optics.

Long-term traditions, studies and experience in these fields provoked our interest in the theoretical study of the evolution of 3D optical pulses in fibers with spatial dependence of the refractive index, in which the effects of nonlinearity of the medium are neglected.

The aim of the present research is to investigate the dispersion mode of propagation of three-dimensional optical pulses in fibers with spatial dependence of the refractive index. An exact analytical solution of the linearized equation is found. Numerical simulations of the obtained solutions are carried out.

P.E4

MEASUREMENT OF FEW-CYCLE FEMTOSECOND PULSES CARRIED BY VORTEX BEAMS USING AN INVERTED-FIELD AUTOCORRELATOR

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In this work we prove the reliability of a home-built collinear inverted-field vortex autocorrelator (IFVAC; Fig. 1) in characterizing ~10-fs laser pulses. We analytically simulated this novel vortex autocorrelation and compared it with the experimental data. As a benchmark we used a commercially available device based on spectral phase interferometry for direct electric-field reconstruction (SPIDER) [1]. As far as the setup is based on a classical inverted-field autocorrelator [2], the vortex plate on the input [3], can be added or removed easily, thus switching between vortex and classical collinear interferometric autocorrelation [1] without any realignment of the setup.

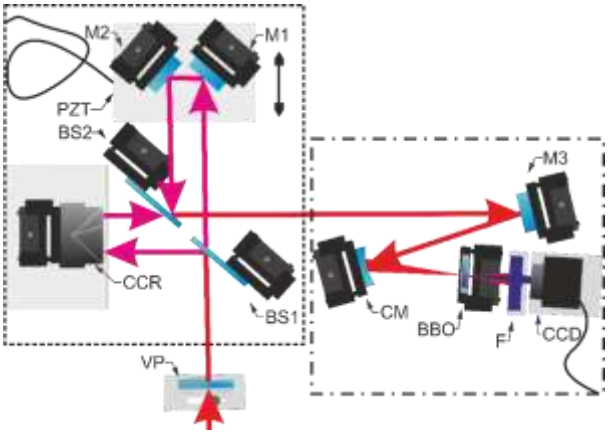

Fig. 1 Inverted field (IF) vortex beam autocorrelator (VAC) setup. Short-dashed rectangle – interferometric part, dash-dotted rectangle – autocorrelation part.

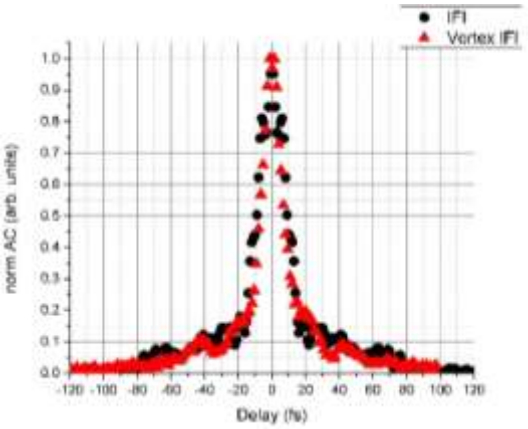

Fig.2 IFVAC signal (red triangles) and autocorrelation signal obtained using classical interferometric autocorrelation (black solid dots).

Applying this novel method, we measured t_{pulse} = 10 fs FWHM. The data obtained with the SPIDER device confirmed this value. In addition, when we switched between the two autocorrelation schemes inserting/taking out the vortex plate VP (see Fig. 1), the obtained results (Fig. 2) confirmed that the novel IFVAC scheme is a reliable option for femtosecond pulse characterization.

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Acknowledgements: This work was supported by the Science Fund of Sofia University, project Nr. 80-10-139/23.04.2020.

P.E5

TRIPLE MIXING OF OPTICAL VORTEX LATTICES FOR FOCUSED BEAMS STRUCTURING

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In this work, we present a versatile approach to beam structuring in the focal plane of a lens by triple mixing of square and/or hexagonal optical vortex (OV) lattices. Based on previous studies [1,2], here we extend the existing results with numerical simulations and experimental evidence, widely discussing some of the possible scenarios for triple mixing, including square-square-square mixing, hexagonal-hexagonal-hexagonal mixing, and the combined square-hexagonal-hexagonal configuration (see Fig. 1). The particular ordering of the phases of the OV lattices placed on two separated spatial light modulators (SLMs) is found to have a negligible effect on the created focal arrays except for the orientation of the structures coming from hexagonal OV lattice(s). Reliable control parameters for the creation of the desired focal beam structure based on the OV lattices node spacing will be discussed. All of the obtained focal beam patterns are found (numerically and experimentally) to be with flat phase profiles. Experimental evidence will be presented and discussed.

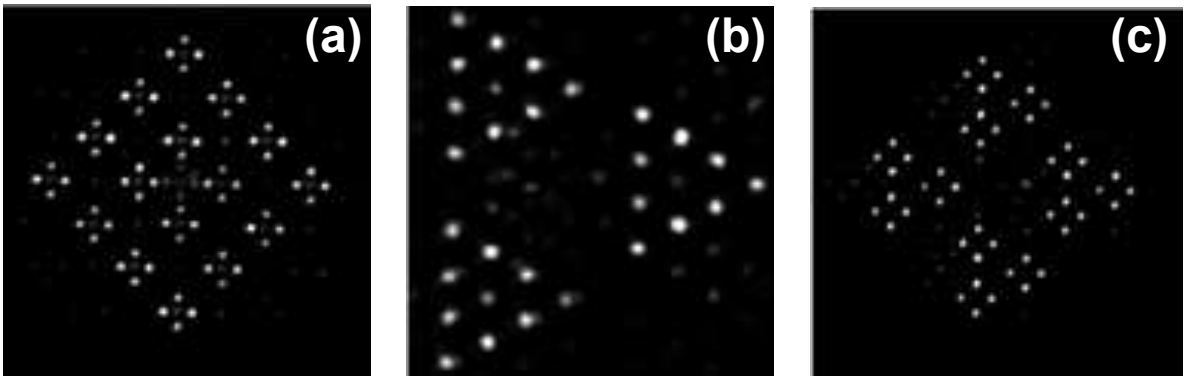

Figure 1. Experimentally recorded focal intensity distributions resulting from triple mixing of OV lattices. The terms node spacing and lattice constant are denoting the distance between two neighboring vortices in any vortex lattice or array. With Δ followed by a subscript we denote the phase distributions sent to the first spatial light modulator SLM1; with δ, phases sent to SLM2. In the following subscript, information regarding the specific type of the used OV lattice is given - *sq* stands for square-shaped, *hex*, for hexagonal OV lattice. The related OV lattice node spacing is denoted afterwards. **(a)** -Triple mixed square-shaped OV lattices with lattice constants Δ_{sq121} and the sum $\delta_{sq41} + \delta_{sq21}$. **(b)** - Triple mixed hexagonal OV lattices with lattice

constants $\Delta_{hex41} + \Delta_{hex81}$ and δ_{hex21}. **(c)** - Triple mixed square-shaped and hexagonal OV lattices with lattice constants Δ_{hex41} and the sum $\delta_{sq21}+\delta_{sq121}$.

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Acknowledgements: This work was supported by the Science Fund of Sofia University, project Nr. 80-10-139/23.04.2020.

P.E6

HIGH-POWER HIGH-BEAM-QUALITY SEALED-OFF LASER SYSTEM OSCILLATING IN THE MIDDLE INFRARED SPECTRAL RANGE ON STRONTIUM ATOMIC TRANSITIONS FOR APPLICATION IN MATERIALS SCIENCE AND TECHNOLOGY

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The discovery that laser radiation at 6.45 μm delivered by tunable free-electron lasers (FELs) provides efficient and precise laser ablation of soft tissue and bones with minimal collateral damage has inspired investigations on strontium and strontium halide vapor lasers. The importance of the wavelength has been proved using a $ZnGeP_2$ optical parametric oscillator (ZPO-OPO) pumped by a Q-switched Er:YAG laser tunable between 6 – 8 μm. It has been also demonstrated that the ZPO-OPO outperformed the FEL as regards the ablation parameters, due to the 50 times shorter laser pulse regardless of the 400 times lower laser pulse energy. Although the applications of tunable laser sources delivering laser radiation at 6.45 μm justify the great efforts made to improve the Sr vapor laser performance, several advanced laser applications, such as precise laser ablation of organic materials, glass and quartz processing, thermal glass cracking, remote sensing of the atmosphere, determination of linear optical properties of newly developed materials, etc., have been also implemented.

We present studies of a large-bore sealed-off gas-discharge tube for a Sr vapor laser excited in a nanosecond pulsed longitudinal discharge and oscillating in the middle infrared (MIR) spectral range with a stable cavity. The laser tube is used as an amplifier in a master oscillator–power amplifier (MO–PA) system. A new optical arrangement is utilized for the MO, as follows: two laser tubes are placed in a negative-branch unstable resonator with magnification $M = 17$. The first laser tube is with copper bromide and windows made of CaF_2. Laser oscillations at 510.6- and 578.2-nm atomic copper lines are used to visualize the optical path. The second laser tube is the actual MO with strontium. A reflective telescope with magnification $M = 1.9$ and a 0.5-mm diaphragm in its confocal plane are also used for spatial adjustment of the MO beam and the PA aperture and for spatial filtering.

High-beam-quality diffraction-limited laser oscillations are obtained at two Sr^+ and several Sr

atomic lines in the MIR spectral region. For precise material processing, the laser beam is focused by an objective lens on samples placed on an X-Y stage. The MO-PA system is applied to microprocessing of quartz, glass, graphite layers, etc.

Acknowledgments: The work is supported in part by the Bulgarian National Science Fund under Grant No. KP-06-H27/5 of 08.12.2018.

P.E15

LONGITUDINAL RADIATION FORCE OF LASER PULSES AND OPTICS OF MOVING NEUTRAL PARTICLES

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As demonstrated by Ashkin [1], it is possible to trap particles by lasers working in a cw mode. The analytical expression of the radiation force on one individual particle is obtained in dipole approximation and, as is well known, is proportional to the transverse gradient of the square of the electrical field. The question of what kind of radiation forces are applied to an ensemble of neutrals from a laser in continuous dielectric media is still open. In this study, measurable parameters – the average effective longitudinal potential and force acting on particles at the level of the pulse spot are presented for a first time. The longitudinal radiation force is proportional to the initial pulse energy and inversely proportional to the pulse time duration. In solids, as silica, the longitudinal force of a 100-femtosecond pulse with initial energy of few nJ is of four-to-five orders of magnitude greater than the molecular bonds. Therefore, the fine ablation with fs pulses in silica can be realized by broken molecular bonds due to this longitudinal PM force. The force is of potential type and in air, for example, the potential of a Gaussian laser pulse with energy $E_0^{pulse} \cong 1$ μJ is thirteen orders of magnitude greater than the Boltzmann energy of free particles. It is possible to confine neutral particles in the pulse envelope, where they will move with the group velocity. Then, the dipole interaction of the moving neutral particles with the electromagnetic field will generate a wave at the carrier-to-envelope frequency instead of at the main one. In a nonlinear regime, the neutral moving particles will not generate a third harmonics but at a frequency proportional to three times the group-phase velocity difference. Such generation was indeed observed in our recent experiments.

The (hydrogen) *neutral* atoms confined into the pulse envelope acquire kinetic energy of order of $E_H^{collision} \cong 1.5$ GeV in a collision geometry. This energy is high enough for a nuclear experiment.

POSTER SESSION II

P.C1

SPRING-TO-SUMMER OBSERVATIONS OF THE AEROSOL LOAD OVER SOFIA-CITY USING NEAR-HORIZONTAL LIDAR SENSING

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Atmospheric aerosols of natural or anthropogenic origin have a significant impact on climatic phenomena and processes on a global and regional scale. In the near-surface atmospheric layers, they have a strong and direct effect on the air quality, local ecosystems and human health. For these reasons, the study and monitoring of the close-to-the-ground aerosol distribution, concentration and dynamics, as well as the localization of aerosol contamination sources and identification of aerosols by type and origin, are of great scientific and public importance, especially over densely populated regions.

In this work, we describe and analyze recent experimental results from nearly horizontal lidar sensing of the distribution and dynamics of the near-surface aerosol load above Sofia City. The lidar sensing advantages in this case arise from the higher efficiency of the laser light interaction with the atmospheric particles, as compared to other remote sensing techniques, such as microwave or acoustic probing. The extinction and/or backscatter-coefficient profiles of the aerosol ensembles along the lidar line-of-sight (LOS) were determined at the lidar wavelengths of 532 nm and 1064 nm (Nd:YAG laser source) and 510.6 nm (CuBr-vapor laser).

The results obtained reflected the ecological peculiarities of the corresponding city regions of interest. Based on the aerosol backscattering/extinction profiles retrieved at different azimuth or elevation angles, two-dimensional color-coded sector maps of the near-surface aerosol density were obtained and overlaid on the topological map of the Sofia region. The analysis of the lidar maps showed a good correlation between the aerosol density distribution and the locations of important sources of aerosol pollutions in the zones of observation, such as city streets with heavy traffic, industrial facilities, densely-populated residential districts, etc. Interesting dynamics was also observed of aerosol masses coming down from Vitosha Mountain to Sofia Valley.

Using lidar and contact facilities, the correlation was also investigated experimentally between the extinction or backscatter coefficient and the integral mass concentration of near-ground aerosol pollution over some districts in Sofia City with differing ecological characteristics. The integral particulate mass concentration was determined using data obtained in parallel by the ecological in-situ station closest to the LOS. Thus, the results obtained of the aerosol mass concentration-to-extinction (or to backscatter) calibration constant of the lidar concerned mainly the site around the nearest station. To help in the interpretation of the results, the

accompanying weather conditions were also followed. The values found of the calibration constant are consistent with those obtained earlier in the same seasons and city districts. They seem reasonable as well when compared to values obtained formerly in different places across the world.

Acknowledgements: This work has been carried out in the framework of the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by Resolution No 577/17.08.2018 of the Council of Ministers and supported by the Ministry of Education and Science of Bulgaria (Agreement No D 01-322/18.12.2019).

P.C2

ESTIMATION OF THE DOUBLE-SCATTERING COMPONENT OF THE LIDAR RETURN FROM MULTICOMPONENT ATMOSPHERE

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Based on a theory developed by Eloranta [1], an estimation is performed of the double-scattering contribution to the lidar return from a multi-component atmosphere containing not only molecular (gas) and aerosol fractions, but other compact aerosol objects as well, such as cirrus clouds, Saharan dust layers, etc. It is shown that the double-scattering component of the lidar return may be estimated by comparing it with the sum of the contributions of each of the atmospheric components evaluated as functions of the altitude, taking into account the scattering properties of the substance under consideration, the angular divergence and the wavelength of the sensing laser beam, and the angle of view of the lidar receiving optics.

The results from the calculations performed show in general that the relative double-scattering contribution is proportional to the angle of view of the receiving optics and the optical thickness of the component of interest, and inversely proportional to the wavelength of the sensing radiation and the altitude and indicatrix peak width of the scattering medium.

The numerical results obtained show that at an angle of view of 2 mrad, the double scattering due return from the molecular and aerosol components and from cirrus clouds and Saharan dust layers is negligible at laser wavelengths $\lambda = 337.1$ nm, 514.5 nm or 1060 nm and clear atmosphere (23 km visibility). In the case of hazy atmosphere (5 km visibility) however, when $\lambda = 337.1$ nm, the double scattering is significant, and will lead to essential lowering of the signal-to-noise ratio of determining the single-scattering return signal.

At a sufficiently small lidar angle of view (e.g., ~ 0.4 mrad), in the absence of optically very thick atmospheric constituents, such as watery clouds, a single-scattering regime of lidar sensing may be achieved. In the opposite case, the results of the sensing may need corrections for the multiple scattering effects [2, 3], especially in the UV spectral zone.

Acknowledgements: This research was supported partly by the Bulgarian Ministry of Education and Science (support for ACTRIS BG, part of the Bulgarian National Roadmap for Research Infrastructure) and the Bulgarian National Science Fund (Grant No. KP-06-N28/10/2018).

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P.C3

ADVANCED PORTABLE DIAL HYGROMETER USING HIGH-POWER PULSED LASER DIODES WITH FIBER- OPTICAL CASCADE COLLIMATOR

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The need for water vapor measurements is determined by the impact of this major greenhouse gas on the global climate formation. The humidity of low atmosphere – the first few kilometers above Earth's surface, is particularly important for modeling and forecasting the weather. Currently, measurements of humidity are performed twice daily by meteorological radiosondes, which involves considerable resources. Besides, insufficient data are thus acquired for the highly-variable boundary layer, which is also inaccessible by the satellite measurements which are restricted to altitudes above 4 km. The development of a compact, inexpensive, eye-safe automated device for remote sensing of humidity becomes imperative.

A laser-based remote-sensing hygrometer is advantageous in obtaining real-time continuous data of high temporal and spatial resolution unattainable by other sensors. Acceptable DIAL performance from a low-power laser diode system demands a broad wavelength region containing optimal water vapor absorption lines undisturbed by other atmospheric gases. The designed DIAL system utilizes the properties of the strong molecular absorption bands of water vapor around 0.86-0.91 μm. The spectral method is based on the integral form of Beer-Lambert's law with the assumption that the profile of a separate absorption line is not resolved. The derived calibration curves are functions of the absorption line strengths modulated by the characteristic broad laser line of the selected laser diodes.

An original DIAL scheme is developed using suitable fiber-optics, which integrates two optical channels of two complementary high-power, pulsed, broad-line laser diodes of different wavelengths. An optimal cascade collimator is also developed using long-tapered optical fibers of decreasing apertures, which ensures effective coupling of the lowest loss and minimal divergence of the laser beam for maximal background light isolation in the lidar signal. Such DIAL provides measurement in a great dynamic range and targeted absorption limit equivalent to atmospheric humidity of 2 g/m^3, up to 3-km lidar paths and a 10% error of signal amplitude.

Acknowledgements: This research has been supported by the Bulgarian Ministry of Education and Science (support for ACTRIS BG, part of the Bulgarian National Roadmap for Research Infrastructure).

P.C4

LIDAR OBSERVATIONS OF MASSIVE SAHARAN DUST INTRUSION ABOVE SOFIA, BULGARIA, IN APRIL 2019

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Airborne Saharan dust, due to its huge amount and large scale of spreading, is one of the key factors determining the atmospheric thermal and radiative parameters and conditions, and consequently affect their impact on the regional and global heating or cooling climate processes. Driven by the air circulation systems in North Africa and the Mediterranean basin, enormous air masses carrying dust from the Sahara Desert often head to the Northeast and cover large parts of Europe, mostly in its southern half. Although such events of long-range Saharan dust transport are observed with increasing frequency in all seasons of the year, even atypically in winter, their strongest and most massive manifestation is in the spring season, especially in the April-May period. During this period, some of the dust intrusion events are so intense and massive that they load the atmosphere over all of Europe with high concentrations of desert aerosols, reaching even its northernmost parts. Such events have a very strong effect on the meteorological conditions and aerosol composition of the atmosphere, as well as on the climatic processes over the continent. Coordinated lidar observations within the European lidar network EARLINET allow for a comprehensive and reliable characterization of these events and their climatic effects. Such an event of large-scale massive transport of Saharan dust over the entire territory of Europe was observed in the second half of April 2019. The Sofia lidar station, as part of EARLINET and the ACTRIS research infrastructure, conducted lidar observations of the atmospheric aerosol load during this period. Some of the results obtained are presented in this report.

Measurements at two wavelengths (1064/532 nm) were implemented using two aerosol channels of a lidar based on a frequency-doubled Nd:YAG laser. Results are presented of studying and analyzing the optical and microphysical properties of detected aerosols, as well as topological and dynamical features of the observed aerosol/dust layers. Height profiles of the atmospheric backscattering coefficient at 1064 nm and 532 nm were retrieved and are discussed. The microphysical properties of aerosol/dust particles were characterized

qualitatively, based on analyzing the retrieved backscatter-related Ångström exponents (BAE) profiles. In order to identify the aerosol/dust particle size-mode distribution, frequency-count analysis was performed of BAE occurrences within particular dust-containing layers. Dust mixing and interaction with other aerosol types of local origin or such captured during the transport were also considered and discussed, based on local radio-sounding data and air-transport modeling and forecasting data. Conclusions are drawn concerning the impacts, both experimentally ascertained and possible, of the massive dust intrusion event on the local atmospheric aerosol structure and the meteorological conditions.

Acknowledgements: The research was funded by the Bulgarian Ministry of Education and Science (support for ACTRIS BG, part of the Bulgarian National Roadmap for Research Infrastructure) and the Bulgarian National Science Fund (Grant No. KP-06-N28/10/2018). It was also partly supported from the European Union's Horizon 2020 Research and Innovation Program under grant agreements Nos. 654109 (ACTRIS-2) and 739530 (ACTRIS PPP).

P.C5

LIDAR DETECTION AND CHARACTERIZATION OF MULTI-TYPE AEROSOL LAYERS IN THE TROPOSPHERE ABOVE SOFIA, BULGARIA

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Aerosols can affect directly and strongly the atmospheric energy budget, climatic processes and weather conditions. In the near-surface parts of the troposphere, they also have a significant impact on the local biosphere, as well as indirectly on human health. For these reasons, the detection and identification of aerosols in terms of type and origin, as well as their optical and microphysical characterization, are of great scientific and practical importance. Lidars are a widely recognized and proven tool for detecting and studying atmospheric aerosols. Very often, in the atmosphere over large parts of Europe, including Bulgaria, intrusions take place of huge amounts of mineral dust from the Sahara Desert. Identifying Saharan dust in the atmosphere by lidar measurements is greatly facilitated by the available online forecast data of its distribution provided by the Barcelona Supercomputing Center (BSC). However, in the absence of desert dust, aerosol layers are often observed in the troposphere by lidar measurements, whose identification by type and origin is not trivial. In such cases it is necessary to involve additional information resources and data. Usually, the most effective ones are the modeling and forecasting data for atmospheric air transport provided by the NOAA HYSPLIT Trajectory Model.

In this paper, we present results of lidar detection and characterization of aerosol layers present in the troposphere over the city of Sofia and obtained in periods for which the BSC forecast did not provide for presence of Saharan dust. The lidar measurements were performed at 1064 nm and 532 nm with the aerosol channels of the Nd:YAG-laser-based lidar of the Sofia lidar station, part of the European lidar network EARLINET and the research infrastructure ACTRIS. Time-averaged vertical profiles of the aerosol backscatter coefficient and the backscatter-related Ångström exponent were retrieved and analyzed. As a result, the tropospheric aerosol loading

density and the dominant aerosol size fractions were assessed. Color-coded height-time diagrams of the vertical distribution of aerosols in the observed layers and its temporal dynamics were also constructed. Combining the lidar observations with a detailed analysis of the NOAA HYSPLIT model forecast data, in particular of a significant number of backward trajectories ending over Sofia in the period of lidar measurements, the detected aerosols were identified by type and origin. The presence was established in the observed layers of considerable amounts of marine aerosols (sea salts) from the Atlantic Ocean and the Mediterranean, as well as continental natural and anthropogenic aerosols mainly originating from Northeastern Europe. In some cases, the presence of Saharan dust was also found, corresponding to periods outside of the BSC dust load forecast ones. This shows the importance of lidar measurements for improving and validating model forecasts. Processes of merging and/or mixing of different aerosol types during the transport or above the lidar site were also established. Conclusions are drawn about the potential climatologic effects of the observed aerosols on a local and regional scale.

Acknowledgements: The research was funded by the Bulgarian Ministry of Education and Science (support for ACTRIS BG, part of the Bulgarian National Roadmap for Research Infrastructure) and the Bulgarian National Science Fund (Grant No. KP-06-N28/10/2018). It was also partly supported by the European Union's Horizon 2020 Research and Innovation Program under grant agreements Nos. 654109 (ACTRIS-2) and 739530 (ACTRIS PPP).

P.D1

DETECTION OF STRESS-INDUCED NEOPLASIA IN THE LOWER PART OF GASTROINTESTINAL TRACT OF RATS USING PHTHALOCYANINES

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The gastrointestinal tract (GIT) tumors are the third most common new cancer cases worldwide, including esophagus, stomach, colon, and rectum neoplasia. As the EUROCARE-4 (http://www.eurocare.it/) investigations showed, the five-year survival rate of this type of oncological disease is about 24% of all cases in Europe. These types of neoplasia are characterized by a high risk and early appearance of metastases. Earlier detection of GIT dysplastic and neoplastic alterations using exogenous markers will contribute to increasing the diagnostic accuracy and the corresponding survival rate. The fluorescent markers, such as photosensitizer drugs used in photodynamic therapy, must be selective to the tumors, non-toxic, clinically approved, and relatively inexpensive [1]. The combination of fluorescence (diagnostic) and photodynamic (therapeutic) properties make such compounds attractive candidates not only for diagnosis but for theranostic applications as well.

In our study, phthalocyanine (AlPc, ZnPc, LuPc – Pcs) compounds were used as exogenous fluorescent markers for diagnostics of GIT adenocarcinoma in laboratory animals (male adult rats (n = 50)) after application of an experimental model of adenocarcinoma formation with metastasis. The neoplastic lesions were developed under the influence of social stress and by chemical stress using nitrosamines during a nine-month period of application [2].

A significant fluorescence signal in the region of 670-720 nm was observed in the neoplastic lesions, which is absent in the normal mucosa. This signal is related to the fluorescence of phthalocyanines accumulated in the tumor area. The autofluorescence background covered the region 450-650 nm with a maximum around 480-520 nm; it originated mainly from protein cross-links and co-enzymes – NADH and flavins signals. Fluorescence from endogenous porphyrins was also observed in the lesions with a maximum at 630-640 nm. Other organs (liver, kidneys, spleen, lungs) were also investigated for presence of metastases. Histological examinations of the lesions were used as a "gold standard".

Visually, the presence was observed of accumulation sites of Pcs in the form of bright pink patches after excitation at 405 nm, compared to the healthy tissue which remained blue-violet due to the autofluorescence signal. This allows one to use the Pcs fluorescence discrimination not only in a spectroscopic mode of detection, but also for imaging of the lesions investigated, which is preferable in the cases of clinical applications during endoscopic observations in humans.

Acknowledgements: This work was supported by the Russian Science Foundation project #18-15-00139 "Optical technologies for early diagnostics of stomach cancer".

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P.D2

ENDOGENOUS AND EXOGENOUS FLUORESCENCE DIAGNOSIS OF TUMORS OF THE GASTROINTESTINAL TRACT LOWER PART

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The standard endoscopy limitations for detecting dysplastic changes of mucosa present significant challenges to and have thus initiated the development of new photodiagnostic techniques complementing the standard endoscopic equipment. Fluorescence spectroscopy is among the most widely examined optical modalities because of its rapid and highly sensitive response to early biochemical and morphological changes in bio-tissues. It could be based on endogenous signals emitted by internal fluorophores in the tissues, such as coenzymes, structural proteins and amino acids, or on exogenous signals originating from applied specific fluorescent markers.

Endogenous fluorescence measurements using UV-VIS excitation wavelengths have revealed a variety of natural fluorophores, including the tyrosine and tryptophan amino acids, coenzymes (NADH and Flavin), collagen and elastin. Deep minima in the tumor fluorescence signals related to hemoglobin re-absorption were observed in the region 540-575 nm. Such a high hemoglobin content was also found as an indication of the tumors vascularization and was clearly pronounced in all dysplastic and tumor sites investigated.

In this work, as an exogenous fluorescent marker we used a photosensitizer from the porphyrins family, namely, the delta-aminolevulinic acid/protoporphyrin IX. The 5-ALA was administered using enema two hours before endoscopic observation and spectral measurements at a dose of 1.5 g per patient (in a 200-ml physiological solution). A high-power light-emitting diode (wavelength of 405 nm) was used as an excitation source (LED-405, 25mW, CW, Polironik Ltd., Russia). The fluorescence signal was fed to an USB4000 (OceanOptics Inc., Dunedin, USA) microspectrometer by an optical fiber introduced through an endoscopic instrumental channel. The fluorescence detected from *in vivo* tumor sites has a very complex spectral origin. It consists of autofluorescence, fluorescence from exogenous fluorophores and re-absorption from the chromophores accumulated in the tissue investigated. However, the fluorescence of 5-ALA/PpIX was clearly pronounced in the 630-710 nm region, having a significant contrast with the surrounding normal mucosa pale fluorescence in the blue-green spectral region. Also, the precancerous mucosa emitted a red light signal, but with lower intensity levels than the carcinoma *in situ* lesions observed. False-positive signals were observed from inflammations in colon and rectum areas, where 5-ALA/PpIX was accumulated as well.

Acknowledgements: The endogenous fluorescence measurements were supported by the Bulgarian National Science Fund of the Ministry of Education and Science under grant #KP06-N28/11/2018. The exogenous fluorescence measurements were supported by the Russian Science Foundation project #18-15-00139. The work of B. Vladimirov and L. Avramov was supported under project #KP06-N38/13/2019 of Bulgarian NSF-MES.

P.D3

INFRARED THERMOGRAPHY IN THE DIGNOSTICS OF HIDDEN INFECTIONS – CASE REPORTS

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Three interesting case reports will be presented that prove infrared thermography's many advantages as a new diagnostic tool, which can be successfully used in detecting hidden pathological processes with vague unclear symptoms.

The first case involved Hashimoto thyroiditis of a 39-year-old woman diagnosed with the disease two years before, in good health but with permanently high thyroid antibodies (TAT). The infrared thermography revealed an inflammation around the second left mandibular molar, which did not show any radiographic signs of pathology. Six months after the extraction of the tooth, the TAT returned into normal ranges.

The second case concerns a 40-year-old female patient with alopecia areata on the right fronto-temporal region – a five-cm lesion. The dermatological treatment gave no results, so the patient was referred to us for focal diagnostics. The infrared thermography showed two sites with hidden infection: one of dental origin – tooth 36 with periodontitis chronica granulomatosa, and a second site in the genital area – a thermal image of endometriosis, a diagnosis later confirmed by a gynecologist. A gynecological operation was performed. The focal infection thus eliminated, the hairless lesion recovered fully.

The third case report is of a 34-year-old healthy male with alopecia areata of the beard and no other complains. The infrared thermography detected active sinusitis of the ethmoidal left sinus. A microbiology test confirmed the presence of *Staphylococcus aureus*; following the administered antibiotic course the hairs recovered fully.

These and many other cases give us reason to consider infrared thermography as being a novel and promising non-invasive and objective diagnostic tool for clarification of difficult to diagnose cases.

P.D4

EX VIVO FLUORESCENCE AND REFLECTANCE POLARIZATION MEASUREMENTS OF GASTROINTESTINAL CARCINOMA LESIONS FOR CANCER DIAGNOSTICS

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Numerous optical techniques have been recently applied in the clinical practice in view of obtaining new data on various different mucosal neoplastic lesions. The use of polarized light for biomedical diagnostics of skin and mucosa has already a long history. Prior studies demonstrated the enhancement of the contrast between the polarimetric values and images of cancerous and healthy zones [1-2].

In this work, surgically removed gastrointestinal tissue (GIT) samples were transported under isothermal conditions and in a solution for safekeeping from the hospital to the spectral laboratory, where their fluorescence and reflectance polarization properties were investigated. All patients received and signed written informed consent. The research was approved by the Ethics Committee of Tsaritsa Yoanna–ISUL University Hospital, Sofia.

The GIT samples containing normal and neoplastic mucosa were studied by fluorescence polarization in an EEMs (excitation-emission matrices) mode and by synchronous fluorescence spectroscopy (SFS). Linear polarizers were placed in the excitation and emission channels of a FluoroLog3 spectrofluorimeter (HORIBA JobinYvon, France) to follow in a broad spectral range (300-800 nm) the characteristic differences in the fluorescence spectra of cancerous and healthy colorectal tissues *ex vivo*. A PAX1000VIS/M polarimeter (400-700 nm, ThorLabs Inc.) was used in a reflectance mode to obtain information about the polarimetric parameters of the GIT samples. The most significant differences were observed in the long-wavelength region (>600 nm) in the case of circular polarization of the pump and probe beams of the measurement unit. Histological analysis was used as a "gold standard" to compare the results of the optical and pathological diagnoses.

Acknowledgements: This work was supported by the Bulgarian National Science Fund of the Ministry of Education and Science under grant #KP06-India-8/07.08.2019 "Polarization-sensitive fluorescence spectroscopy and microscopy for cancer detection". The work of O. Semyachkina-Glushkovskaya and E. Borisova was partially supported by the Russian Science

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P.D5

EXPERIMENTAL VALIDATION OF DEPOLARIZING MUELLER MATRIX MODEL VIA EX VIVO COLON SAMPLES

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An experimental validation of a previously reported depolarizing Mueller matrix model [1] is crucial to understanding the light-tissue interactions and morphological alterations originating from malignant tissue zones in terms of their optical properties. Furthermore, the results presented are sufficient to validate a Monte Carlo simulation code developed in LPICM. Once extracted from an experimental Mueller matrix via symmetric decomposition, the polarimetric quantities were compared with previously determined reference parameters measured on *ex vivo* colon samples. Our results indicate a potential experimental applicability of the theoretical model for supplementary diagnostic information obtained from histological slides and used for tissue identification during the pathological analysis currently used as a golden standard in histopathology.

Acknowledgements: This work was supported by the National Science Fund of the Bulgarian Ministry of Education and Science under grants #KP06-N28/11/2018 and #KP06-N38/13/2019.

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P.D6

THEORETICAL STUDY OF LASER-BASED PHOTOTHERAPIES' IMPROVEMENT VIA UPCONVERTING NANOPARTICLES

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The clinical translation of coherent light-based theranostics procedures such as photodiagnosis (laser induced fluorescence – LIF) and phototherapy (e.g. photothermal therapy – PTT, photodynamic therapy – PDT) has been limited to skin pathologies and tumors which are easily accessible (e.g. through endoscopes). Aelivering non-ionizing light to deeper tissues, up to 1 cm, has been limited to wavelength's emission in the so called "optical window", spanning approximately the NIR range (from 650 to 1200 nm), where no specific tissue chromophores or exogenous photosensitizers absorb or scatter the incident light. As a solution for deep tissue theranostics interventions, the introduction of new upconverting nanoparticles (UPCNPs) in the tumor area is being investigated worldwide. These have the potential: (i) to be detected by emitting light of a shorter wavelength than the one they absorb, (ii) to further emit visible light which excites photosensitizers accumulated in tumor causing damage to the nearby cancer cells by producing reactive oxygen species (ROS), and (iii) to be activated causing additional photothermal destruction of cancer cells. As the development of biophotonics techniques permits bioimaging on a nanoscale, both photodynamic and photothermal sensing should be achieved at cellular level with minimum perturbation, i.e., in absence of any physical contact between cells and sensing units at a single-cell level via optical tweezers.

In our work, we discuss the biophotonic upconversion mechanism of the nanoparticles' excitation/emission on a cellular level, under laser trapping conditions, via considering laser radiation of NIR (specifically at λ = 808 nm) for optimal penetration in biological tissues. Moreover, a theoretical simulation model will be presented for evaluation of the electric field distribution in optically trapped particles. Water or ethanol soluble UPCNPs with maximum absorbance wavelength at λ = 808 nm and emission at 545 nm and 660 nm will be studied. The photoluminescence of biocompatible UPCNPs could provide a promising powerful tool for PDT single-cell analysis and/or for photothermal enhancement and sensing in an optical tweezers' platform.

Acknowledgments: The author G.K. would like to state that his part of this research has been co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Program «Human Resources Development, Education and Lifelong Learning» in the context of the project "Strengthening Human Resources Research Potential via Doctorate Research" (MIS-5000432), implemented by the State Scholarships Foundation (IKY) [Scholarship number: 2018-050-0502-14578]. The authors M.M. and A.A.S. gratefully acknowledges the funding of the European Regional Development Fund (ERDF) and National Funds "Synergy ELI-LASERLAB EUROPE, HiPER & IPERION-CH.gr (MIS 5002735)", 2017.

P.D7

PHOTOSENSITIZERS-FREE BREAKTHROUGH TECHNOLOGY OF NON-INVASIVE PHOTO-IMMUNOTHERAPY OF GLIOMA

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Brain tumors are among the most feared of all forms of cancer with very limited treatment options and a poor prognosis. It has been recently discovered that the meningeal lymphatic system (MLS) is essential in generating an efficient immune response against brain tumors and clearing the brain of toxins and macromolecules. In our pioneering study, we demonstrate an important role of MLS in resisting glioma's growth that can be modulated by photosensitizers-free photo-stimulation (Phs-free-PS) by using a quantum-dot 1268-nm laser generating singlet oxygen without Phs. We clearly show that a four-week course of PS at 357 J/cm^2 causes an effective suppression of glioma's growth and an increase in the survival rate via PS-activation of the drainage and clearing functions of the MLS associated with PS-induced immune response including the prevention of autophagy and high proliferation of glioma cells with stimulation of apoptotic cell death. Our findings clearly demonstrate that Phs-free-PS might be a breakthrough technology of non-invasive photo-immunotherapy of glioma that can be used as a course of long and repeated alternative treatment of brain tumors.

Acknowledgments: This work was supported by grants: RBRF 20-015-00308_a, RBF — 20-15-00090, RF Goverment Grant 075-15-2019-1885.

POSTER SESSION III

P.B1

MULTI-ANALYTICAL SPECTROSCOPIC APPROACH TO CHARACTERIZATION OF POLYCHROME SURFACES – APPLICATION IN CULTURAL HERITAGE PRESERVATION

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Preservation of cultural heritage is a particularly delicate subject given the uniqueness and the high social value of the precious items. A large and important part of its activities is the characterization of the composition of the objects of interest. Generally, these objects comprise complex materials which implies the need for a comprehensive analytical approach. This report demonstrates the potential of applying several spectroscopic techniques for the characterization of different materials with polychrome surfaces that are of specific interest in the conservation practice, such as ceramics, frescoes, paintings, etc. The multi-analytical approach consists of optoelectronic techniques that are well established in the field of heritage science, namely laser-induced breakdown spectroscopy (LIBS), X-ray fluorescence spectroscopy (XRF), and Fourier transform infrared spectroscopy (FTIR). The aim is to show and validate the complementarity of the experimental data acquired by the spectroscopic methods and to compare the advantages of each method applied in the different cases. The spectral data obtained could be implemented in comprehensive databases which could be used by a large community of interdisciplinary specialists handling a certain conservation-restoration protocol.

Keywords: LIBS, XRF, FTIR, polychrome surfaces, heritage science

P.B2

ENHANCED ABSORPTION AND TRANSPARENCY COHERENT MAGNETO-OPTICAL RESONANCES IN HOT POTASSIUM VAPOR

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Magneto-optical spectroscopy is a tool which is extensively applied in many scientific fields, largely due to the widely available single-frequency near-infrared laser diodes that cover the spectral region of the first resonance line of alkali vapor. With the advances in diode laser production technology, these applications can now be extended to the violet/blue spectral region. A key feature of this type of coherent spectroscopy is the possibility to register magneto-optical resonances with very narrow spectral width, determined by the ground-state hyperfine level lifetime. The hot potassium vapor is a very promising candidate for the efficient preparation of such narrow resonances based on a single hyperfine (hf) optical transition, since the ground-state hyperfine splitting of K is smaller than the Doppler width of the D_1 and D_2 optical transitions (first resonance lines). The overlapping of the transitions starting from a single ground-state hf level can be very profitable, because it acts against the hf optical pumping that can compromise the formation of good contrast magneto-optical resonances. Potassium vapor is used in the most sensitive optical pumping atomic magnetometers, which operate at high temperatures in order to achieve high alkali vapor densities and narrow optical resonances.

In this communication we present our experimental results on the preparation of magneto-optical resonances in potassium using excitation of the second resonance line with a wavelength 404.4 nm. The magneto-optical resonances are registered in Hanle configuration, i.e. monitoring the atomic fluorescence vs the applied magnetic field B scanned around zero value. Excitation of the second resonance line leads both to direct fluorescence at the excitation wavelength and to cascade decay with fluorescence at the wavelength of the first resonance transition. These two types of fluorescence are experimentally discriminated by using appropriate filters at the violet (404.4 nm) or the infrared first resonance line of K (770.1 nm).

The 404.4 nm excitation of K induces coherent superposition of the ground state Zeeman sublevels at B = 0, which can be measured by the direct 404.4 nm fluorescence as a function of the magnetic field. The atomic polarization formed is further transferred to the atomic levels of the first resonance line. This transfer is evidenced by the registration of a narrow magneto-optical resonance in the fluorescence from the $4p^2P_{1/2}$ and $4p^2P_{3/2}$ levels (the infrared lines), which is of opposite sign, for the hot potassium vapor case. It should also be noted that even after multiple cascade transitions, the resonance observed on the infrared lines has a much better signal/noise ratio compared to that on the excited second resonance line. Therefore, the study of these sub-Doppler-width magneto-optical resonances in hot potassium vapor will be useful for the further development of the high-resolution magneto-optical laser spectroscopy.

Acknowledgements: This work was supported by the National Science Fund of Bulgaria under contract DO08-19/2016 "New coherent and cooperative effects in hot alkali vapor" as well as goszadanie: #3.4903.2017/6.7, AAAA-A17-117052210003-4". S.T. acknowledges the National Program "Post-Doctoral Students" RMS, No 271/2019.

P.B3

SUPER - RESOLUTION FAR-FIELD INFRARED MICROSCOPY

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Different vibrational microscopy techniques, such as coherent anti-stokes Raman microscopy (CARS), sum-frequency generation (SFG) microscopy and Fourier–transform infrared absorption microscopy are commonly used for the investigation of biological interfaces with high chemical selectivity, but their spatial resolution is limited by the diffraction of light. In 1994, Hell demonstrated the possibility of bypassing the spatial resolution limit due to diffraction in fluorescent microscopy using the stimulated-emission-depletion (STED) process. STED microscopy achieves resolutions down to few nanometers on biological structures. Other methods in fluorescence microscopy using fluorescence chromophores have thereafter been developed circumventing this Abbe diffraction limit, including ground state depletion (GSD), nonlinear structured illumination microscopy (SIM), stochastic optical reconstruction microscopy (STORM), and photo-activated localization microscopy (PALM). Label free sub-diffraction chemical imaging techniques have also been proposed, such as depletion of the ground state population, periodical suppression of the signal by controlling the relative phase between the pump light and the Stokes light in the CARS technique and addition structured illumination method with wide field geometry in the SFG technique.

We recently theoretically proposed that super-resolution can be achieved in label-free infrared microscopy by exploiting the non-linearity intrinsic to any optical transition. We review our proposed concepts and compare the advantages of three configurations such as pump-probe, differential absorption, and attenuated total reflection configurations. We then highlight recent experimental demonstrations achieved in label-free super-resolution chemical imaging that succeed in exploiting these novel concepts on nano-structure defects in a single layer of graphene.

P.B4

MODELING AND ANALYSIS OF THE RI SENSITIVITY IN PLASMONIC SENSOR BASED ON MIM WAVEGUIDE-COUPLED STRUCTURE

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Surface plasmon polaritons (SPPs) are waves that propagate along the surface of a conductor due to the interaction between the free electrons of the conductor and an electromagnetic field. Various devices have been designed based on SPPs phenomena such as sensors, lasers, filters. The optical sensors have been focused on refractive index (RI) measurement in biomedical, chemical, and gas, and have been intensively studied in recent years, such as the solution concentration and pH value, which can be measured via RI changes, and all that because of their high sensitivity, fast reaction where the structural parameters of the sensor has a key role in its sensitivity and transmission spectrum.

In this study, we propose a high-sensitivity sensor structure consisting of a metal-insulator-metal (MIM) waveguide and a resonator that can be used as an RI plasmonic sensor with various capabilities in various areas where composed. The transmission characteristics of light in the sensor under different RIs are simulated by using the finite-difference time-domain method.

P.B5

USING NON-EQUILIBRIUM LASER PYROLYSIS OF ORGANOSILICON COMPOUNDS IN TECHNOLOGIES FOR PROFILE CORRECTION OF POLISHED SURFACES

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Currently, there is an increasing interest in laser additive technologies, which are used in various fields of materials production. Studies have appeared on the use of surface shape correction of polished parts by deposition of coatings with varying thickness. Silica films are prepared by vapor decomposition of organosilicon compounds in the presence of oxygen or ozone. Since the pyrolysis rate depends on the temperature, the desired relief can be formed by creating a calculated pattern of inhomogeneous heating of the surface by laser radiation. Positive examples of the use of this method have been demonstrated in the creation of spherical surfaces or surfaces with a weak slope. In cases of heating by cw laser radiation, the radii of curvature or the magnitude of the relief gradients were limited by the thermophysical characteristics of the substrate material, which determine the spatial resolution parameters of the inhomogeneities

formed. The limits of these possibilities can be expanded by the use of pulsed heating, when the controlled values are the pulses duration and repetition rate, along with the power density of the laser radiation. These issues are considered in this paper.

Mathematical modeling of the process of non-stationary laser pyrolysis in various modes was carried out, the results of which were evaluated in terms of the deposition rate of the silicon dioxide coating and the ability to provide relatively sharp changes in its thickness. It was shown that by applying pulsed heating in this technology, significantly higher surface temperatures can be used to deposit films in comparison with those that are optimal in the case of stationary chemical vapor deposition. Under conditions of short laser pulses, surface irradiation is not accompanied by such a significant heating of the volume of ambient air as is inevitable with equilibrium pyrolysis. This minimizes unwanted losses from homogeneous chemical reactions as a result of a shift in priority to a heterogeneous process on the surface.

The theoretical analysis data were well confirmed by the experimental results. As samples, polished fused silica plates were used. The small temperature coefficient of linear expansion of the substrate material precluded the possibility of cracking even at sharp temperature changes. Heating was carried out by a pulsed CO_2 laser at a wavelength of 10.6 μm. Local surface heating was achieved in the range up to 800 ^oC. The SiO_2 films formed were the result of pyrolytic decomposition of tetraethoxysilane in the presence of ozone.

The formed surface profile of fused silica samples was studied by means of laser phase-shifting interferometry. It is shown that the proposed technology allows for surface shaping and local adjustments of its profile with specified gradients as a result of a programmed scanning of a laser beam over the sample surface.

P.B6

DUAL-BEAM EIA RESONANCE IN A ^{87}Rb CELL WITH ANTI-RELAXATION COATING

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Destruction of the laser-induced coherence in the ground state of alkali atoms is manifested as an ultra-narrow resonance. Depending on the geometry of irradiation and observation, the coherent spectroscopy studies involve coherent population trapping (CPT), electromagnetically induced transparency (EIT) or electromagnetically induced absorption (EIA).

In our recent research, we studied EIA on the D_1 ^{87}Rb line by applying the pump-probe scheme suggested in [1]. The main advantage of this scheme is the high resonance contrast, an important parameter in many applications. In our work performed in a paraffin-coated cell [2], we found that unlike the resonance in a buffer gas cell detected in the same experimental scheme, in a coated cell the EIA resonance exhibits a typical complex shape registered in CPT and EIT experiments and arising from the existence of two atomic sub-ensembles in the vapor cell that have

different relaxation rates determined by the laser excitation conditions. The lifetime of the atoms responsible for the wide pedestal is defined by their time-of-flight across the laser beam. The second ensemble of atoms forms the narrow resonance, whose width is determined by the time of coherence preservation after collisions with the cell walls. Our attention has been focused on the narrow component, because it has a bigger amplitude-width ratio, which is preferable in many applications.

In the present work, we studied the effect of the atomic vapor density and the pump laser light intensity on the resonance contrast in order to optimize the amplitude ratio of the wide and narrow components, and to achieve a high amplitude-width ratio value for the narrow component of the EIA resonance.

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Acknowledgements: This work was supported by the Bulgarian National Science Fund, Contract No DN 08-19/14.12.2016 "New coherent and cooperative effects in hot alkali atoms".

P.D8

EIGHT-YEAR FOLLOW-UP OF LOW-LEVEL LASER THERAPY (LLLT) EFFECT IN PATIENTS WITH AGE-RELATED MACULAR DEGENERATION

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Age-related macular degeneration (AMD) is the leading cause of blindness among the population over 65 in developed countries [1]. AMD is divided into two types: a dry (non-exudative) form of macular degeneration in about 90% of cases of macular degeneration characterized by drusen, and a wet form of macular degeneration, with growth of neovessels of the choriocapillaris through the Bruch's membrane, called choroidal neovascularization [2]. The objective of this study is to examine the long-term effects of low-level laser therapy (LLLT) in patients with a dry form of AMD.

The research was implemented for a period of eight years. In total, 45 patients (22 men and 23 women, 90 eyes) with a dry form of AMD and a mean age of 67.5 ± 2.2 years were included. The LLLT was applied by a CW He-Ne laser (633 nm, 1 mW/cm^2) to patients with drusen in the macular area. Laser radiation was applied six times every year transpupillary for 3 min once in two days to the macula. Thirty-six patients with AMD (72 eyes) were randomly selected to

receive mock treatment (control group 17 men and 19 women with a mean age of 67.2± 3.8 years). The visual acuity was followed for an eight-year period. The Perimetry and the Amsler tests were used to examine central scotomas. The fluorescein angiograms and OCT of the AMD and control groups were examined.

We found a reduced visual acuity in all patients in the control group after eight years. There was a statistically significant increase in the visual acuity ($p<0.001$, end of study versus baseline) for AMD patients for the period of eight years after LLLT. In the LLLT group, we observed a reduction in scotomas and drusen. The results show that the LLLT is an effective treatment that improves the visual acuity in dry-form AMD for a long period of time.

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Acknowledgments: The work was supported in part by the Bulgarian National Science Fund under project KP-06-H29/112018 „Phthalocyanine photosensitizers against microbial resistance".

P.D9

BIOCONJUGATES OF PHTHALOCYANINE WITH STEROID UNITS FOR PHOTODYNAMIC THERAPY

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The development of latest photosensitizers (PS) for antimicrobial photodynamic therapy (aPDT) focuses on the bioconjugation of the known PSs, such as phthalocyanines, with biologically-active molecules with cationic charge so as to facilitate the properties responsible for aPDT [1]. The uptake, localization and, moreover, the antimicrobial activity of PS are connected with their structure. There are several requirements to the new PSs, including that they have to act effectively towards the pathogenic strains, but especially towards the resistant Gram-negative species organized in biofilm matrixes.

The study emphasizes a comparison between the properties of the basic structure of phthalocyanine zinc complex (ZnPc) and those of the newly synthesized ZnPc with a steroid (ZnPcSt). A new synthetic scheme includes an azide-alkyne cycloaddition reaction applied to obtain a new ZnPcSt molecule, which after alkylation was turned to the positively charged derivative. The study presents a comparison of the photophysical and photochemical properties and the photooxidation of cholesterol by the novel phthalocyanine functionalized with steroid moieties. The main light-associated properties were studied in comparison to the basic Zn(II) phthalocyanine core molecule. A further understanding of the mechanism of the PS interactions with membranes of pathogenic species is discussed with respect to the PDT efficiency.

Acknowledgements: The work was partially supported by the Bulgarian National Science Fund under project KP-06-H29/11, Dec. 2018.

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P.D10

NEAR-INFRARED AUTOFLUORESCENCE SPECTROSCOPY AND PHOTOBLEACHING DETECTION OF HUMAN CUTANEOUS TISSUES – TOOL FOR MELANIN-PIGMENTED SKIN CANCER DETECTION

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A number of optical techniques have been applied recently in the clinical practice to obtain new data on different skin neoplasia. One of the most sensitive approaches is based on detecting the endogenous fluorescence of pathological alterations in cutaneous tissues, including development of cancerous tissues. The fluorescence technique provides information on the biochemical alterations and on the morphological changes in the extracellular matrices of the tissues investigated. The UV-VIS autofluorescence diagnostics relies on detecting the emission of amino acids, proteins, co-enzymes and vitamins, which have overlapping excitation and emission spectra in the ultraviolet and visible spectral ranges. This leads to some difficulties in the spectral analysis and to a low specificity of evaluation of the lesions' stage. This has provoked studies of autofluorescence signals as possible diagnostic indices in the red and near-infrared spectral ranges, where pigments, such as porphyrins and melanin, have fluorescent emissions far from those of the bulk of other endogenous fluorophores.

In the current study, an excitation laser source at 785 nm (100 mW, CW) was used to obtain fluorescence of endogenous melanin in benign, dysplastic and malignant *ex vivo* pigmented cutaneous lesions. The samples were obtained after surgical removal during standard excision procedure and split for spectral analysis and histological verification. The samples of benign (BN-5) and dysplastic (DN-3) nevi, as well malignant melanoma (MM-7) were used as representative for harmless/harmful cutaneous neoplasia with similar melanin pigmentation. Emission in the range of 800-1100 nm was detected and compared using an USB4000 (OceanOptics Inc., USA) microspectrometer. Photobleaching dynamics was observed for the maxima of emission at 825 nm with a step of 30 seconds, 10 minutes period of time.

These near-IR autofluorescence spectra can be assigned to a single fluorophore if an appropriate excitation wavelength is applied, which simplifies and hastens the analysis related to the appearance and concentration of a given type of endogenous fluorophore, while also allowing for an evaluation of parameters, such as photobleaching dynamics, as diagnostic indicators for assessing the tissue state. The diagnostic accuracy of MM lesions validation reached 93,3% when the values of NIR fluorescence intensity and rate of photobleaching were used to discriminate nevi from melanoma lesions.

Acknowledgements: The NIR fluorescence steady-state measurements were supported by the National Science Fund of the Bulgarian Ministry of Education and Science under grant #KP06-N28/11/2018. Photobleaching analysis is a result of work on the projects for collaborative research with Russian and Latvian groups under research project of NSF-MES No KP06-Russia/19/28.09.2019 "Multivariative Raman and fluorescence diagnosis of cutaneous tumors" and by the project for inter-academic exchange with Latvia "Multispectral and fluorescent imaging of skin tumors".

P.D11

MACHINE-LEARNING-BASED CLASSIFICATION OF STOKES MUELLER POLARIZATION IMAGES FOR TISSUE CHARACTERIZATION

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Microstructural analysis of tissues plays a crucial role in the early detection of abnormal tissue morphology. Polarization microscopy, an optical tool to study anisotropic properties of

biomolecules, can distinguish normal and malignant tissue features even in the absence of exogenous labelling. To facilitate the quantitative analysis, we have developed a polarization-sensitive label-free imaging system based on Stokes-Mueller calculus. Polarization images of squamous cell carcinoma (SCC) tissue samples were obtained using various input polarization states and Stokes-Mueller images were reconstructed using Matlab software. Further, polarization properties, such as degree of linear and circular polarization, anisotropy, were reconstructed from the Stokes images. The Mueller matrix obtained were decomposed using the Lu-Chipman decomposition method to acquire individual polarization properties of the sample, such as depolarization, attenuation and retardance. By using the statistical parameters obtained from polarization images, a support vector machine (SVM) algorithm was trained to facilitate the tissue classification associated with its pathological condition.

Keywords: Stokes-Mueller polarization microscope, tissue imaging, support vector machine.

Acknowledgements: We acknowledge Prof. K. Satyamoorthy, Director, Manipal School of Life Sciences for his encouragement, and Manipal Academy of Higher Education, Manipal, India for providing the infrastructure facilities. We also thank Dr TMA Pai Ph. D. Scholarship for fellowship. This work is supported by the Department of Science and Technology (DST) - Science and Engineering Research Board (SERB) (Project No ECR/2016/001944) and DST (Project No DST/INT//BLG/P-03/2019), Government of India.

P.D12

OCCLUSAL SPLINTS – CHANGES IN THE MUSCULAR ACTIVITY

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Bruxism is considered in dentistry an oral parafunction of involuntary grinding and clenching of the teeth. Occlusal splints are the most common method of preventing bruxism and its consequences. Their application significantly reduces the pathologies of the dental and periodontal structures. The infrared thermography (telethermography, telethermometry, electronic thermography, or digital infrared telethermographic imaging) is a noncontact method of temperature measurement where the detector is held remotely pointing to a single spot. In a clinical set up, a normal temporomandibular joint (TMJ) examination using thermography had showed symmetrical thermal patterns with a mean ΔT values of 0.10 ^{o}C. Scientific findings have suggested that telethermography can distinguish between asymptomatic patients and patients with temporomandibular joint dysfunction (TMD), where the findings are asymmetrical.

The purpose of the study is registering by means of infrared thermography changes in the muscular activity during the period of occlusal splint prophylaxis. Infrared thermography images were taken of 26 patients diagnosed with sleep bruxism. Patients were preliminarily

diagnosed clinically and objectively by a BiteStrip® disposable miniature electromyography device. Each patient of the group had four thermographies taken – directly before starting the preventive treatment with an occlusal splint, and two weeks, one month and three months after the start. In the timeline of this study, the patients were wearing the splint during sleep for a minimum of six hours. A Flir T335 infrared thermal camera was used for the imaging. Both thermal and a normal image were taken and analyzed by the Flir Reporter Pro 9 software.

The infrared imaging of the masticatory muscles activity of patients with bruxism showed a certain temperature change three months after the start. The pathological masticatory movement of such patients leads to TMJ disorders and muscular over reactivity which in the beginning is a reversible process. If not taken care of, the pathology might become irreversible thus causing serious pain and dysfunction. The positioning of TMJ back to normal by splints led to normalization of the whole mastication process – objectively observed by infrared thermography imaging.

Infrared thermography can be considered an alternative and auxiliary diagnostic method for bruxism and its negative consequences to the masticatory system and can prove the possible association of specific muscles of the cranio-cervico-mandibular complex with an increased muscular activity seen in bruxism patients.

P.D13

PHOTODIAGNOSTICS AND PHOTODYNAMIC TREATMENT OF STEM CELLS CULTIVATED FROM HUMAN GLIOBLASTOMA TUMORS

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Glioblastoma (GBM) is the most common and most malignant type of brain tumor. The average survival rates in patients with newly diagnosed GBM is only about 14 months, despite use of aggressive surgery, radiation therapy and chemotherapy. Glioblastoma, unlike other malignant tumors, rarely spreads outside of the brain and the main cause of death is the local intracranial progression.

Photodynamic therapy (PDT) using 5-ALA/PpIX from the family of porphyrins and aluminium-phthalocyanine (AlPc) has proven its effectiveness in the treatment of different neoplasia, including brain ones. The mechanism of action is based on the formation of singlet oxygen resulting from the absorption of light at a specific wavelength from a photosensitizer molecule that is selectively accumulated in the tumor cells.

Application of porphyrins and phthalocyanines as photosensitizers leads to their selective accumulation in glioblastoma cells due to their hem metabolism disorders and could be used effectively for intraoperative fluorescence staining of the tumor formation and differentiation from normal brain parenchyma. The aim of this work was to investigate the photodynamic properties of 5-ALA/PpIX and AlPc on stem cell cultures isolated from glioblastoma. Supernatant samples of photosensitizer-treated cell lines were used for evaluation of the photosensitizers' accumulation in the cell lines investigated, using excitation in the spectral ranges of Soret' band (360-410 nm) and \Q-band (600-650 nm). The emission detected was used to evaluate the efficacy of the photodynamic treatment during PDT irradiation and of inducing apoptosis and necrosis processes in cell lines treated with the photosensitizers. Several variables were studied, such as histochemical and genetic variants of glioblastoma, various photosensitizers' concentrations and light-emitting parameters. The results of this *in vitro* work will be used as the basis for a further *in vivo* application on animal models of glioblastoma with applying irradiation using intracranial light sources and for a subsequent transfer of the protocols developed of photodynamic treatment of glioblastoma lesions in such model systems for the needs of human medicine.

Acknowledgments: This work was partially supported by the Bulgarian National Science Fund under grant #KP06-N23/8/2018 "Innovative photodynamic methods for treatment of stem cells cultivated from glioblastoma tumors" and under grant #KP06-N38/13/2019 "Development of methods of biophotonics as a basis of oncological theranostics - 2".

POSTER SESSION IV

P.A7

A PARAMETRIC STUDY OF SUB-PICOSECOND LASER ABLATION OF THIN METAL FOILS

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With their ultrashort pulse width and ultrahigh peak power, femtosecond lasers excel at processing materials whose thicknesses is less than 500 microns. Numerous experiments and theoretical analysis have testified to the fact that there are solid grounds for the future applications of femtosecond laser micromachining [1,2]. However, with the high costs and

complexity of these devices, it is a sub-picosecond laser that might be an alternative when it comes to micromachining of thin metal foils. Furthermore, investigating the sub-picosecond laser pulses interaction with matter could provide a better understanding of the ablation mechanisms and experimental verification of existing models for the ultrashort pulse regime.
In this article, we present research on sub-picosecond laser pulses interaction with metal foils of a thickness of less than 250 microns under various laser pulse parameters. The research was conducted with two types of ultrafast lasers: a lab-designed sub-picosecond Yb:KYW laser (650 fs) and a commercial femtosecond Ti:S laser (35 fs). The results show how the pulse duration, energy, repetition rate, wavelength and irradiation time affect the micromachining process.

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P.A8

MODIFICATION OF THIN CARBON FILMS BY UV_C LIGHT

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We modified single- to few-layer nano-sized graphene films grown by pulsed laser deposition (PLD) on ~300-nm SiO_2/Si substrates [1]. The samples were irradiated by a UV_C lamp (wavelength of 254 nm) for 15, 30, 60 and 90 minutes in air atmosphere. The light was directed almost parallel (about 1 - 1.5º angle of incidence) to the films' surface. The influence of the modification was evaluated by ellipsometry, X-ray photoelectron and Raman spectroscopy studies. The results are compared and discussed with reference to our previous results reported in Ref. [2].

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Acknowledgements: The authors gratefully acknowledge the financial support by the National Science Fund of Bulgaria under grant DN18/9-11.12.2017.

P.A10

STUDY OF THE CONTRAST OF LASER MARKING OF EGGS

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Laser technologies are among the major priorities in the development of our economy and society in the 21st century. One of the main applications of lasers is laser marking. The laser marking method is widely used in many industries, including the food industry. The report considers the possibility of using laser technology to mark chicken eggs. The contrast of the laser marking is the main criterion for determining its quality. The study examines the functional dependences of the contrast on the main technological parameters of the process of marking: output laser power (7 – 32 W) and processing speed (50 – 300 mm/s). As a result of the research, the optimal technological parameters for marking eggs with CO_2 laser system have been determined.

P.A11

PHOTOINDUCED CHIRALITY IN AZOPOLYMER-BASED NANOCOMPOSITES WITH DIFFERENT TiO_2 NANOPARTICLES CONCENTRATIONS

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After its discovery, photoinduced chirality in azopolymer materials has been studied with growing interest because of its potential applications. According to our previous investigations, it is possible to induce chirality in an amorphous azopolymer with high linear photo-anisotropy by illumination with elliptically polarized light. In the present work, we study the photoinduced chirality in thin nanocomposite films based on the azopolymer poly[1-[4-(3-carboxy-4-hydroxyphenylazo)benzenesulfonamido]-1,2-ethanediyl, sodium salt], shortly PAZO, doped with TiO_2 nanoparticles with a size of 20 nm. The thickness of the prepared films is approximately 450 nm and the concentration of the nanoparticles varies from 0 to 10 wt. %. A beam emitted by a He-Cd laser (λ = 442 nm) is used, with the input ellipticity varying from –1 (left circularly polarized light) to +1 (right circularly polarized light). The ellipticity was adjusted by using a quarter-wave plate. We studied the dependences of the output ellipticity

and the angle of self-rotation of the polarization azimuth on the input ellipticity. Based on the experimental data obtained, we can analyse the dependence of the self-rotation of the polarization azimuth on the concentration of the nanoparticles. The results show that small concentrations of nanoparticles lead to an enhancement of the self-rotation, thus, of the chirality.

Acknowledgements: This work is financially supported by contract H38/15 with the National Science Fund of Bulgaria. Equipment of INFRAMAT (Research Infrastructure from National roadmap of Bulgaria), supported by Contract D01-284/17.12.2019 with Bulgarian Ministry of Education and Science is used in the present investigations.

P.A12

PULSED LASER CO-DEPOSITION IN AIR: A WAY OF FABRICATING COMPOSITE NANOSTRUCTURES

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The paper presents results of applying a method based on pulsed laser co-deposition of a noble metal and a magnetic oxide for fabrication of composite nanostructures. The experimental scheme includes two nanosecond laser beams at the wavelength of 1064 nm that ablate two targets – Au and Fe_2O_3. The process is realized in air – a condition that leads to a fast condensation of the ablated material into nanoparticles. By choosing different geometries of the ablation plumes and the substrate, we could produce composites of oxide nanoparticles decorated by noble metal ones. By applying a magnetic field close to the substrate, these nanostructures could be aligned into chains oriented by the field. The influence was studied and is presented of the various processing parameters, namely, ablation geometry, laser fluence and target-to-substrate distance. The method can be optimized for fabrication of complex composite nanostructures with applications in sensors, optics and magneto-optics.

Acknowledgements: This work is financially supported by the Bulgarian National Science Fund under Project KP-06-H37/20.

P.E1

HIGHER-ENERGY WINKING STATES OF EXCITED SCHRÖDINGER'S CATS AND THEIR NON-LINEAR SOLITON ANALOGUES

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We consider how the higher-energy excited Schrödinger's cats can be transformed into the even and odd winking states, the main feature of which consists in the periodic jumping of the probability density distribution from one to other regions of space. In particular, the winking states can be formed among closely displaced ground and arbitrary-order coherent states involved into the Schrödinger's "alive" and "dead" cat dynamics. From a pedagogical standpoint, it is worth mentioning that the general analytical solution for arbitrary-order winking states can be obtained practically without any calculations. We use only the method of mathematical induction and the "often forgotten" quantum-mechanical Husimi and Taniuti symmetry transformation. We show that the Husimi and Taniuti gauge invariance establishes a one-to-one correspondence between the harmonic oscillator eigenstates and the higher-energy coherent states of the same order in such a way that their space and time-dependent phase factors are identical for all orders of coherent states. By way of illustration, we exemplify the main logical-operation properties of winking states up to the fifth-order. In the last part of the work, we present the non-linear soliton analogues of the winking states.

P.F4

ANTIBACTERIAL PROPERTIES OF Ta-BASED CERAMIC COATINGS DEPOSITED BY MAGNETRON SPUTTERING

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One of the main problems of using implants in traumatology, orthopedics, and cardiovascular surgery is the risk of postoperative bacterial infections. A solution to this problem is the development of new biomaterials with antibacterial components, such as copper or silver dopants. Another approach is to generate reactive oxygen and nitrogen species that act on various bacterial strains. Implant surface modification by forming ceramic coatings are a promising way of improving the biocompatibility and antimicrobial activity of medical devices. The aim of the present study was to study the effect of composition and surface properties of

metal Ta, oxide Ta_2O_5 and oxynitride TaON films on the functional characteristics of ceramic coatings and their bactericidal activity in vitro tests.

Stainless steel samples (AISI 316) were used as substrates. Ta, Ta_2O_5 and TaON coatings by were deposited by magnetron sputtering in a high-vacuum pumping system with a base pressure of about 1×10^{-3} Pa. The magnetron discharge power was 4 – 5 kW. An ICP source with RF power up to 1 kW was applied for oxygen activation. The coatings thickness, adhesion properties, hardness and elastic modulus were evaluated by standard methods. The surface morphology and topography were observed by a JSM-7100F electron scanning microscope. The elemental distribution and chemical composition of the coatings were analyzed by energy dispersive X-ray (EDX) spectroscopy. Advancing contact angles of coated surfaces were evaluated by tensiometric measurements (Kruss 12). X-ray photoelectron spectroscopy was carried out using an ESCALAB MkII (VG Scientific) electron spectrometer using AlKalpha X-ray source (hν = 1486.6 eV).

The Gram-negative microbial strain *Escherichia coli* ATCC 11229 was selected for testing and diluted in sterile saline to a cell density of 10^4 CFU/ml (colony-forming units per milliliter); 0.1 ml of the suspension was placed at the surface of sterile and fat-free Ta-based coated and control (stainless steel) plates in Petri dishes. The plates were held for 24 hours at room temperature. To determine the number of surviving microorganisms, 10 ml were washed from plates with sterile saline. The suspension was seeded on tryptone soy agar and incubated at 37 ± 1 ^oC for 18-24 hours. The statistical correlation was determined of the results of antibacterial activity tests between the coated samples and control. The bacterial-viability tests demonstrated a strong bactericidal activity of the Ta-based coatings. The activation of antimicrobial surface properties of various medical products is very challenging for many biomedical applications.

Acknowledgements: The research was supported by an international scientific cooperation program between the Bulgarian and Ukrainian Academies of Sciences, the international scientific cooperation project 08-03-20 of the Ukrainian Academy of Sciences, and by project #T20UKA-015 of the Foundation for Fundamental Research of Belarus.

P.F1

RF MAGNETRON SPUTTERING OF $Bi_{12}TiO_{20}$ THIN FILMS ON VARIOUS SUBSTRATES

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We deposited $Bi_{12}TiO_{20}$ (BTO) thin films on various substrates (glass, quartz, stainless steel (SS304), (001) Si and sitall ceramics) by RF magnetron sputtering. The films had a uniform thickness of 1.2 μm. The X-ray powder diffraction results revealed that they were amorphous, while the Bi/Ti ratio varied between 9.5/1 and 11.8/1, as found by energy dispersive X-ray analysis (EDX). Further, the films deposited on glass and SS304 substrates were modified by laser radiation (CuBr laser with fundamental wavelength $\lambda = 511$ nm) to obtain an ordered cubic phase. The films deposited on quartz and on (001) Si substrates were thermally annealed at about 500 ^{o}C for a few hours. The modified films were characterized by Raman spectroscopy, scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDX), as well as by X-ray diffractometry.

Acknowledgements: The authors gratefully acknowledge the financial support of the European Regional Development Fund, Postdoctoral research aid No 1.1.1.2/16/I/001 research application "Analysis of the parameters of the process of laser marking of new industrial materials for high-tech applications, Nr. 1.1.1.2/VIAA/3/19/474".

P.F2

ALTERNATIVE TECHNIQUE FOR DIRECT IMMOBILIZATION OF BIOMOLECULES

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The development of biosensors requires continuous optimization of the biorecognition layers. The immobilization of biomolecules by chemical means requires their embedding into a so-called embedding matrix – a hydrogel. This results in the deposition of not only biomolecules, but also of other substances on the desired surface, which reduces the sensitivity and specificity due to the non-specific reactions occurring in the layer.

The direct immobilization of biomolecules has a number of advantages in applications for biosensors – it allows for preserving their biological activity, as well as their natural structure. In addition, only the desired molecules are deposited on the sensor surface and incorporation into a hydrogel and surface pre-treatment are no more nessesarry.

We use the MAPLE technique for direct immobilization of biomolecules, showing the advantages of this method. In this work, we present the MAPLE processing parameters that ensure the successful immobilization of biomolecules weighing 670 kDa.

Acknowledgements: This work was supported by the National Science Fund of the Ministry of Education and Science under project #DN 18/8/2017 "Biochip based on new plasmon structures and nanostructured bio-sensing elements".

P.F3

PREPARATION AND CHARACTERIZATION OF HIGHLY CRYSTALLINE 2D $NbSe_2$ THIN FILMS

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Very few 2D superconductors exist in nature, the single-layer niobium diselenide ($NbSe_2$) being the first among them that remains a superconductor in its isolated 2D form without the need of a special substrate [1]. Furthermore, the charge density wave (CDW) order – spatial modulation of both the electron density and the atomic lattice – has been revealed to be a genuine 2D electronic phenomenon in $NbSe_2$. 2H-$NbSe_2$ is a metal, a superconductor with T_c ~7.2 K and a CDW system with T_{cdw} ~33 K. The layers are stacked together via van der Waals interactions and can be exfoliated into thin 2D layers. The preparation of samples of $NbSe_2$ of high crystalline quality with the desired crystal structure is of primary importance in studying their properties. Single crystals of $NbSe_2$ having a layered structure were grown by a chemical vapor transport technique (CVT) using bromine as a transporting agent. Energy dispersive analysis by X-ray (EDAX) determined the stoichiometry of the grown single crystal. X-ray diffraction (XRD) studies were performed for structural characterization.

CVD thin film samples were prepared by thermally-assisted selenization of magnetron-sputtered Nb film in Ar/H_2 gas mixture flow. The thin films were characterized structurally by XRD as well as by XPS methods to obtain the crystal quality and chemical composition and stoichiometry. Optical and electrical properties are further examined towards device applications.

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Acknowledgments: This work is supported by the Bulgarian Ministry of Education and Science under the National Research Program "Young scientists and postdoctoral students" approved by DCM# 577/17.08.2018 and DFNI KP-06-28/8.

P.F5

CONTACT RESISTANCE OF TUNGSTEN COATINGS DEPOSITED ON Cu AND Al CONDUCTORS

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Copper and aluminum are the materials most widely used in electrical installations and in electronics as pins, cables, electric bus bars etc., due to their electrical and thermal properties. However, some drawbacks related to corrosion, poor mechanical properties and electrical erosion resistance hinder their application as electrical contacts. These limitations can potentially be overcome by an appropriate technology for surface treatment.

It is known that the tungsten is characterized by good mechanical properties, high thermal conductivity, high melting point, low electrical resistivity and high electrical erosion resistance. This is why our research dealt with the effect of a tungsten coating on the contact resistance of Al and Cu conductors.

The coatings were deposited on Al and Cu conductors by electron-beam evaporation of a tungsten target. During the experiments, the electron beam power was 918 W and the deposition time was 90 s. Before deposition of the tungsten coating, each sample was preheated to 250 ^{o}C and 450 ^{o}C. The input energy density was 1.644 kJ/mm^2.

The structure of the samples was analyzed using X-ray diffraction (XRD). The surface roughness was studied by atomic force microscopy (AFM) The electrical contact resistance hysteresis of the tungsten coatings on Al and Cu conductors' samples was also measured. The results obtained are discussed as concerning the technological conditions used for deposition of the coatings.

P.F6

EVALUATION OF THE ACCURACY OF FIXED PROSTHETIC CONSTRUCTIONS MADE BY MILLING AND PRINTING. EFFECT OF TEMPERATURE CHANGES

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The aim of this study was to evaluate the internal and external fit accuracy of fixed metal-ceramic prosthetic constructions made by milling and printing and follow the of temperature changes on their accuracy.

An acrylic resin tooth for a metal-ceramic crown was prepared according to the standard guidelines. A standard intraoral silicone impression was taken and a stone model was made, which was scanned by an extraoral digital scanner and a digital copy of the prosthetic field was created. The digital copy was used to create a digital prototype of the future metal substructure for a metal-ceramic crown. With the same data, a metal substructure was made by milling and by 3D-printing. The internal surface of both samples was measured. The stone model preparation surface was also measured. All data were compared to the digital prototype. Following the standard technology, a dental technician applied ceramic material by hand in layers and the constructions were sintered. After the thermal procedure, once again the substructures internal surface was measured and compared with the previous data. The constructions were finished by glazing by the dental technician applying the last ceramic layer and sintering it. The construction`s internal surface was again measured and the data were compared with the previous data. Conclusions about the temperature changes caused by the sintering process on the metal substructures were drawn using the data obtained by the measurements made at the different stages, namely, the difference of the internal fit of the constructions made by milling and 3D-printing will not affect the crowns ergonomics. The quality of the internal fit for the construction made by milling is better than that made by 3D-printing. Negligible changes in the internal surface were found after the temperature changes caused by the sintering process for both types of constructions.

Both technologies could be used to produce high-quality accurate metal substructures as needed by fixed prosthetic dental medicine. The temperatures changes caused by the sintering process during the standard metal-ceramic technology affect negligibly the constructions internal fit.

POSTER SESSION V

P.A13
NANOSECOND LASER ABLATION OF COMPOSITE THIN FILMS IN LIQUID

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This paper presents results on nanosecond laser ablation of composite thin films immersed in liquids. The composite films were prepared using a classical on-axis pulsed laser deposition technology, but with a target consisting of two sectors of different composition. Multicomponent films containing ZnO, TiO, and Ag, were thus deposited on a substrate. The as-prepared multicomponent samples were then immersed in liquid media and irradiated by nanosecond laser pulses. This resulted in the production of colloids composed by multicomponent nanoparticles. The optical properties of the colloids were evaluated by optical transmittance measurements in the UV– VIS spectral range. Transmission electron microscopy was used to visualize the nanostructures formed in the solution, as well as to evaluate of their size distribution. On the basis of selected area electron diffraction measurements, the phase composition of the samples was determined.

Acknowledgements: The authors acknowledge the financial support of project KP-06-N37/20 "Formation and physical properties of composite nanostructures of metal oxides and noble metals" under the "Competition for financial support of basic research projects – 2019".

P.A14
FABRICATION OF AQUEOUS COLLOIDS OF TiO_X AND Ag COMPOSITE NANOSTRUCTURES BY MEANS OF PULSED LASER ABLATION

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Pulsed laser ablation in liquids (PLAL) was used for preparation of composite nanostructures based on TiO_x and Ag. Plates of bulk Ti and Ag immersed in the corresponding liquid served as targets and were irradiated by a pulsed nanosecond Nd:YAG laser Its fundamental wavelength, the second, third and the fourth harmonic were used both to fabricate and to change the chemical composition and the morphology of the created nanostructures. The procedure for fabricating complex nanostructures consisted of three phases. Consecutive laser ablation of the

selected targets was followed by post-ablation irradiation of the obtained colloid of the complex nanostructures. The changes in the characteristics of the complex nanostructures were indirectly evaluated by analyzing the profile of the optical transmission spectra of the colloids. The colloids properties were controlled by varying the laser beam parameters. Transmission electron microscopy was applied for direct visualization of the nanostructures shape, while their chemical composition and morphology were assessed by applying HRTEM and SAED.

P.A15
ANALYSIS OF THE PROCESS OF LASER ABLATION OF MARBLE SURFACES

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Over the last decade, laser surface treatment of stones has gained increasing scientific interest. New technologies and processes based on different types of laser sources and processing modes are being studied. This report presents results from examining the process of laser ablation of a marble surface using a fiber laser. Three factors influencing the process of laser marking and engraving were studied: power, processing speed and step between raster lines. The functional dependences between these factors and the contrast of the graphic image produced were established. The optimal operating intervals for this group of technological parameters were analyzed. Due to the very-high definition laser ablation, wording, drawings and images can be re-created and processed with unique accuracy. In addition, the reduction of manufacturing time and resources used in the process makes this technology an environmentally friendly and extremely cost-effective solution.

Acknowledgements: The authors gratefully acknowledge the financial support of the European Regional Development Fund, Postdoctoral Research Aid No. 1.1.1.2/16/I/001 research application "Analysis of the parameters of the process of laser marking of new industrial materials for high-tech applications, No. 1.1.1.2/VIAA/3/19/474".

P.B7

DETERMINING THE QUANTITY OF ANTIMONY IN ARCHAEOLOGICAL BRONZE ARTEFACTS BY LASER-INDUCED BREAKDOWN SPECTROSCOPY (LIBS)

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Laser-induced breakdown spectroscopy (LIBS) is an emerging analytical technique for qualitative and quantitative elemental analysis of a variety of materials based on the atomic emission of a spark produced by a laser beam focused on the surface of the sample. When the objects investigated are archaeological artefacts, it is essential to avoid damaging the sample. One of the advantages that make LIBS preferred in the field of archaeometry is its micro-destructive nature. The elemental composition of ancient materials provides valuable information on the origin and use of archaeological artefacts and on the manufacturing technologies as well. In this work, a group of six bronze archaeological artefacts (axes and spearheads) dated from the Late Bronze Age and Early Iron Age (14^{th} – 10^{th} century BC) were analyzed using the LIBS technique in order to determine the quantity of antimony. The antimony concentration in these items is of particular interest, since depending on the amount of this element one can conclude whether the artifacts are locally produced or imported. The quantity of antimony initially was estimated after generating a calibration curve with a set of two standards. However, accurate determination of concentrations over 1% with the available bronze standards is a difficult task because the antimony concentration in these standards is up to 0.59%. Therefore, we applied an approach of multi-elemental quantitative analysis of LIBS spectra called calibration-free laser induced breakdown spectroscopy (CF-LIBS). The approach is based on measuring the line intensities and plasma properties (plasma electron density and temperature). This eliminates the need for matrix-matched standards. The applicability of the proposed method and the accuracy of the results are compared with results from X-ray fluorescence (XRF) analyses.

Acknowledgements: This work was supported by the Bulgarian Ministry of Education and Science under the National Research Program "Young scientists and postdoctoral students" approved by DCM # 577 / 17.08.2018.

P.B8

OPTICAL FILTER BASED ON METAL-INSULATOR-METAL PLASMONIC COUPLED CAVITIES

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Surface plasmon polaritons (SPPs) are propagating waves that travel along a metal-dielectric interface due to interactions of free electrons in the metal side with the incident photons from the dielectric side. The most important property of SPPs is the lateral confinement and guided transportation of electromagnetic energy in a sub-wavelength usable for high integration purposes. Hence, structures based on SPPs have arisen as the appropriate alternative for high integration nanophotonics applications.

In this study, an optical filter based on plasmonic metal-insulator-metal (MIM) waveguide-coupled resonators was investigated and simulated. The proposed structure was made of silver as the metal layer. It is possible to realize filtering function between desired wavelengths using the proposed structure with appropriate geometrical parameters for the resonators. Two-dimensional simulations utilizing the finite-difference time domain algorithm were used to obtain filter function. The proposed filter and selector have potential applications in highly integrated optical circuits.

P.B9

INVESTIGATION OF DIFFUSION PROCESSES OF AQUEOUS SOLUTIONS IN CAPILLARIES BY MEANS OF LASER INTERFEROMETRY

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Exchange processes in capillaries are of interest in the analysis of a number of applied problems in the field of biology, chemical technology and ecology. Some features of mass transfer in model thin capillaries are investigated in this paper.

Thin flat channels were formed by plane-parallel glass plates and filled with aqueous solutions. The high optical transparency of the tested samples allowed the use of optical methods for analyzing the contents of the capillary, in particular, such based on the known relationship between the refractive index of the composite solution and the concentration of its components. In the present paper, the effectiveness of laser interferometry and phase shifting interferometry is shown for the problems under consideration. An analysis of the sequence of recorded digital

images made it possible to analyze the dynamics of the exchange processes in the capillary during its interaction with a large volume of solvent.

It is established that in most cases the phenomenon is characterized by two stages. At the beginning of the mass transfer process, the result of the viscous flow prevails over the effect of mutual diffusion. Then the role of diffusion appears. The main attention was paid to the study of aqueous solutions of surfactants, which in most cases are organic substances with a high molecular weight. The experimental values of typical parameters of the temporal characteristics of various compositions were compared with the data of mathematical modeling of mass transfer processes. The features are shown of the chemical structure of the dissolved substances that affect the rate of exchange processes. For example, the time for cleaning a capillary of polyethylene glycol tert-octylphenyl ether when immersed in a cuvette with clean water is 1.5-2 times longer than for sodium dodecyl sulfate. In many cases, the patterns observed are consistent with the results of a comparison of the molecular weights of the dissolved components. Significant changes can be made to the quasi-equilibrium flow of the processes under consideration through the use of ultrasonic vibrations. It is shown that all stages of these processes can be monitored using the experimental technique developed. It is also shown that the registration of 2D patterns of the optical density distribution inside the capillary and their dynamics using the described interference technique allows us to describe the course of chemical reactions limited by a closed small volume. In particular, the positive role of ozone is shown, which can be used to clean capillaries from organic contaminations.

P.E7

OPTICAL CONTROL OF ALKALI VAPOR DENSITY IN ANTIRELAXATION COATED CELLS

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Antirelaxation (AR) coatings are organic films (as, for example, paraffin, PDMS, OTS, SC-77 etc.) used in optical cells containing alkali metal vapor to reduce the depolarization of alkali atoms after collisions with the cell's walls [1,2]. The long-lived ground state polarization in AR coated cells is a basis for the development of atomic clocks, magnetometers, quantum memory, slow light experiments, and precision measurements of fundamental symmetries.

At thermal equilibrium, the atomic density in a cell with alkali atoms is defined by the coldest point of the cell. Usually, this is the reservoir (the stem), which is kept some degrees colder to avoid atomic deposition on the cell walls. The main disadvantage of the thermal control for application in AR coated cells is the deterioration of the AR properties of the coating at high temperatures [2,3].

Another way to control the alkali metal atomic density in AR coated cells is light-induced atomic desorption (LIAD). LIAD is a non-thermal process in which atoms are desorbed from the walls (AR) coated vapor cell under illumination. In the cases when high atomic densities at

low temperature and/or small dimensions are needed, usually LIAD is applied as an atomic dispenser. Density control by LIAD is considerably faster than the thermal control and does not degrade the AR properties of the coatings. Long-term LIAD density stabilization has been reported in a few works, but due to the influence of the stem, the technique requires increasing light intensities to sustain the atomic density [4].

In this work, we report our investigations on optical control of the atomic density in AR coated cells under different illumination and in different AR coated cells view of achieving high density, low relaxation rate and long-term stability. The work is interesting for the development of new all-optical controlled and miniaturized vapor cell-based sensors with long-term stability.

Acknowledgements: This work was supported by the National Science Fund of Bulgaria (Contract No DN 08-19 /2016 "New coherent and cooperative effects in hot alkali vapor"). S.T. acknowledges the support of the National Program „Post-Doctoral students" RMS No 271/2019.

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P.E8

FIBER-COMPATIBLE MINIATURE DYE LASER

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Our research was focused on a miniature dye laser formed by a micro-cavity filled with a dye solution as the active medium. The basic structure of the laser is a standard fiber-optic glass ferrule, in one of the openings of which two optical fibers with flat end facets are placed forming a Fabry-Perot cavity. The void between the fibers is filled with the Rhodamine 6G dye dissolved in glycerin. Laser oscillations are achieved using a pulsed pumping light with a wavelength of 337 nm from a TEA nitrogen laser. The micro-cavity is transversely excited by the pump laser and the output is collected by a fused silica fiber having core/cladding diameters of 105 μm/125 μm. The laser design allows its future use in lab-on-a-fiber, lab-on-a-chip and micro total analysis systems.

Acknowledgements: The authors acknowledge the financial support of "Project of junior basic researchers and postdocs – 2018", Bulgarian National Science Fund, project KP-06-M28/2.

P.E9

HIGH-BEAM-QUALITY SEALED-OFF MASTER OSCILLATOR – POWER AMPLIFIER SYSTEM OSCILLATING IN THE VISIBLE SPECTRAL RANGE ON COPPER ATOMIC TRANSITIONS FOR MICROMACHINING IN SCIENCE AND TECHNOLOGY

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One standard application of lasers is in industry for cutting, welding, drilling, etc. of materials. The range of application of laser radiation is determined by the radiation properties, namely, power, wavelength, beam geometry, divergence, etc. The precision of many operations carried

out by lasers depends on the so-called beam quality. For quite a lot of manipulations, the beam quality is associated with the minimum size of the spot that needs to be treated by laser light. Theoretically, this size is diffraction limited.

If a circular laser beam of diameter ID has a top-hat shape of the laser-beam radial intensity distribution, which fits well with our experiments, the diffraction-limited divergence, DL, is calculated as $DL = 2.44\lambda/ID$. Accordingly, for $\lambda = 510$ nm and $\lambda = 578$ nm, the DL is 104 μrad/118 μrad for a 12-mm ID and 62.3 μrad/70.5 μrad for a 20-mm ID, respectively. However if the optical arrangement can somehow produce beams with a Gaussian profile, we could expect a further decrease of the diffraction limit by a factor of 1.9, so that a divergence of 30-40 μrad would become feasible [1].High-beam-quality (near diffraction limit) laser oscillations have been produced in our lab long ago and consequently reported many times [2-4]. The real application on a large scale in material processing has been hindered by many problems.

We describe a copper-bromide-vapor-laser-based master oscillator – power amplifier laser system using low-power high-beam-quality laser radiation from either of two fully compatible and replaceable oscillators. The system was developed and investigated in view of the laser energy parameters required for efficient laser processing of materials.

Acknowledgments: The work is supported by the Bulgarian National Science Fund under Grant No. KP-06-H37/2 of 06.12.2019.

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P.E10

DYNAMICS OF PARTON-LIKE SOLITON STRUCTURES IN NONLINEAR COHERENT STATES

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Nonlinear analogues of coherent states arise in the framework of the nonlinear Schrödinger equation models with confining harmonic oscillator potentials. We clarify the profound physical linkage between the quantum-mechanical Schrödinger coherent states and their nonlinear solitonic analogues. Guided by a remarkable, but obviously only formal, analogy between the soliton negative self-action energy and the nuclear binding energy, we reveal how the nonlinear ground and coherent states could be built up from the parton-like solitonic constituents when the absolute value of the soliton binding energy increases. The enhancement of the soliton binding energy contribution to the total conserved energy of the nonlinear ground and coherent states radically changes their internal structures and allows one to apply the formal analogies from the parton model of nucleons.

P.E11

STUDY OF RING-ARRAY-CONCENTRATOR FOR Nd:YAG SOLAR LASER PUMPING

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In this paper, we report a numerical study of a Nd:YAG solar laser side-pumped by a ring-array concentrator (RAC). The study aims at optimizing the RAC system and the optical resonator parameters by using the ZEMAX and LASCAD software.

Solar laser output power of 34.8 W was numerically calculated for a multimode laser operation, corresponding to a solar-to-laser conversion efficiency of 2.3 %, indicating an improvement relative to that of the previous side-pumped Nd:YAG solar lasers [1, 5].

Keywords: Side-pumped solar laser, ring-array concentrator, fused silica light guide, ZEMAX and LASCAD simulation.

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P.E12

CONVOLUTION THEOREM REVISITED: TRIPLE MIXING OF SQUARE OPTICAL VORTEX ARRAYS

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Optical vortices (OVs) are associated with isolated point singularities with helical phase profiles around them, leading to a characteristic ring-shaped intensity profile. They are characterized by an integer number *l* which is usually referred as the topological charge (TC) of the OV [1,2]. The basic interactions between two OVs are rather simple. If two OVs with equal charges are placed on a common background beam, they repel each other and rotate. If the TCs are opposite, the OVs attract and translate in a direction transverse with respect to the background beam [3]. Stable propagation of large OV ensembles is to be expected if the signs of the OVs are alternative [4]. A reliable technique for bright multi-spot pattern formation with flat-phase profiles in the focus of a lens by mixing square and/or hexagonal OV lattices is presented in [5].

Here, an extension of the possibility for mixing square-shaped OV lattices is realized by the triple mixing of such lattices. Fig.1(a) shows one such possible mixing leading to a beam structuring in the focus of a lens. Let us recall that a thin lens performs a Fourier transformation in space. Hence, in view of the Convolution Theorem, controllable and more complicated sculpting of the bright focal structures can be achieved (see Fig. 1 (b-d)), with the possibility to additionally host a 1-D, quasi-2-D singular beams, and even an OV in each of the bright focal beams. Extended numerical and experimental evidences will be presented and discussed.

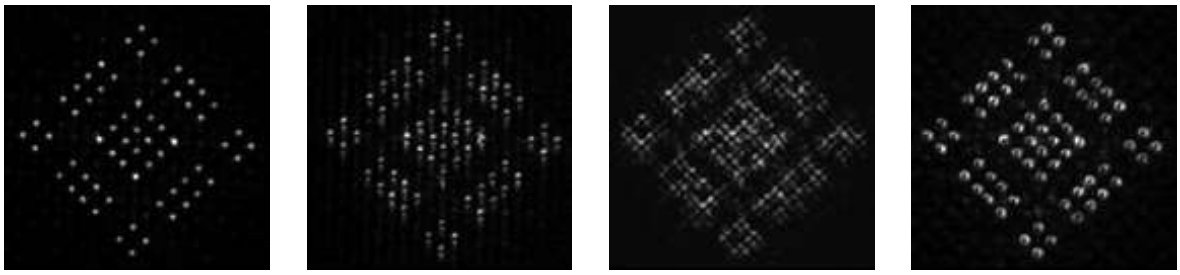

Figure 1. Experimentally-recorded focal intensity distributions resulting from triple mixing of square-shaped OV lattices. **(a) -**Triple mixed square-shaped OV lattices with lattice constants Δ_{sq41} and the sum $\Delta_{sq21+sq101}$. Additional structuring of the far-field intensity profiles of the same triple mixed square-shaped OV lattices by adding 1-D dark beam **(b)**, a quasi-2-D dark beam **(c),** and by hosting an OV **(d)**, in each bright focal beam of the structure.

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Acknowledgements: This work was supported by the Science Fund of Sofia University, project Nr. 80-10-139/23.04.2020.

POSTER SESSION VI

P.A16

LASER PARAMETERS EFFECT ON ULTRA-SHORT LASER PROCESSING OF SiC

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Crystalline silicon carbide (SiC) is a very attractive material for applications in the fields of microelectronics, MEMS and biomedicine mainly due to its chemical inertness and mechanical strength. It is used for SiC MEM sensors, micro motors and resonators [1]. In the biomedical field, SiC is emerging as a promising material for additional coating of biomaterials due to its useful properties (hardness, lightness, impermeability and good compatibility). For instance, it is used in combination with bioglass for bone regeneration and as coating of some metal alloys, as it forms a bone-like layer on the surface upon contact with body fluids [2].

We studied the changes on the SiC surface induced by irradiation with ultrashort laser pulses in view of further biomedical applications. Nanostructures were formed on the surface of a silicon carbide sample by using a regeneratively amplified Ti:sapphire femtosecond laser emitting at 800 nm. The laser parameters (power, energy and number of applied pulses) were varied and the resulting surface morphological changes were investigated. By modifying the topography of the silicon carbide substrates, one can significantly improve the bioactivity properties of this material, which after proper optimization of the laser parameters could make its biomedical applications even more successful.

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Acknowledgements: The work was supported financially in part by the Bulgarian National Science Fund under project KP-06-H 38/5 (2019-2022), "Functionalization of 3D printed fibrous scaffolds via femtosecond laser patterning", and by the National Scientific Program "Young scientists and post-doctoral students" DCM No. 577/17.08.2018 (2020), "Preparation and design of porous polymer-based bio-interfaces and cell matrices by laser-induced microstructuring".

P.A17

LASER MARKING AND ENGRAVING OF HOUSEHOLD AND INDUSTRIAL PLASTIC PRODUCTS

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Laser marking and engraving has developed in many ways into an attractive process for the identifications of consumer goods made of plastic. It is a quick and inexpensive process that offers a variety of flexible options for designing identification products (barcodes, security information, codes).

The paper reports studies on the possibility of marking PVC products of different colors used in the electronics industry. The work was performed using a CO_2 laser technology system. The functional dependences on the width and depth of the marking lines on the main technological parameters – average power and processing speed – are analyzed. The analysis aims to help determine the optimal working intervals for marking and engraving by the bar coding method, as well as for the coding and reading of information on household PVC products used by visually impaired people.

P.A18

FINITE ELEMENTS SIMULATION OF LASER MARKING OF ALUMINUM

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The paper presents and discuss an experimentally-validated finite elements model simulating the speed influence on the laser marking process. Numerical experiments were performed to determine the temperature fields created by laser light incident on samples of aluminum, a material with wide industrial use. The numerical calculations were carried out on the example of a fiber laser and a CuBr laser. Plots were drawn of the dependence of temperature on the speed for two power densities of the two lasers. Preliminary working speed intervals were determined for the power densities studied.

Acknowledgements: The authors gratefully acknowledge the financial support of the European Regional Development Fund, Postdoctoral Research Aid No. 1.1.1.2/16/I/001 research application "Analysis of the parameters of the process of laser marking of new industrial materials for high-tech applications, Nr. 1.1.1.2/VIAA/3/19/474".

P.A19

NONLINEAR PROPERTIES OF SYNTHESIZED POLYMERS FOR REGENERATIVE MEDICINE APPLICATIONS

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Nowadays, one of the main focuses of regenerative medicine is searching for alternatives to the conventional treatment strategies for repair or replacement of missing or malfunctioning human tissues and organs. Promising results have been achieved through tissue engineering approaches, offering solutions for improved functionality and biocompatibility of material implants inside the biological environment. The selection of materials for tissue engineering applications is based on several important factors [1-2], such as biocompatibility and bioresorbability, controllable rate of degradation, proliferation and differentiation, and mechanical properties matching those of the tissues surrounding the implant. Research on the mechanisms of interaction of various polymer biomaterials with femtosecond laser pulses contributes in general to the optimization of the biomaterials' surface in view of further application.

In this research, the polymers under study were microprocessed by a femtosecond Ti:sapphire laser emitting at 800-nm central wavelength with a pulse duration of 35 fs and a repetition rate of 1 KHz. The laser pulse energy was controlled by an attenuator and measured by an energy meter. The experiments were performed in air with the laser beam focused by a lens and a telescopic optical path to guide it to an XY planar stage. Analyses were performed of the polymer samples related to characterizing their structure, composition and stability. The nonlinear properties and effects of the polymers were determined by measuring the non-linear refractive index n_2 and the multiphoton absorption coefficient β by a modified *z*-scan method [3].

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P.D14

ASSESSING THE TEMPERATURE INCREASE DURING PHOTODYNAMIC THERAPY: A SIMULATION MODEL

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Photodynamic therapy (PDT) is a non-invasive procedure used for the treatment of malignances, as well as for skin diseases (e.g., acne) and eye disorders (e.g., macular degeneration). It is based on the generation of cytotoxic products after the excitation of absorbed photosensitizing drugs by monochromatic (mainly) non-ionizing radiation.

The wavelength (λ) chosen is usually in the 630 nm to 700 nm region resulting in a limited penetration depth in tissue. It is absorbed mainly by the drug, melanin and hemoglobin molecules and practically not at all by water. The relatively low irradiance (*E*, expressed in mW/cm^2) values and the time of treatment, which, in most cases, lasts for a few minutes, result in limited photothermal effects that are usually overlooked.

Therefore, in this study we assess the temperature distribution during PDT in a cancer bearing mouse model. The COMSOL Multiphysics® software is used to create a user-friendly application that could be used in the treatment planning step of PDT. The application takes as input various parameters, such as laser power, beam radius, irradiation time, body and room temperature and returns the maximum tissue temperature and irradiance values at user specified time points. Moreover, the spatial distribution of the temperature and the irradiance and the percentage of acute necrosis and damaged tissue are presented in the form of interactive 3D plots. Hence, through this application the physician and/or the medical physicist can adjust the treatment parameters in order to avoid or induce hyperthermic effects, before or in parallel with the photodynamic ones.

Acknowledgments: The author G.K. would like to state that his part of this research was co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Program "Human Resources Development, Education and Lifelong Learning" in the context of the project "Strengthening Human Resources Research Potential via Doctorate Research" (MIS-5000432), implemented by the State Scholarships Foundation (IKY) [Scholarship number: 2018-050-0502-14578]. The author M.M. gratefully acknowledges the funding of the European Regional Development Fund (ERDF) and National Funds "Synergy ELI-LASERLAB EUROPE, HiPER & IPERION-CH.gr (MIS 5002735)", 2017.

P.D15

EXPERIMENTAL STUDY OF THE ANTI-HERPES VIRUS ACTIVITY OF SILVER NANOPARTICLES

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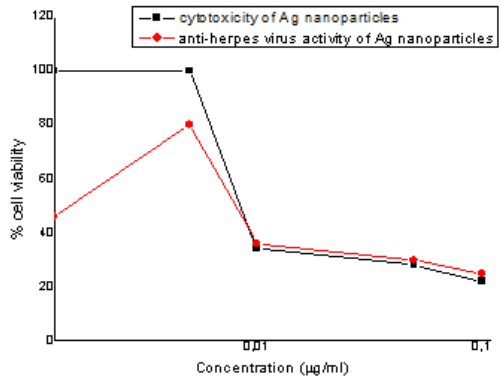
It is widely known that the silver nanoparticles are non-toxic, while having an inhibitory effect against various bacteria, viruses and fungi. Recent clinical and laboratory studies have shown the colloid silver's efficacy against various viruses, including HIV, by way of inhibiting their replication within human cells through attachment to their DNA/RNA [1]. We studied experimentally the activity of silver nanoparticles in a colloidal solution against the *herpes simplex virus* (*HSV*), which causes keratitis herpetica simplex, a viral infection of the eye.

The silver nanoparticles used were synthesized electrolytically. The herpes simplex virus type 1, Victoria strain (HSV-1) was provided Prof. S. Dundarov, National Center of Infectious and Parasitic Diseases, Sofia. The *in vitro* cytotoxic effects of the Ag nanoparticles were examined using Madin-Darby bovine kidney cells. The antiviral screening was based on the viral yield reduction technique.

To conduct correctly the antiviral experiment, it is necessary to determine in advance the doses at which the silver nanoparticles are non-toxic to the cells in which they are administered. For this purpose, their cytotoxicity was determined; the dose-response curve from which their CC_{50} (0.008 µg/ml) was determined is shown in Figure 1. The dose-response curve demonstrating the activity of the silver nanoparticles against the herpes virus is shown in Figure 1 and reveals a weak inhibition of the HSV-1 replication with a selective index SI = 8.



This preliminary study shows that the silver nanoparticles are non-toxic and have an antiviral effect.

Keywords: silver nanoparticles, *in vitro* study, herpes simplex virus, antiviral properties, antiviral drug

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P.E13

A FULLY INTEGRATED ALL-FIBER-OPTIC DYE LASER

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We present an innovative compact all-fiber-optic structure suitable for implementing fully integrated dye lasers. The structure is based on a standard fiber-optic glass ferrule with two parallel openings with diameters of 125 μm along its length. In one of the opening a Fabry-Perot cavity is created using two fused silica optical fibers with flat end facets. In the second opening, an angle-polished optical fiber with reflective metal coating is placed, with the help of which the active medium is pumped transversely. The dye used is Rhodamine 6G dissolved in glycerin pumped by 337.1-nm wavelength laser pulses. The ferrule-based design allows for a simplified set-up procedure and integration of the pumping system to the basic structure of the laser, thus making the device very compact. The laser has the potential to be used as a light source in field measurement applications.

Acknowledgements: The authors acknowledge the financial support of "Program of junior basic researchers and postdocs – 2018", Bulgarian National Science Fund, project KP-06-M28/2.

P.E14
RAMAN SELF-SCATTERING EFFECT INDUCED BY THE PEREGRINE SOLITON

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The Peregrine soliton (PS) arises in the framework of the nonlinear Schrödinger equation model (NLSE), which has a wide range of applicability – from nonlinear femtosecond optics, Bose-Einstein condensates and plasmas to ocean monster (rogue) waves and hurricanes. We show that the Peregrine soliton embedded into the high-power N-soliton pulse acts as the universal trigger of the self-induced nonlinear effects. In the maximum of the N-soliton pulse compression region, the spectrum of the Peregrine soliton progressively broadens and reaches the bandwidth of the maximal modulation instability (MI). The MI gain bandwidth coincides exactly with the PS central peak compression degree; so that the PS triggers the self-induced MI with maximal increment and gives rise to peculiar structures of the N-soliton pulse and its spectrum. We demonstrate that in a similar manner, the embedded PS triggers the soliton Raman self-scattering effect. The Raman self-scattering soliton effectively "eats" half of a pedestal and extends considerably to the zero intensity regions giving rise to the nonlinear Moses effect.

P.F7
TUNING THE PHOTOLUMINESCENCE PROPERTIES OF ALD Al-DOPED ZnO

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Zinc oxide (ZnO) is an n-type semiconductor with a direct band gap. It is well-known that chemical doping and intrinsic lattice defects greatly influence its electronic and optical properties. Control of defects is therefore key in achieving viable applications of ZnO. Doped ZnO thin films are of technological importance because of their great potential for numerous applications – most notable in transparent conducting electrodes (1).
We studied the effect of thermal annealing on the structural and optical properties of ZnO and Al-doped ZnO (AZO) thin films prepared by atomic layer deposition (ALD). The thermal annealing was performed in different atmospheres, including air, argon, nitrogen, and hydrogen/argon. X-ray diffraction (XRD) analysis, scanning electron microscopy (SEM) and AFM were used for structural and morphological characterization of the as-deposited and the annealed films. The optical properties were measured by spectrophotometry. The photoluminescence (PL) properties of the as-deposited and the films annealed in different gas atmospheres (2) were studied using a FluoroLog 3-22 spectrofluorometer (Horiba Jobin Yvon)

with excitation and emission in the range 200-950 nm. The photoluminescence of ZnO was found to be tunable in a wide range through chemical doping and annealing.

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Acknowledgments: This work is supported by the Bulgarian National Science Fund under project # DFNI KP-06-H-28/8. Research equipment from the distributed research infrastructure INFRAMAT (part of the Bulgarian National road map for research infrastructures) supported by the Bulgarian Ministry of Education and Science under contract D01-284/17.12.2019 was used for the AFM measurements.

P.F8

ELECTROCHEMICALLY STABILIZED CARBON MATERIALS FOR SUPERCAPACITOR PROTOTYPES

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We implemented supercapacitor prototypes using a product derived from soot as an active electrode material. Despite the soot's highly developed surface and capacitive properties, some compounds in it makes it unstable during the charging process. We used an irreversible electrochemical reaction leading to anodic oxidation and cathodic reduction of the soot. The initial organic compounds are thus changed into different products. As a result of the electrochemical treatment with different electrochemical potentials, different parts of the organic compounds are affected, so that more stable compounds remain without removing all functional groups. The material produced was investigated by IR and TEM spectroscopy. The supercapacitor prototypes were multiply charged and discharged and their capacitances were determined and compared.

Acknowledgements: This work was supported in part by the Bulgarian National Science Fund under Contract No. KP-06-M27/7.

P.F9

OPTICAL PROPERTIES OF THIN HfO_2 COATINGS DEPOSITED BY DC REACTIVE MAGNETRON SPUTTERING

Stanislava Rabadzhiyska[1], Maria Ormanova[1], Stefan Valkov[1], Nikolay Ivanov[1], Kamen Ivanov[3], Andreana Andreeva[2], Ruslan Bezdushnyi[2], Peter Petrov[1]
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Thin oxide films with precisely controlled properties have been attracting the interest of researchers as promising for the development of many modern technologies. One such material is hafnium oxide (HfO_2), which is characterized by very good thermal, chemical, and mechanical stability and high transparency over a wide wavelength range. HfO_2 exhibits low optical absorption and dispersion and high refractive index and dielectric constant, which makes it an attractive material for potential applications in optical coatings and microelectronics [1,2]. Thin films based on HfO2 are used as optical filters, ultraviolet heat mirrors, antireflection coatings and in space applications. In the field of electronics, it is a leading candidate to replace SiO_2 dielectrics in gate oxides due to a low electron tunneling effect and high permittivity [3,4]. In view of the mentioned excellent optical and electrical properties, HfO_2 thin films are envisioned as promising candidates for optical information storage.

On the other hand, the HfO_2 properties strongly depend on the method and deposition conditions. In our study, HfO_2 coatings were deposited on polished microscopic glass and silicon substrates by direct current (DC) magnetron sputtering. Five sets of thin films were deposited using different substrate bias voltages: –85 V, –100 V, –115 V, –130 V and –145 V. The experiments were carried out at a temperature of 300 ^oC with the current kept constant.

The samples' crystallographic structure was assessed by X-ray diffraction and the surface topography and roughness were determined by atomic force microscopy. The coatings thickness was measured on cross-sectional scanning electron microscopy images. The optical properties of the as-deposited HfO_2 coatings were determined based on transmittance measurements in the ultraviolet, visible and near infrared region by a spectrophotometer and the reflection and absorption coefficients were estimated by a homemade multifunctional laser system.

Keywords: HfO_2 coatings, DC magnetron sputtering, XRD, AFM, optical properties

Acknowledgments: This work was financially supported by the National Science Fund at the Bulgarian Ministry of Education and Science under project 17/07.

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P.F10

EFFECT OF Ni AND Al SUBSTITUTION ON THE STRUCTURAL AND MAGNETIC PROPERTIES OF Y-TYPE HEXAFERRITE $Ba_{0.5}Sr_{1.5}Zn_{2-X}Ni_XFe_{11.92}Al_{0.08}O_{22}$ POWDERS

B. Georgieva[1], S. Kolev[1], K. Krezhov[1], Ch. Ghelev[1], D. Kovacheva[2], L.-M. Tran[3], M. Babij[3], A. Zaleski[3], B. Vertruyen[4], R. Closset[4], T. Koutzarova[1]

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The multiferroic materials, which exhibit a simultaneous existence of long-range magnetic and ferroelectric orders, have recently driven significant research interest in the fields of both basic and applied sciences in search of promising materials for development of novel devices and technologies. In particular, the Y-type hexaferrites have been the subject of intensive characterization related to studying the magnetoelectric (ME) effect.

We report studies on the effect of substituting the non-magnetic Zn^{2+} cations with magnetic cations (Ni^{2+}), and of the magnetic Fe^{3+} cations with non-magnetic Al^{3+} cations in Y-type hexaferrite $Ba_{0.5}Sr_{1.5}Zn_{2-x}Ni_xFe_{11.92}Al_{0.08}O_{22}$ powders on their structural and magnetic properties and parameters. In this research, the Y-type hexaferrite powders were synthesized by citric acid sol-gel auto-combustion. After the auto-combustion process, the precursor powders were annealed at 1170 °C in air to obtain the $Ba_{0.5}Sr_{1.5}Zn_{2-x}Ni_xFe_{11.92}Al_{0.08}O_{22}$ materials. The effects of Ni and Al substitution on the structural, microstructural properties and phase content were investigated in detail using X-ray powder diffraction and scanning electron microscopy. Hysteresis measurements were performed by a physical-property-measurement-system (PPMS) (Quantum Design) at 4.2 K and at room temperature. The *ac*-magnetization was measured in an *ac*-magnetic field with an amplitude of 10 Oe and frequency of 1000 Hz to determine the magnetic phase transitions.

Acknowledgments: B. Georgieva was supported by the Bulgarian Ministry of Education and Science under the National Research Program "Young scientists and postdoctoral students" approved by DCM # 577/17.08.2018. This work was supported by the Bulgarian National Science Fund under contract DN 08/4 "Novel functional ferrites-based magneto-electric structures"; by contract KP-06-India-2 "Application of thin $ZnFe_2O_4$ films in various spintronic devices"; by a joint research project between the Bulgarian Academy of Sciences and WBI, Belgium; and by a joint research project between the Bulgarian Academy of Sciences and the Institute of Low Temperature and Structure Research, Polish Academy of Sciences.

Postdeadline

Poster Session II

P.F11

SYNTHESIS AND CHARACTERIZATION OF MULTILAYER GRAPHENE FOR FLEXIBLE OPTOELECTRONIC DEVICES

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Graphene demonstrates unique potential for the next generation technology owing to its exceptional optical and electrical properties. Moreover, due to its ultra-high carrier mobility and elasticity, graphene is regarded as an excellent candidate to replace the currently used indium tin oxide (ITO) in modern flexible displays.

We describe the synthesis process of large area-graphene grown by atmospheric pressure chemical vapor deposition and transferred on polyethylene terephthalate substrates. The quality of the structure was assessed by scanning electron microscopy, Raman analysis and optical spectroscopy, and the sheet resistance stability was evaluated after 1200 bending tests. The graphene structure was then applied as a transparent conductive electrode in flexible devices: several graphene-based polymer dispersed liquid crystal devices were fabricated and their electro-optical properties, such as voltage-dependent transmittance, response time and flexibility were measured. The results obtained open up great potential of graphene integration into the next generation ITO-free flexible and stretchable optoelectronics.

Acknowledgments: This work is supported by the Bulgarian National Science Fund, project DFNI KP-06-N-28/8 and the Ministry of Science and Technology (MOST), Taiwan, under contracts MOST 107-2221-E-009-120-MY3 and MOST 109-2927-I-009-507.

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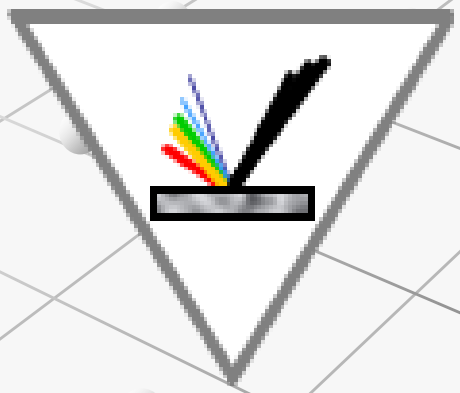

21-24 September 2020