XXII International Conference and School on Quantum Electronics

LASER PHYSICS AND APPLICATIONS

BOOK OF ABSTRACTS

19 SEPTEMBER
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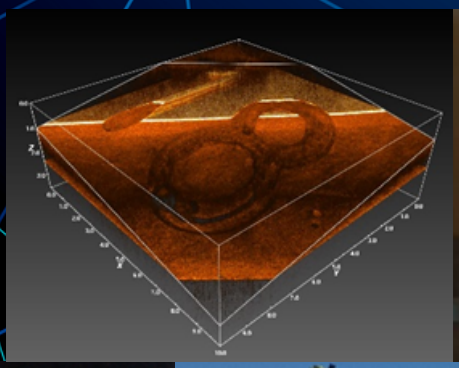

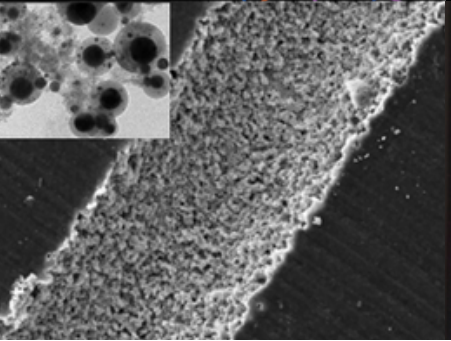
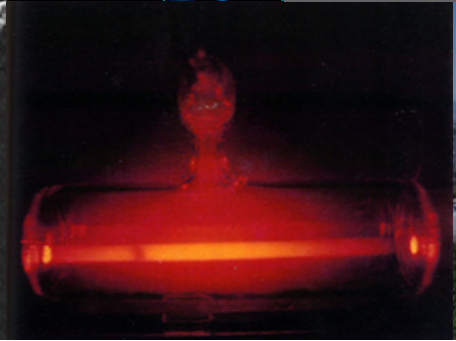

XXII INTERNATIONAL CONFERENCE AND SCHOOL ON QUANTUM ELECTRONICS

"LASER PHYSICS AND APPLICATIONS"

VIRTUAL FORUM

19-23 September 2022

BOOK OF ABSTRACTS

ABOUT THE ACADEMICIAN EMIL DJAKOV INSTITUTE OF ELECTRONICS

72 Tsarigradsko 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.

XXII INTERNATIONAL CONFERENCE AND SCHOOL ON QUANTUM ELECTRONICS

"LASER PHYSICS AND APPLICATIONS"

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TOPICS:

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B. Laser spectroscopy and metrology

C. Laser remote sensing and ecology

D. Lasers in biology and medicine

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INVITED LECTURES

LASER - MATTER INTERACTIONS

IL.A1

SERS ACTIVE SUBSTRATES FOR NEONICOTINOIDS STUDY

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Different basic substrates, as Si wafers, (001) SiO_2, printer paper, Al_2O_3, micro-processed (001) SiO_2 or diamond abrasive films have been used to create active Ag and Au nanostructures. Varieties of deposition techniques, as pulsed laser and thermal deposition, followed by pulsed laser annealing have been applied and the results were compared. Advanced substrates of Au and Ag on Si were produced and used for surface-enhanced Raman spectroscopy (SERS) detection of the imidacloprid neonicotinoid insecticide (Nuprid 200 SP) in quantities much smaller than usually applied in the agricultural medicine. The intensity of the SERS peaks increased at least by an order of magnitude after pulsed laser annealing of the metal films and formation of nanoparticle arrays. Thus, the enhancement factor (EF) was estimated to be $\geq 10^4$ as the limit of detection (LOD) reached was <0.5 nM. The properties of the advanced substrates were compared and discussed. The importance is emphasized of this relatively cheap and easy method in regulating, monitoring and controlling the level of such chemicals as pollutants in the environment, thus protecting the human and especially honey bee health.

IL.A2

FEMTOSECOND-LASER SURFACE STRUCTURING WITH GAUSSIAN AND SPATIALLY SHAPED BEAMS

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Extensive research work has been carried out on the structuring of the surface of solid targets by femtosecond (fs) laser pulses. The most striking and investigated phenomenon resides in the ubiquitous generation of laser induced periodic surface structures (LIPSS) [1], in which quasi-regular patterns of subwavelength features are observed over almost any type of material, including metals, semiconductors, dielectrics, and polymers. Moreover, other surface features with a suprawavelength period and quasi-regular patterns are also formed under appropriate experimental conditions. Finally, the surface of solid samples or thin-film overlayers can be textured thus forming patterns of holes or reliefs with a particular spatial arrangement.

We will make a comprehensive overview of recent investigations on the LIPSS and patterns formed on various materials by irradiation with fs laser pulses characterized by a Gaussian or a spatially variant beam-intensity profile [2].

Besides the main achievements reported in the literature, we will address our recent experimental work [3,4], giving an explicit picture on various aspects of the process of subwavelength ripples and suprawavelength grooves generation by a Gaussian beam and its dependence on experimental parameters like pulse fluence, number of laser pulses, repetition rate of the laser pulse sequence, processing environment (air vs vacuum). Moreover, we will illustrate the use of beams with spatially variant polarization and intensity achieved by exploiting vector vortex fs light beams to produce spatially variant patterns of LIPSS [5]. Further, we will illustrate the use of both Gaussian and vector vortex beams for the generation of large-area surface structured and patterned surfaces, also discussing some of their applications. Finally, the possible mechanisms envisaged to explain the formation of the surface structures and still open issues on the subject will be briefly discussed.

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IL.A3

LASER INSCRIPTION OF DIFFRACTION GRATINGS IN POLYMERS FOR OPHTHALMIC APPLICATIONS

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Nowadays, modifying the refractive power of the eye to correct refractive visual errors is carried out by refractive laser surgery. Among the techniques commonly used, the most noteworthy are laser in situ keratomileusis (LASIK), and photorefractive keratectomy (PRK) [1]. These techniques use UV laser radiation to reshape the cornea through photo-ablative decomposition processes that are destructive, invasive, and irreversible. In addition, these procedures may entail postsurgical complications and secondary visual effects, such as dry eye, stromal haze, irregular astigmatism, and keratoconus [2].

Short and ultrashort laser pulses have been widely applied to fabricate two- and three-dimensional permanent structures inside transparent optical materials, such as waveguides, photonic crystals, diffraction gratings, beam splitters, etc. [3]. In recent years, the Direct Laser Writing (DLW) and Direct Laser Inscription (DLIP) techniques have been proposed as novel approaches to changing the refractive index and, hence, the refractive power in optical devices for ophthalmic applications by using the inscription of diffractive elements, such as diffraction gratings [4-10].

In this work, the fabrication of diffraction gratings by the DLW and DLIP techniques is revised. Linear periodic patterns were structured both on the surface and inside polymers commonly used for soft contact lenses and intra-ocular lenses. The compositional and optical properties induced in the processed areas and the maximal refractive index change achieved is compared in terms of the laser processing technique, the thermal regime, and the pulse duration.

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IL.A4

FEMTOSECOND-LASER-INDUCED CARBONIZATION AND GRAPHITIZATION

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Polymer materials, such as rubbers, plastics, and natural resins, are widely used in applications that require lightweight and flexibility. Extensive studies have been conducted on the degradation and modification of polymer materials by chemical, optical, or thermal methods for imparting them with mechanical strength, hydrophobic or hydrophilic properties, desirable optical properties, and/or electrical conductivity. When a laser is used as the heat source for thermal degradation of polymers, the modification of the material into a conductive structure is possible in the limited area that is irradiated with the laser. That is, by simply scanning the laser beam, a conductive structure with an arbitrary shape can be directly written on a bendable and stretchable elastomer. In this presentation, our study on laser-induced carbonization and graphitization by using a femtosecond laser, consisting of three topics as follows, will be described.

1) Laser-induced graphitization of PDMS for flexible electronics [1,2]

   By applying a higher laser power, highly conductive structures composed of graphitic carbon, which has been referred to as laser-induced graphene (LIG), can be fabricated by irradiating laser pulses on polydimethylsiloxane (PDMS). Femtosecond laser direct writing of highly crystalline graphene on native PDMS and its application for a highly sensitive piezoresistive sensor will be described, as well as the discussions on the formation mechanisms.

2) Laser-induced graphitization of natural materials [3]

   The fabrication of highly conductive graphitic carbon from cellulose nanofiber (CNF) film will be described. In the case of high-repetition femtosecond laser irradiation, it is considered that strong optical effects, in addition to thermal effects, contribute to the degradation of CNFs, resulting in the formation of highly crystalline graphitic carbon. Recent achievements by using other natural precursors will also be presented.

3) Formation of graphene quantum dots [4]

   Graphene quantum dots (GQDs) have emerged as a promising new class of environmentally friendly quantum dots with unique properties. We demonstrated the simultaneous synthesis and patterning of GQDs based on the technique of laser-induced graphitization. Arbitrary fluorescent 2D and 3D patterns can be readily patterned without pre-and/or post-treatment. The

proposed method expands the possibilities of GQDs for applications in novel flexible three-dimensional optoelectrical devices.

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IL.A5

LASER-BASED SCAFFOLDS FOR TISSUE ENGINEERING APPLICATIONS

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Understanding the mechanisms by which the topographical cues of extracellular matrix (ECM) affect cellular responses, such as proliferation, adhesion, growth, orientation, and differentiation, is fundamentally important for tissue engineering/regenerative medicine applications. However, the complexity of the hierarchical micro/nanotopography of ECM renders extremely difficult the investigation of cell-substratum response, thus revealing the need of the development of *in vitro* experimental models with defined surface topography. Towards this scope, research efforts have been focused on lasers as tools for 2D and 3D structuring materials, as they do not require harsh processing conditions (chemicals or high temperature). These technologies can help the generation of well-controlled three-dimensional structures in a precisely predictable manner where it is easy to modulate the chemistry and the underlining topography. Such 3D structures are valuable tools as model scaffolds in tissue engineering and regenerative medicine approaches.

Ultrafast pulsed laser irradiation is considered as a simple and effective microfabrication method to produce structures with controlled geometry and pattern regularity. Specifically, using laser precision 3D micro/nano fabrication techniques, silicon substrates comprising arrays of parallel oriented elliptical microcones (MCs) were fabricated to investigate whether a discontinuous geometry comprising anisotropic features at the subcellular level could influence the morphology, outgrowth and differentiation of nerve, neuroglial and neuronal stem cells (NSCs). It was found that the distinct geometrical characteristics of a discontinuous topographical pattern alone could influence a variety of neuronal and neuroglial cell functions, however in a different manner. In the PC12 cell study, the surfaces roughness did effectively influence the PC12 cells' differentiation fate. In primary cell cultures, it was shown that the distinct anisotropic morphology of the microconical surfaces did affect the outgrowth orientation of both neurons and Schwann cells in a surface dependent manner.

Direct Laser Writing (DLW) is a non-linear stereolithographic technique based on two-photon polymerization, allowing the fabrication of 3D scaffolds. These 3D scaffolds were used in order to establish a biomimetic experimental model for the co-cultivation of glial and neuronal cells.

The laser patterned substrates and the 3D scaffolds presented here could be used as model scaffolds for the systematic exploration of the role of 3D microtopography on cell differentiation and neural network outgrowth, with the ultimate goal of providing mechanistic insight to guide the development of clinically relevant strategies for nerve repair.

LASER SPECTROSCOPY AND METROLOGY

IL.B1

HARMONIC DUAL DRESSING OF SPIN ONE-HALF SYSTEMS

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Controlled modifications of the quantum magnetic response are produced in dressed systems by a high-frequency, strong and not-resonant electromagnetic field. This quantum control is greatly enhanced and enriched by the harmonic, commensurable and orthogonally oriented dual dressing theoretically discussed here. The secondary field enables a fine tuning of the qubit response, with the control parameters being amplitude, harmonic content, spatial orientation and phase relation. Our analysis is based on a perturbative approach and includes few numerical solutions. The long-time dynamics is described in terms of an anisotropic effective static magnetic field representing the handle for the system full engineering. Through a low-order harmonic mixing, the bichromatic driving generates a rectified static field acting on the spin. The Zeeman response becomes anisotropic in a triaxial geometry and includes a quadratic contribution. Our dressing increases the two-level energy splitting, improving the spin detection sensitivity. On the low-field direction, it compensates the static fields applied in different geometries. A resonant spin exchange between two species having very different magnetic response, as electron and nucleus, is allowed by the dressing. The spin temporal evolution includes a micromotion at harmonics of the driving frequency whose role in the spin detection is examined and can be exploited in quantum information. The results presented here lay a foundation for additional applications to be harnessed in quantum simulations.

IL.B2

HIGH RESOLUTION MOLECULAR SPECTROSCOPY IN MICROMETRIC THIN CELLS

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Shrinking the size of atomic and molecular cells is a fascinating prospect with applications in quantum sensing and fundamental physics. Miniature atomic cells have been proposed, for example, as portable atomic clocks [1] and hollow-core fibers have been filled with molecular gases for applications in frequency referencing [2]. Although compact, the above devices remain mesoscopic (confinement larger than the excitation wavelength). Atomic thin cells have been used to probe atoms under sub-wavelength confinement conditions allowing fundamental studies of the Dicke effect [3] and applications in quantum technologies [4]. High-resolution probing of sub-wavelength confined molecules is however, more challenging due to the small probabilities of molecular transitions, and has so far been demonstrated only on a macroscopic cell via selective reflection spectroscopy [5]. Here we extend thin cell platforms to high-resolution molecular spectroscopy. We probe the $\nu 1+\nu 3$ line of acetylene at telecommunication wavelengths (1.53 μm), and SF_6 as well as NH_3 rovibrations at mid-infrared wavelengths (10.6 μm). Our experiments are a first important step towards the fabrication of compact and simple frequency references at telecommunication wavelengths without resorting to nonlinear spectroscopic techniques like saturated absorption. We are currently working towards fabricating a new generation of thin cells of nanometric thickness suited for studies of the fundamental molecule-surface Casimir-Polder interaction.

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LASER REMOTE SENSING AND ECOLOGY

IL.C1

GROUND-BASED PASSIVE AND ACTIVE AEROSOL REMOTE SENSING. CURRENT TECHNIQUES AND RECENT ADVANCES

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Atmospheric aerosols, although considered as minor atmospheric components, play an important role in a wide range of weather and climate phenomena on local, regional, and global scale. In this context, the motivation is high to characterize their properties and monitor their variability and trends. Existing ground-based and space observing systems are devoted to these roles. In this lecture, we focus on the ground-based aerosol remote sensing observation systems. In the atmosphere, aerosols are interacting through scattering and absorption processes with the natural solar radiation and with the artificial radiation emitted by laser sources. Instrumentation designed to detect and characterize atmospheric particles are therefore based on these atmospheric processes. In the lecture we will show how and what sun/sky/moon photometer techniques provide to the fundamental scientific questions, taking the example of the widely distributed AERONET network. Such technique provides access to the essential atmospheric variable integrated over the whole atmospheric column. The limitation of this technique is that the vertical distributions of aerosol properties are not reachable. This is why the combination of photometer and lidar techniques is very relevant to overcome some of the limitations of both instruments, e.g. lidar during daytime observations. In this lecture, we will address this synergy method as well as present some recent results obtained with the high performance Mie-Raman-Fluorescence lidar in operation at the ATOLL facility located at Lille University. Most of these activities have been carried out in the frameworks of the aerosol remote sensing component (CARS) of the ACTRIS infrastructure, CaPPA (Chemical and Physical Processes in the Atmosphere) and AGORA-Lab research and development programs.

Keywords: climate, aerosol, air quality, remote sensing, photometer, lidar, synergy, ACTRIS, AERONET, EARLINET, AGORA-Lab

IL.C2

LARA – A NEW CONCEPT FOR HIGH-ACCURACY LASER RANGING

Klaas Bergmann

TOPTICA-Projects and (retired from) Physics Department, Technische Universität Kaiserslautern

The "LARA-System" for high-accuracy laser ranging works on an entirely different concept than currently available on the market and thus, it has some unusual properties. The platform is a laser with cavity-internal frequency-shifted feedback. Structures down to 1- accuracy (the lateral resolution is determined by the laser spot size, typically 10 μm or less) can be measured at a rate of a few kHz. One field of application is surface topography, in particular monitoring structures formed by laser ablation. In those applications, the LARA laser beam propagates coaxially with the ablation lasers and measures between ablation laser shots. The physics behind the new concept will be briefly explained and examples with data taken by the new ranging tool shown.

IL.C3

LASER APPLICATIONS FOR ATMOSPHERIC MONITORING

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Laser applications for Atmospheric Remote Sensing are experiencing a very fruitful era. Already since a number of decades, the ground based application of advanced laser techniques for studying the atmosphere has become popular, but nowadays, space borne laser applications for atmospheric monitoring are transitioning from demonstration, to operational.

In this presentation, an overview of a range of laser applications for atmospheric remote sensing will be addressed. Starting from the needs for atmospheric parameters, the various techniques to address these issues will be presented and illustrated. Starting from the core of the technique, elastic (backscatter) lidar, other techniques such as Differential Absorption Lidar (DIAL) for trace gas detection and Raman lidar for quantitative aerosol profiling, will be addressed. Space borne applications will also be shown.

LASERS IN BIOLOGY AND MEDICINE

IL.D1

RECENT ADVANCES IN MUELLER POLARIMETRY FOR TISSUE DIAGNOSIS

T. Novikova[1,2]

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Developing accurate and reliable methods for tissue diagnosis presents a problem of paramount importance because the early detection and grading of any disease significantly improves patients' treatment and quality of life. A variety of optical techniques (e.g. optical coherence tomography, spectral fluorescence, Raman spectroscopy, etc.) have been explored recently to assist medical doctors in making decisions, but each technique has its limitations (e. g. measurement time, spatial resolution, reliability, side effects, etc.). Recently, the potential of multi-spectral imaging Mueller polarimetry was extensively explored and proved to be a promising optical modality for many biomedical applications.

Complete custom-built imaging Mueller polarimetric systems based on ferroelectric liquid crystals for fast polarization modulation that operate in the visible wavelength range were used for visualization and staging of cancerous lesions [1,2], digital histology [3, 4], regenerative medicine, etc. Wide-field polarimetric images of thick colon [5], cervical [6] and brain specimens [7] recorded in reflection geometry revealed the extreme sensitivity of polarized light to structural anisotropy of tissues related to the presence of collagen fibers or bundles of neurons, as validated by histology analysis. Tissue malformations break the intrinsic optical anisotropy of a healthy tissue, thus leading to an increase of the contrast between healthy and anomalous zones in the polarimetric images compared to unpolarized intensity images. These contrasts can be used for optical diagnosis of the tissue and delineation of pathological zones. Studies of thin sections of gastric tissue biopsies [8], full thickness skin equivalents [9] and frozen / thawed collagen gel films by a transmission Mueller microscope have also revealed contrasts in polarimetric images of the depolarization, scalar retardance and orientation of the optical axis of linear birefringent medium that are not present in intensity images. Possible applications include automated digital histology to support the diagnosis of a pathologist and development of optimal protocol for tissue cryopreservation. Our theoretical and numerical studies by a Monte Carlo approach shed light on the origins of the contrasts observed.

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IL.D2

FLUORESCENCE LIFETIME IMAGING AND ITS APPLICATION FOR BIOMEDICAL DIAGNOSTICS

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The "LARA-System" for high-accuracy laser ranging works on an entirely different concept than that of the currently available on the market and thus, it has some unusual properties. The platform is a laser with cavity-internal frequency-shifted feedback. Structures down to 1 μm accuracy (the lateral resolution is given by the laser spot size, typically 10 μm or less) can be measured at a rate of a few kHz. One field of application is surface topography, in particular, monitoring structures formed by laser ablation. In those applications, the LARA laser-beam fluorescence lifetime imaging (FLIM) is widely used in diverse areas of biophysical research and biomedical diagnostics. Using fluorescence decay parameters as an endogenous contrast allows for imaging of certain molecular species within the living systems. In this talk, we will discuss three applications of FLIM. Firstly, the use will be discussed of FLIM for assessing tumor heterogeneity and optimizing personalized therapy [1]. Secondly, application of fluorescence probes for microviscosity whose lifetime is indicative of microenvironment will be analyzed in the context of peptides self-assembly into fibrillar nanostructures [2]. Finally, we will address the capabilities of FLIM in studying degradation of biomaterials.

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IL.D3

IN-VIVO NON-CONTACT IMAGING OF THE HUMAN EYE WITH HIGH-SPEED CELLULAR RESOLUTION OPTICAL COHERENCE TOMOGRAPHY

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Potentially blinding diseases that affect different parts of the eye, such as the retina, cornea and limbus, cause morphological, vascular and functional changes in the ocular tissue. We have developed a high-speed optical coherence tomography (OCT) technology capable of volumetric imaging of the cellular structure of ocular tissue, as well as simultaneous imaging of morphological, vascular and functional changes in the eye induced by various ocular pathologies.

LASER SYSTEMS AND NONLINEAR OPTICS

IL.E1

HOW TO CONTROL LASER BEAM FILAMENTATION, ROGUE WAVE FORMATION, AND RELATED PHENOMENA

Robert W. Boyd

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and
Institute of Optics, University of Rochester, Rochester NY USA

In this talk, I describe the current understanding of several interrelated self-action processes including self-focusing, small-scale filamentation (beam breakup), rogue wave formation, and caustic formation. I begin with a historical overview of the development of the understanding of self-action effects in nonlinear optics and particularly of the process of filamentation. I then review some of specific topics of current interest that rely on the process of filamentation. Examples include supercontinuum generation, air-lasing, applications of filamentation, the relation of filamentation to rogue waves, and filamentation induced by structured light beams including vector and Poincaré beams. Lastly, I address the question of how to prevent the occurrence of filamentation when this process is undesired.

IL.E2

GENERATION AND CHARACTERIZATION OF LONG-RANGE (QUASI-)NON-DIFFRACTING GAUSS-BESSEL BEAMS

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Along with the infinite plane waves and the Airy and the Ince beams, the Bessel beams (BBs) are one of the four known exact solutions of the Helmholtz equation. The BBs are non-diffracting in the sense of the remarkable stability of the central peak (or the central ring) with respect to diffraction broadening. Because real (e.g., Gaussian) laser beams have finite transverse sizes, the central peaks of the BBs generated in the experiments have a low but still non-zero diffraction divergence. As a consequence, they are denoted as (quasi-)non-diffracting.

In this talk we will describe a novel scheme for transforming Gaussian beams into long-range (quasi-)non-diffracting Gauss-Bessel beams (GBBs) [1,2,3] by creating and subsequently annihilating optical vortices (OVs) thereafter Fourier-transforming the ring-shaped beam into a GBB. The key results can be summarized as follows: (*i*) The higher the topological charge of the used OVs, the narrower the central peak of the GBB; (*ii*) The typical divergences of the central peaks of the GBBs is in the sub-40-microradian range over propagation distances of several meters; (*iii*) The experimental scheme is wavelength-tolerant in the sense that vortex phase plates designed for a specific wavelength can be successfully used at much different wavelengths; (*iv*) Using a reflective spatial light modulator, long-range GBBs are successfully generated in the fields of sub-7-fs laser pulses; (*v*) Let us recall that the Gouy phase is measured relative to that of an infinite plane wave, and an infinite plane wave does not experience diffraction. In view of this, one might think that (quasi-)non-diffracting GBBs have zero (or negligible) Gouy phase. Our recent experimental data showed that under relatively weak focusing of the initial hollow ring-shaped beam, the Gouy phase of the GBB is found to change linearly at a rate of 77 some 0.2π/cm over a distance of 45 cm. Under moderate focusing, the linear vs. propagation distance Gouy phase reached a slope of (1.0π/mm) over distances exceeding 4 mm. The theoretical results are found in a good quantitative agreement with the experimental data.

The described results may have significant consequences in e.g., nonlinear optics, since the observation of nonlinear processes requires that high peak-intensity be maintained over a relatively long propagation distances at a proper phase matching.

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D01-401/18.12.2020 (ELI ERIC BG), by the Scientific Fund of Sofia University (80-10-181/27.05.2022), and by the DFG (project PA 730/7).

IL.E3

PRODUCING A FEW-FEMTOSECOND LWFA-BASED X-RAY SOURCE USING A SUB-PW 13-FS LASER PULSES FOR APPLICATIONS FROM MOLECULAR DYNAMICS TO LOW-DOSE BREAST CANCER DETECTION AND GLOBAL FOOD SECURITY

Jean Claude Kieffer

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In this presentation, I discuss how a sub-PW short laser pulse (13 fs) generated by the thin-film compression technique can be focused and used in a real experiment. The technique is opening a route towards the production of a few-fs hard X-ray pulses (30 keV) and the generation of PW power in a single-cycle pulse. I will discuss the application of such an X-ray source from molecular dynamics to early breast cancer detection and global food security.

IL.E4

QUASI-STATIONARY OPTICAL GAUSSONS

Anjan Biswas

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This presentation deals with the dynamics of optical solitons with log-law nonlinearity, also known as optical *Gaussons*, in the presence of perturbation terms. The governing model is the nonlinear Schrödinger's equation that carries logarithmic form of nonlinear refractive index. A few perturbation terms are included to get a better understanding of the *Gausson* transmission dynamics. These include intermodal dispersion self-steepening effects, saturable amplifiers, and others. A multiple-scale perturbation analysis is implemented to retrieve the quasi-stationary optical *Gaussons* solution. The definition of the phase that is introduced reveals a couple of resonant conditions that cannot be otherwise recovered.

IL.E5

THE EXTREME LIGHT INFRASTRUCTURE: MULTI-DISCIPLINARY SCIENCE AND RESEARCH APPLICATIONS OF ULTRA-INTENSE AND ULTRA-SHORT LASER PULSES

ALLEN WEEKS

ELI ERIC Director General

The Extreme Light Infrastructure (ELI) is the premier research center for scientists to access the most advanced and intense lasers in the world. Established in 2021, ELI ERIC is an international user organization for multi-disciplinary research using extreme intensity and ultra-short laser pulses [1]. The ELI Beamlines facility in the Czech Republic and ELI ALPS in Hungary are complementary, providing access to experiments in physics, chemistry, radiography, fusion, environment, materials sciences, nanotechnologies, biology, and biochemistry [2]. The talk details their status and the first ELI Call for Users [3], including the ELI Nuclear Physics Facility being built in Romania. Sources, instruments and the proposal process will be presented.

ELI has received funding for the IMPULSE Project from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 871161

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IL.E6

FEMTOSECOND PUMP-PROBE ELLIPSOMETRY AS PART OF ULTRA-FAST LASER SYSTEMS & APPLICATIONS AT ELI BEAMLINES

Martin Zahradník

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ELI Beamlines is a part of the ELI-ERIC pan-European research network of user facilities providing the international community with state-of-the-art high-power, high-intensity, short-pulsed laser systems. ELI Beamlines developed four high-power lasers suitable for various applications, with a peak power ranging up to 10 PW, and a pulse length down to 15 fs. The applications include, for example, studies in plasma physics and exotic physics under extreme conditions, ion acceleration used for hadron therapy, or laser-driven X-ray sources and ultra-fast optical spectroscopies for molecular, biomedical, and materials sciences.

Here, a special focus is dedicated to the beamline of broadband femtosecond pump-probe ellipsometry, which has recently attracted considerable attention of the user community. Using a femtosecond driving laser and a whitelight supercontinuum, the technique combines the advantages of ultra-fast pump-probe experiments with those of conventional broadband spectroscopy. Therefore, it allows acquisition of the dynamic evolution of optical properties in a spectral range from 350 nm to 750 nm with a time resolution of 100 fs, and with the possibility of tuning the pump excitation between 200 nm and 2 μm.

Similarly to conventional ellipsometry, the ultra-fast beamline is especially suitable for, though not limited to, characterization of thin films of solid state materials. After initial experiments on bulk semiconductors (Ge, Si, InP) mapping the dynamic evolution of critical points [1], the ellipsometry was further used for probing the dynamics of hot charge carriers [2] and birefrigence in thin ZnO films [3]. Most recently, we reported on a photo-induced insulator-to-metal transition in thin films of cobaltites [4], or ultra-fast changes in the absorption onset of zincblende GaN [5]. The experimental progress is also driving the development of new models and theories, as shown by the recent advanced in the theoretical analysis of critical points and coherent acoustic phonon oscillations in semiconductors [6]. Ongoing projects include investigation of phase-change materials, piezzoelectric layers, plasmonic nanostructures, or biomolecules, demonstrating a wide application potential and versatility of the technique presented, which can successfully serve in a large range of user experiments in materials science.

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IL.E7

ULTRAFAST ELECTRON DYNAMICS IN SOLID-STATE MEDIA

Peter Dombi

Head of Ultrafast Science and Applications Division, ELI-ALPS, Hungary

Research infrastructure at the ELI-ALPS facility in Hungary is particularly suitable for the investigation of femtosecond and attosecond electron dynamics in atomic and molecular systems, as well as condensed matter. Highlighting a particularly important research line within this field, I will present recent research results on different aspects of ultrafast electron dynamics in solids. I will also introduce state-of-the-art instrumentation at ELI-ALPS, including a unique NanoESCA endstation and the XUV beamline that can drive experiments there.

ALTERNATIVE TECHNIQUES FOR MATERIAL SYNTHESIS AND PROCESSING

IL.F1

LASER-BASED TECHNIQUES FOR 3D PRINTING OF INORGANIC MATERIALS

Benedicte Vertruyen, Damien Coibion, Raphael Closset, Renaud Hastir, Karl Traina, Audrey Schrijnemakers, Frederic Boschini

GREENMAT, CESAM Research Unit, University of Liege, Belgium

According to the introduction to the latest ISO/ASTM norm (ISO/ASTM 52900:2021), additive manufacturing "is the general term for those technologies that successively join material to create physical objects as specified by 3D model data". Numerous techniques exist for the layer-by-layer building of polymeric, metallic or ceramic objects; the world of 3D printing (as it is commonly called) is made even more complex by a rather bewildering variety of names and acronyms. Amongst all these additive manufacturing techniques, several rely on lasers, for example, to induce photopolymerization or to melt/sinter metallic powders.

After a brief general overview, I will focus on two of these techniques: stereolithography and laser-based powder bed fusion. I will illustrate their principles with results taken from literature and from the work of our group on the stereolithography of hydroxyapatite and zirconia.

IL.F2

NANOLITHOGRAPHY IN RESEARCH AND INDUSTRY

Ivan Kostic

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The aim of this work is to overview important and interesting inventions and technical solutions that have enabled the success of the top-down nanofabrication in preparing nanometer structures. The focus is on nanolithography as the crucial technology in the top-down approach, in particular, the sub-wavelength optical lithography, the electron-beam lithography (EBL) and the scanning probe lithography.

Nanolithography is an essential top-down fabrication technology with a broad range of applications. Generally, there are two types of nanolithography technologies. The first type duplicates the pattern of the mask. This is suitable for high-volume production because of the high throughput as the pattern over an entire mask or mold is duplicated in one step. The main technologies are optical nanolithography, extreme ultraviolet nanolithography, charged particle projection nanolithography, X-ray nanolithography, and nanoimprint nanolithography.

The second type is direct patterning of the patterns. In that case, nanopatterns are generated in a sequential manner, thus it has low throughput and is suitable for R&D or the production of mask or mold used by the first type. This includes electron-beam nanolithography, ion-beam nanolithography, scanning-probes nanolithography, and electron-beam-induced deposition.

In the semiconductor industry, chipmakers are pushing the technology processes and the resolution down to nanometers and are investing unbelievable volume of finances for that. Top-down nanofabrication technologies are the main and still the prevailing technology in semiconductor industry for mass production of semiconductor devices, integrated circuits, semiconductor chips for computers and information storage.

In the research and development, throughput is not an important issue. Moreover, researchers are often working with small samples which are reasonable for investigation of new phenomena and characteristics of new devices. Therefore, nanolithography is used in a wide range of applications, including nanoelectronics, molecular electronics, quantum devices, sensors, optoelectronics, nanophotonics, high-frequency electronics, spintronics, molecular electronics, Bit-patterned media, quantum dots, nanowires, carbon nanotube-based devices, new 2D materials-based devices, nanomechanical devices, nanosystems, nanofluidics, production of nanoimprint templates, rapid prototyping of nanodevices and others. New perspectives of nanolithography are expected in emergent applications, such as new computation schemes, biomedicine, robotics, the Internet of Things, and others. New strategies of the combination of bottom-up and top-down strategies offers additional opportunities for advanced nanofabrication

An appropriate lithography technology exists for each need. The choice of an appropriate nanolithography technology for each case should take in account aspects such as resolution, cost, throughput, and complexity (the amount of steps required to perform the processing and the difficulty of these steps). Nanolithography boundaries are constantly shifting in terms of feature dimensions down to the range of nanometer units due to researchers' efforts to overcome various limiting factors in achieving maximum resolution.

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IL.F3

COMPARISON OF LASER AND ARC-BASED DIRECT ENERGY DEPOSITION METHODS

Anton Evdokimov

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Additive Manufacturing (AM) boasts the ability to produce components with a previously unachievable level of geometric complexity in prototyping and end-user industrial applications, such as aerospace, automotive, and medical industries. Direct Energy Deposition (DED) is a family of AM technologies that uses a directed heat source to melt a feedstock material. DED of metals allows the manufacturing of large-scale metallic components at a much higher deposition rate compared to other AM technologies. With DED technologies, the feedstock material (in the form of wire or powder) is fed through a narrow nozzle and melted by a heat source. Depending on the process, the heat source can be an electric arc, a laser or electron beam, or plasma. The most common DED processes are Wire Arc Additive Manufacturing (WAAM) and Laser Metal Deposition (LMD). We introduce the WAAM and LMD processes and provide the comparison regarding basic criteria, such as build rate, part complexity, and fabrication costs. The advantages and disadvantages of the laser heat source over the arc for DED processes are extensively discussed.

ORAL SESSIONS

PRESENTED CONTRIBUTIONS

ORAL PRESENTATIONS – Session I

OP.D1

FLUORESCENT STUDY OF WASTEWATER – THE EFFECT OF LOW QUANTITY OF DISINFECTANT

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In the last few years due to the COVID-19 pandemic, the pollution with large quantities of medicaments, disinfectants and essential oils raised the importance of their detection in wastewater. New diagnostics techniques are being continuously developed. Some promising methods for the estimation of contaminators of different origin are based on the optical and spectral characteristics of the examined water. Those could be used in determining the exact pollutant.
The spectroscopic examination could also be conducted in real time under *in vivo* conditions. In this research, we use fluorescence spectroscopy to investigate the purity of water samples from the discharge of the Iskar River near the treatment plant in the town of Samokov (Bulgaria) and the influence of small amounts of disinfectant (ethanol). The results show that fluorescence can be used to determine the purity of water samples and small amounts of alcohol in wastewater.

OP.D2

EFFECTIVE APPLICATION OF A SUITABLE SINGLE PULSE OF Nd:YAG AND Nd:GLASS LASERS (WAVELENGTH 1.064 μm) FOR CLEANING INITIAL CARIOUS LESIONS OF HUMAN TEETH. EXPERIMENTAL STUDY

Todor Uzunov[1], Margarita Deneva[2], Valko Kazakov[2], Pepa Uzunova[3], Nadejda Kaimakanova[4], Marin Nenchev[2]

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We report the results of an experimental study of using pulsed Nd:YAG and Nd:glass lasers (wavelength 1.064 μm) with energy parameters in a single pulse suitable for effective cleaning of initial carious lesions (diameter 1 – 3 mm) of permanent teeth in combination with tooth preparation for final restorative procedures. These solid-state lasers are among the most suitable lasers for dental applications due to their simple design, convenience for use in dental fiber optic systems, effective bactericidal therapy and low cost. The lasers used in the study operate in the simplest mode of operation, free running emission, when the pulse duration is ~0.2 ms. We found the usable energy parameters of the laser pulses, which allow one to form the necessary clean hole at the site of the lesion without increasing the temperature of the pulp chamber wall up to 43 °C (when soft tissue necrosis occurs), while also avoiding the formation of a crack in the enamel. The procedure consists of irradiating with single pulses of energy of ~2 – 5 J, energy density of ~50 – 130 J/cm^2 and pulse duration of ~500 ns – 2 ms. A special arrangement (with ~0.1 °C accuracy) shows a permissible T_{in} ~8 °C temperature rise of the pulp chamber for the noted pulse energies (Fig.4). Because of the short pulse duration, a water spray reduces the temperature rise by only ~2°C. A comparison with treatment by a sequence of pulses with the same sum energy (~10 pulses/1 Hz with low energy ~0.1 – 0.35 J, sum energy 3.5 J, Fig.3) shows the advantages of using single pulses. To obtain correctly comparable results from different measurements, we performed averaging of the results for several similar lesions, as well as appropriate lesion simulations and single lesion reconstruction. The presented studies of pulp chamber heating and crack formation demonstrate that treatment with single laser pulses of energy of ~4 J and (100 – 130) J/cm^2 can be assessed as the safety limit of direct treatment of the noted initial lesions. Examples are shown in the photographs below.

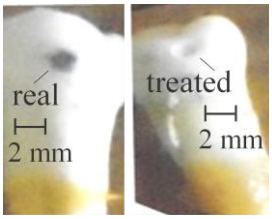

Fig.1.

Fig.2.

Fig.3.

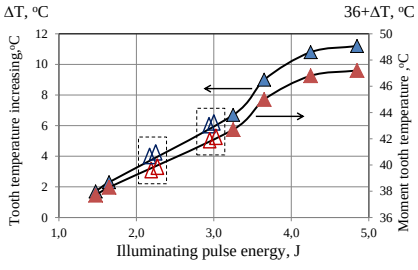

Fig.4.

Fig.1. Examples of a real carious lesion (left) and (right) – good cleaning of a uniform lesion; pulse of 2.6 J;100 J/cm^2 (formation at the lesion site of conical clean holes with diameters of 1.6 mm (top) and 0.7 mm (bottom), depth 0.5 mm); **Fig.2**. Simulated lesions "s" and after treatment "t", 2-J pulse, 120 J/cm^2; **Fig.3**. Treatment with low-energy pulse sequence; **Fig.4.** Pulp chamber temperature plots.

Although the treatment of initial lesions is not a typical case in dental practice, the good results show the possibility of its effective use. Such cases are associated with practically continuous control (almost every shot) of the teeth of the selected patient, including children. The implementation of a suitable computer system is the basis for the future.

OP.D3

APPLICATIONS OF A SINGLE LASER PULSE OF Nd:DOPED LASERS FOR CLEANING SMALL-DIAMETER CARIOUS LESIONS. MODELING AND ANALYTICAL STUDY

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In this work, we analytically developed the experimental results reported in Ref. [1] on the cleaning of small-diameter (1 – 3 mm) initial teeth lesions by single-pulses of Nd:YAG and Nd:glass lasers (wavelength 1.064 μm). The study included modeling, computer analysis and some additional experiments to measure the tooth parameters required. We consider the conversion of light energy into heat energy and their balance in the illuminated lesion, including the light propagation in the lesion tissue accompanied by the processes of tissue heating, melting and ablation. In order to obtain a cut with the required tooth diameter, we report important experimental data on enamel and dentin thickness. The analytical treatment included a physical description of the processes noted in combination with computer programming. A close comparison of the analytically obtained results with the experimental results in [1] confirmed the correctness of the modeling. In [1], single light pulses are used emitted by the considered lasers with energy 1.3 – 4 J; density 40 – 100 J/cm^2 (considering laser pulse duration from a few hundred ns to 2 ms, i.e., the simplest case of free running laser emission). A water spray applied in the experimental work [1] reduces the temperature rise to only ~ 2 ^{o}C due to the short pulse duration, but removes the ablation particles in an inexpensive way.

As we show, the developed computer program allows one to enter the tooth parameters in combination with the enamel and dentin thickness in the area of the lesion position on the tooth and obtain the energy necessary to properly clean the lesion by a single laser pulse with the possibility of heating the tooth, especially the tooth chamber wall. Thus, the expected application of the procedure would involve medical devices that combine a suitable computer control and a laser with proper laser light delivering part. The program presented in the work must be implemented in the computer with input maps of the teeth with their characteristics for the patients of the respective geographical region and ages. The dentist should enter the patient's age, the position of the teeth in the tooth chart, the lesion diameter and its position on the corresponding tooth. A computer subsystem should control the energy of the cleaning laser pulse delivered by the laser system.

The work [1] is the first, experimental, part of the two connected works, and is also proposed for presentation at the conference.

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ORAL PRESENTATIONS – Session II

OP.D4

APPLICATION OF FLUORESCENCE SPECTROSCOPY FOR ANALYSIS OF DIFFERENT ONION VARIETIES DURING STORAGE IN STOREHOUSE

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The present study aimed to establish the application of fluorescence spectroscopy for a comparison of three onion genotypes after harvest and at certain intervals of storage period. The genotypes were stored in a storehouse under ambient conditions. This will allow the method to be applied as non-invasive quality control of onion produce during storage.

The experimental studies were performed with sixty-three accessions (21 after three months of storage, 21 after 6 months of storage and 21 after 9 months of storage). The weight of the bulbs was measured individually.

The equipment for emission fluorescence spectra generation is mobile and has applicability in local characteristics of the produce. In its adjustment (optical tuning), a systematic engineering approach based on the classical principles of modern optoelectronics is applied. The results of the experiment will contribute to the optimization of the time for analysis of onion genotypes and will support the breeding process in its initial stages when it is necessary to qualify a large set of samples.

OP.D5

SYNCHRONOUS FLUORESCENCE SPECTROSCOPY FOR CLASSIFICATION OF GASTROINTESTINAL TISSUES BY A SUPPORT VECTOR MACHINE

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Autofluorescence spectroscopy has been proven to be a valuable tool for assessing suspicious tissue lesions through endoscopic surveillance of the gastrointestinal tract. However, the full diagnostic potential of the fluorescence spectroscopy for discriminating between pathologically altered tissues is still to be developed.
One of the fields in need of improvement is the set of optical parameters used for tissue differentiation. The ones implemented in the clinical practice lack sufficient specificity, hence lead to high rate of false positive results during examination.
We investigated through synchronous fluorescence spectroscopy ex vivo tissue samples of healthy and cancerous gastrointestinal tissues. The results obtained were processed by a support vector machine to evaluate the diagnostically valuable spectral peculiarities. Classification of healthy and cancerous gastrointestinal tissues using this method provides differentiation with diagnostic accuracy of up to 95%.

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*The work was submitted after the death of this author. Her contribution is of great significance.

OP.D6

DIAGNOSIS OF SKIN LESIONS BY A PROTOTYPE CLINICAL DEVICE WITH DIFFUSE REFLECTANCE SPECTROSCOPY

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Cancerous and precancerous skin conditions occupy one of the leading places in oncology. Early detection of suspects and temporary referrals to a specialist are critical to a successful treatment. Numerous optical techniques are being used to obtain new data from cutaneous neoplasia. Diffuse-reflectance spectroscopy is one of these techniques due to its high sensitivity in detecting subtle tissue alterations. Light scattering events inside the skin tissues change significantly in the development stage of skin lesions. This change in the tissue scattering properties in the diffuse reflectance spectrum may provide classification of different skin lesions based on diffuse reflectance measurements.

We investigated diffuse-reflectance spectroscopy for diagnostic of skin lesions and as a result an optical device for clinical application was developed. This work presents the results obtained by the prototype device for the reflective ability of endogenous melanin in pigmented skin benign, dysplastic, and malignant cutaneous lesions *in vivo*.

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*The work was submitted after the death of this author. Her contribution is of great significance.

OP.D7

PDT AND PD OF HUMAN GLIOBLASTOMA WITH 5-ALA/PPIX AND n-GalLuPc

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Glioblastoma (GBM) is the most common and severe type of brain tumor. Unfortunately, surgery and subsequent radiotherapy and chemotherapy do not lead to effective results in the treatment of this type of malignancy, due to its specific morphology. Only about 6% of the patients of advanced age survive 5 years after being diagnosed with GBM. Therefore, scientists are trying to find alternative methods that would lead to more effective and long-term treatment of glioblastoma cells. Photodynamic therapy (PDT) and photodiagnostics (PD) are such unconventional methods for treating and diagnosing malignant tumors. More than 20 experiments were carried out with stem cells cultivated from human glioblastoma tumors. We used two types of photosensitizers – 5-ALA/PpIX and n-GalLuPc. After the irradiation supernatant samples of photosensitizer-treated cell lines were used for evaluation of photosensitizers' accumulation in the cell lines investigated, using excitation in the spectral ranges of Soret' and the Q-band. The emitting spectra is correlated with the total induced cell death in the treated cells. After considering the overall effectiveness of the two photosensitizers n-GalLuPc showed higher efficiency. These results 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 obtained protocols of photodynamic treatment of glioblastoma lesions in such model systems for the needs of human medicine.

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*The work was submitted after the death of this author. Her contribution is of great significance.

ORAL PRESENTATIONS – Session III

OP.E1

NONPARAXIAL SOLITONS IN AIR

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In the present work, the soliton regime is investigated of propagation in air of ultra-short long-wavelength infrared laser pulses. The dispersion of atmospheric air in the mid-infrared and long-wavelength infrared shows anomalous group-velocity dispersion regions with wavelengths in the ranges of 3.5 μm to 4.2 μm and 9.3 μm to 13.5 μm [1]. In these spectral regions, the atmospheric air is transparent. On the other hand, the nonparaxiality leads to a waveguiding regime of femtosecond pulses with the shape of light disks (the transverse size is much bigger than the longitudinal one) [2]. The waveguiding regime allows reducing this 3D+1 task to a 1D+1 problem in the same manner as in optical fibers. The combination of anomalous group-velocity dispersion and atmospheric nonlinearity is a basis for observing optical solitons in the air transparency regions of the indicated wavelengths. The equation in our research is the 1D+1 nonlinear nonparaxial amplitude equation written in Galilean and laboratory coordinate systems. A new analytical solution is found in the form of a bright soliton. The critical power for observing these solitons is of two orders of magnitude less than the critical one for self-focusing. This is why no conditions exist for ionization of the media.

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OP.E2

ROTATION OF THE POLARIZATION ELLIPSE FOR BROAD-BAND AND NARROW-BAND OPTICAL PULSES. ANALYTICAL SOLUTIONS

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The evolution of broad-band laser pulses propagating in various types of waveguides has recently attracted particular research interest. Currently, for phase-modulated femtosecond pulses it is easy to achieve that the condition $\Delta\omega \approx \omega_0$ holds true. It is known that it is possible to reach the attosecond region where the spectral bandwidth of the pulse happens also to be of the order of the carrier frequency. Light pulses that fulfill this initial condition are described as being broad-band pulses, while those not fulfilling it are known as narrow-band ones.

The well-known system of nonlinear Schrödinger equations (SNSE) can be used to describe the propagation of the two components of the amplitude function of the electrical field of narrow-band laser pulses ($\Delta\omega << \omega_0$) in optical fibers and planar waveguides.

However, in the framework of the optics of ultra-short laser pulses with femtosecond or attosecond duration, one has to use the generalized system of nonlinear amplitude equations (GSNAE). The main difference between the SNSE and the GSNAE is the presence of two nonparaxial terms in the GSNAE. The advantage of the GSNAE in comparison with the SNSE is that the amplitude equations describe successfully the propagation of light pulses of both types (broad-band and narrow-band).

We investigated the parametric interaction of two components of one optical pulse using both the SNSE and the GSNAE. It is important to point out that in the framework of the SNSE, the exchange of energy between the components due to the degenerate four-photon parametric mixing was investigated in [1,2]. The effect was called rotation of the polarization ellipse. In this work, the problem is also considered and solved using the GSNAE and the periodic solutions of both systems are compared. A difference in the period of oscillations of the energy exchange between the two components is found. This difference has been displayed in a number of numerical calculations.

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OP.B1

DFT SIMULATION OF THE RAMAN BANDS OF SINGLE LAYER GRAPHENE

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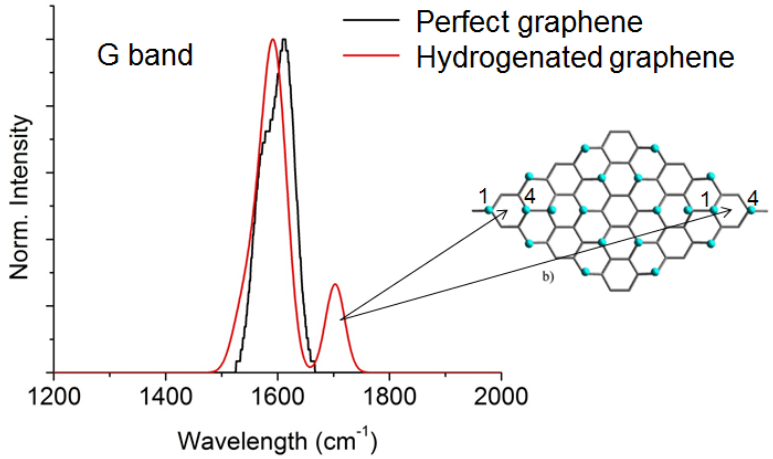
Raman spectroscopy is one of the most suitable tools for studying few-layer graphene. The position of the G band in the spectra of perfect single-layer graphene with sp^2-hybridized carbon atoms and hydrogenated graphene with 27.7 % sp^3-hybridized carbon atoms were simulated using computational chemistry methods, namely, the DFT method with PBE functional. In the case of perfect graphene, a Raman band is predicted at 1612 cm^{-1}. In the case of the hydrogenated structure, a new feature appears, namely, along with the intense band, now shifted to 1591 cm^{-1}, an additional feature located at 1703 cm^{-1} is clearly seen. The latter is due to oscillations involving six atomic benzene cycles containing two sp^3-hybridized C atoms at positions 1 and 4. As expected, the G band widens in the transition from the sp^2 structure to the sp^2/sp^3 one. As the proportion of sp^3-hybridized atoms in the structure increases, a red shift of the intense Raman peak is observed, which is in accordance with the experimental data. This study shows the possibility of simulating Raman spectra using computational chemistry and DFT methods.



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OP.E3

THERMAL EFFECTS IN Nd:YVO_4 AND Nd:$GdVO_4$ BLOCK CRYSTALS UNDER DIODE END-PUMPING AT 914 NM

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Neodymium-doped vanadate materials are currently among the most widely used laser crystals for diode laser end-pumped solid-state lasers, particularly for the generation of high repetition rate picosecond pulses and continuous-wave (CW) operation. However, the performance of these lasers, including the output power scaling and the beam quality, are limited by the thermal effects dues to the conversion of a part of the pump energy into heat.

In this paper, we report on a numerical study of the thermal effects within both a-cut crystals Nd:YVO_4 (1.0 at %) and Nd:$GdVO_4$ (1.5 at %) pumped by a diode laser emitting at 914 nm. The temperature and stresses distributions and the thermal lensing parameters were calculated by the finite element method using the LASCAD© software. The results obtained show that the Nd:$GdVO_4$ is the best candidate for high-power diode laser end-pumped solid-state lasers because of its lower thermal effects.

Keywords: Nd:YVO_4, Nd:$GdVO_4$, temperature distribution, stress distribution, thermal lensing, thermal fracture

POSTER SESSIONS

PRESENTED CONTRIBUTIONS

POSTER SESSION I

P.A1

POLARIZATION PROPERTIES TUNING OF TWO-DIMENSIONAL POLARIZATION HOLOGRAPHIC GRATINGS INSCRIBED IN AZOPOLYMER THIN FILMS

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Azopolymers are efficient photoanisotropic materials; this is why they are commonly used for inscription of polarization-selective diffraction gratings by polarization holography. More often, however, the characteristics of one-dimensional (1D) gratings are studied.

We present real-time diffraction efficiency kinetics and polarization properties of two-dimensional (2D) polarization holographic gratings, each of them obtained by overlapping two perpendicular 1D gratings. The gratings are consecutively inscribed in thin films of the azopolymer poly[1-[4-(3-carboxy-4-hydroxyphenylazo)benzenesulfonamido]-1,2-ethanediyl, sodium salt], shortly PAZO. The recording laser is a He-Cd laser (λ = 442 nm) and the two interfering beams are with left and right circular polarizations (LCP and RCP). Varying the recording conditions and type of azopolymer film used allows us to tune and optimize the polarization properties of the resulting 2D grating.

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P.A2

SURFACE STRUCTURING OF β-TCP AND TRANSITION TO α-TCP INDUCED BY FEMTOSECOND LASER PROCESSING

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Calcium phosphate (CP) is used for bone regeneration in a variety of forms (coatings, cements and scaffolds) [1] due to its bioactivity being able to exhibit osteoconductive and even osteoinductive behavior [2]. The release of calcium (Ca) and phosphorus (P) triggers the activity of osteoblasts and osteoclasts thus favoring bone regeneration. Different kinds of crystalline phases of CP exhibit different behavior in terms of solubility by releasing ions or different mechanical properties, etc. [3]. Tricalcium phosphate ($Ca_3(PO_4)_2$, TCP) is one of the most widely studied CPs for application in the regenerative medicine; TCP has a C/P ratio of 1.5 and exists in two stable crystalline phases, α and β. The β-phase, having a slower dissolution dynamics in a biological environment, ensures a mechanical support for a longer period, while the α-phase provides a faster release of ions and is able to trigger biological response.

In this work, a femtosecond (Ti:Sapphire) laser with a pulse duration $\tau < 130$ fs, a repetition rate $f = 1$ kHz and a wavelength $\lambda = 800$ nm was used to process the surface of β-TCP tablets. The processing resulted in a surface morphology modification, the flat mirror-polished surface turning rough opaque. The processed surface showed the formation of micro- and nano-roughness; also, a partial phase transformation from β-TCP to α-TCP was detected. A significant improvement in the surface wettability for three different liquids (water, ethylene glycol and diiodomethane) was seen. This implies an increase in the surface free energy as well.

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P.B1

OBSERVATION OF MAGNETO-OPTICAL SIGNAL IN Rb CONTAINED IN A "BUFFER GAS" OF Cs CONFINED IN A SUB-MILLIMETER OPTICAL CELL

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Recently, the advances in quantum magnetometry have attracted increasing attention due to their numerous applications [1-5]. The working principle of these instruments is based on atomic state population control, where the atomic energy levels depend on the magnetic field. An interesting coherent effect is the Coherent Population Trapping (CPT), in which alkali atoms are prepared in a coherent state which is non-absorbing for a resonant optical field [1]. One of its realizations is in the so-called ground-state Hanle configuration, where a single light wave is used for the preparation of the coherent state, and the signal is registered as the dependence of the transmission/fluorescence on the scanned around zero value external magnetic field.

For miniaturization purposes, it is important to study these effects in different types of confinement of the atoms. We use a cell with sub-millimeter thickness [2,3]. In these cells, the main contribution to the absorption/fluorescence signal comes from atoms moving parallel to the cell walls, i.e. perpendicular to the wave vector of the laser beam. This leads to registration of sub-Doppler features in the absorption and fluorescence signals by means of single-beam spectroscopy. In our previous work we have registered coherent magneto-optical signals in a 700 μm cell filled with Cs (and containing a small residual amount of Rb) [4,5]. Heating the cell leads to releasing of more Rb atoms, whose fluorescence signal is measurable [6].

Here we will present our first results on the registration of magneto-optical signals at the D2 line of Rb contained in such cell, so the Rb atoms are confined in a "buffer gas" of hot Cs atoms and a small amount of Cs dimers.

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P.C1

CASE STUDY OF BIOMASS-BURNING AEROSOL EVENTS OVER SOFIA, BULGARIA, BASED ON AERONET SUN PHOTOMETER DATA

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The atmospheric aerosol particles strongly influence the solar energy redistribution between the Earth's atmosphere and surface and could thus condition multiple atmospheric phenomena and significantly impact the climate and the living conditions on the Earth. Besides, the submicron fraction of the aerosol ensembles, the fine dust particles (FDP), can have extremely harmful effects on human health. The permanent monitoring and studying of the aerosol properties and dynamics contribute to the better understanding of many atmospheric processes, including the climate change, and assist the city authorities in being timely informed of a dangerous FDP concentration rise above the permissible levels.

The anthropogenic and biomass-burning (BB) smoke FDP are characterized by high light absorptivity and take an active part in the solar energy exchange. Therefore, the main purpose of the present work is to study the peculiarities of specific aerosol events over Sofia, Bulgaria, with prevailing BB smoke characterized by a strongly dominating fine particle fraction causing a relatively high atmospheric turbidity.

The analysis of the aerosol situations over Sofia is based on a wide set of columnar aerosol characteristics evaluated automatically by AErosol RObotic NETwork (AERONET) algorithms using results of specific automatic procedures of measuring the direct sun/moon irradiance and the sky radiance by a Cimel CE318-TS9 sun/sky/lunar photometer. The sun photometer has been functioning since 5 May 2020 in the Sofia Site in the Institute of Electronics, Bulgarian Academy of Sciences that is contributing to AERONET and is involved in European Aerosol Research Lidar Network (EARLINET) and Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS) activities.

The main aerosol characteristics employed in the analysis are the aerosol optical depth (AOD) and the Ångström exponent (AE), the volume size distribution (VSD) and the single-scattering albedo (SSA) of the aerosol particles. The particle sphericity factor (SF), depolarization ratio (DR) and the real part of the refractive index n_r are also considered.

The analysis performed shows that aerosol situations with a strongly prevailing fine particle fraction (around 100 nm in size) with relatively high turbidity (AOD > 0.3), Ångström exponent (AE > 1.5 – 1.6), and sphericity factor (SF ~ 99%), and low depolarization ratio (DR ~ 0.002) take place mainly in the summer and early autumn, when the wildfire activity is at its maximum. Because of their small sizes, the scattering from such smoke particles decreases rapidly with the light wavelength λ, faster than the absorption. Correspondingly, the AE is relatively large in magnitude, and the SSA is sharply decreasing with λ, beginning from

0.85 – 0.95 at λ = 440 nm. The relative occurrence of BB aerosol situations is estimated to be around 9 %.

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P.C2

LIDAR MONITORING OF PARTICULATE MATTER IN THE LOWEST ATMOSPHERIC LAYERS OVER SOFIA

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The present study comments on results of a monitoring the aerosols in the lowest atmospheric layers above Sofia by using lidar remote sensing. More than 20 lidar measurements were carried out in the period January – June 2022. The lidar system emitted laser pulses nearly horizontally within the planetary boundary layer (PBL); the reflected pulses were collected to calculate the range corrected signals and to produce color-coded time-distance diagrams. These diagrams, superimposed on a map of the city to illustrate the location of the aerosol layers, were published on the website of the Laser Radar Laboratory of the Institute of Electronics at:

http://www.ie-bas.org/Departments/LidarData_Horizont/Quicklooks-Horizont.htm

The laser beam of a Cu-Br vapor laser emitting the wavelength of 510 nm was directed towards the center of Sofia. In a clear atmosphere and good weather, the measurement distance reached 10 km. The aerosol content as a function of the distance consistently increased, as shown by the time-distance diagrams. At short distances from the lidar, air masses with an increased content of aerosols were registered due to their location above a thoroughfare with heavy traffic. At greater distances, the laser beam was reflected by atmospheric layers with less content of dust and exhaust gases. Thus, the blue color representing the observation of a clear air mass dominated the color-coded diagrams. Relatively often, namely, in nine diagrams, slightly denser aerosol formations were observed at the end of the lidar sounding target pointing to the existence of some local source of aerosols.

We discuss in more detail the results of two sets of measurements, which seem to us to be of special interest. The first one, conducted on April 4, 2022, was implemented on an inclined path of laser pulse propagation. We started the measurement from a horizontal direction and increased the inclination of the laser beam by a step of one degree with each subsequent measurement. Ten measurements were made, which correspond to a vertical sector of 10 degrees to the earth's surface. Thus, an aerosol layer at the altitude of ~ 0.5 km became clearly noticeable on the time-distance diagram from that day.

The diagram constructed using the results from measurements performed on June 16, 2022, was typical in the sense that areas of increased aerosol content in the atmosphere were observed over the urban regions with heavy traffic. At the height of the lidar beam propagation, the

atmosphere was stationary and the light signals reflected from the aerosol layers had a good contrast and were well distinguishable.

The results presented in our previous studies [1] show that remote sensing can be very effective when quantitative evaluation has been combined with in situ sampling for PM qualitative assessment; this was not done in this work.

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P.D1

OPTICAL COHERENCE TOMOGRAPHY *EX VIVO* OF NON-PIGMENTED SKIN LESIONS

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A variety of optical techniques is available for skin cancer detection allowing a more detailed and unbiased examination of the skin compared to examination by the naked eye alone. Early accurate detection of all skin cancer types is essential to conducting adequate and timely treatment to improve morbidity and survival rates among patients.

The optical coherence tomography (OCT) is a noninvasive diagnostic method that can generate high-resolution en face and cross-sectional images of the superficial layers of the skin and *in vivo* to a maximum depth of 2 mm.

In the current paper, we discuss OCT images of non-pigmented skin lesions *ex vivo* and their correlation with histology and applicability to clinical applications.

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P.D2

IMMOBILIZATION VIA MAPLE FOR BIOSENSORS APPLICATIONS

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Matrix-assisted pulsed laser evaporation (MAPLE) is a method alternative and complementary to pulsed laser deposition. It appears to be especially suited for the construction of biosensors, since it permits depositing organic materials onto solid substrates with a high degree of thickness and uniformity control.

We used the MAPLE technique for making an immunosensor based on surface plasmon resonance (SPR) by immobilization of antibody on an SPR transducer.

We report on our approach to the MAPLE technique, which ensures the deposition of monoclonal antibodies (MO Ab) while retaining their chemical and physical structure, as well as their bioactivity. We consider the significance of our approach in the context of its ability to

provide good adhesion between the deposited molecules and the substrate, which eliminates the necessity of a built-in matrix for immobilization. This direct immobilization thereby avoids the negative impacts of built-in matrixes on the sensitivity and specificity of biosensors. This has allowed for the achievement of a record sensitivity in SARS CoV-2 S-structural protein detection.

The bioactivity of molecules immobilized under optimal MAPLE parameters is a consequence of the interaction between protein molecules and laser irradiation. The impact of the interaction was evaluated by studying the chemical and structural properties of the deposited films.

The UV spectra of deposited layers of (MO Ab) and of MO Ab dissolved in DEPS water were compared. We showed that the main characteristic bands are expressed in both spectra. This suggests that the immobilization of MO Ab was performed without significant destruction of the molecule. Studying the structure of the deposited films of MO Ab by TEM confirmed that intact immobilization of antibody molecules was achieved.

The UV spectra of a deposited layer of MO Ab treated with S-protein was compared with the spectra of mixed solution of MO Ab and S-protein at given concentrations. The observed similarity of spectra confirmed the binding of the S-protein to the deposited MO Ab on the SPR transducer.

Our SPR transducer is a gilded diffraction grating over which MO Ab was deposited. SPR was used to characterize the binding affinity of the S-protein to MO Ab. We obtained a very pronounced SPR response as a function of the S-protein concentration and achieved a record sensitivity of about 30 fM, thus confirming the MAPLE deposition viability.

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P.E1

DYNAMICS OF THE SOLITON BOUND STATES IN THE HIGHER- ORDER SCHRÖDINGER-TYPE EQUATIONS

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Bound states of two solitons (the breather solutions on a zero background) are constructed for the higher-order nonlinear evolution equation of the Schrödinger type. This hierarchy of exactly integrable equations includes an infinite number of equations with dispersion terms of the third, fourth, and higher orders. We present special conditions for the existence of breather solutions for the complex modified KdV equation, the Hirota equation, the Lakshmanan-Porsesian-Daniel model, and integrable equations with fourth and fifth order dispersion. All these equations possess variable dispersion and nonlinearity coefficients. The soliton parameters and variable dispersion and nonlinearity coefficients satisfy the specific conditions for the appearance of standing and moving soliton breathers. We analytically studied the dynamics of the breathers and determined their periods. Of fundamental importance is the remarkable fact that higher-order nonlinear and dispersive effects included in the new equations of higher orders of the Schrödinger hierarchy, as a rule, do not destroy soliton breathers and do not transform

them into dispersive waves. On the contrary, we show that new soliton breathers can appear within the next higher orders of the NLSE hierarchy.

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P.F1

COMPARATIVE ANALYSIS OF THE STRUCTURAL AND MECHANICAL PROPERTIES OF Al AND Ta-BASED CERAMIC COATINGS DEPOSITED BY MAGNETRON SPUTTERING

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In recent years, special attention has been paid to nitride and oxide coatings based on Ta and Al as promising candidates for various applications in modern medicine. Ceramic coatings of aluminum nitride (AlN), aluminum oxide (Al_2O_3), and nanocomposite multilayer coatings are widely used as protective coatings against wear, diffusion and corrosion. Recently, tantalum has also been proposed as an alternative to other commonly used metallic materials for orthopedic implants. In addition, many studies have shown that tantalum and its compounds demonstrate excellent chemical stability, biocompatibility and osteoconduction, as well as antibacterial properties for further use in medical practice.

The main purpose of the study was a comprehensive evaluation of the structural and the nano-mechanical properties of mono- and two-layer nanostructured coatings AlN/Al_2O_3, TaN/Ta_2O_5 on the surface of metallic materials for biomedical applications.

Stainless-steel samples (AISI 316) were used as substrates. The process of mono- and two-layer coatings deposition by magnetron sputtering was performed in a high-vacuum pumping system with a base pressure about 1×10^{-3} Pa in an atmosphere of reaction gases, namely, oxygen and nitrogen. The samples were cleaned by standard methods in an ultrasonic bath before deposition. The magnetron discharge power was 4 – 5 kW. An ICP source for oxygen activation with RF power up to 1 kW was used.

The deposited coatings' characteristics were studied using various techniques. The morphology and topography of the surface of the mono- and two-layer coatings were studied by electron scanning microscopy using a JSM7001F (JEOL, Japan) device. Analysis of the chemical composition of the nanostructured mono- and two-layer coatings AlN/Al_2O_3, TaN/Ta_2O_5 was performed using energy dispersive X-ray spectroscopy (EDX) analysis by an INCA Energy 350 analyzer (Oxford Instruments, UK). The phase composition of the mono- and two-layer coatings was determined by X-ray diffraction analysis (XRD) using a DRON-4 diffractometer in the Bragg-Brentano configuration with Cu-Kα radiation and a selectively absorbing Ni filter. X-ray photoelectron spectroscopy (XPS) was carried out using an ESCALAB MkII (VG Scientific) electron spectrometer using an Al-Kα X-ray source (excitation energy $h\upsilon$ = 1486.6 eV). The thickness of the coatings was measured by a Calotest device. The adhesion properties were measured by standard methods with the use of a Revetest scratch

tester (CSM Instruments). The hardness parameters, modulus of elasticity and H/E ratio, were evaluated by nano-indentation methods using a G200 device (CGM).

The results of the study open prospects of using new technologies for applying mono- and two-layer nanostructured nitride-oxide coatings based on aluminum and tantalum in the development of medical devices of modern medicine – components of endoprostheses, implants, catheters, and prosthetic nets for hernia surgery.

Acknowledgements: The research was supported by the international scientific cooperation program of the Bulgarian-Ukrainian Academies of Science.

P.F2

LOW-TEMPERATURE ELECTRICAL TRANSPORT IN THIN CARBON FILMS DEPOSITED ON SiO_2/Si SUBSTRATES BY PULSED LASER DEPOSITION

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In this study, electrical transport studies were performed on thin carbon films deposited on SiO_2/Si substrates by pulsed laser deposition (PLD). The experiments were carried out on 320 – 420 nm SiO_2/Si substrates and on a hydrogenated diamond-like carbon (DLC) film deposited on SiO_2/Si. The structural studies by means of XPS, SEM, and Raman spectroscopy revealed that the films can be characterized as nano-sized carbon phases possessing different phase composition (i.e., the ratio sp^3/sp^2 hybridized carbon, etc.). The electrical conductivity/resistivity of the films was measured in the temperature range 10 K < T < 300 K. The four-contact Van der Pauw method and two contact schemes were applied. Some films showed low room-temperature resistivity ($\rho = (0.1 - 1.5)\times10^{-3}$ Ω m) and consisted predominantly of sp^2 hybridized carbon with a Raman spectrum similar to that of nano-sized graphene depending on the deposition conditions and substrates used. The thinnest (0.5 nm only) layer deposited directly on SiO_2 exhibited relatively low specific resistance (~10^{-3} Ω m), which can be taken as an indication of good deposition conditions of graphene-like layers, see [1].

The current-flow mechanism was explored at temperatures from 300 K down to 10 K. The temperature dependence revealed a non-metallic behavior – the conductivity decreased with the decreasing temperature, as opposed to the typical metal behavior. A model of variable range hopping (VRH) mechanism was applied at low temperatures drawn from transport in nanocrystalline disordered systems.

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POSTER SESSION II

P.A3

A PARAMETRIC STUDY OF ULTRA-SHORT LASER SURFACE PATTERNING OF FREEZE-FOAMED TCP-Zr: EFFECTS OF LASER PARAMETERS ON SURFACE MORPHOLOGY

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The need for novel strategies for bone tissue regeneration has driven the development of new materials and methodologies that could improve the current standards. Tricalcium phosphate has proven to be a suitable material for repairing bone defects, while a key aspect in the manufacturing of such scaffolds is porosity. This work presents a novel method for improving the surface microporosity of tricalcium phosphate – zirconia (TCP-Zr) cell scaffolds by applying ultra-short laser treatment.

The surfaces of three-dimensional TCP-Zr scaffolds fabricated via freeze-foaming were processed by a femtosecond laser (λ = 800 nm; ν = 500 Hz; F = 0.08 J/cm^2; N = 5). X-ray diffraction (XRD) analysis was performed to monitor a potential change in the phase of TCP. Scanning electron microscopy (SEM) was used to assess the morphological alterations on the surface of the scaffolds as a result of the laser irradiation. The surface wettability was assessed before and after laser processing by measuring the water contact angle.

The results showed evident changes in the surface morphology after laser treatment as processed areas appeared to have improved microporosity compared to control zones. Ceramic phase analysis showed that the surface modification did not lead to any phase transition, meaning that the crystallinity was not affected. The preliminary wettability assessment did not reveal substantial differences between laser processed and control areas; however, further analyses will be carried out to confirm these results.

The surface porosity improvement at a micro level could enhance the cellular adhesion to the scaffold, as well as the flow of nutrients within the scaffolds and the excretion of cellular waste outside the scaffold. These processes are of crucial importance for the integration of the material within the damaged tissue. Our preliminary findings showed that the application of femtosecond laser irradiation to the ceramic composites did not alter their structure and did not induce any mechanical damage to the material. Thus, the next step in our research would involve the beginning of *in vitro* studies to assess the biocompatibility and the effects of the femtosecond laser treated scaffold on bone cell viability, proliferation and differentiation.

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P.A4

SURFACE MODIFICATION OF NITRIDE CERAMICS BY MEANS OF pS LASER PULSES

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The laser-assisted processing of silicon nitride (Si_3N_4) and aluminum nitride (AlN) ceramics is a method ensuring successful production of ceramics parts with complex features suitable for laboratory and industrial applications.

This work reports on the effects induced by irradiation by picosecond laser pulses (wavelength of 800 nm) on silicon nitride and aluminum nitride ceramics in dependence of the laser fluence and the number of pulses in air and in a gas environment. The decomposition of the laser treated zones, the ablation rate and the ablation depth geometry are discussed in relation to the irradiation conditions and microstructure with the purpose of determining the optimal laser-beam parameters needed to achieve crack-free processing and the intended ceramics surface activation.

Scanning electron microscopy is applied for direct visualization of the morphological relief of the laser-treated areas. The chemical composition variations in dependence of the process parameters are assessed by applying X-ray photoelectron spectroscopy and Raman spectroscopy.

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P.A5

MODIFICATION OF CARBON BLACK BY LASER IRRADIATION

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The effect was studied of treating Cabot Corporation *SPHERON 5000* carbon black in a suspension in bi-distilled water by laser irradiation ($CuBr_2$ laser with fundamental wavelength λ = 511 nm and 2-kHz repetition rate). The carbon black suspensions were prepared by mixing 0.10 g carbon black previously treated by acetone [1] in 100 ml bi-distilled water. Different laser-beam fluencies and different irradiation times were used in order to optimize the modification process. The modified suspensions were decanted after sedimentation and dried. The powder fractions obtained were studied by scanning electron microscopy, X-ray diffraction and Raman spectroscopy.

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P.B2

DETECTION OF WEAK MAGNETIC FIELDS OF CURRENT-CARRYING METALLIZED MICRO-TRACKS USING MAGNETO-OPTICAL SIGNALS IN A PUMP-PROBE BEAM CONFIGURATION

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Among the numerous applications of the methods of quantum magnetometry, medical applications are rapidly developing and expanding.

With our present work, we show the possibility to detect remotely the conductivity of current carrying metallized micro-tracks using all-optical magnetometry based on zero-field level crossing magneto-optical resonances. These tracks have been developed for application in neuro-electrode interface technologies and bionics. They are prepared in two steps: first, surface modification and activation of optically-transparent biocompatible polymers (PDMS in our case) by means of UV-VIS pulsed laser light, and second, metallization of the laser treated tracks via electroless deposition of metal. Studies show that after metallization its "electrical characteristics" are preserved when applying tension, bending, and torsion to the implant device.

When the micro-wires are live and operational, the current generates a very weak magnetic field, whose detection is a measure of their operation. The method we use utilizes the so called zero-field level-crossing (magneto-optical) resonances in alkali-metal vapor, which in the present case is Rb. The standard configuration for registering such magneto-optical resonances involves a single-beam spectroscopy, whereby the beam transmission is registered as a function of an orthogonal magnetic field scanned around its zero value. We use a modified configuration scheme, which involves two optical beams serving as a pump and a probe, which have linear and mutually orthogonal polarizations, as described in [1]. The detecting medium is ^{87}Rb vapor contained in a cell with anti-relaxation (paraffin) coating of the walls.

The feasibility of a remote performance test (conductivity – non-conductivity) using the method described in [2] is demonstrated on two samples: (i) micro-wires prepared by nanosecond pulsed laser structuring and activation of PDMS with subsequent electroless Pt metallization, and (ii) micro-wires prepared by femtosecond laser structuring and Ni metallization.

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P.C3

LIDAR OBSERVATIONS ON WINTER AND SPRING SAHARAN DUST LOAD EVENTS OVER SOFIA, BULGARIA

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Aerosols have significant impacts on the climate, ecosystems, and human health. Therefore, detecting aerosol layers, identifying particle's type and origin and characterizing their optical, microphysical, geometrical, and dynamical properties are of great scientific and practical importance. LIDAR (LIght Detection And Ranging) is a well-established and proven remote sensing technique for determining the listed aerosol characteristics with high resolution in nearly real time. Sahara Desert is the largest source of natural mineral aerosols (dust) on Earth. Due to its relative proximity to Europe, enormous amounts of desert particulate matter are frequently transported to the continent. Since the year 2000, Saharan dust episodes over Mediterranean and Europe have been subjected to systematic scientific observations within the European Aerosol Research Lidar Network (EARLINET) and now within the Aerosols, Clouds, and Trace gases Research InfraStructure (ACTRIS). The transport of Saharan dust to Europe takes place through advection of warm air masses mostly from the south-southwest, being so typical for spring and summer. However, in recent years, winter Saharan dust load events have also been reported for various locations over Europe, including Sofia. In this work, we give a description of lidar observations of atmospheric aerosols present above Sofia, Bulgaria, during episodes of Saharan dust intrusions in periods of minimum (in winter) and maximum (in spring) activity of dust transport to the region. The measurements were conducted in February and April 2021, with the two aerosol channels (at 532 nm and 1064 nm) of a Nd:YAG-laser-based lidar. The aerosol/dust layering and optical and microphysical properties were characterized. Colormaps of the vertical aerosol distribution and its temporal dynamics were constructed. Time-averaged vertical profiles of the aerosol backscatter coefficients and the corresponding backscatter-related Ångström exponents were retrieved and analyzed. The lidar results obtained were supported with in-situ measurement data by the Bulgarian National Automated System for Environmental Monitoring (NASEM). The Saharan origin of the aerosols detected was identified using the SKIRON modeling system of the University of Athens, the BSC/DREAM8b model of the Barcelona Supercomputing Center, the NOAA HYSPLIT Model backward trajectories, as well as by satellite imagery from the NASA's MODerate resolution Imaging Spectroradiometer (MODIS). Conclusions were drawn on the effects of dust events on the local weather and troposphere, in terms of seasonal specificity.

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P.D3

NON-PHOTODYNAMIC ACTION OF COBALAMIN (B_{12}) IN CANCER CELLS EXCITATION BY A SOLAR SIMULATOR

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The natural porphyrinoids, the so-called cobalamins, are macroheterocycles with absorption spectra in the UV region and two intensive maxima around 260 nm and 360 nm. Owing to the porphyrinoid-type structure, it is assumed that this natural cobalt porphyrinoid-type complex could act as photosensitizer for photodynamic therapy (PDT). PDT as a phenomenon is initiated by proper light irradiation of a photosensitive compound resulting in electron transitions from the ground state to excited singlet and triplet states; the latter as long-lived states being able to participate in photochemical reactions with the surrounding molecules. Most often, two mechanisms of photosensitization take place, namely, electron/proton transfer (Type I) and energy transfer from molecules in a triplet state to the ambient oxygen atmosphere (Type II).

Our initial studies of the natural cobalt complex cobalamin (Cbl) suggested the presence of photo-physicochemical properties suitable for PDT photosensitizers. The compound was assessed for a non-photosensitizer action in a wide concentration range on breast cancer cell line in irradiation by a solar simulator used for safety tests. In spite of the porphyrinoids structure of the natural porphyrinoid, the study suggested a lack of efficiency of photocytotoxicity for the applied treatment conditions: short incubation time (2 hours) and soft light from solar simulator (< 1 J cm^{-2}). The observed non-photodynamic cytotoxicity without light application suggested another mechanism of action for this porphyrinoid type compound. For comparison, two phthalocyanine zinc complexes (ZnPc1 and ZnPc2) were evaluated with an efficiency of photocytotoxicity towards breast tumor cell line in nanomolar concentrations. The selectivity was also tested on a normal cell line typical for the surrounding tissue. In conclusion, the Co(III) porphyrinoid-cobalamin showed no PDT efficiency in the case of irradiation by a typical-spectrum commercial solar simulator.

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P.E2

OPTIMIZATION OF THE TEM_{00}-MODE SOLAR LASER OUTPUT POWER USING DIFFERENT PUMP-CAVITY SCHEMES

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In this paper, different pump cavity schemes, such as circular, elliptical and close-coupled, were numerically studied in order to achieve a uniform pumping distribution along a 6-mm diameter, 65-mm length Nd:YAG rod and hence improve the TEM_{00}-mode solar laser output power and solar collection efficiency.

In our solar laser system, a 2-m diameter parabolic mirror was used to concentrate the solar radiation into its focal spot. A fused silica light-guide with a circular cross section was also used to collect and transmit the solar radiation from its output end to the laser pump cavity.

The optimal solar laser design parameters were found using the TracePro© non-sequential ray-tracing method and LASCAD© laser cavity analysis codes.

Our numerical results show that the close-coupled pump cavity was the best configuration allowing obtaining the highest laser performance, namely, 5.6-W continuous-wave TEM_{00}-mode laser power, corresponding to 1.86-W/m^2 collection efficiency and 5.4-W laser beam brightness figure of merit.

Keywords: Solar laser system, pump cavity shape, TracePro software, LASCAD software.

P.E3

APPLICATION OF POLYMERIC MATERIALS IN FREE-SPACE OPTICS FOR COMMUNICATIONS

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Free-space optics for communications refers to the transmission of modulated visible or infrared light through the atmosphere to transmit data over distances from several meters to kilometers. The operating wavelengths are usually correlated with one of the atmospheric windows at 785 nm, 850 nm and 1550 nm. Visible wavelengths between 400 nm and 700 nm are applied for shorter distances. The free-space optics is a preferred optical technology because no spectrum licensing or frequency coordination with other users is required. The point-to-point laser signal is extremely difficult to intercept, and therefore communications are secure and no interference from or to other systems or equipment is possible.

In this report, polymer optics is designed of the transmitter and the receiver of a communication system with a laser source. The polymers used are the acrylic materials polymethyl methacrylate (PMMA) and Optorez 1330 of Hitachi Chemicals (alicyclic methacrylate copolymer), polystyrene (PS), polycarbonate (PC or Bayer). The proposed telescopic system of the transmitter consists of a doublet objective from PS and PMMA and an eye-piece made of PC and PMMA to minimize the spherical aberrations. The receiver optics is more precise to collect as much as possible of the incoming light and to couple it to the optical fiber. It consists of PMMA, PC and an inside lens made from Optorez. Selection of materials in lens design is accomplished based on their transmission, refraction and dispersion. The aberrations are calculated by means of the OSLO optics software.

Propagation through free space follows the Lambert-Beer's law and the scattering is considered by aerosols and small dust particles, often referred to as particulate matter. Environmental changes in temperature, pressure, moisture, etc. are also discussed.

P.E4

SCALING THE MID-IR RADIATION AT 7 µm - TWO-STAGE DOUBLE-PASS 195 MHz NARROW-BANDWIDTH DFG SYSTEM

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High-precision spectroscopic measurements require lasers with a narrow linewidth and high stability in the emitted wavelength. Some applications require pulsed lasers with high pulse energy (in the mJ range) and short (nanosecond) pulse duration. The motivation behind our work is the generation of high-energy output radiation (>1.5 mJ) tunable around 6785 nm with a narrow linewidth $\Delta\lambda < 70$ pm (450 MHz) at 25 Hz pulse repetition rate for muonic hydrogen atom spectroscopy [1]. We have previously demonstrated the generation of 0.5 mJ mid-IR radiation with narrow-linewidth <30 pm (195 MHz) in the spectral region 6730 – 6840 nm by implementing a single-stage double-pass optical scheme [2]. In the quest of higher energies, we propose a two-stage geometry of the DFG system based on the well-known fact that the DFG can be considered as a process of amplification of the signal pulses. In our case – pump (1064 nm), signal (1262 nm) and idler (6785 nm) – the emission of each photon at 6785 nm occurs simultaneously with the emission of a 1262 nm photon. With photons energy ratio $E_{@1262} \approx 5.376 \times E_{@6785}$, the generation

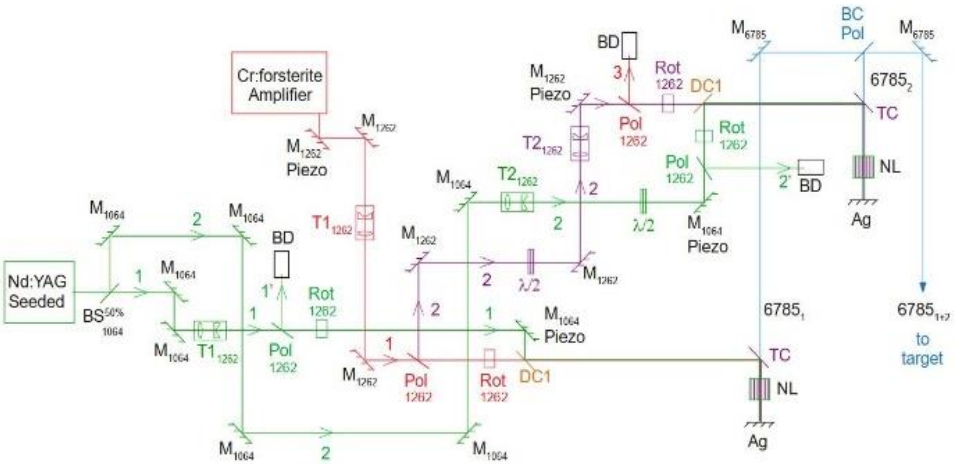

Figure 1. Schematic setup of the two-stage double-pass DFG.

of each 1 mJ radiation at 6785 nm, will add to the energy available at 1262 nm ~ 5.376 mJ. Thus, making it feasible to use the amplified light at 1262 nm in a second DFG process placed in parallel.

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P.F3

HARDNESS COMPARISON BETWEEN Co–Cr METAL ALLOY SPECIMENS MADE BY DIFFERENT METHODS

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The aim of this study is to compare the hardness of Co-Cr metal alloy specimens made by different methods and how it is influenced by multiple temperature changes.

Fifty-four samples are made by three different methods and are accordingly divided in three groups – group M (Milling), group LP (Laser Printing) and group LW (Lost Wax), with 18 samples each. All of them contain three subgroups with six samples – metal samples (subgroup 1), metal samples with three layers of ceramic (subgroup 2) and metal samples with four layers of ceramic (subgroup 3). Their Vickers microhardness is evaluated by a weight of 1 kg applied for 20 sec. The results are summarized in tables.

The average microhardness is the highest for the samples of group LP – 509; followed by group M – 440, and 401 for group LW. For the subgroups, the best result are exhibited by the samples of subgroup 2 – 462, followed by subgroup 3 – 454, and subgroup 1 – 434.

P.F4

INFLUENCE OF THE WELDING ARC HEAT INPUT ON THE MICROSTRUCTURE AND MICROHARDNESS OF WIRE-ARC ADDITIVELY MANUFACTURED AlSi5 COMPONENTS

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Keywords: WAAM, Al4043, AlSi5, heat input, microstructure.

For the purpose of this research, we manufactured single-track details in the shape of thin walls with a length of 100 mm and a height of 80 mm. Two welding speeds were chosen for this experiment – 0.8 m/min and 1.2 m/min, corresponding to the following heat inputs: 120 J/mm and 80 J/mm. The gas modulated arc welding (GMAW) technique in an Ar gas environment was used for the build-up of the specimens, implementing the cold arc pulse method. The structure of the specimens was studied using X-ray diffraction (XRD) carried out by CuKα radiation with a wavelength of 1.5406 Å, and scanning electron microscopy (SEM). Furthermore, the Vickers microhardness of the samples was determined using a ZwickRoell DuraScan 10/20 G5 unit at a force of 1 N. An initial preferred crystallographic orientation towards the (220) plane was observed in the detail built at the lower speed, followed by a 45^{o} preorientation of the unit cells to the (200) plane. Implementing the higher welding speed caused a build-up of the specimen in the (311) crystallographic plane. Due to the more dynamic nature of the welding process at that speed, a self-annealing process was noticed whereby the specimen's preferred crystallographic orientation towards the substrate changed towards the (200) plane. A higher number of defects in the structure of the specimen built at the speed of 1.2 m/min was detected using both optical microscopy and SEM. The changes in the specimen's hardness at the different growth stages was also examined. The results are discussed regarding the possibility of optimizing the build-up process in relation to the technological conditions.

Acknowledgements: The work was financed in part by the Bulgarian National Science Fund, project # KP 06-DO 02/1 (2019).

POSTER SESSION III

P.A6

ULTRA-SHORT LASER STRUCTURING OF 3D MICROFABRICATED NON-RESORBABLE POLYSTYRENE POLYMER TO ANCHOR CELLULAR ADHESION

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Tissue engineering is emerging as a preferred choice for regeneration of irreversible bone tissue defects. It's main "weapons" are the artificially created biocompatible three-dimensional cellular matrices that mimic the extracellular matrix's structure and provide a mechanically stable inert substrate for the natural growth of cells. These porous scaffolds provide sufficient inner surface for cell adhesion, migration, proliferation and protrusion "inside" the temporal implant, facilitating in this way the natural bone ingrowth and vascularization. This leads, eventually, to overgrowing the surface of the biomimetic implant with recipient self-formed bone tissue, thus avoiding a possible immune response.

In the current study, 3D polystyrene (PS) non-resorbable synthetic cellular bone scaffolds fabricated by 3D microfabrication technology were additionally structured by applying femtosecond (fs) laser radiation with variable parameters thus achieving optimal laser processing conditions for creating a 3D matrix with enhanced fiber surface properties. The main aim is the establishment of surface structured microporous biomimetic scaffolds providing improved cell adhesion, infiltration and formation of an extracellular matrix. The 3D laser-functionalized PS samples were investigated by SEM, EDX, confocal and roughness analyses for evaluation of their morphological and chemical properties before and after performing the fs structuring. A WCA evaluation was also performed. Future experimental work will include *in vitro* cellular studies for determining the optimal structuring laser parameters providing osteoconductive and osteoinductive qualities of the 3D fs-microstructured PS scaffolds.

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P.A7

HIGH-POWER DIFFRACTION-LIMITED SEALED-OFF MASTER OSCILLATOR - POWER AMPLIFIER SYSTEM OSCILLATING IN MIDDLE INFRARED SPECTRAL RANGE ON STRONTIUM ATOMIC TRANSITIONS FOR APPLICATION IN MATERIALS SCIENCE AND MEDICINE

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Laser oscillations in the middle infrared (MIR) spectral range have been provided by several tunable lasers, such as free electron lasers, optical parametric oscillators, laser systems based on difference frequency generation, quantum cascade lasers, etc. Their development is justified by a large variety of relevant applications in medicine, laser spectroscopy, precise materials processing, remote sensing of the atmosphere, determination of linear optical properties of novel materials, etc.
The rapid continuous development of the Sr vapor laser in the last few years resulted in achieving record-high average laser power and laser pulse energy by a single-tube laser, together with low-power diffraction-limited laser radiation delivered by master oscillator – power amplifier (MO–PA) systems. Some applications, like precise microprocessing of quartz, ceramics, etc., which are characterized by a high ablation threshold, impose severe requirements on the laser power and laser pulse energy. Since the laser radiation is diffraction-limited, the laser intensity will depend on the laser beam diameter and output laser characteristics. Using large-bore laser tube as an amplifier, a considerable increase in both parameters could be achieved. It is well known that the laser beam diameter in the focusing plane depends on the focusing distance and laser beam divergence. The focusing distance is limited by the spherical aberration, while the laser beam divergence has a minimal value for a certain laser beam diameter. This minimal value of the laser beam divergence could be reduced with an increase in the laser beam diameter.

We studied a large-bore sealed-off gas-discharge tube for a Sr vapor laser with a stable cavity excited in a nanosecond pulsed longitudinal discharge and oscillating in the MIR spectral range. This laser tube is used as an amplifier in the MO–PA system. For spatial adjustment of the MO beam and the aperture of PA and spatial filtering as well, a mirror telescope with magnification $M = 2$ and a 0.5-mm diaphragm in its confocal plane is also applied.

High-beam-quality diffraction-limited laser oscillation is obtained at two Sr^+ and several Sr atoms lines in the MIR spectral region. For precise material processing, the laser beam is focused by an objective on samples placed on an X-Y stage. The MO–PA system is applied to micromachining of quartz, sapphire, hard biological tissues, various polymers, etc.

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

P.B3

COHERENT MAGNETO-OPTICAL RESONANCES ON THE POTASSIUM D2 LINE IN MODIFIED HANLE CONFIGURATION FOR MAGNETOMETRY APPLICATIONS

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Magneto-optical spectroscopy is extensively applied in many scientific fields [1]. A key feature of this type of coherent spectroscopy is the possibility to register narrow magneto-optical resonances (MOR), whose width is determined by the ground-state hyperfine (hf) level lifetime. Potassium (K) 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, since for K the hf groundstate splitting is smaller than the Doppler width, the nonlinearity of the Zeeman splitting dependence on the magnetic field is more significant than that for other alkali atoms and the isotopic shifts of the two stable isotopes (^{39}K, ^{41}K) are smaller than the Doppler width [2].

A new approach to the development of optical magnetometers based on the D2 line of K in Hanle effect configuration of crossed laser beam and magnetic field was reported in our previous work [3]. Magnetically unshielded 8-mm-long cell (containing K + 30 Torr Ne) was used in order to reduce the influence of the laboratory magnetic field B_{lab} gradients to the MOR spectral width. The spectral transitions overlapping results in very good signal, non-critical to laser frequency shifts. Moreover, this principle of magnetic field measurement allows the development of a self-calibrated optical magnetometer with potential for calibrating various commercially available magnetometers that need frequent calibrations.

A new method for observing narrow-width and high contrast MOR of EIA in Hanle configuration was proposed in [4]. It is based on a special configuration of electromagnetic fields composed of two counter-propagating laser beams with perpendicular linear polarizations and a static magnetic field applied along the wave vectors. To improve the properties of the subnatural-width resonance, a buffer gas or a cell with an antirelaxation coating should be used. Moreover, estimates have shown that show the openness of a transition can cause an ultra-high contrast of a subnatural-width resonance in the probe-wave absorption coefficient (up to 104% and even more), when its profile contains a nonlinear EIA signal almost without a noticeable background.

In this work, we report the result of an experimental investigation of MOR in a modified Hanle effect configuration based on counterpropagating pump and probe laser beams with orthogonal polarizations in the K cell with buffer gas used in [3].

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P.C4

DIAL HYGROMETER BASED ON HIGH-POWER LASER DIODES: CALIBRATION FUNCTION AND LASER RADIATION MODULATION

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The paper reports on the use of the differential absorption lidar (DIAL) technique based on laser diodes of ~100-W pulsed power [1] for remote sensing of atmospheric humidity. While these devices are used in various areas due to their high power and quality, the spectroscopic applications have been hindered by their broad laser line (~5 nm) formed in a multi-junction resonator. In [2], calibration functions are derived for the lidar signal in differential water vapor absorption on the wavelengths of 850 nm and 905 nm. The invariance found around the wavelength of 0.911 μm is found optimal for DIAL measurements. The integral water vapor absorption spectrum modulating the laser line is proven suitable for detection of humidity in a high dynamic range independent of the atmospheric pressure and temperature.

In this work, an investigation is carried out on the temperature dependence of the radiation of the selected laser diodes. The operational wavelength of the laser diodes is set via the case temperature depending on their tuning capacity with a thermal coefficient of 0.27 nm/^{o}C. The thermal stabilization of the laser wavelength in the operational range is essentially simplified compared to other hygrometers using laser diodes [3] owing to the integral character of the detected water vapor absorption spectrum. The testing of the temperature sensitive component incorporate an LD coupled to a compact thermal controller driving a Peltier thermoelectric cooler and a thermal sensor. A PC interface defines user-selectable modes for high-precision thermal stabilization combined with an overall effective and energy consuming system design.

Acknowledgments: This research was funded by the Ministry of Education and Science of Bulgaria (support for ACTRIS BG, part of the Bulgarian National Roadmap for Research Infrastructure).

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P.D4

FUNCTIONALIZATION OF 3D-PRINTED FIBROUS SCAFFOLDS VIA LASER PATTERNING FOR REGENERATIVE MEDICINE PURPOSES

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The research in the field of the regenerative medicine is largely focused on studying the surface properties and the geometry effect of biomaterials on the cell behavior thus leading to another major factor, the specific biological response at a cellular level. The biomaterial-bioenvironment interaction is extremely complex and, therefore, offers many challenges to scientists in determining the optimal morphology, topography and physico-chemical characteristics of biomaterials.
In this study, we focused our attention on the geometry and laser pulse duration effects on the functionalization of 3D-printed fibrous scaffolds via laser patterning in view of applications in regenerative medicine. The polymers used for 3D porous scaffold were poly(-caprolactone) (PCL) and composite PCL-HA (hydroxyapatite). The preparation of the 3D matrix from a synthetic polymer material suitable for scaffold in bone engineering was accomplished by 3D printing techniques for fabrication of mesoscale structures with dimensions of several millimeters. The microprocessing of the 3D polymer scaffolds created was performed via femtosecond laser modification. The specimens were processed by a Ti:sapphire laser emitting at 800-nm central wavelength with a pulse duration of 35 fs at a repetition rate of 1 KHz; the results were compared with those obtained with a 130-fs pulse duration. Different printing geometries for the inner shape of the scaffolds were applied, such as crossed fibers and "snowflakes". The structures fabricated and synthesized can be used as templates for cell culturing and implants for bone and cartilage tissue engineering.

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P.E5

GENERATION OF GAUSS-BESSEL BEAMS IN A WIDE SPECTRAL RANGE BY USING SINGLE VORTEX PHASE PLATE

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In this work, we study a novel scheme for laser beam shaping. It allowed us to obtain long-range quasi-non-diffracting Gauss-Bessel beams (GBBs) starting with a TEM_{00} Gaussian beam. It is proven to be applicable in a wide range of wavelengths. The idea is based on optical vortex (OV) annihilation phenomenon [1,2,3]. We intentionally imprinted OVs with opposite signs of their topological charges (TCs) in Gaussian input beams. This resulted in the creation of a well-formed thin ring-like transverse intensity distribution. If we initially have a converging field input, in the artificial far field (and meters behind it) the obtained ring-shaped profile is naturally transformed into GBB. A basic advantage of the proposed setup is its lack of spectral sensitivity. We demonstrate the ability to transform beams at 445 nm, 532 nm, 633 nm, and 800 nm by a single vortex plate (VP) designed for 532 nm.

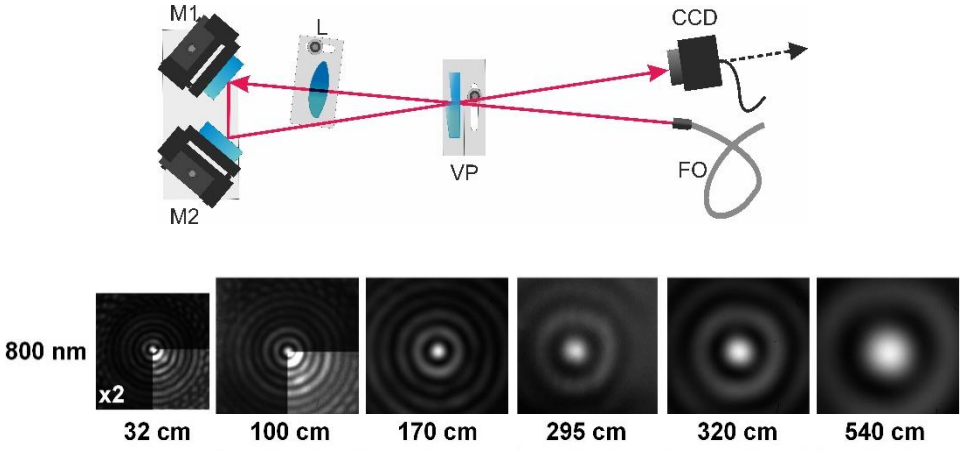

Fig.1 Upper frame: Experimental setup containing fiber optics input FO, vortex plate VP; lens L, folding mirrors M1, M2, and a charge-coupled device camera CCD. **Bottom panels:** Transverse intensity profiles when using a Ti:Sapphire laser (800 nm) and a VP designed for 532 nm (|TC|=32) at distances ranging up to 540 cm.

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P.E6

CONTROLLABLE FEMTOSECOND BEAM SPLITTING AND COHERENT BEAM RECOMBINATION USING ARRAYS OF SINGULAR BEAMS

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Coherent beam combining (CBC) is a term denoting a group of methods developed for achieving higher power/energy and enhancing the spectral brightness of laser emission while preserving the beam quality [1]. On the other hand, the beam filamentation is a complex nonlinear process (see e.g. [2]), potentially promising for subsequent pulse compression, provided there is a reliable way to coherently combine the sub-beams after the beam filamentation is terminated. An essential argument in favor of the feasibility of the idea is the phase-locked white light continuum observed experimentally by Bellini and Hänsch [3]. At high beam/pulse intensities, the laser beams tend to be unstable. A possible way of avoiding such instabilities is the controllable splitting of the beam into sub-beams, which only makes sense if there is a reliable way to coherently recombine them. In this work, by using specially designed phase plates with arrays of optical vortices we show an experimental realization of controllable femtosecond beam splitting followed by filamentation and a final coherent beam recombination. We will present results in nonlinear media – ambient air and in fused silica, which confirm the feasibility of the proposed technique and provide a reasonable motivation for further analytical and experimental studying.

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P.F5

SURFACE MODIFICATION OF Ti6Al4V ALLOY BY CONTINUOUS ELECTRON BEAM

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In this work, a Ti6Al4V alloy was electron-beam surface modified (EBSM) by a continuous electron beam. During the treatment process, the beam current was 25 mA, the electron-beam scanning frequency was 200 Hz, the speed of the sample motion was 5 mm/s and 10 mm/s, and the scanning figure was in the form of a Lissajous curve ¼. The phase composition and microstructure of the obtained samples were investigated by X-ray diffraction and optical microscopy, respectively. The microhardness was also studied. The results obtained for the mechanical properties of the surface layers are discussed concerning the applied technological conditions and the formed phase composition and microstructure.

Keywords: electron-beam surface modification; titanium alloy; phase composition; hardness.

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P.F6

INFLUENCE OF TRANSITION METAL-NITRIDE THIN FILMS ON THE ELECTRICAL CONTACT RESISTANCE OF COPPER SUBSTRATES

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In the present study, TiN and VN surface coatings are formed on copper substrates, and their influence on the electrical contact resistance (ECR) of the primary material is studied. The coating materials are sputtered on the surface of the substrates for 60 minutes using a reactive magnetron sputtering system. Their thickness is measured using an optical profilometer. The phase structure of the coatings is studied by X-ray diffraction using Cu Kα radiation and the surface roughness is analyzed by means of atomic force microscopy (AFM). The electrical contact resistance of non-coated and coated samples is measured using an impedance analyzer using the parallel electrodes method. A linear frequency sweep in the range of 40 Hz to 1 MHz, with a 5 kHz step is used to determine the influence of the skin effect on the electrical contact resistance of the probes. The results obtained indicate the possible implementation of TiN and VN as protective coatings in the design of low-powered non-commutating and commutating electrical contacts in regard to the electrical contact resistance.

P.F7

INVESTIGATION OF THE INFLUENCE OF THE PROCESSING SPEED AND THE LINEAR PULSE DENSITY ON THE LASER SURFACE TEXTURING PROCESS

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Fine-tuning laser parameters is necessary to achieve the desired quality of the process of laser surface texturing. This requires a set of experiments to assess the influence of the main process parameters on the quality of the surface of a treated alloy. By varying the laser parameters, different laser-material interactions, such as heating, melting, or evaporation can be observed. This study analyzes the influence of two interrelated processing parameters in laser surface texturing – the speed of beam motion on the surface on the one hand, and, on the other, the linear pulse density. They ultimately have a direct impact on the resulting microstructure, hydrophilicity, and electrochemical properties of austenitic steel (AISI 304). By adjusting the

pulse repetition rate of a 1064-nm fiber laser from 500 kHz to 1000 kHz at a constant speed of 100 mm/s, the surface wettability changes from hydrophobicity to hydrophilicity. All surfaces treated with laser scanning speeds varying from 20 mm/s to 200 mm/s at a constant rate of 500 kHz are hydrophobic. As a result, the changed ability to repel liquids alters the corrosion properties of the steel in a 0.5-M H_2SO_4 solution. The results allow one to distinguish ranges of laser-beam parameters that could be useful in selecting certain properties of the stainless-steel surface layer.

POSTER SESSION IV

P.A8

LASER-ASSISTED FABRICATION OF METALLIC COMPOSITE NANOSTRUCTURES IN AQUEOUS SOLUTIONS

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Pulsed laser ablation in liquids (PLAL) is utilized for synthesis of composite nanostructures based on TiO_x and ZnO combined with noble metals, namely, Ag, Au, Pt and Pd. The metallic plate immersed in water is ablated by irradiation by a nanosecond Nd:YAG pulsed laser. Its fundamental wavelength and the second, third and the fourth harmonic are used to fabricate and to modify the morphology of the nanostructures. The procedure for synthesizing complex nanostructures consists of three consecutive phases: laser ablation of the selected targets followed by post-ablation irradiation of the obtained colloid of the complex nanostructures. According to the profile of the optical transmission spectra of the colloids, the changes in the morphological characteristics of the complex nanostructures are indirectly evaluated. The colloids' properties are controlled by varying the laser beam parameters. Transmission electron microscopy is applied for direct visualization of the nanostructures' shapes. The chemical composition and the morphology are assessed by means of HRTEM and SAED. The photocatalytic properties of the nanostructures are also measured.

Acknowledgments: 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" Program of the Bulgarian National Science Fund.

P.A9

SURFACE MODIFICATION OF NITRIDE CERAMICS BY NANOSECOND AND FEMTOSECOND LASER PULSES

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Results are presented on surface structuring of aluminium nitride (AlN) and silicon nitride (Si_3N_4) ceramics by nanosecond and femtosecond laser pulses. The laser processing is performed by a Nd:YAG laser system at 1064 nm and pulse duration of 15 ns, and by a Ti:Sapphire one at 800 nm and pulse duration of 75 fs. The surface morphologies induced by a variety of processing parameters, as applied laser fluence and number of pulses, are studied for both laser systems. It is found that the surface structuring induced is expressed by a variety of micro- and nanostructures whose characteristics that can be controlled by the laser parameters. The ablation process is found to be related to material decomposition in the case of ns laser pulses, while for ultrashort pulses, a direct ablation of ceramic material and negligible decomposition dynamics are realized. The surface structuring demonstrated can be used for fabrications of materials with electronics and optoelectronics applications.

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P.A10

SOME INITIAL RESULTS ON MODIFICATION OF aC:H FILMS BY PULSED LASER IRRADIATION

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It has recently been shown both theoretically [1] and experimentally [2] that a significant modification of aC:H films is possible using UV irradiation even with a very low irradiation fluence. For example, the sp^3-hybridized carbon and the oxygen-containing radicals content decreases notably [2].

We present some initial results on the modification by UV laser irradiation of aC:H films with a thickness of about 40 nm. The fourth harmonic (λ = 266 nm) of a Nd:YAG laser system (fundamental wavelength λ = 1064 nm) was used. The modified areas of the aC:H films were characterized by optical microscopy, Raman spectroscopy and by atomic force microscopy.

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P.A11

ZnO-NiO COMPOSITE NANOSTRUCTURES PRODUCED BY ATMOSPHERIC PLD

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Metal oxides, such as ZnO, SnO_2, WO_3, TiO_2, In_2O_3, etc., have been widely studied as materials for gas sensors. Among them, ZnO is one of the most promising and reliable material due to its specific properties, namely, optimal conductivity, low toxicity, low cost, chemical and thermal stability, as well as the capability of being grown easily in a variety of nanostructures. Gas sensors based on ZnO nanostructures are used to detect different gases, such as H_2, CO, NO_2, NH_3, H_2S, ethanol, acetone, hydrocarbons, human breath, etc. Recently, it was established that the coupling of two different semiconductors with different energy levels of photogenerated electron-hole pairs enhances their functional properties. In particular, the combination of *p* and *n* type binary semiconductor oxides could form a *p-n* junction at the interface and lead to an effective separation of electron-hole pairs. Among the various *p*-type oxides, nickel oxide (NiO) is a highly active material with a wide bandgap and has been extensively studied for various applications, such as catalysis, gas sensing, battery cathodes, magnetic materials, photovoltaic devices, etc.

In this study, ZnO-NiO binary composite oxide was synthesized by pulsed laser deposition in view of gas sensor application. This technology was performed in air at atmospheric pressure (PLD in open air or Atmospheric PLD). A mosaic target formed by a ZnO target partly covered by a Ni slice was used for ablation. The attention was focused on the structure, morphology, and optical properties of the samples with various Zn/Ni radios. It was found that composites consisting of ZnO and NiO were formed during ablation process in air. As a whole, the morphology of the composite samples represents a highly porous nanostructure. The sample microstructure shows that the nanostructures are formed by ZnO and NiO nanoparticles with a size in the range of 4 – 20 nm. Preliminary results on the gas-sensing properties of the metal-oxide nanostructures were obtained.

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P.F8

COMPARATIVE STUDY OF MAGNETIC PROPERTIES OF HEXAFERRITES SYNTHESIZED BY DIFFERENT METHODS

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Hexaferrites have been intensively studied for many years as materials for permanent magnets, high-density recording media, microwave devices, biomedical applications, etc. In recent years, research has been focused on the appearance of the magneto-electric effect in some hexaferrite systems and the possibility of their use as single-phase multiferroic and magnetoelectric materials. We report studies on the correlation between the microstructure, the magneto-crystalline structure and the magnetic properties in hexaferrites, including magnetic phase transitions. The role is discussed of the synthesis procedure on the structural and magnetic properties of the resulting hexaferrite powders. These were synthesized using two different methods: modified sol-gel auto-combustion and ultrasonic co-precipitation. The particles size of the M-type hexaferrite powders obtained by sol-gel auto-combustion was between 100-150 nm, with the particles having an almost perfect hexagonal shape and being very thin, while those obtained by ultrasonic co-precipitation had a particle size between 25-100 nm with irregular shapes between spherical and plate-hexagonal. The magnetization did not change significantly with the particles size, whereas the coercivity was reduced to 44 Oe as the particles size diminished. In general, the magnetic characteristics do not depend significantly on the method of synthesis in the case of Y-type hexaferrites.

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P.E7

NONAUTONOMOUS SCHRÖDINGER SOLITONS IN EXTERNAL POTENTIALS: SELF-COMPRESSION, AMPLIFICATION, AND DECAY OF THE BOUND STATES

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In recent years, strong evidence has been obtained that the inverse scattering transform (IST) method with a varying spectral parameter (nonisospectral IST problem) provides a general research strategy for understanding the integrability of nonautonomous nonlinear equations with variable coefficients and external potentials. This strategy allows us to discover novel nonautonomous dynamical models with new classes of nonautonomous soliton solutions. In this presentation, we report on a generalized nonautonomous nonlinear Schrödinger equation (NLSE) with linear, parabolic, and cubic external potentials obtained in the framework of the nonisospectral generalization of the IST method. We demonstrate that nonautonomous solitons arising in this model, similar to the previously known nonautonomous solitons of different nonlinear dynamic systems, interact elastically and generally move with varying amplitudes, speeds, and spectra adapted both to external potentials and to dispersion and nonlinearity variations. We show also that nonautonomous solitons of the introduced model possess novel features. Namely, a decay of the soliton bound states was observed due to the dependence of the soliton amplitudes on their velocities arising in the framework of this novel NLSE model.

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P.E8

NEW VECTOR-TYPE OPTICAL VORTEX STRUCTURES IN ISOTROPIC MEDIA

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In the present work, the formation is studied of vector-type vortex structures in isotropic media. This type of vortices exist in the electric field components and generate a depolarization in the vector field of the laser spot. Their behavior is governed by a system of amplitude equations. Additionally, new solutions have been found that describe similar type of vortex structures in an optical fiber. These optical vortices admit amplitude-type singularities only. The vortex structures observed within the vector amplitude function have ring-like structures. The variation is investigated of the intensities of the *x* and *y* components of the amplitude function along the axis of the fiber.

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P.E9

SINGLE-FREQUENCY Cr:FORSTERITE MASTER-OSCILLATOR POWER-AMPLIFIER LASER SYSTEM WITH OUTPUT ENERGY > 45 mJ

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One of the most favorable characteristics of the Cr:forsterite lasers is the presence of a broad absorption band, which overlaps with the operating wavelengths of many commercially available pump lasers. In addition, broadly tunable coherent radiation characterized by a single frequency or single longitudinal mode (SLM) operation and narrow linewidth [1] may be obtained in the near infrared (NIR) spectral region (1150 – 1330 nm).

We present a nanosecond single-frequency Cr:forsterite master-oscillator power-amplifier laser system generating an output energy of 45 mJ at 10.5% quantum efficiency, with a narrow linewidth of only 0.5 pm (95 MHz) and measured beam-quality factor M^2_x=1.94, M^2_y=1.70. This system was developed as part of a previously reported system based on a single-stage double-pass optical scheme generating 0.5 mJ mid-IR radiation in the spectral region 6730 – 6840 nm with a narrow-linewidth <30 pm (195 MHz) [2], for the needs of muonic hydrogen atom spectroscopy [3].

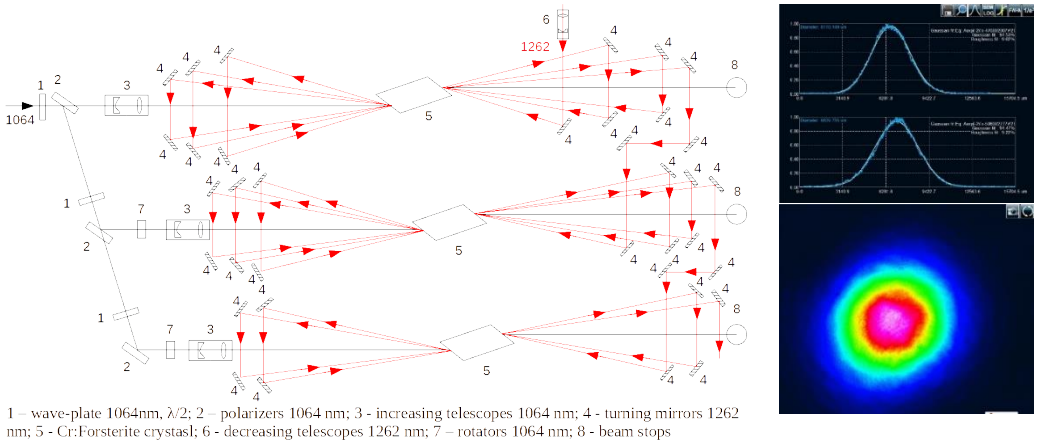

Figure 1. Schematic setup of the Cr:forsterite master-oscillator power-amplifier laser system and beam cross-section.

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P.F9

CARBON CONTENT EFFECT ON THE CAVITATION EROSION RESISTANCE OF Cr-C COATINGS DEPOSITED BY ARC PVD

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An experimental study was carried out on the cavitation destruction of stainless steel samples (12Cr18Ni10Ti) with thick Cr-C coatings depending on the carbon concentration in the range 2 – 25 at %.

The Cr-C coatings are promising candidates for various anti-erosion applications due to their ability to form amorphous and nanocrystalline structures. The cavitation-erosion properties of coated materials are significantly affected by the basic properties of the substrate and the coating. The Cr-C system has several interesting characteristics. For example, the hardness of the synthesized chromium carbide can vary up to ten times depending on the technological deposition parameters and coating composition. The most interesting property of the Cr–C system is the ability to form glassy structures in a wide range of carbide concentrations.

The aim of the study is a comparative analysis of the carbon content effect in the range from 2 at % to 25 at % on the resistance to cavitation erosion of Cr-C coated samples by means of the rotating disk method.

Cr-C coatings were deposited by Arc PVD on stainless steel samples (X18H10T). A low-alloyed alloy cathode was used for sputtering. The arc current was 130 A at a potential bias of the substrate of about 80 V. The Cr-C coatings were deposited in a toluene-argon atmosphere with a varying C_7H_8/Ar gas flow ratio. The substrate temperature was controlled by an IR pyrometer and maintained within the range of 350 – 400 °C. The distance between the samples and the cathode was 270 mm. The erosion resistance was evaluated by tests carried out on a rotating disk unit in the laboratory of IMP PAN (Szewalski Institute of Fluid-Flow Machinery). The thickness of the coatings was measured by a Calotest and the coatings adhesion was estimated using the Rockwell indentation test. Scanning electron microscopy (SEM) by a JEOL JSM 7001A device was used to analyze the surfaces' morphology and structure. An analysis of the average elemental composition of the coatings was performed on the same microscope by energy dispersion X-ray spectroscopy (EDX) using an Oxford Instruments INCA-350 device.

The results show that the erosion rate of the coated samples was more than four times lower than that of the uncoated samples. The Cr-C coated samples with carbon content about 25 at %

demonstrated the least surface destruction as compared to the other coated and reference samples.

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POSTER SESSION V

P.A12

LASER ABLATION OF TRANSPARENT MEDIA BY FEMTOSECOND LASER IRRADIATION

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The current presentation is a case study of ongoing in-depth extensive fundamental research on the plasma formation and relaxation dynamics in transparent media induced by mid- and short-wavelength infrared laser pulses. The motivation of the research is based on the aim of contributing to better understanding the mechanism of interactions between femtosecond laser irradiation and solid transparent materials leading to new technological applications in, e.g., non-linear optics, nanostructure generation, bioimaging and 5D data storage. The experimental investigation is performed on a fs-laser system setup including a regenerative Ti:Sapphire amplifier emitting at 800 nm central wavelength with a pulse duration of 35 fs and 1 kHz repetition rate. The working parameters such as laser energy and number of pulses are varied. The laser energy applied is in the range from 5 μJ to 250 μJ and is varied at a step of 10 μJ. The experimental measurements are applied on the following investigated glass samples – doped with silver nanoparticles, $CaSi_2$, borosilicate and fused silica. The effects of the applied laser pulses and the resulting laser induced modifications, damages and ablation thresholds are investigated and compared. The results from this case study will contribute information to the main research project on the plasma formation and dynamics induced by femtosecond infrared laser pulses in solid transparent media.

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P.A13

MODIFICATION OF MICRO-CRYSTALLINE GRAPHITES BY PULSED LASER ABLATION IN A FLOW-MODE SUSPENSION

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It was recently shown that graphene-like phases: graphene, defected graphene, graphene oxide (GO) and reduced graphene oxide (rGO) can be synthesized by laser ablation of a graphite target immersed in water [1], as well as by laser irradiation of a fine suspensions of graphite micro-crystals in bi-distilled water [2]. We present results on modification of graphite suspensions in bi-distilled water by laser irradiation in a flow-mode system. The fundamental wavelength (λ = 1064 nm) and the third harmonic of a Nd:YAG laser system were used in our experiments**.** The morphology of the sedimented and dried powders was studied by transmission electron microscopy (TEM). Their phase composition and structure were explored by Raman and XP spectroscopy, GIXRD, as well as by TEM.

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P.A14

HIGH-POWER DIFFRACTION-LIMITED SEALED-OFF MASTER OSCILLATOR - POWER AMPLIFIER SYSTEM OSCILLATING IN VISIBLE SPECTRAL RANGE ON COPPER ATOMIC TRANSITIONS FOR PRECISE MICROMACHINING IN MATERIAL SCIENCE AND TECHNOLOGY

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The copper bromide (CuBr) vapor laser is a quite promising low-temperature variant of the copper-vapor laser oscillating at the atomic copper lines 510.6 nm and 578.2 nm with a comparable average laser power and a three-fold higher efficiency. The rapid continuous development of the atomic CuBr vapor laser led to a considerable improvement of the laser tube reliability and of the laser characteristics, namely, average output power, laser pulse energy, beam quality, etc., that considerably extends the scope of applications. The master oscillator – power amplifier (MO–PA) laser system based on the atomic CuBr vapor laser is well established as a laser source used for precise micromachining in the industry for drilling, cutting, scribing, marking, welding, etc. of various materials. The laser-beam quality quantitatively expressed by the so called beam propagation factor (M^2) is crucially important in these applications. Unfortunately, even for diffraction-limited beams with any transverse distribution of the laser intensity, the laser-beam divergence and hence the focusing spot diameter depend on the laser beam diameter. It is well known that the use of a large-bore laser tube as an amplifier results in an increase in the output laser parameters and quite conveniently reduces the focusing spot diameter.

The use of a double-pass amplifier, although quite useful for low-power oscillators (tens of mW) that cannot saturate a one-pass amplifier, significantly reduces the output of the MO–PA system and requires further amplification of the laser radiation using a third laser tube. Though it was proved feasible in our previous unpublished work, maintaining three high-voltage power supplies operational and synchronized is definitely not practical. Thus, we developed and studied a new MO–PA system. The achievement of diffraction-limited laser beams ($M^2 = 1$) is confirmed by the detailed study on the laser-beam divergence using measurement of the focusing spot diameter through optical microscopy and experimental determination of the laser ablation threshold of optical grade fused quartz at different focusing distances. The average output power of the MO is increased by up to several watts. A considerable increase in the MO–PA output is obtained using a large-volume laser tube as a PA. Laser intensity exceeding 1 TW cm^{-2} is achieved by the new MO–PA CuBr vapor system.

For precise material processing, the laser beam is focused by an objective on samples placed on an X-Y stage. The MO-PA system is applied to precise microprocessing of optical-grade fused quartz, stainless steel, copper, silicon, etc.

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P.C5

THE SAHARA DUST TRANSPORT EVENT IS STUDIED WITH A SPACEBORNE LIDAR CALIOP

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The principal instrument of the CALIPSO satellite, which was launched in early 2005, is the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP). CALIOP provides total backscatter profiles at two wavelengths, which are used to calculate aerosol and cloud backscatter and extinction. The sensor also monitors the backscattered return's linear depolarization, allowing the cloud phase to be determined and the presence of non-spherical particles to be detected. in this paper, the spaceborne lidar CALIOP observations, as well as HYSPLIT analyses, were used to follow a Sahara dust transport event that occurred in the summer of 2021 and its effect on northern Algeria. Based on data from the (CALIOP), the relative amount of active dust emission across the Sahara Desert is investigated.

Keywords: Sahara, Dust, Transport, CALIOP, Lidar

P.D5

OPTICAL PROPERTIES OF 3D-PRINTED ORTHODONTIC RETAINERS

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3D printing is a widely used technology finding applications in a wide variety of dental disciplines, including the production of different types of orthodontic appliances. Studies and knowledge regarding directly printing orthodontic retainers and their optical properties are still limited.

This work was aimed at studying the optical properties of 3D-printed orthodontic retainers.

Two different specialized 3D printers were used – NextDent® 5100 3D Printer and Form 2, with their corresponding biocompatible materials – NextDent OrthoFlex and Formlabs Dental LT Clear V1. Specimens were also made via thermoforming using Erkodur foils and the Erkoform 3D+ machine. The optical properties were tested using a source of monochromatic light and a spectrometer, which measures the intensity of the light transmitted through the specimens at different wavelengths.

Values for the intensity of light transmitted through the specimens were registered at the spectrometer at 1024 different wavelengths and in four points for each specimen. The results obtained were statistically processed. Depending on the material and its processing, the amount of light passing through the specimen varied from 37.91% to 78.47%. The best optical

properties were observed for the thermoformed specimens, whereas with the 3D-printed specimens the polishing diminished the intensity of the transmitted light.

The transparency of thermoformed materials is superior to that of the 3D-printed ones. Polishing the materials reduced their optical properties. Due to the lack of polishing systems on the market from the respective manufacturers and the use of universal rotational instruments for polishing resin, we assume that different instrument choice might affect the results. Despite the fact that less light is transmitted through the 3D printed specimens, the materials offered clinically acceptable and satisfying optical properties.

P.D6

LINEAR POLARIMETRY FOR ANALYSIS OF DEGENERATIVE SKIN ALTERATIONS

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Investigation and characterization were carried out of the basic polarimetric characteristics of histological samples with different cutaneous degenerative conditions (Raynaud syndrome, lupus and scleroderma) to evaluate the potential for analysis of degenerative skin alterations. Stained and unstained histological samples from the different groups of degenerative conditions of the skin were histologically addressed and were used for polarimetric measurements. The linearly polarized beam of a diode laser (wavelength of 635 nm) was used to irradiate the samples and the polarimetric measurements were conducted by polarimeter working in the visible spectral range 400 – 700 nm.
We will present the results of histology tissue slides evaluation through Stokes polarimetry in transmission geometry. These studies allow analysis of degenerative skin alterations in collagen anisotropic structuration in extracellular matrix and could be used as indicators of the tissue condition. This will allow the development of a generalized polarimetric features database for degenerative skin conditions.

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P.E10

OPTIMIZATION OF A PUMPING CAVITY DESIGN TO IMPROVE THE LASER EXTRACTION EFFICIENCY

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Although currently solid-state lasers, including fiber lasers, are mainly pumped by laser diodes, flash lamp-pumped only lasers still have certain advantages (The price per watt of power generated is much lower compared to laser diodes). As the laser diode emission spectrum is completely encompassed into the absorption bands of the active laser medium, each type of the active medium requires a particular type of diode laser. In contrast, flash lamp-pumping can be considered as universal.

In this paper, it is shown that the use of two linear lamps cavity design allows one to homogenize the absorbed pump light distribution within the whole amplifier medium, thus increasing the laser extraction efficiency. The non-sequential ray tracing method is used through the TracPro© software for optimization and dimensioning of the laser pumping cavity.

Keywords: Solid-state lasers, diode-pumped lasers, flash lamp-pumped lasers, pump cavity.

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P.E11

NONLINEAR STAGE OF MODULATIONAL INSTABILITY INDUCED BY RAMAN SELF-SCATTERING EFFECT

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This presentation is devoted to the study of the unexpected physical mechanisms of induced modulational instability (IMI) caused by the Raman self-scattering effect. We developed analytical and numerical approaches in the theory of IMI in the framework of the nonautonomous nonlinear Schrödinger equation model, taking into account three mathematical models of the Raman self-scattering effect and the arbitrary-order group velocity dispersion. Direct computational experiments, which studied in detail the main features of the IMI in the femtosecond time domain revealed that the sliding pump effect at the nonlinear stage of the higher-order IMI gives rise to the soliton self-cleaning effect. The typical evolution of IMI and

its spectral dynamics at the stage of nonlinear development are characterized by the appearance of rogue wave-like self-compressing peaks and their separation from broad pedestals. Thus, the shelf-like dispersion waves that arise around the soliton play the role of a sliding pump. Shelf dispersion waves emitted by the rogue wave-like peaks are removed due to the sliding pump effect, and as the result, the soliton self-cleaning effect leads to the formation of high-contrast soliton pulses. The same effects take place at the nonlinear stage of development of the higher-order IMI induced by the strong Raman self-scattering. Hence, the Raman self-scattering effect induced by the delayed Raman nonlinearity should be considered as a trigger for the self-cleaning of soliton trains formed at the nonlinear stage of IMI. From a conceptual point of view, we conclude that the physical nature and relaxation (or time-delayed) mechanisms of the self-defocusing nonlinearity play a crucial role in the dynamics of the IMI.

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INVESTIGATION OF THE CHANGE IN WETTABILITY PROPERTIES AND CORROSION BEHAVIOR OF AISI 304 AFTER LASER SURFACE TEXTURING

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Stainless steel is a widely used material in the industry, architecture, and medical instruments. However, after various thermal processing of stainless steels, chromium carbides can be formed, which locally depletes the chromium available to form a passive film and reduces the corrosion performance. Laser surface treatment can change the surface chemistry of the steel and improve some electrochemical characteristics, such as pitting potential. However, these characteristics are influenced by the laser power, pulse width, distance between the lines, scanning speed, etc., which all change the surface chemistry and characteristics of laser surface texturing. Simultaneously, the ability to repel liquids that cause corrosion actions could combine to enhance the corrosion performance. Since the wettability of a solid surface depends both on its topography and chemical nature, micro structuring of an austenitic steel surface is an effective way of fabricating hydrophobic or super hydrophobic corrosion-resistant surfaces. For this reason, this study discusses the effect of laser power density in the impact zone and the distance between raster lines on the microstructure, wettability, and corrosion resistance of austenitic steel (AISI 304) when exposed to nanosecond fiber laser radiation. The results indicate that parameter-controlled micro structuring can be used to form both hydrophilic and hydrophobic surfaces with different electrochemical performance.

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IMPACT OF ANNEALING AND SOFT TEMPLATE CONCENTRATION ON OPTICAL AND SENSING PROPERTIES OF WET-DEPOSITED SiO_2 THIN FILMS

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Wet deposition is a versatile way of preparing thin films with diverse chemical composition and properties that could be controlled and tuned simply by varying the processing parameters. Low-cost and simple facilities are additional advantages of the wet-deposition methods.

The present study demonstrates deposition of porous SiO_2 thin films using a combination of sol-gel, soft-templating and spin-coating methods. The recipe for Si-sol using TEOS as a precursor and ethanol as solvent was optimized in order to obtain transparent and stable sol. Commercially available triblock co-polymer Pluronic 123 was considered as a soft template and its concentration and volume fraction to sol were varied. To achieve the final composition of silica films, different annealing regimes were implemented where the annealing temperatures and duration were optimized.

The films's optical properties were calculated using nonlinear curve fitting of the reflectance spectra measured in the UV-VIS spectral range. The surface morphology and structure of the films were characterized by transmission electron microscopy (TEM) and selected area electron diffraction (SAED). The porosity and optical sensing ability of the films were tested by measuring their reflectance spectra prior to and during exposure to acetone vapor, which served as a probe molecule.

The influence of the soft template composition and the annealing regimes on the SiO_2 properties were revealed and application of the films studied as sensitive media for opto-chemical sensing was discussed.

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LASERS PROCESSING OF COMPOSITE MATERIALS

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Composite materials consisting of fibers and binders of natural and artificial origin are increasingly used in various fields of industry. Often, processing of the materials obtained into finished forms is difficult and expensive. Treatment of composite materials, such as milling, cutting, or grinding, is now dominant. Lately, lasers have been increasingly used in various production processes. It should be noted that modern industrial production is unthinkable without the use of laser equipment. However, when using lasers, initial adjustment of their parameters is necessary for optimal material processing.

Considering different lasers and the materials to be processed, the parameters to be set differ and the quality of the processing to be obtained changes.

In this research, samples of composite materials were prepared consisting of a binder – epoxy resin and a reinforcing material – hemp, flax, and carbon fibers. The composite materials obtained were studied in terms of the quality of processing by a fiber laser.

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