Book of Abstracts
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Xincheng Yao	University of Illinois Chicago, USA
Ahmed Hassanein	Purdue University, USA
Egor Ilyukov	Saratov State University, Russian Federation
Constantin Meis	CEA – Saclay, France
Alena Zavadilová	Czech Technical University in Prague, Czech Republic
Pericle Varasteanu	IMT Bucharest, Romania
Ling-An Wu	Chinese Academy of Sciences, China
Alexandra Mocanu	National Institute for Research and Development in Microtechnologies, Romania
Rudolf Korsmik	Saint Petersburg state marine technical university, Russian Federation
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6th International Conference on Photonics Research

INVITED PRESENTATION

Id-678

Quantized Field of Single Photons. The Photon Electric Field and the Photon Wave Function

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Abstract: The association of the density of states theory to the vector potential quantization of the electromagnetic field leads naturally to the definition of the photon quantization volume, ascribing an intrinsic physical geometrical property to a single photon state. Photons are not point particles and constitute a particular case in particles standard model.

It is drawn that the single photon electric and magnetic fields are proportional to the square of the frequency. Based upon the vector potential with quantized amplitude, we define a photon non-local wave function representing an amplitude probability for the photon localization normalized with respect to the photon quantization volume. In addition, the established photon wave function satisfies Maxwell's propagation equation and Schrödinger's equation with the relativistic massless particle Hamiltonian as well as a Schrödinger-like equation for the vector potential single photon operator.

The electron-positron charge is deduced naturally from the photon vector potential quantization revealing the strong physical relationship between leptons and photons while putting the basis for understanding the mechanisms of their mutual transformations.

The electromagnetic vacuum derives straightforward from the photon vector potential function and has both classical and quantum representations. It permits to remedy to the zero-point energy shortcomings and singularities in quantum electrodynamics. Finally, the photon wave function is naturally related to the electromagnetic vacuum states setting the fundamentals for understanding the vacuum polarization and entanglement.

Keywords: Photon Quantization Volume, Photon Electric and Magnetic Fields, Photon Wave Function, Vector Potential Quantization, Electron-positron Elementary Charge, Vacuum Polarization, Electromagnetic Vacuum.

6th International Conference on Photonics Research

INVITED PRESENTATION

Id-683

Laser-induced Heating Decimated Luminescence Nanothermometry using Robust LaOF:Yb^{3+}, Er^{3+} Upconversion Nanophosphors

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Abstract: A microwave-assisted hydrothermal route was used to synthesize LaOF:0.05 Yb^{3+}, x Er^{3+} ($0.001 \leq x \leq 0.05$) upconversion nanoparticles (UCNPs). Luminescence nanothermometers based on LaOF:Yb^{3+},Er^{3+} UCNPs were also investigated. Laser-induced heating is a bothersome factor that can lead to the degradation of several temperature-sensing probes. One way to eliminate this influence on the thermal readouts is to identify the critical point of the laser power that produces undesirable effects on the probe and operate the laser excitation source at safe levels below this point. Unfortunately, most luminescent probes must be pumped by lasers operating at alarming power levels that can either disintegrate the probe or produce counterfactual results. The fluorescence intensity ratio (FIR) of the UCNPs was recorded using the visible (red) and near-infrared (NIR) regions, at different temperatures. The impact of laser-heating on the UCNPs was prevented by identifying the optimal operating conditions of the laser that could be used to record the FIRs without compromizing the integrity of the UCNPs. The behavior of the UCNPs against the laser exposure time and power was analyzed to recognize the critical point of the laser power, below which laser-heating of the UCNPs was negligible. In this scenario, LaOF: Yb^{3+}, Er^{3+} UCNPs proved to be a highly sensitive and durable temperature sensing probe that can operate efficiently at low laser powers. Up to power densities below 18 W/cm^2, the laser-induced heating was easily nullified from the thermal readouts of this temperature sensor, thus, preventing the need for temperature calibrations in the measurements. The LaOF: Yb^{3+}, Er^{3+} UCNPs demonstrated consistent thermal readouts with impeccable accuracies at low laser power density (6.91 W/cm^2). These UCNPs exhibited remarkable durability and reusability over multiple thermal cycles. The impressive relative and absolute sensitivities, and noteworthy temperature resolution of the LaOF: Yb^{3+}, Er^{3+} UCNPs indicates their potential for luminescence nanothermometry applications. This approach can be perceived as a benchmark for testing luminescent materials using nanothermometry.

Acknowledgment: The authors are highly thankful for the support provided by the South Africa Research Chair Initiative of the Department of Science and Technology (No. 84415), extending financial support from the University of the Free State to carry out the research work.

Keywords: Nanothermometry, Phosphors, Luminescence Materials, Laser Heating, LaOF: Yb^{3+}, Er^{3+}.

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INVITED PRESENTATION

Id-685

Stripe Patterned Photonic Crystals: Preparation and Properties

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Abstract: Miniaturization and multiplexing of photonic crystals (PhCs) are important aspects of their large-scale application. Here we present an approach based on the self-assembly of stripe patterned colloidal PhCs, followed by their inversion using a photocurable resin. SiO_2 colloidal spheres were synthesized by seeded growth. The stripe patterned colloidal PhCs were obtained by the vertical deposition method with the intermittent motion of the meniscus. A polymerization of ethoxylate trimethylolpropane triacrylate photocurable resin filling voids in the stripe opal templates was used for the inversion. PhC properties of the periodically repeated inverse stripes were proved by recording local reflectance spectra, and reflectance peaks over 40 % associated with the first photonic stop band were observed.

One of the most attractive applications of opal and inverse opal structures is the preparation of substrates for surface enhanced Raman scattering (SERS). Stripe patterned structures activated by a gold layer or gold nanoparticles can contain many microscopic SERS-active stripes periodically arranged on the same substrate and therefore seem very promising for automating multiple SERS tests.

Acknowledgment: The work was supported by the Russian Science Foundation (Grant Number 23-23-00252).

Keywords: Photonic Crystal, Inverse Opal, Stripe Patterned Structure, SERS.

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INVITED PRESENTATION

Id-687

Laser-induced Breakdown Spectroscopy of Uranium

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Abstract: Uranium has numerous geochemical forms of presence in rocks, forms separate minerals or is isomorphically present in other minerals. It can therefore enter the environment natural way, by weathering and leaching of rocks, or by anthropogenic manner associated for example with ore processing. Determining the presence of uranium in geological structures is important for both geological exploration or for determining possible ways of migration, given that uranium is very soluble in the aqueous environment and therefore passes well into underground and surface water sources.

LIBS analysis, enabling the determination of the uranium occurrence in minerals and other rock components is very fast, robust and efficient, it can be performed both in situ and in laboratory conditions. However, in the places with people fluctuation, LIBS in-situ measurement is difficult because of the risk of damage to the human eye by the randomly reflected laser beam. That is the main motivation we tested LIBS using lasers from the eye safe spectral region, therefore the emission wavelengths close to 1.4 μm or longer. At the same time, we dealt with the problem of possible respiratory exposure to vaporized sample containing uranium in laboratory conditions or places with limited air exchange.

This study has a significant practical impact for the implementation of the detection of the uranium presence in different types of rocks with regard to the minimization of health risks. This can be possibly utilized in a variety of research applications for rapid determination of total concentration of uranium in environmental samples.

Acknowledgment: This research is financially supported by CZ.02.1.01/0.0/0.0/16_019/0000778.

Keywords: Laser-induced Breakdown Spectroscopy, Uranium.

6th International Conference on Photonics Research

INVITED PRESENTATION

Id-699

Polymer Photonic Crystals: Synthesis, Characterization and Applications

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Abstract: Optical materials have garnered a lot of interest in the last 20 years because of their numerous potential applications in light controlling applications. The ever-evolving technology in the field of electrooptical devices or medical applications has enabled the development of innovative and economical methods to obtain optical materials appropriate for smart applications, such as hybrid or polymeric solar cells, lasers, polymeric optical fibers, chemo- and biosensors. Considering the above, the purpose of this work is to review existing uses of polymer photonic crystals (PPCs), which offer a new, attainable platform for light tailoring devices using chemical polymerization methods. Soap-free radical aqueous polymerization or copolymerization represent one of the most facile polymerization methods to obtain colloidal particles that self-assemble in 3D arrays in which the spheres are disposed as CCP (cubic close packed) or HCP (hexagonal close packed) structures starting from rigorous selection of monomers and co-monomers based on their water solubility. PPCs characterization techniques focus on emulsion stability as measured by ζ potential and photonic band-gap (UV-VIS analysis), in addition to size, morphology, and aggregate formation (determined by SEM, TEM, AFM, DLS, etc.). These findings are highly significant because they provide a new tailoring capability for the development of PPC-based materials for optical devices and medicinal applications.

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Keywords: Polymer Photonic Crystals, Monomer Solubility, Colloidal Particles, Polymer Photonic Crystals Characterization, Polymer Photonic Crystals Applications.

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INVITED PRESENTATION

Id-702

"Ghost" Imaging Goes to Shorter Wavelengths

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Abstract: Based upon the second-order correlation of intensity, "ghost" imaging (GI) promises new capabilities for imaging at all optical wavelengths, and has even been demonstrated with atoms, electrons and neutrons. Our group started research on visible GI and performed the first experiment with true incoherent thermal light. In the near infrared, we have also realized a modified form of GI known as single-pixel imaging, which is also based on intensity correlation. In 2018 we first demonstrated X-ray GI with a simple table-top setup, without the need for a synchrotron beamline or monochromator, and obtained images with a much higher contrast-to-noise ratio compared to projection X-ray imaging for the same radiation dose. By using compressive sensing the number of exposures required and hence the radiation dose can be greatly lowered, possibly down to single-photon levels. A resolution of 10 μm was later achieved with a source of size 37 μm, overcoming the resolution limit of incoherent X-ray imaging. We also demonstrated energy-resolved X-ray GI, and more recently imaged objects made of Mo, Ag and Sn through their absorption edge spectra with a spatial resolution of 100 μm. Our experiments demonstrate the potential applications of X-ray GI in fields as diverse as biomedicine, material science, and even analysis of cosmic events.

Keywords: Ghost Imaging, X-ray Absorption Edge Spectroscopic Ghost Imaging, Single-pixel Imaging.

6th International Conference on Photonics Research

INVITED PRESENTATION

Id-704

Surface Plasmon Resonance based Sensors: from Prism Coupling to Direct Excitation

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Abstract: Over the next decade, the surface plasmon resonance (SPR) market is expected to surge from $910 million in 2022 to $1807.7 million in 2032. This growth is driven by rising demand for label-free, real-time, and highly sensitive and selective sensors. As a result, there is a critical need for innovative designs beyond the widely used Surface Plasmon Resonance sensors employing the Kretchmann configuration. In this paper various SPR sensors configurations such as the classical dielectric-metal-sensing medium to more advanced ones like dielectric-dielectric-metal-2D materials/dielectric-sensing medium will be investigated from the point of view of resonance strength (i.e. minimum of reflectivity at resonance), full width at half maximum (FWHM) which quantifies the losses in the system, and sensitivity (i.e. displacement of resonance angle for a small modification of sensing medium's refractive index). In addition, various methods of optimization of the sensors' configuration starting from single objective to multi-objective will also be presented together with the associated drawbacks which were often neglected, thus leading to unrealistically or poor performance configurations. Furthermore, a new class of SPR sensors that emerged from the optical states that forms at the interface of a Distributed Bragg Reflector (1D photonic crystal) and a thin metallic layer placed on top of it (i.e. optical Tamm States) will be studied. The advantage of these sensors is the direct excitation of surface plasmons, polarization invariance in comparison with the classical sensors which requires a coupling layer and could be excited only with TM polarized light. In conclusion, in this presentation the evolution of SPR sensors configurations from coupling layer-based ones to more compact ones based on DBRs along with methods of enhancing their response will be discussed.

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Keywords: Surface Plasmons, Optimization, SPR, Optical Tamm States, Distributed Bragg Reflectors.

6th International Conference on Photonics Research

INVITED PRESENTATION

Id-710

Optimization of EUV Photons from Laser Produced Plasma in Advanced Nanolithography Devices

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Abstract: Extreme ultraviolet (EUV) photons are needed to advance the manufacturing of the next generation of computer chips to continue speeding the calculations clock. Laser Produced Plasma (LPP) devices with Tin (Sn) targets are currently the leading design in the development of EUV photon sources for the advanced nanolithography. The developments and optimizations of LPP sources for EUV lithography include research started from simple planar targets to high frequency droplet targets. Several criteria were considered for the optimization of LPP systems including high conversion efficiency (CE) from laser energy to EUV photon output and collection, minimized debris production and mitigation, components lifetime, and source brightness for the high volume manufacturing (HVM) devices. From the most points of view, small liquid Sn droplets, fragmented and evaporated by an initial pre-pulse laser for the following subsequent heating and ionization by the main laser pulse, showed the best results and currently have the highest priority for further investigation and optimization. We studied and simulated several Sn targets geometries and sizes heated by various lasers with different parameters to predict EUV photons emission, collection, source size and intensity, atomic and ionic debris production, as well as effect of debris on LPP device components lifetime, e.g., multi-layer mirror (MLM) collection system.

Optimization of commercial devices using liquid droplets requires consideration of two major objectives: maximum conversion efficiency and EUV power and minimum debris production. Investigation of Sn-doped materials for producing optically thin plasma was conducted to reduce EUV photons loss due to self-absorption and to minimize Sn debris. Recent optimization of small Sn droplets with pre-pulse technique demonstrated achieving HVM requirement for the advanced nanolithography systems. We studied various laser beam parameters along with droplet sizes to determine conditions that affect EUV emission and absorption as well as debris production and effects. The process of optimization included advanced computer simulation and experimental benchmarking of LPP devices with single and dual-beam pulses, producing enough volume of vapor/plasma mix that can be efficient source of EUV photons emission, optically thin for EUV photons collection and, at the same time, relatively dense to reduce energetic ions generation. We used our comprehensive HEIGHTS computer simulation package for modeling analysis, optimization, and LPP system design. The HEIGHTS results agreed well with our CMUXE experimental data.

Acknowledgment: This work was supported by Intel, Extreme, NSF, KLA, and Purdue University.

Keywords: Laser Produced Plasma, Liquid Metals, Extreme Ultraviolet, Nanolithography, HEIGHTS.

6th International Conference on Photonics Research

INVITED PRESENTATION

Id-712

Polarization Characterization of Ballistic and Multiply Scattering Photons in Retinal OCT Bands

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Abstract: Optical coherence tomography (OCT) is revolutionizing eye disease diagnosis and treatment assessment through its unparalleled ability to precisely section individual retinal layers. Understanding the hyper- and hypo-reflective bands in retinal OCT is pivotal for accurate clinical interpretation. However, precise interpretation of the anatomical origins of outer retinal OCT presents technical challenges owing to the delicate nature of the retina. Typically, four hyper-reflective OCT bands are observed in the outer retina of the human eye. While interpretations of the first (1st) and fourth (4th) bands are relatively consistent, the second (2nd) and third (3rd) bands remain contentious topics.

In principle, OCT signals originate from two primary sources: directly reflected photons from layer-like structures, such as the photoreceptor inner/outer segment (IS/OS) junction, or multiply scattered photons from diffuser-like cellular structures like mitochondria in the ellipsoid zone (EZ) and retinal pigment epithelium (RPE). To address this challenge, our study introduces a novel polarization-sensitive Full-Field OCT (FF-OCT) technique. This FF-OCT system provides parallel-polarization and cross-polarization OCT measurements, predominantly capturing directly reflected ballistic photons and multiply scattered photons, respectively. Notably, parallel-polarization OCT unveils layer-like structures more effectively, including the inner plexiform layer (IPL) sub-layers, outer plexiform layer (OPL) sub-layers, and rod/cone OS tips, compared to cross-polarization OCT. Through a comparative analysis of parallel-polarized and cross-polarized OCT images of the outer retina, we discovered that the 2nd outer retinal OCT band results from contributions from both the EZ and the IS/OS junction. Similarly, the 3rd outer retinal OCT band appears to reflect contributions from both the interdigitation zone (IZ) and photoreceptor OS tips.

Furthermore, we conducted polarization OCT optoretinography (ORG) to investigate light-driven dynamics of photoreceptor OS in the human retina. Parallel-polarization OCT revealed a light-induced shrinkage of the photoreceptor OS (measured as the distance between the 2nd and 3rd bands), alongside an increase in the sub-retinal space (measured as the distance between the 3rd and 4th bands). Conversely, cross-polarization OCT indicated an elongation of the distance between the 2nd and 3rd bands. Notably, the magnitude of cross-polarization OCT, primarily influenced by multiply scattering light, exhibited significant alterations with changes in light condition.

In summary, parallel-polarization OCT excels in detecting ballistic photons from layer-like structures, while cross-polarization OCT predominantly captures multiply scattered photons. This enables parallel-

polarization OCT to robustly identify the photoreceptor IS/OS junction and OS tip location under varying light conditions, facilitating verification of light-driven photoreceptor OS shrinkage. In conventional OCT, the presence of multiply scattered photons poses challenges in reliably identifying the photoreceptor IS/OS junction and OS tip location, thereby impacting the accuracy of OS quantification. The comparative use of parallel-polarization and cross-polarization OCT offers a robust method for quantitative assessment of retinal morphology and enhances ORG sensitivity for improved functional evaluation of retinal physiology.
Keywords: OCT, Retina, Photoreceptor, Ophthalmology, Optoretinography.

6th International Conference on Photonics Research

INVITED PRESENTATION

Id-715

Structure and Mechanical Properties of Increased Strength Shipbuilding Steel Joints Produced by Hybrid Laser-arc Welding

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Abstract: Laser welding in the shipbuilding industry dates back to the late 1980s for welding steel up to 20 mm thick and using CO_2 lasers. In the shipbuilding industry, the use of hybrid laser-arc welding (HLAW) is of a special interest because it can be used with lower requirements for preparation and assembly of butt joints compared to laser welding. HLAW technology achieves high quality of the weld at low level of deformation and the cost of a weld is reduced, which allows a shipyard to get additional commercial advantages in the market. In this paper, the research on producing welded butt joints of E36 steel with thicknesses of 8, 16 and 28 mm was performed. Nondestructive inspections, metallographic investigations and mechanical tests were carried out to assess the quality of welded joints. As a result of experiments and technological works, the possibility of achieving the highest quality level of welded joints according to ISO 12932:2013 was ascertained. The weld is produced uniformly with a smooth transition to the base metal, according to the results of inspection. Surface defects controlled by visual inspection and penetrant testing, and also internal defects controlled by ultrasonic and optical metallography are within the acceptable level. The analysis of the macrostructure showed typical weld zones, where the impact of laser and arc sources on the formation of the weld pool can be identified. The strength and plasticity values are within the allowable range for this class of steel. Static tensile fracture occurs in the base metal. The values of impact toughness of various sections of welded joints, also pass the requirements for steel E36. As a result of the research, the HLAW technology was certified for compliance with the requirements of the Russian Maritime Register of Shipping rules. The results of the certification formed the basis for making additions to the MR Regulations describing the requirements for hybrid laser-arc welding. Updating of MR regulations will allow to apply the new welding technology in manufacturing of MR observation objects with the appropriate quality level.

Acknowledgment: The research was funded by the Ministry of Science and Higher Education of the Russian Federation as part of strategic academic leadership program “Priority-2030”, strategic project “Industrial digital technologies” (contract № 075-15-2021-1206 dated 30.09.2021).

Keywords: Hybrid Laser-arc Welding, Shipbuilding, Increased Strength Steels, Structure, Mechanical Properties.

6th International Conference on Photonics Research

INVITED PRESENTATION

Id-716

Direct Energy Deposition Of Functionally-graded Materials

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Abstract: The development of additive manufacturing opens up opportunities in the field of creating new materials and products with specified service properties The most promising technology in the field of additive manufacturing for the production of functionally-graded materials and compounds is the technology of direct energy deposition (DED). DED technology can be used to produce high-precision workpieces, including large-size workpieces. Pure metal and alloy powders with different chemical compositions can be used in the DED process. The content of powders with different chemical composition can be in situ varied by using several powder feeders during the fabrication process, which allows to obtain the required gradient layers.

In the DED process, new alloys with constant or variable compositions can be produced directly during the manufacturing of the product. This approach opens up a wide range of perspectives in designing and manufacturing products whose operating conditions can be predicted, including the effects of the environment as well as the loads that are applied to a particular part of the product. Functionally-graded materials for joining steel with titanium, various titanium alloys, various steels, and high-entropy alloys with layer-by-layer changes in chemical composition during DED process have been obtained in the research. The results of this study can serve as a framework for the creation of products of functionally graded materials by additive manufacturing methods.

Acknowledgment: The research was funded by the Ministry of Science and Higher Education of the Russian Federation as part of strategic academic leadership program “Priority-2030”, strategic project “Industrial digital technologies” (contract № 075-15-2021-1206 dated 30.09.2021).

Keywords: Direct Energy Deposition, Dissimilar Joints, Functional Graded Materials, Phase Composition.

INVITED PRESENTATION

Id-717

Bluetooth Technology in Scientific Applications

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Abstract: Bluetooth Low Energy (BLE) is a powerful wireless data transmission and receiving protocol that enables communication between smart devices. It could find a lot of different applications in scientific instruments due to networking feasibility, low power supply and impressive bitrate for wireless protocol. One may find the BLE layer system incomprehensible, while another may not see any fundamental differences from the familiar UART. There are many commercial modules available that can assist with starting to use the BLE protocol without requiring specific knowledge of circuit engineering or programming. Most of them are limited in functionality due to firmware and serv as UART-bridge. In the report, we will discuss the advantages and implementation of the protocol for scientific instrumentation applications. We will also provide the guidelines for the BLE stack operation and present an example - a software and hardware realization of semi-wireless electroencephalography (EEG) recording BLE device. The EEG device is created using a commercially available module that doesn't require any special firmware and works together with an STM32 controller. The implementation of the Internet of Things (IoT) concept is essential for modern scientific laboratory needs. As the number of instruments that send experimental data increases, it becomes necessary to connect them to a wire bus and then run this bus to a master device. All of this labor-intensive operation is done in order to read the data via UART on a PC. Or add a commercially available BLE module and access experimental data at any time on any device, including PCs, mobile phones, and any device that can receive Bluetooth.

Acknowledgment: The study was supported by Grant from RSF 23-75-30001.

Keywords: Bluetooth Low Energy, Electroencephalography, Photobiomodulation.

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ORAL PRESENTATION

Id-680

A New Method for Measuring the Flux Density of Terahertz Radiation

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Abstract: In non-destructive testing using terahertz radiation, one of the techniques is the transmission method. This method often uses a linear scanner for terahertz imaging, which provides better image resolution than a matrix detector. The scanner and the terahertz radiation source are located on opposite sides of the examined object. Since the currently used radiation sources (IMPATT diodes) have a low power of several dozen milliwatts, it is important to precisely direct the terahertz radiation stream onto the linear structure of the scanner's detectors. For this purpose, a measurement system was developed that allows measuring the density of terahertz radiation falling on the scanner's detectors. This system enables optimal configuration of the scanner and the radiation source during non-destructive testing using the transmission method. The developed measurement method makes it possible to determine the density of the terahertz flux incident on the surface of the detector line with an accuracy of 0.5 cm^2. The article presents measurement principles and sample results.

Acknowledgment: This research was funded by the National Center for Research and Development (Project no. DOB-SZAFIR/02/A/001/01/2020).

Keywords: Terahertz Radiation, Radiation Sources, Transmission Method, Nondestructive Testing.

ORAL PRESENTATION

Id-705

Opto-electronic Sensor of Hydrogen

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Abstract: In the last decade, motivated by the global climate change, considerable attention of the world scientific community has been turned to the search for alternative energy sources. Hydrogen occupies the most important place among them. Since hydrogen is a flammable and explosive gas, large-scale production of pure hydrogen, its transportation, storage and usage requires highly efficient, fast and safe hydrogen sensor to control possible leaks. It is well known that palladium metal can absorb hydrogen gas up to 1000 times of its own volume. As a result, its crystal lattice swells, and mechanical, electrical, and optical properties change. We studied the optical transparency of palladium layers in the wavelength range of 0.5–1.5 μm in gaseous media containing hydrogen from 0.1 to 100 vol.%. The layers of different thickness were deposited by vacuum thermal deposition on optical glass substrates. At hydrogen concentrations between 1 and 10%, a significant increase in the transparency of palladium layers is observed. Moreover, the linear increase of the layer transparency was observed with increase in the hydrogen concentration in the analyte. A sensor is proposed that measures the concentration of hydrogen from the optical transparency of the palladium layer. The optical unit includes spectrally matched pair of LED and photodiode with palladium layer in between. The integrated electronic board includes a pulsed power supply of the LED, the lock-in detector and amplifier, DAC and the digital signal processing unit. Better than 1000 ppm of hydrogen content was detected in laboratory conditions.

Acknowledgment: The authors thank the staff of the Laboratory of Infrared Optoelectronics (LIRO) of the A.F. Ioffe Physico-Technical Institute and their colleagues for their collaboration in studies of the effect of hydrogen on the optical transparency of palladium films cited in this abstract.

Keywords: Hydrogen Energy, Hydrogen Sensor, Metallic Palladium, Optical Transparency, Optoelectronic Sensors.

6th International Conference on Photonics Research

ORAL PRESENTATION

Id-719

An Investigation on the Electrical Conductivity Mechanism of PEDOT:PSS: Insights from UV-Vis-NIR Absorption Spectroscopy and Solvent Interaction Studies

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Abstract: Conductive polymers play a crucial role in various industries due to their unique electrical, optical, and mechanical properties, enabling advancements in fields such as electronics, energy storage, and biomedical applications. With the trends towards miniaturization, developments in wearable technologies, including downsized batteries, flexible, human-motion-compatible batteries, highlights the importance of conductive polymers. Among the conductive polymers, PEDOT:PSS stands out for its high conductivity, stability, and compatibility. However, the conductivity mechanism within polymer chains remains uncertain due to their complex structure. This study provides an explanation of the electrical conductivity mechanism of PEDOT:PSS using UV-Vis-NIR absorption spectroscopy. It also explores the interaction of polar organic solvents such as ethylene glycol (EG) and dimethyl sulfoxide (DMSO with PEDOT:PSS polymer chains and their UV-Vis-NIR absorption behavior. PEDOT:PSS inks containing 5% vol EG, DMSO, or a mixture of EG and DMSO were separately prepared and spin-coated onto glass substrates. UV-Vis-NIR absorption spectra were measured within a wavelength range from 200 to 1300 nm. Tauc plots and Urbach energy values were calculated using absorption data in the UV region. It is concluded that the interactions between PEDOT:PSS polymer chains and polar organic solvents alter electron tunneling and hopping mechanisms.

Keywords: PEDOT:PSS, Conductive Polymers, Electrical Conductivity, UV Absorption.

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ORAL PRESENTATION

Id-720

Synthesis of Graphene from the Photothermal Reaction and It's Effect on the Properties of Polyvinylidene Fluoride

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Abstract: Photothermal reactions are chemical reactions initiated or driven by the combined effects of light (photo) and heat (thermal) energy. Laser-induced graphene (LIG) is a material fabricated using a photothermal reaction. This process involves irradiating a precursor material, such as polyimide, with a laser. The microstructural, elemental, and electronic properties of the resulting LIG were investigated. Fabricated LIG was then incorporated into a polyvinylidene fluoride (PVDF) matrix at concentrations of 5%, 10%, 15%, and 20%, alongside pure PVDF for comparison. The resulting composites were analyzed to understand the effect of LIG on their surface morphology, cross-section, and phase composition. Elemental analysis revealed the elemental composition of the composites. Finally, the electrical properties of the composites were analyzed, and the relationship between their structure and properties was investigated.

Keywords: Laser-Induced Graphene, PVDF, Composite, Electrical Conductivity.

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POSTER PRESENTATION

Id-676

Autonomous Vehicle Operation using Light Sensors, Computer Vision and Machine Learning

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Abstract: This paper presents the research study of converting a regular motor vehicle into an autonomous one, utilizing the latest light sensors, communication technologies and control architectures. Autonomous vehicles are becoming increasingly popular in the modern world, to lessen the burden of physical driving. However, safety is an ever-prevalent issue, as well as the cost of technology and implementation.

The proposed design focused on light sensors and the related control field, by exploring the feasibility of utilizing a deep machine-learning model of UNET architecture, with a Residual Network (ResNet) encoder, to enhance vision capability of lane detection. An investigation to reduce the cross-track error of the vehicle with an extended variation of the Pure Pursuit controller and Stanley controller was undertaken. The design applied computer vision techniques to acquire lane imagery from camera light sensors and train a deep learning model to perform semantic segmentation, which detected and distinguished between left and right boundaries.

The lane detection pipeline provided the platform for the lateral and longitudinal control methods to facilitate the movement of the vehicle under limited restrictions, with pre-installed actuation and motor devices to control the acceleration pedal and steering wheel angle. Simulations were performed using the CARLA simulator, which is an open-source software, to test the design standard and performance of autonomous vehicle. The intention of the CARLA simulation was to examine the cross-track error of the vehicle under several environmental conditions and system restrictions, to observe the performance of the vehicle. A practical simulation was then setup by capturing and labelling real-world lane imagery to re-train the model and compare the dice loss and predictions of the lane boundaries, with the model used for the CARLA simulator, to warrant validation of the design.

Keywords: Autonomous Vehicle, Light Sensors, Computer Vision, Machine Learning.

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POSTER PRESENTATION

Id-703

Intelligent Diagnosis Method of Gastric Disease based on Traditional Chinese Medicine and Hyperspectral Imaging

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Abstract: To achieve a rapid and convenient early screening for gastric diseases, and to overcome the observational limitations of traditional Chinese medicine (TCM) inspection, an intelligent gastric disease diagnostic system based on TCM and hyperspectral imaging is proposed. According to the TCM theory, patients' tongue examination information is acquired through hyperspectral imaging, and a machine learning algorithm is employed for the intelligent classification of gastric diseases. The key contributions of this research include 1) the development of a hyperspectral imaging system tailored for TCM inspection, enabling the acquisition of spectral images covering 30 bands from visible to near-infrared within 1.5 seconds; 2) characterization of digital features related to the spleen and stomach based on TCM theories, including color, shape, and texture, extracted from tongue spectral images; 3) establishment of the relationship between the extracted digital features and gastric disease diagnostic labels using machine learning algorithms for disease classification and recognition. The proposed method achieves an area under the curve (AUC) of 0.949 for classifying the presence or absence of gastric diseases, indicating that the developed approach lays a foundation for early diagnosis of gastric diseases and the digitization and intelligence of TCM.

Keywords: Hyperspectral Imaging, Feature Extraction, Machine Learning, Traditional Chinese Medicine, Gastric Disease Diagnosis.

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POSTER PRESENTATION

Id-706

Opto-electronic Sensor of Methane

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Abstract: In the context of global climate warming, reducing emissions of carbon-containing gases into the atmosphere has come to the forefront. Of the fossil fuels, the most low-carbon and environmentally friendly is methane, a highly flammable and explosive gas. It is important to control its leaks to prevent man-made disasters. The report presents the results of the development of a compact digital optical-electronic methane sensor for the use in gas vehicles. The sensor operates on the principle of absorption of infrared (IR) radiation by methane molecules as it passes through the optical sensor cell, and provides a maximum sensor sensitivity of 500 ppm of methane in air in laboratory conditions. The use of modern solid-state narrow-band IR radiation sources in the mid-wavelength range in the development of the opto-electronic methane sensor allows us to produce a prototype methane sensor with such advantages as compactness, ultra-low power consumption (several mW), high speed, fire safety, and operability in a wide range of temperatures and air humidity for a long time (more than 5 years). The digital signal processing and interface make it easy to integrate such a sensor into the digital environment for controlling the systems of a modern vehicle.

Keywords: Low-carbon Energy, Mid-IR LEDs, Optical Absorption, Opto-electronic Methane Sensor.

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POSTER PRESENTATION

Id-713

Photoacoustic and Laser Ultrasound Combined Tomography: Advantages for Biological Tissue Diagnostics

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Abstract: In OA mode, absorption of laser radiation causes heating and fast nonuniform expansion of the object, which results in the generation of acoustic pulses. In LU mode, laser radiation is absorbed in a built-in OA generator where a broadband acoustic probe pulse is generated. This optoacoustic generator is a special material that has high laser radiation absorption efficiency, high thermal expansion coefficient, and acoustic impedance which matching the acoustic impedance. First toroidally focused 2D real-time laser-ultrasonic imaging system was demonstrated. The system is capable of visualizing an acupuncture needle 0.2 mm in diameter located at ~4 cm depth in water. The lateral spatial resolution is better than ~0.32 mm and axial spatial resolution was ~30 μm. The achieved frame rate was up to 30 Hz. The depth dependency of the sensitivity region width and lateral resolution were experimentally measured and discussed. The array was intended to be used as a part of combined real-time photoacoustic and laser-ultrasonic imaging system. It was shown that it is possible to locate a medical needle greater than 0.63 mm in diameter inside a blood vessel model with an outer diameter of 1.6 mm and 2.4 mm using combined OA and LU imaging in real time. The combined OA and LU imaging system can be used not only for diagnostics of biological objects, but also to for examining the structure of various materials.

Keywords: Photoacoustic Tomography, Laser Ultrasound Tomography, Blood Vessels Diagnostics, Photoacoustic Array, Toroidal Focusing System.

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POSTER PRESENTATION

Id-714

Pulsed and Continuous Lasing at NV–centers in Diamond

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Abstract: The broadband photoluminescence of the color centers in diamond, covering the near and middle infrared spectral range, the high quantum efficiency of the nitrogen-vacancy (NV–) centers at room temperature, as well as the excellent optical and mechanical properties of diamond crystals allow it to be considered as a promising solid-state active medium for the laser systems development. The report demonstrates the first achieved generation of pulsed radiation with a duration of 1 ns in the visible range (carrier wavelength 720 nm) with a spectral width of 20 nm and an energy of up to 48 μJ at the NV– centers of a diamond, which was pumped using a pulsed laser at a wavelength of 532 nm. It was found that an increase in power or in the duration of pumping causes a decrease in the effective gain, which prevents the creation of a continuous laser on the diamond NV centers pumped at a wavelength of 532 nm. The use of a continuous 640 nm laser diode with a power of up to 300 mW made it possible to realize the conditions necessary to achieve continuous laser generation. The maximum gain achieved was about 3%, which is close to the threshold of continuous laser generation.

Keywords: Nitrogen-vacancy Centers, Diamond Crystal, Nanosecond Laser, Tunable Laser, Continuous Wave Laser.

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