BOOK of ABSTRACTS

12th International Symposium

«OPTICS & ITS APPLICATIONS»

15 - 19 October, 2024
Yerevan, Armenia

12th International Symposium

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Edited by Narine Gevorgyan and Lusine Tsarukyan

YEREVAN

2024

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«ՕՊՏԻԿԱՆ ԵՎ ԴՐԱ ԿԻՐԱՌՈՒԹՅՈՒՆՆԵՐԸ»

15 - 19 սեպտեմբեր, 2019
Երևան, Հայաստան

Տեղեկություն սիմպոզիումի վերաբերյալ և զեկուցումների թեզերը

Նաիրնե Գևորգյանի և Լուսինե Ծառուկյանի խմբագրությամբ

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2024

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Program highlights

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- *Sectional presentations*
- *Poster presentations*
- *Student presentations*
- *Student chapters presentations*
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- *Social events*

Topics

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- ✓ *Quantum Information*
- ✓ *Biophotonics*
- ✓ *Optical properties of nanostructures*
- ✓ *X-ray optics and applications*
- ✓ *Beam optics*
- ✓ *Strong field optics*
- ✓ *Spectroscopy*
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- ✓ *Fiber optics*
- ✓ *Integrated photonics*
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- ✓ *2D materials*
- ✓ *Nanophotonics*
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- ✓ *Singular optics*
- ✓ *Mathematical methods in optics*

Student chapters' poster presentations

EPS RAU Young Minds

OPTICA IPR Armenia Student Chapter

OPTICA RAU Student Chapter

OPTICA Yerevan State University Student Chapter

SPIE RAU and NAS Student Chapter

SPIE Yerevan State University Student Chapter

Symposium Venue

15 October

Morning session:
National Academy of Sciences of Armenia
24, Marshall Baghramian Ave., Yerevan 0019, Republic of Armenia

Evening session:
Institute of Applied Problems of Physics of the NAS
25 Hr. Nersisyan St, Yerevan 0014, Republic of Armenia

16 October

Institute of Applied Problems of Physics of the NAS
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17 October

Yerevan State University
1 Alex Manoogian St., Yerevan 0025, Republic of Armenia

18 October

Morning session:
A.I. Alikhanyan National Science Laboratory
2 Alikhanyan Brothers St., Yerevan 0036, Republic of Armenia

Evening session:
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19 October

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Acknowledgement

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Plenary Speakers

Sultan Dabagov

INFN – Laboratori Nazionali di Frascati, Via E. Fermi 54, Frascati (RM), Italy

Channeling as Novel Optical Solution for Beams and Radiations

Channeling has been introduced by Lindhard as a new phenomenology to explain deep penetration of charged particles into the crystals aligned along well-defined crystallographic directions. The phenomenology is based on multiple small angle deflections of the beams due to strong synchronised interaction with many atoms/nuclei of the crystal that can be described based on the continuous potential approach.

For more than half century of research, the channeling principles have been applied for description of many both non-crystal and non-charged particles phenomena, becoming an effective tool to handle various beams not only for theoretical studies but essentially for experimental and technological ones.

In this lecture I'm going to introduce the meeting's participants to the physics and history of the channeling phenomenon, as well as to the successful studies and results obtained that prove its ability to act as efficient optical solution to form charged and neutral beams, including high frequency radiation fluxes.

Tigran Galstian

Université Laval, Québec, Canada

Liquid crystals for life sciences; from host media to optoelectronics devices

Liquid crystals are anisotropic liquids, which have gone from curiosity objects to devices (displays) that are omnipresent in our life. The understanding of their physical and chemical properties and the progress in life sciences has shown that nature is full of examples of matter that behaves like liquid crystals (membrane, myeline, mucus, synovial fluid, etc.). Not surprisingly, a new wave of interest is growing for their applications in life sciences.

In this report, I shall describe recent developments in this research field, ranging from host applications (where liquid crystals are used as host media for bacteria) to optoelectronic investigation tools (where liquid crystals are used in imaging devices to study brain).

Tigran Shahbazyan

Jackson State University, USA

Photoluminescence of metal nanostructures

We present an analytical model for plasmonic enhancement of metal photoluminescence (MPL) in metal nanostructures. In such systems, the primary mechanism of MPL enhancement is excitation of localized surface plasmons (LSP) by recombining carriers followed by LSP radiative decay. For plasmonic structures of arbitrary shape, we obtain explicit expressions for the MPL Purcell factor and MPL spectrum in terms of metal dielectric function and the LSP frequency. We find that the interference between the direct and LSP-mediated processes explains the blueshift of MPL spectral peak relative to the LSP resonance in scattering spectra observed in numerous experiments.

Roman Sobolewski

University of Rochester, USA

Terahertz Photonics

The field of terahertz (THz) science and technology [1] is still in its early age but has already gained a very large international interest due to its numerous applications ranging from security screening, e.g., at airports, through ultrafast communications, radioastronomy, to nonionizing biomedical spectroscopy, medical imaging and diagnostics, and industrial food quality control. The THz radiation is situated between the infrared and microwave regions in the electromagnetic spectrum with a bandwidth ranging approx. from 0.3 to 30 THz. In the colloquial term, we can talk about the "THz gap," i.e., a region of the electromagnetic radiation spectrum where it is very difficult to successfully operate "classical" either electronic or photonic devices. For even the fastest FET-type transistor structures, the THz frequency of operation is extremely high, while THz quanta have the energy much smaller than the thermal energy background at room temperature. One of the most interesting forms of THz radiation are subpicosecond in duration bursts of electromagnetic waves. These, so-called, THz transients are, typically, characterized by a sub-picosecond time duration and a ~0.1 to ~6 THz spectral range, and are generated using optical femtosecond laser pulses. We review our current THz photonics research, aimed towards generation and subsequent detection of sub-picosecond electrical transients for time-resolved (THz-bandwidth) spectroscopy studies of novel materials, most recently, *ex-vivo* imaging of normal and tumor biological tissues [2]. We also demonstrate novel spintronic THz emitters. Spintronic nanostructures manipulate simultaneously electron's charge and spin and emerge as a new direction in generation of THz transients, due to their robust and simple thin-film technology, low cost, and emission of ultra-broadband signals. The inverse spin Hall effect is the core emission mechanism of THz transients from spintronic nanostructures, such as ferromagnet/heavy metal nanobilayers [3]. Future prospects of THz photonics will complete our presentation.

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Invited speakers

Marina Aghayan

A.B. Nalbandyan Institute of Chemical Physics of NAS, Armenia

Tallinn University of Technology, Estonia

FACT Industries OÜ, Estonia

Optics and 3D printing

The national laboratory of Armenia is named after its founder Artom Alikhanyan. It was traditionally a laboratory to study high energy phenomena
3D printing technologies are developing rapidly. The global market is expected to grow from USD 17.5 billion to USD 37.4 billion at a CAGR of 16.5 % during the period of 2024-2029 [1]. One of the market drivers are new technological advancements and materials which expands the applications of 3D printing technologies. Currently, many materials, including metals, ceramics, polymers, and various composites can be used to manufacture 3D objects.

Manufacturing of optics by 3D printing technology is a promising direction which can lead to new features and engineering solutions. It enables manufacturing of small 3D items with complex geometry and multi-function. Different parts composed of various materials can be interconnected achieving better properties. Another advantage is the low cost of small scale, customized production and waste less manufacturing.

Various 3D printing technologies are used to prepare optical devices. Stereolithography is an upcoming method to manufacture optical sensors, microlenses [2,3]. Selective laser sintering fabrication of microelectronic parts, micron-scale 3D helical structures, diffractive terahertz band lenses [3]. Gradient refractive index optics and some transparent ceramics were prepared using Direct ink writing technique [4,5]. Fused Deposition Modelling is intensively used in Diffuse Optics [6]. The application of 3D printing technologies in optics is wide. Each method has its limitations and advantages over others. However, using the proper technology and material it is possible to achieve the necessary properties.

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Arsen Babajanyan

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Advanced Near-Field Visualization of Electromagnetic Distributions in RF Anisotropic Nanostructures Using Thermo-Elastic Optical Microscopy

Arsen Babajanyan[1], Artyom Movsisyan[1], Hasmik Manukyan[1], Gagik Manukyan[1], Narek Nazaryan[1], Kiejin Lee[2]

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In this work, we present advancements in the characterization of anisotropic materials using near-field microscopy, specifically through the Thermo-Elastic Optical Microscope (TEOM) system [1-3]. The TEOM (Fig. 1), a highly sensitive and spatially precise tool, visualizes temperature and electromagnetic near-field distributions by measuring the absorption of electromagnetic fields via an indicator film. This method offers significant potential for detecting defects in thin thermo-electro-conductive films due to variations in microwave absorption between defective and non-defective areas.

We conducted experiments to visualize microwave electric and magnetic near-field distributions of radio-frequency (RF) filters using the TEOM. A novel optical indicator (OI), designed from a periodic dielectric-metal metasurface structure, was developed to independently visualize the electric field components (Ex and Ey), depending on its orientation. Numerical simulations were performed to verify the functionality of these indicators, and the results aligned well with experimental data. Moreover, 3D reconstructions of the microwave near-field distribution were created to analyze the field intensity and distribution relative to the distance from the RF filter.

The newly developed OI, based on indium tin oxide (ITO) glass, demonstrated effective visualization of both x and y components of the electric field across a range of operating frequencies. The technique successfully captured the spatial distribution of the microwave near-field by varying the distance between the OI and RF filter, allowing for comprehensive 3D field reconstruction. These 3D visualizations open up new opportunities for investigating interference phenomena. Finally, we discuss potential enhancements for the TEOM system using advanced optical indicators, offering promising directions for future research and applications in material characterization and defect detection in RF systems.

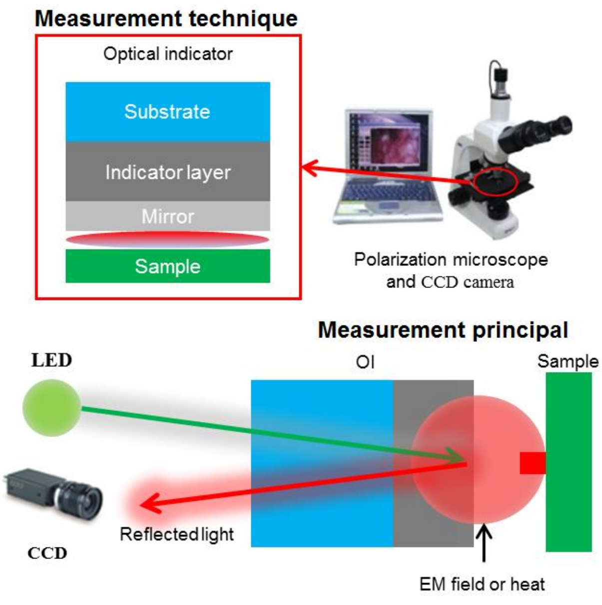

Fig. 1. The Schematic diagram and operational principle of TEOM.

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David Blaschke

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Particle production in strong, time-dependent fields

After a short introduction to the actual status of creating strong, time-dependent electric fields in the focal spot of high-intensity laser colliders and the Schwinger formula for electron-positron pair production in time-independent electric fields with the critical field strength $E_C = 1.3\ 10^{18}$ V/m, we review the kinetic equation formulation of pair production which is appropriate for the situation of time-dependent external fields [1].

We discuss the dependence of the particle production on the field strength and pulse shape. We enlighten the importance of decoherence for a finite residual particle density after the cessation of the pulse. We show how the assistance of a second coherent laser field can assist the Schwinger effect and increase the particle production rate [2,3]. We apply the formalism to particle production in heavy-ion collisions and derive two lessons: 1) the shorter the pulse, the closer the residual particle density is to the maximum of its time-dependence; 2) the produced particles can be described by a thermal spectrum analogous to the Hawking-Unruh effect, where the Hawking temperature is related to the average string tension $<\sigma>$ as $T_H = (<\sigma>/2\pi)^{1/2}$.

The spectrum of produced pions shows an anomalous enhancement in the low-momentum sector which stems from an overpopulation of the pion phase space by the nonequilibrium production provess and can be interpreted as a precursor of Bose-Einstein condensation [5].

Finally, we discuss that a time-dependent scalar mean field which occurs in the context of chiral symmetry breaking during the cooling of a quark-gluon plasma fireball in an ultrarelativistic heavy-ion collision can serve as a source term for scalar meson production and, via subsequent two-pion decay, also for an overpopulation of the low-momentum pion spectrum. Analogously, in the framework of a conformal cosmology approach, one can discuss a source term for particle production from the time-dependent scalar dilaton field.

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Tobias Dornheim

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Towards highly accurate diagnostics of extreme states of matter with x-ray Thomson scattering

Matter under extreme densities, temperatures and pressures is ubiquitous throughout our universe and naturally occurs in a variety of astrophysical objects, including giant planet interiors (e.g. Jupiter, but also exoplanets), brown dwarfs, white dwarf atmospheres, in the outer layer of neutron stars and during meteor impacts. On Earth, such extreme states are important for technological applications such as the discovery and synthesis of novel materials. A particularly important application is given by inertial fusion energy (IFE), where both the fuel capsule and the ablator material have to traverse this *warm dense matter* regime in a controlled way to reach ignition. Indeed, the recent spectacular news from the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory in California, USA, who have reported a net energy gain of the burning plasma with respect to the compression energy [1], opens up the intriguing possibility to develop IFE into a clean, safe and nigh abundant source of energy in the future.

In the laboratory, warm dense matter is created in large research facilities such as the European XFEL in Germany, SACLA in Japan, and the NIF, SLAC, and the OMEGA laser in the USA using a variety of techniques. Here, a key challenge is given by the accurate diagnostics of the created samples due to the extreme conditions and the ultrafast time scales. Over the last years, the X-ray Thomson scattering (XRTS) technique---also known as inelastic X-ray scattering---has emerged as a promising method of diagnostics as it is, in principle, capable of giving microscopic insights into the probed sample in the form of the electronic dynamic structure factor [2]. In practice, however, the interpretation of XRTS measurements has relied on theoretical models that are based on a number of de-facto uncontrolled assumptions. Consequently, the quality of the thus inferred system parameters has remained unclear.

Here, I present an overview of a new approach that allows for the model-free interpretation of XRTS spectra *in the imaginary-time domain* [3-5]. The latter naturally emerges in Feynman's celebrated path integral formulation of statistical mechanics and, by definition, contains the same information as the usual spectral representation, only in an a-priori unfamiliar representation. At the same time, working in the imaginary-time allows one to deconvolve the physical information from effects due to the X-ray source and the detector. This, in turn, opens up the way for the model-free extraction of important system parameters such as the temperature [3] without the need for any approximations or simulations.

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Davit Ghazaryan

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Anisotropic optical properties and emergent phenomena in van der Waals crystals

The growing family of van der Waals crystals has been recognized as a promising platform for the investigation of novel effects and their implementation in a variety of functional devices. The nature of their out-of-plane bonds, i. e., their explicit layered structure, instantly suggests emergence of anisotropic mechanical, optical, and electronic properties at z direction. Furthermore, the families of van der Waals crystals that also naturally possess in-plane anisotropic properties (xy plane), appear more interesting as they significantly enrich the research scope. Though the nature of in-plane bonds in constituent 2D layers of those van der Waals crystals is covalent, their unique crystal structures still stand as one of the major factors behind the anisotropy. Here, we will present our recent findings in orthorhombic and triclinic van der Waals crystals (and heterostructures) that exhibit outstanding anisotropic optical properties and may be of great use for the creation of next-generation optical and nanophotonic devices [1-3].

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David Hayrapetyan

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Mollow triplet in Two-Impurity dumbbell quantum dot

The current study uses various computational methods to determine the eigenvalues and eigenvectors of a specific system-namely, a two-impurity, two-electron system within a dumbbell-shaped quantum dot. Initially, the single-electron, single-impurity problem is resolved using the effective mass approximation and the finite element method. Subsequently, a technique similar to the linear combination of atomic orbitals is applied to derive singlet–triplet states. The research work deeply investigates the key characteristics of the mentioned states, with a particular focus on their energy splitting and exchange times. Additionally, it highlights the dynamic evolution of the singlet–triplet two-level system, illustrating its manipulation through detuning and Rabi frequency. The Mollow triplet spectrum is also calculated and analyzed under various initial conditions. The findings of this research have significant implications across multiple domains, including the advancement of quantum information processing, the enhancement of optoelectronic device performance, and the development of innovative sensing and communication technologies.

Paytsar Mantashyan

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Impact of Bessel laser beam on excitonic complexes in quantum dot

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[2]Russian-Armenian University, 123 H. Emin, Yerevan, Armenia

This theoretical study investigates the response of a strongly oblate GaAs ellipsoidal quantum dot to an intense laser field with a Bessel intensity profile at non-resonant extreme violet and simultaneously resonant mid-infrared laser irradiation. Mainly, the linear and nonlinear optical properties of biexcitons in quantum dot are observed. Due to the complexity of the considered particle, all calculations are performed in the framework of the variational method. The biexciton energies for different values of applied intense laser field magnitude on the small geometrical parameter of ellipsoidal quantum dot are calculated. The nonlinear optical properties, including the oscillator strength, third-order nonlinear susceptibility, absorption coefficient, and refractive index change, are evaluated. Numerical results reveal the dependence of the exciton and biexciton energies on the intensity of the laser field and the geometrical parameters of the quantum dot. Additionally, the dependencies of the third-order susceptibility, absorption coefficient, and induced refractive index change on photon energy near the one-photon resonance and two-photon resonance are analyzed. Biexciton recombination radiative lifetime on the small semiaxis of the ellipsoidal quantum dot for the

different values of the laser field influence is estimated. Finally, the visualization of the localization region of biexciton in the quantum dot is performed.

Aram Papoyan

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Scanning technique for optical transmission imaging of strongly-scattering objects with ballistic photons

Svetlana Shmavonyan[1], Aleksandr Khanbekyan[1],
Marina Movsisyan[1], **Aram Papoyan**[1]

[1]Institute for Physical Research, NAS of Armenia

We present a spatial scanning technique for optical transmission imaging of strongly-scattering objects based on spatially-selective registration of ballistic photons originating from modulated (pulsed) laser radiation. The registration system counts the number of transmitted pulses at any pixel, forming a grayscale image. By choosing modulation regime, it is possible to record a real analog image or to outline contours of the image features, without necessity of software image processing. The developed system is tested on model scattering object (stack of paper) and biological object (human hand). Due to the automatic adjustment of the signal level, realized by the appropriate laser modulation mode, formation of an image with a structure uniformly pronounced across the aperture has been attained, even under conditions of significant changes in background transmission.

Armen Sargsyan

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Influence of buffer gas pressure on the formation of subnatural N-resonances formed in rubidium atomic vapors

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The N-resonance process is an available and effective method for obtaining narrow (down to subnatural linewidth), and contrasted resonances, using two continuous lasers and alkali atomic vapors [1,2]. Here we investigate the impact of buffer gas partial pressure on the contrast and linewidth of N-resonances formed in the D1 line of an 85Rb thermal vapor. N-resonances are compared to usual Electromagnetically Induced transparency (EIT) resonances, and we highlight their advantages and disadvantages. Our measurements were fulfilled with five vapor cells, each containing Rb and Ne buffer gas with different partial pressures (ranging from 0 up to 400 Torr). Thus we have experimentally found an optimum Ne partial pressure that yields the best contrast, for which we provide a qualitative description. Finally we study the behavior of the N-resonance components when a magnetic field is applied to the vapor cell. The frequency shift of each component is well described by theoretical calculations. Thanks to narrow linewidth and high contrast, N-resonances can have a number of important applications (as much as EIT resonances) in a variety of fields, such as information storage, quantum communication, optical magnetometry or metrology and etc. [3].

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Exciton states and electroabsorption in CdSe nanoplatelets

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In the effective mass approximation, single-particle, excitonic states, and interband and intraband transitions in CdSe nanoplatelet are considered in the presence of an external axial uniform electrostatic field. It has been demonstrated that under the influence of the field, the binding energy between the electron and the hole in the nanoplatelet decreases compared to the case in the absence of the field. It is shown that with increasing electric field strength, the resonant frequencies of interband electroabsorption undergo a red shift. On the other hand, the resonance frequencies of intraband absorption shift to the region of high energies. A similar shift of photoluminescence spectrum peaks under the influence of the field has been observed. The results of theoretical calculations of the luminescence threshold frequency values are in good agreement with the corresponding experimental data.

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Phase-change nanodroplets for biomedical imaging

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Here we will present applications of nanosized liquid contrast agents that are based on perfluoropentane and perfluorohexane in biomedical imaging.[1-5] These nanodroplets are stabilized in an aqueous media by a lipid layer, which can be modified with targeting ligands to enable molecular-specific interactions and imaging. The contrast agents can be synthesized with uniform sizes below 200 nm and undergo liquid-to-gas transition triggered by either an external pulsed laser or ultrasound. The phase transition can be reversible or irreversible depending on multiple parameters including the composition of the nanodroplets, their size, temperature, and parameters of an external activation. In this talk, we will discuss the optimization of composition (i.e., core and coating) of nanodroplets for applications in imaging of tissue biomechanical properties and molecular photoacoustic and ultrasound imaging.

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Oral Presentations

Enhancement and manipulation of quantum entanglement in three-spin clusters by non-conserving magnetization and electric field

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The quantum entanglement of spin states in molecular magnets has important applications in quantum information technologies and quantum computing. Currently, qubit models based on magnetic molecules are being used to develop quantum computation and communication technologies. We consider two models of three-spin molecular magnets with additional features that allow one to manipulate and enhance their entanglement. The first model is a mixed-spin (1/2, 1, 1/2) triangle with two g-factors. The second model is a spin-1/2 triangle with the Katsura-Nagaosa-Balatsky (KNB) mechanism, providing the coupling between spin degrees of freedom and the external electric field. It is shown that non-conserving magnetization originated from the non-uniformity of g-factors leads to an essential increase of the entanglement of certain spin states along with the rich structure of zero-temperature phase diagrams. Whereas, the model with magnetoelectric coupling due to the KNB mechanism offers a wide possibility of manipulation of quantum entanglement by the electric field, both using its magnitude and direction.

Luminescence Enhancement of All-Inorganic Lead Halide Perovskites Thin Films under Proton Irradiation

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Lead halide perovskites (LHPs) have emerged as a promising new class of materials for light-emitting diodes (LEDs) due to their distinctive crystal structure and exceptional optoelectronic properties [1]. One of the most remarkable characteristics of LHPs is their near-unity photoluminescence quantum yield (PLQY) [2], indicating that nonradiative relaxation processes—often responsible for energy losses—are effectively minimized. These losses are typically caused by defects within the material, which can act as traps for charge carriers, reducing the overall efficiency of light emission.

In this study, we investigate the impact of proton irradiation on the luminescence properties of $CsPbBr_3$ and $CsPbI_3$ perovskite thin films, deposited by Physical Vapor Deposition (PVD), with a particular focus on understanding the mechanisms behind luminescence enhancement.

Our findings reveal a notable increase in quantum yield following proton irradiation, attributed to the irradiation-induced growth in particle dimensions and a corresponding reduction in grain boundaries. The expansion of particle size leads to fewer non-radiative recombination sites, thereby enhancing the efficiency of photoluminescence. Additionally, the reduction in grain boundaries reduces the likelihood of charge carrier trapping, further contributing to the increased quantum yield.

This study demonstrates that controlled proton irradiation can effectively enhance the luminescent properties of lead halide perovskite thin films by modifying their microstructure. These insights provide valuable guidance for optimizing perovskite materials for high-performance optoelectronic devices, emphasizing the potential of irradiation techniques in advancing the development of next-generation technologies.

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Investigation of irradiated DNA/porphyrin complexes by optical methods

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This study investigates the interaction between ultrashort electron beams and DNA in the presence of porphyrins, focusing on their potential as radiosensitizers in cancer treatment. DNA damage induced by ionizing radiation, including single- and double-strand breaks, was analyzed using advanced electron beam technology at the AREAL accelerator (5 MeV energy, sub-picosecond pulses). DNA structural changes were assessed via spectrometric melting analysis, with melting temperature (T_m) and melting interval (ΔT) serving as indicators of radiation-induced damage.

The results reveal that ultrashort electron beams induce dose-dependent DNA damage, as evidenced by reductions in T_m and increases in ΔT. In the presence of Zn-containing porphyrins (e.g., $ZnTOEPyP_4$), DNA exhibited increased stability and resistance to damage at lower doses (2 Gy), while higher doses (4 Gy) reduced the protective effect. In previous work, we demonstrated that $CuTOEPyP_4$ porphyrins enhanced DNA stability at specific concentrations under electron beam irradiation, highlighting their ability to modulate the extent of radiation-induced damage [1].

The study underscores the complex interplay between porphyrin concentration and radiation dose, emphasizing the potential of porphyrins as radiosensitizers for precision radiation therapy. These findings align with prior investigations into the role of porphyrins in stabilizing DNA and mitigating X-ray-induced damage [2]. Further research is needed to optimize the use of porphyrins in clinical applications and improve their therapeutic potential [3].

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Integrable model of a two-dimensional singular spherical oscillator in a constant magnetic field

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We proposed a spherical generalization of the two-dimensional singular oscillator and considered its behavior in a constant magnetic field. We showed that this system is also exactly solvable at the classical level, presenting its explicit classical solutions. Without a doubt, the proposed system is also exactly solvable in the quantum level.

It is interesting to analyze the optical properties of the proposed model with regard its possible application to the description of ring-shaped quantum dots.

Hybrid organic-inorganic perovskite thin films for solar cell applications

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Perovskites, characterized by their ABX_3 crystal structure, have attracted considerable interest as potential materials for many applications such as solar cells, display materials, batteries, etc. Typically made from a hybrid organic-inorganic lead or tin halide-based structure, they offer outstanding properties such as excellent light absorption, high charge-carrier mobility, and adjustable band gaps. Their ease of fabrication and potential for low-cost production, along with rapidly improving power conversion efficiencies that are now comparable to traditional silicon-based solar cells, highlight their promise in the photovoltaic field. However, challenges remain, particularly regarding stability and toxicity.

In our study, we investigated simple and hybrid perovskites using machine learning (ML) models, density functional theory (DFT) calculations, and solvothermal synthesis. To address stability concerns, we initially focused on lead-containing organic-inorganic perovskites, aiming to identify stable compositions, while toxicity challenges will be tackled next. We began with data mining and applied seven ML algorithms to predict the band gap energies of 44000 perovskite compositions generated by our team. The best-performing model was found to be linear regression. Based on its band gap energy, $FAPbBr_{1.125}I_{1.875}$ emerged as one of the top compositions for solar cell applications. Although the data was small (110 samples), we found that several ML algorithms, such as linear regression, gradient boosting, and random forest were able to precisely predict energy band gaps of newly generated perovskites. Linear regression algorithm was found to work well, due to very carefully and precisely chosen data.

The ML results were further validated through DFT calculations and experimental work. Band gap energies were theoretically determined using DFT and correction through added potentials and are in a good agreement with

ML predicted results. Synthesis was carried out using the solvothermal method, and uniform thin films were obtained via spin coating technique. The UV-Vis spectroscopy was used to determine band gap energy of the chosen composite, which coincides with ML predicted data and in a good agreement with DFT results.

Proton Beam Irradiation of Pure and Cerium-Doped Zinc Orthosilicate

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Improved thermal barrier coatings (TBCs) hold the potential to allow future gas turbines to operate at elevated gas temperatures. Substantial efforts are currently underway to identify novel materials that outperform the existing industry standard. Additionally, TBCs are being explored for applications in spacecraft as a safeguarding layer against extreme heat, considering that spacecraft operating in outer space are subject to constant exposure to cosmic rays, particularly high-energy protons, electrons, and neutrons in the MeV range. Hence, it is of paramount importance to scrutinize how these barrier coatings behave under irradiation conditions. In our research, we investigate the resilience of silicate compounds, which were synthesized using a hydrothermal microwave method, when exposed to proton beam irradiation. To achieve this, we subjected zinc silicates and cerium-doped zinc silicates to 15.5 MeV protons with doses ranging from 10^{13} to 10^{15} protons per square centimeter (p/cm2). In our previous works we have already shown that these materials, in particular Ce–Zn_2SiO_4, show higher stability to electron irradiation compared to pure zinc silicate. X-ray diffraction (XRD), and scanning electron microscopy (SEM) were used to characterize the phase composition, and morphology of materials. The diffuse reflectance and absorption measurements of materials before and after proton irradiation indicated that the Ce–Zn2SiO_4 sample exhibits better radiation resistance compared to pure Zn2SiO_4. The research results showed that the radiation resistance of the material irradiated with protons and at the same time their crystal structure is preserved.

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Probing The Effect of 15.5 MeV Proton beam on The Optical and Structural Properties of Graphene Layers

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Liquid phase exfoliation is a simple and affordable for graphene production [1,2]. It can find applications in extreme conditions such as proton radiation background in space [3]. This study presents the effect of irradiation with 15.5 MeV protons on the infrared spectra and structural properties of liquid-phase exfoliated graphene. The influence of adsorbed acetone molecules and functional groups on these characteristics is described. Subsequently, samples undergo irradiation up to fluence of 10^{15} proton/cm 2 using a cyclotron source. Fast Fourier Transform Infrared (FTIR) spectra of irradiated and non-irradiated samples are compared. Changes in absorption, reflection, and transmission behaviors induced by irradiation are identified. The effect of irradiation on the density of defects in graphene is studied by means of Raman spectroscopy. A comparative analysis of FTIR and Raman spectra reveals that the Fermi level decreases after irradiation. This effect is further validated by studying the I-V characteristics of both irradiated and non-irradiated samples.

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Generation of localized orientational structures induced by Gaussian and vortex beams in chiral nematic liquid crystal

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We have developed methods for generation of localized orientational structures in chiral nematic liquid crystals (LC) by low-power Gaussian and vortex beams. The structures such as cholesteric spherulites are of interest as tunable optical elements or components of more complex optical and photonic systems, for example, microlens arrays [1] or two-dimensional diffraction gratings [2].

It is well known that ensembles of cholesteric spherulites can be obtained by rapid cooling from the isotropic phase of a chiral nematic or from electrohydrodynamic instability when a low-frequency electric field is applied [3]. However, in these two cases, an ensemble of localized structures with a non-uniform spatial distribution is usually formed. On the other hand, simultaneous optical generation of an ensemble of localized structures allows one to control their position, but requires high powers of the recording light beam, starting from 50-70 mW per one structure [4,5]. The use of a photoactive chiral nematic with a light-controlled pitch of the cholesteric helix allows one to reduce the optical power of the recording light beam down to tens of nanowatts. However, this requires the use of a specific chiral molecular additive and constant illumination of the LC sample to maintain the structure existence [6,7].

In current work, we investigate the thermal and orientational effects of focused Gaussian and vortex beams on frustrated chiral nematic films. High responsiveness of the chiral liquid-crystalline material is reached by doping with a bis-azobenzene dye. We analyze the features of the generated localized chiral structures at various parameters of the light beam and LC film, as well as the evolution of the formed chiral structures. Our results reveal different mechanisms for the formation of localized chiral structures. Moreover, they demonstrate a new simple approach to record localized chiral structures with a light beam power of only a few milliwatts. This means that the proposed approach can be successfully applied to generate complex ensembles of chiral structures during their simultaneous formation.

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Functionalized Graphene Oxide Liquid Crystalline Systems Under External Fields

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Over the past decade, considerable attention has been focused on the synthesis and development of graphene oxide (GO) among graphene-family materials, owing to its exceptional physicochemical properties and its ability to form a liquid crystalline (LC) phase [1]. GOLC offers additional tuning and controlling opportunities, due to structural ordering, optical anisotropy, elasticity, electro-optical and non-linear optical properties, as well as its sensitivity to electric and magnetic fields, light, mechanical and temperature changes. The potential applications of this material can be significantly expanded through its functionalization. Particularly, GOLC functionalized with organic molecules, is crucial in modern biomedicine, drug delivery, tissue engineering, and sensing technologies, owing to its relatively long-term biocompatibility and functionality [2]. Decoration of functionalized GOLCs with nanoparticles also reveals additional possibilities for cutting-edge applications.

In this study, we focus on the electrochemical exfoliation and characterization of GO, as well as their LC phase formation possibilities. Additionally, the structural, electrochemical and electro-optical properties of GOLC materials are enhanced by incorporating amino acids and decorating with nanoparticles due to large surface area and functional groups of GO. The presence of nanoparticles in GOLC structure and its functionalization led to an essential increase in its local anisotropy, to a significant change in the isotropic to liquid crystalline phase transition, a notable change in the elasticity, and significant increase in the tunability. Further, response behaviour of functionalized and decorated GOLC in external fields is studied. The findings offer promising prospects for producing GOLCs with enhanced responsiveness and multifunctionality.

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The crystals of L-arginine sulfosalicylates and L-nitroarginine sulfosalicylate

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L-Arginine (L-Arg) and amino acid salts are known for their nonlinear optical and piezoelectric properties, while the polar P21 and P1 groups also have pyroelectric and ferroelectric effects [1]. So far, the following crystals of amino acid salts suitable for application are known with good properties: pyroelectric TGS [2] and LADB [3], nonlinear optical LAP [4], as well as BPI [5]. Salicylic acid and its derivatives, particularly 5-sulfosalicylic acid dihydrate (C7H6O6S·2H_2O or SSA·2H_2O), are known for their anti-inflammatory activity [6]. Therefore, the search and study of salts of L-Arg and SSA·2H2O is of interest both from the point of view of finding crystals with the above-mentioned properties, as well as studying structural features and formation mechanisms.

This work refers to the growth and study of the L-NNA·SSA, L-Arg·SSA and L-Arg·2SSA·H_2O crystals obtained from the interaction of LNNA/L-Arg and SSA·2H_2O. The crystals were studied and identified by the method of FT-IR spectroscopy. Thermal and nonlinear optical properties of crystals were studied. The crystal and molecular structure of the L-Arg·2SSA·H_2O was determined by the X-ray diffraction method at 100K.

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Radiation from a charged particle rotating around a ball of a dispersive matter

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The results of theoretical investigations of the spectral-angular distributions of the radiation generated by an electron rotating around a ball of a dispersive matter are presented. Previously, for nondispersive dielectric ball was shown that for certain values of the problem parameters, at certain harmonics, the electron may generate radiation field quanta exceeding in several dozens of times those generated by electron rotating in a continuous and transparent medium having the same real part of permittivity as the ball material (resonant radiation). In this work, we show that by choosing the dispersion law it is possible to achieve the generation of "resonant" radiation simultaneously at several neighboring harmonics.

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Two-Photon Polymerization 3D Printing of Optical Waveguide Tapers Designed and Optimized with EPSO Algorithm

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Designing optical waveguide components is a crucial aspect of photonics, yet traditional methods are often time-consuming due to the iterative process of fabrication, characterization, and redesign. To streamline this process, we focus on the specific task of optimizing a waveguide taper. We begin with Finite-Difference Time-Domain (FDTD) simulations as a preliminary step and gradually evolve from simple taper shapes to more complex ones, which are refined using Evolutionary Particle Swarm Optimization (EPSO) to meet geometric constraints. We then fabricate over 100 tapers using two-photon polymerization (2PP) and characterize them to evaluate the accuracy of the simulation-based approach. Although the experimental outcomes are not as optimal as the simulations suggest, they generally follow the predicted trends, and the designs optimized through EPSO demonstrate strong performance.

This work was supported by the Science Committee of RA (Research project № 22RL-060).

Determination of the signal power arising from the detection of single photons of different energies by a thermoelectric sensor with different operating temperature

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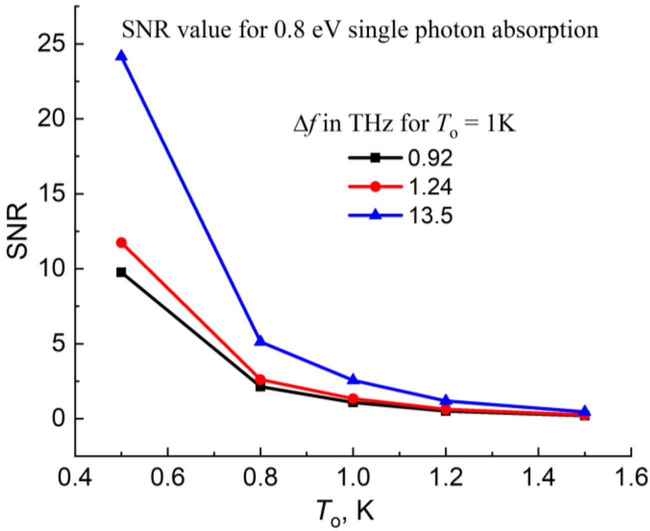
We present the results of modeling and simulation of heat propagation processes in the thermoelectric sensor operating in the temperature range 0.5 – 1.5 K. Absorption of single photons with energies from near infrared to far ultraviolet is considered. The multilayer thermoelectric sensor consists of an absorber (W), a thermoelectric layer ($La_{0.99}Ce_{0.01}B_6$), a heat sink (Mo), and a dielectric substrate (Al_2O_3). The heat transfer processes in the thermoelectric sensor of certain designs were investigated using the three-dimensional matrix method for differential equations based on the heat propagation equation from a limited volume. The temporal dependencies of the average temperature of the layers' surfaces were calculated. Using these data, the temporal dependence of the signal caused by the absorbed photon, namely, the electrical voltage arising at the boundaries of the thermoelectric layer, was determined. The total noise equivalent power of the thermoelectric sensor was calculated and compared with signal power. The signal-to-noise ratio was determined for all considered photon energies and sensor operating temperatures To for the different signal bandwidths Δf. It was found that the signal-to-noise ratio increases with an increase in the energy of the absorbed photon, increase of signal bandwidth, and a decrease in the operating temperature of the sensor. Figure presented the dependence of SNR from sensor operating temperature for different signal bandwidth in the case of 0.8 eV single photon absorption. We have shown that a signal-to-noise ratio greater than unity can be obtained for detecting photons with an energy of 0.8 eV and many times greater than unity for detecting photons with higher energies.


SNR value for 0.8 eV single photon absorption
Δf in THz for T_o = 1K
0.92
1.24
13.5
SNR
T_o, K
0
5
10
15
20
25
0.4
0.6
0.8
1.0
1.2
1.4
1.6

Kinetic equation approach to pair production in Graphene

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Graphene, with its linear dispersion relation near Dirac points mimicking massless Dirac fermions, exhibits a plethora of fascinating phenomena at the intersection of condensed matter and high-energy physics. In this talk, we explore electron-hole pair production in a kinetic equation formalism. The formalism is capable of describing the equivalent physics of the Schwinger effect as well as the pulse-assisted dynamical Schwinger process. Finally, we consider some extensions of the model and compare it with the existing methods and highlight some potential applications.

Influence of Temperature on Intraband Transitions in CdSe Nanoplatelets

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In this study, linear and nonlinear optical effects on colloidal CdSe nanoplates (NPL) were investigated, taking into account the influence of temperature. In particular, the coefficients of linear and nonlinear optical absorption for intraband transitions in the conduction band are determined. It is demonstrated that nonlinear effects are significantly weaker than linear effects; on the other hand, taking into account the influence of temperature leads to a broadening of the absorption curves and a decrease in the absorption peak.

The possibility of the second and third optical harmonic generations in the considered CdSe NPL system was also studied. The impact of the number of nanoplatelet monolayers on the character of the above-mentioned parameters has been revealed.

A New Approach to Chlorination and Dechlorination of Graphene Layers

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Graphene, a two-dimensional material composed of a single layer of carbon atoms arranged in a honeycomb lattice, has garnered significant attention due to its remarkable mechanical, electrical, and thermal properties [1,2]. In our research, we present a novel approach to the chlorination and dechlorination of graphene layers. Utilizing a specialized liquid treatment, we achieve precise chlorination of graphene, while dechlorination is accomplished through targeted proton beam irradiation. These techniques offer an innovative pathway for controlling the chemical composition and properties of graphene [3].

Our study leverages Raman and FTIR spectroscopy, along with Raman imaging, to analyze the structural and chemical modifications induced during these processes. Zeta potential measurements further elucidate the surface charge variations, while I-V measurements reveal the corresponding electrical characteristics.

Notably, proton beam dechlorination opens exciting possibilities for graphene's potential applications in cosmic environments, where radiation resilience and tunable electronic properties are critical. This research highlights new directions for graphene functionalization and expands the material's applicability in advanced technological and space-oriented fields.

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Optical Reservoir Computing With Additional Degree of Freedom

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Reservoir Computing (RC) is a computational approach based on a Recurrent Neural Network. There are many implementations of Reservoir Computing with physical technologies. One of them is Optical RC, which uses the speed of light to its advantage. The reservoir in this case is represented by a scattering media. Mixing of light inside the scattering media represents mixing inside the reservoir. We propose an advanced optical scheme with additional degree of freedom. It provides a better control over the mixing and, therefore, an ability to adapt the system to tasks of different difficulties. Our experimental results show the increase of accuracy in a simple retrieval task. For a task with higher difficulty, results were comparable with the experimental results on a regular Optical RC setup without additional degree of freedom. Besides that, we perform the time predictions on spatiotemporal chaotic datasets obtained from the Kuramoto-Sivashinky equation using optical setup and compare them to the results of simulations with corresponding mixing.

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Engineering arbitrary transmission matrix of the optical system with scattering medium based on spatial light modulation

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Today, machine learning algorithms are rapidly developing, requiring the computation of largescale matrix products. It is known that optical devices can perform linear operations that are applicable in the fields of optical analog computation and machine learning. We propose a method for forming an arbitrary transmission matrix using a scattering medium and a spatial light modulator, which will modulate the phase and amplitude of light. We successfully engineered several arbitrary matrices, and the identity matrix with some error as latter is more complex to construct compared to other matrices. The obtained results have applications in the fields of optical computation and optical imaging. In optical computation, they can be used to calculate the product of large-scale matrices. In optical imaging, they can be used for focusing light after passing through a scattering medium using the DFT matrix, for imaging in scattering medium conditions using the identity matrix, and for other purposes.

Few-particle Intraband Transitions in the Asymmetric Ellipsoidal Quantum Dot

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One particle and a few-particle states have been investigated in the strongly oblate asymmetric ellipsoidal Quantum Dot (QD). All semiaxes are nonequal to each other at the same time semiaxis c in the axial direction is much smaller than two other a and b semiaxes. In the frame of the adiabatic approximation have been shown that the motion in the XOY plane can be described within a two-dimensional asymmetric oscillator approximation. Pair-interacting particle states are described in the frame of the exact solvable Moshinsky model. There have been shown that under the influence of long-wave radiation, the intraband transitions in the few-particle system satisfy the generalized Kohn's theorem conditions. Under the influence of long-wave radiation optical transition diagrams have been obtained.

QED-Based Synchrotron Extension for PIConGPU to Optimize Laser Wakefield Accelerators as X-Ray Sources

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This presentation introduces a Quantum Electrodynamics (QED)-based synchrotron radiation extension for the Particle-in-Cell (PIC) simulation framework PIConGPU, enabling precise modelling of high-energy photon emissions and their impact on plasma dynamics.

The work demonstrates how introducing an angular dispersion to the laser pulse in Laser Wakefield Accelerator (LWFA) setups enhances photon production by increasing electron oscillations and breaking the symmetry of plasma bubbles.

This approach provides critical insights into optimizing LWFA setups for high-energy photon generation, advancing compact accelerator technologies for scientific and medical applications.

General Overview in X-ray Technologies for Cancer Cell Detection and Treatment

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The study of biological systems through biophotonics and X-ray optics explains the energy conversions and optical interactions affect cellular and molecular behavior. The ability of light and radiation to penetrate tissues is used for medical imaging and therapy. X-ray optical technologies, like crystallography and fluorescence, are often used to study cellular structures at the molecular level. This method can accurately map biological materials.

X-ray machines and detectors improve the ability to determine between healthy and malignant tissues. So far, it is known for us, that the development of this technology has not an analogy for early and accurate cancer diagnosis.

On the other hand, biophotonics focuses on the interaction between light and biological matter for imaging and treatment. Photodynamic therapy (PDT) use specific wavelengths of light to activate photosensitizing agents. Selective beams select and destroy cancer cells, but not healthy tissue. In addition, most importantly, it provides a powerful tool against cancer with minimal side effects.

Currently, X-ray technology is actively being developed for the treatment of cancer diseases. The paper discusses the role of biophotonics and X-rays in the advancement of cancer treatment methods. Shows how these technologies contribute to effective therapy. Using the physical properties of energy transformation and optical interactions, researchers are breaking barriers in the fight against cancer and trying to defeat tumors with better imaging and therapy.

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Engineering Electromagnetic Hotspots in Gap-Surface Plasmon Resonators

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The ability to engineer and manipulate electromagnetic hotspots at the nanoscale is pivotal for advancing nanophotonics, particularly in applications such as sensing, spectroscopy, and quantum optics [1]. Gap-surface plasmon nanodisk resonators, characterized by their ability to confine light to nanoscale volumes, offer a powerful platform for generating and controlling these intense electromagnetic fields[2]. Our study focuses on the design and optimization of electromagnetic hotspots within gap-surface plasmon nanodisk resonators.

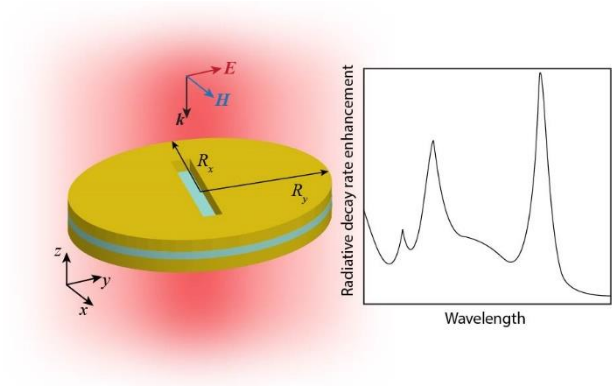

Fig. Schematic of the slotted Gap-surface plasmon resonator and its radiative decay rate enhancement spectrum.

Through numerical simulations, we systematically investigate the impact of various geometric parameters—such as the disk shape, gap width, and disk height—on the localization and enhancement of electromagnetic fields. Our results reveal that the interplay between the disk and gap dimensions plays a crucial role in determining the strength and distribution of the hotspots.

Moreover, we explore the potential of these engineered hotspots to interact with nearby emitters, such as fluorescent molecules or quantum dots, thereby modifying their radiative decay rates. The study highlights how precise control over the nanodisk geometry can maximize the Purcell effect, leading to substantial enhancements in spontaneous emission rates.

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Non-Hermitian control of Hermitian waveguide arrays

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The quantum entanglement of spin states in molecular magnets has important applications in quantum information technologies and quantum computing. Currently, qubit models based on magnetic molecules are being used to develop quantum computation and communication technologies. We consider two models of three-spin molecular magnets with additional features that allow one to manipulate and enhance their entanglement. The first model is a mixed-spin (1/2, 1, 1/2) triangle with two g-factors. The second model is a spin-1/2 triangle with the Katsura-Nagaosa-Balatsky (KNB) mechanism, providing the coupling between spin degrees of freedom and the external electric field. It is shown that non-conserving magnetization originated from the non-uniformity of g-factors leads to an essential increase of the entanglement of certain spin states along with the rich structure of zero-temperature phase diagrams. Whereas, the model with magnetoelectric coupling due to the KNB mechanism offers a wide possibility of manipulation of quantum entanglement by the electric field, both using its magnitude and direction.

Exciton-polaritons in Mie voids

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Spherical nanoparticles are certainly one of the most traditional subjects of interest in photon-ics for which no fundamental questions were believed to remain unanswered [1, 2, 3]. How-ever, a structure such as spherical vacuum voids in dielectric materials did not attract re-searchers' attention until recently [4]. Mie voids -- as they can be perfectly described by Mie theory [5] -- demonstrate the typical resonant properties of dielectric cavities, and they de-pend on the materials in which they are formed. In the present work, we theoretically investi-gate these dependencies and the corresponding coupling occurence for various systems, Fig. 1.

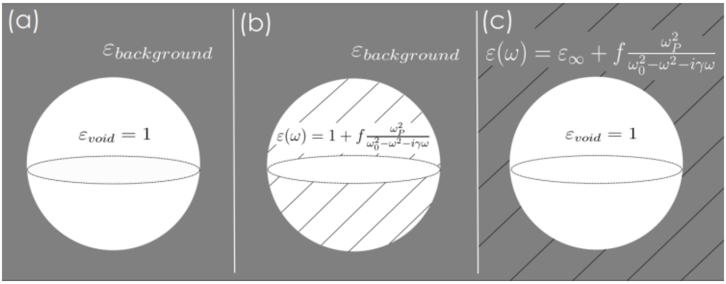

Fig. 1. Schematics of the three classes of systems analyzed in the work. **(a)** an empty Mie void in a dielectric of constant permittivity; **(b)** a Mie void filled with a resonant medium; **(c)** an empty Mie void in a resonant dispersive medium.

We focus on the analysis of hybrid states - polaritons. For the case of Mie voids filled with a resonant medium, Fig. 1(b), we observe different types of coupling and develop analytical criteria of polariton formation. We also examine these states for Mie voids in dispersive mate-rials, Fig. 1(c), seeing both strong and weak coupling, and characterize the resonant increase of quality factor depending on the environmental parameters. The results will open new pro-spects for material design and control of electromagnetic radiation in nanostructures.

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Generation of surface polaritons on cylindrical interfaces

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We investigate the surface polaritons, propagating on a cylindrical interface between two media, generated by charged particles. By using the general expression for the Green tensor of the electromagnetic field in the geometry of a cylindrical waveguide immersed in a homogeneous medium, the electromagnetic fields are presented for two cases of a point charge motion. The first one corresponds to a charge moving outside the cylinder parallel to its axis. In the second geometry the charge uniformly circulates around the cylinder along a circular trajectory with the center on the cylinder axis. The energy losses in the form of surface polaritons are studied for the general case of the dielectric permittivity dispersion of the active medium. The numerical examples are presented for the special case of the Drude model.

Optical phonon self-energy in graphene with spin-orbit coupling

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Optical phonon modes in graphene exhibit Raman scattering with a line width of 13 cm^{-1} at the center of the Brillouin zone at 1580 cm^{-1} (G band). It can be used to estimate the distance of the Fermi energy (ε_F) from the Dirac points [1]. The influence of the Rashba spin-orbit coupling (SOC) induced by an external electric field in single-layer graphene on the frequency shift and broadening of the optical phonon peak was studied. Expressions have been obtained for the latter depending on ε_F and Rashba's SOC constant (δ). It was shown that if the phonon peak broadening caused by the electron-phonon interaction disappears in the absence of SOC [2], and the frequency deviation exhibits a logarithmic behavior when ε_F is equal to the half of the adiabatic value of the optical phonon frequency (ω_0), then with the presence of SOC the phonon logarithmic characteristics of frequency deviation are observed when $\varepsilon_F = (1/2)\sqrt{\omega_0^2 - 4\delta^2}$ or $\varepsilon_F = (1/2)\sqrt{\omega_0^2 - 4\omega_0\delta}$. Along with the further increase of ε_F, the frequency deviation caused by the electron-phonon interaction increases. At the same time, the SOC significantly affects the frequency deviation and broadening of the optical phonon peaks only at small values of ε_F.

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Time Resolved Photoemission Spectrometer

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Sergey Abrahamyan[1], Arsen Ghalumyan[1], Hayk Elbakyan[1], Aram Kakoyan[1],
Hasmik Rostomyan[1], Anna Safaryan[1], Gagik Sughyan[1], John Annand[2],
Kenneth Livingston[2], Rachel Montgomery[2], Patric Achenbach[3],
Joseph Pochodzalla[4], Dimiter L. Balabanski[5], Satoshi N. Nakamura[6],
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Recently an advanced Radio Frequency Timing (RFT) technique has been developed [1, 2]. By converting the time of arrival of incident keV electrons to a hit position on a circle, ellipse or spiral by means of radio frequency electromagnetic fields lying in the range 500-1000 MHz, this device achieves extremely precise timing. Test studies with the RF synchronized femtosecond laser beam demonstrated ∼10 ps time resolution and 0.2 ps/hour stability. The RFT has potential applications in many fields of science and industry [2, 3]. We report the RFT based photoelectron spectrometer (Fig. 1). RF synchronized photons (3) directed to the sample target (8). The emitted electrons are accelerated by a voltage V ∼2.5 kV applied between the target (8) and an accelerating electrode (7). The accelerated electrons are deflected through 90 deg. by the permanent magnet (4) and pass through a collimator (5) before entering the electrostatic lens (9). This focuses the electrons on the position-sensitive detector (PSD) consisting of a dual chevron microchannel plate (MCP) (11) and delay-line anode (12). However before reaching the PSD, the electrons pass through the RF deflection system (10), which performs circular sweeps of keV electrons by means of a 500 MHz radio frequency electromagnetic field. By converting the time of arrival of incident electrons to a hit position on a circle, this device achieves picosecond precise timing and can be used for time resolved photoemission studies [4]. Results of experimental studies from Tantalum, Gold and Graphen will be presented.

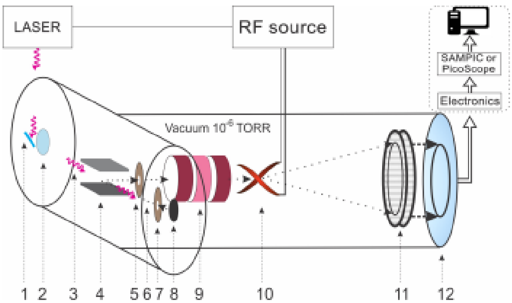

Fig. 1. Schematic of the spectrometer RF. 1 – mirror; 2 – quartz window; 3 – photons; 4 – magnet; 5 – collimator; 6 – photoelectron; 7 – accelerating electrode; 8 – sample target; 9 – electrostatic lens; 10 – RF deflector; 11 – MCPs; 12 – delay line anode.

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Poster Presentations

UV-Visible Spectroscopy and Circular Dichroism methods in the Study of DNA-Porphyrin Complexes

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The interaction of porphyrins H_2TOEtPyP4 and ZnTOEtPyP4 with DNA was studied using UV-visible, circular dichroism (CD) spectra and melting curves. CD spectroscopy used as a tool to detect changes to DNA upon complex formation with porphyrins. Cationic porphyrins interact with DNA via intercalation, groove binding and external binding with self-folding along the DNA helix. The induced optical activity is a characteristic property for different binding modes: negative peak in Soret band characterizes the intercalated porphyrin, and positive Cotton effect belongs to externally bound porphyrins on DNA sites. Bisignate patterns of induced signals indicate exciton coupling of closely located porphyrin units. An increase in the concentration of porphyrins leads to structural changes in the DNA double helix; In the UV region, an inversion similar to the B-Z transition observed in the CD spectra. Such a twisting of the DNA molecule leads to an increase in the ability of porphyrins to bind to DNA. UV-visible spectroscopy was used to obtain absorption spectra and thermal melting curves of DNA in the presence of porphyrins. It was shown that ZnTOEtPyP4 stabilizes the DNA double helix much more strongly than H_2TOEtPyP4. The binding constant (K_b) and stoichiometry (n) for DNA-porphyrin complexes were determined from the binding isotherms. The binding constants of the studied porphyrins with DNA are approximately of the same order, but the exclusion parameter of ZnTOEtPyP4 is twice as large as the exclusion parameter of H_2TOEtPyP4. It is known that porphyrins are capable of forming *H*-type aggregates in aqueous solutions, characterized by a weak red shift and slight hypochromism. Thus, we conclude that ZnTOEtPyP4 molecules with axial ligands can be wedged between DNA base pairs or in the minor groove by flat pyridyl rings of side radicals, but the porphyrin core is located outside the helix, occupying fairly extended sections of the helix.

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Electrical Properties of Doped Zinc Oxide Films and Memory Cell on their Basis

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There is a great interest in materials for one-transistor capacitive memory elements (1T1C DRAM Floating-gate MOSFET) based on a non-junction gate FET with high memory density. ZnO film is an interesting material for creating such memory, since electric properties of ZnO can be controlled by donor or acceptor impurity. The electric properties and conductivity mechanisms of ZnO and ZnO:Li films were investigated in wide frequency and temperature range to demonstrate the possibility of creating a memory cell that combines a capacitor and a field-effect transistor. It was shown that the frequency dependencies of the conductivity are well described by the Mott theory. It has been established that the mechanism of ac conductivity undergoes qualitative changes with increasing lithium concentration: hopping conductivity is replaced by correlated hops through the barrier and tunneling of small radius polarons. Proposed DRAM has a good potential for memory applications because it has a high reading speed; the ratio of currents in states "1" and "0" is about 107, and the holding time exceeds 1 mksec. The mechanisms of charge carrier transport of undoped and doped ZnO thin films were studied. The frequency dependences of the conductivity were studied and interpreted from the point of view of various mechanisms of polaron conductivity in the framework of the Mott theory of hopping conductivity. The results obtained were used for creation of the single-transistor capacitive memory elements (1T1C) and field-effect transistors with floating-gate.

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The investigation of irradiation effect on DNA/cisplatin complexes in presence of AgTOEPyP4 Porphyrin by absorption spectroscopy method

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The aim of this work was to study the influence of X-rays on the DNA and palatinate DNA complexes in presence of porphyrin at different doses of irradiation. To evaluate the enhancing properties of radiation exposure in the presence of these compounds by optical methods[1]. The interaction peculiarities of AgTOEtPyP4 porphyrin with DNA duplexes in presence cisplatin identified by monitoring the changes in absorption spectra in the Soret region. The relative concentrations of complexes (the ratio of the number of porphyrin to the number of DNA base pairs) were adjusted to be 0.01; 0.02; 0.04.The binding constant (K_b) and stoichiometry (n) were determined from binding isotherms for both complexes of porphyrin with platinated and non platinated DNA[2]. The binding constants of the studied porphyrin at platinated DNA are approximately two times higher than non platinated DNA.

Evaluation of DNA/ligand complexes by the UV-thermal melting method is a powerful method to double helix stability characterization [3]. Melting curves of the irradiated DNA molecule already differ from the melting curve of non-irradiated DNA. Thus, irradiation with an X-ray beam leads to structural changes in DNA, which directly affects the melting curves and, consequently, the melting parameters[4]. Thermal melting experiments of DNA and *cisPt*DNA complexes at different relative concentrations of porphyrin were performed at different doses of irradiation (2 Gy and 4 Gy). The melting temperature increases for DNA/cisplatin complexes with an increase in the relative concentration of cisplatin even after irradiated (becomes equal to the melting temperature of the non-irradiated complex).

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Proton Irradiation Tolerance of on $CsPbBr_3$ Perovskites Thin Films

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In this work $CsPbBr_3$ perovskite thin films, obtained through double source physical vapor deposition method were subjected to proton–beam irradiation in order to assess the durability and radiation tolerance of perovskite solar cells against space radiation. There 2 series of samples were made–one for various energies from 1.4 MeV to 15.5 MeV, and the other for various doses from 10^{14}–$5x10^{15}$ p/cm^2. We evaluate the effects of proton beam irradiation by analyzing light absorption properties, crystal structure, and morphology using UV–Vis spectroscopy, X–ray diffraction, and electron microscopy correspondingly.

The results show that dual source vapor deposition is an efficient method for large-scale homogeneous sample preparation. Proton irradiation causes facet reorientation in $CsPbBr_3$ thin films. Microscopy analysis shows that proton irradiation causes grain growth in $CsPbBr_3$ thin films. Photoluminescence quantum yield as well as time resolved photoluminescence measurements show, that optical properties of proton irradiated samples are improved due to elimination of part of grain boundaries and particle grain growth.

The results of the research show that solar cells based on all-inorganic lead halide perovskites can be efficiently applied in space as solar energy harvesters.

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Spectral Analysis of Structural Transitions in G-Quadruplex and i-Motif DNA Structures in the Presence of Urea

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We investigate the impact of urea on the G-quadruplex and i-motif structures of telomeric DNA segments using circular dichroism and UV spectrophotometry methods. Conducted at pH 5.5 and 200 mM Na+, our findings reveal that both Tel22C and Tel22G form stable i-motif and G-quadruplex structures, respectively, under these conditions. We demonstrate that urea (0−8 M) induces destabilization of these structures; however, it does not lead to their complete destruction as observed in thermal denaturation experiments. The melting of the G-quadruplex and i-motif structures occurs at distinct temperature ranges, with G-quadruplex melting beginning at temperatures where i-motif melting is already complete. This separation in melting temperatures is consistent across varying urea concentrations, highlighting the differential stability of these nucleic acid structures in the presence of urea.

The Aesthetic Aspect of Glass Application in Optics

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Nowadays, architectural design has radically transformed the appearance of facades of residential buildings, residential buildings, offices, etc. using glass. Glasses, although fragile, are amorphous bodies formed by supercooling the melt, and they are a complex silicate glassy system of polymerized molecules. However, optical quartz glass is a piece of quartz sand glass with slow heating and cooling, formed as a pure, homogeneous, isotropic, less dense than crystalline quartz material. However, the strength properties of quartz glass are quite higher, and even with high thermal resistance. The analysis revealed that quartz glass is a dielectric material due to its electrical conductivity, and in the presence of a fictitious temperature, the glass cools rapidly. Glass samples with identical composition and with different fictitious temperatures can be sharply differentiated by individual properties, for example, radiation resistance. In a wide spectral range of the wavelength of electromagnetic radiation, the dependence of the refractive index on the frequency of light (often analyzed as the usual case) is a nonlinear system called normal dispersion, if the refractive index increases with the frequency of light. With abnormal dispersion, the refractive index decreases and the detected insignificant fragments are located near the absorption line of the substance. The dependence of the dielectric constant of quartz glass on the frequency of radiation, as well as the regression between the refractive index and wavelength for a transparent medium, is clearly reflected in the Sellmeyer dispersion model. In the UV range of the spectrum, the refractive index of the lens decreases with increasing wavelength, and the focal length, on the contrary, increases. A real lens cannot direct the image to a point, therefore, the image loses clarity, distortions (artifacts) appear. The causes of distortion are considered to be aberration and scattering spots. The higher the refractive index, the more delicate the lens.

Computational Insights into UV Spectrophotometric Behavior of PMMA in the Presence of Pharmaceutical Pollutants through Atomistic Calculations

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Polymers are widely used in environmental applications, particularly in water treatment systems [1]. Pharmaceuticals such as β-blockers (nadolol and pindolol) are emerging contaminants commonly found in water, posing significant risks due to their persistence and bioactivity. Understanding how these pharmaceuticals interact with polymers at the molecular level is crucial for optimizing their use in filtration and purification technologies [2]. This work presents a computational study on how the adsorption of nadolol and pindolol onto polymethyl methacrylate (PMMA) affects the polymer's UV spectrophotometric properties. Using density functional theory (DFT) and time-dependent DFT (TD-DFT), we simulated the UV absorption spectra of PMMA before and after pharmaceutical adsorption. We aim to provide insights into the changes in PMMA's electronic structure and optical transitions resulting from these interactions. Preliminary results indicate substantial shifts in the UV absorption spectra of PMMA after pharmaceutical adsorption, with notable changes in peak positions and intensities. These shifts suggest that the electronic environment of PMMA is altered by the presence of adsorbed nadolol and pindolol, primarily through non-covalent interactions. The computational approach provides a detailed understanding of these effects, which could aid in the design of advanced PMMA-based materials for the removal of pharmaceuticals from water. This study highlights the power of computational simulations in predicting UV spectrophotometric changes in polymer systems, contributing to the development of more efficient and environmentally sustainable water purification technologies.

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Photonic crystal cell nanolaser as an optical frequency standard

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Nanolasers (NL) used as optical frequency standards (OFS) are characterised by a high degree of stability and reproducibility of the emission frequency. At the same time, researchers and developers of NLs primarily solve the problem of obtaining the maximum power of radiation while maintaining coherence, stability and reproducibility of the frequency of radiation was considered only in individual cases [1].

To improve stability, a model of the NL on quantum dots with frequency stabilisation was developed. For this purpose, it is proposed to use a photonic crystal with a defect in which iodine molecules are placed to act as frequency references (Fig. 1 (a)).

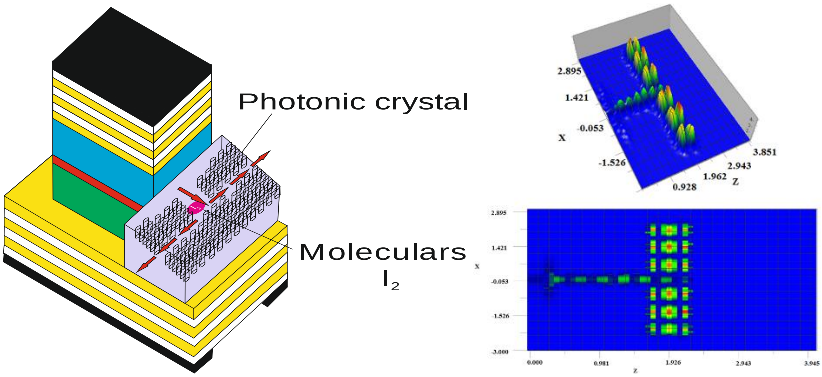

Fig. 1. Schematic of a frequency stabilised quantum dot laser (a) and TE-wave propagation in a photonic crystal with a T-shaped defect (b)

Photonic crystal with a T-shaped defect was modeled to direct NL radiation through iodine molecules for frequency stabilization. The crystal consists of dielectric rods in a hexagonal lattice, with a rod radius-to-lattice constant ratio of 0.25. Photonic band gaps for TE polarization were calculated using the PWE method, located between 0.53-0.84 μm and 1.04-1.45 μm, for λ = 633 nm. The T-shaped defect outputs stabilized radiation and enables heterodyne frequency comparison. Radiation at 630-650 nm is localized in the defect. The finite difference time domain numerical modelling method was used to investigate the field distribution in photonic crystals. Результат моделювання наведено на рисунку 1 (б).

As can be seen from the simulation results (Fig. 5), the NL radiation is concentrated in the defect of the photonic crystal. Output of radiation beyond the boundaries of the photonic crystal defect is limited by the forbidden zone for λ=633 nm. The particles placed in the defect are used to stabilise the NL emission frequency.

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Enhancing Information Transmission Methods Using Femtosecond Radiation

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In telecommunications, there is increasing interest in developing stable sources for the third fiber optic transmission window, particularly ring fiber lasers with passive mode-locking. Erbium-doped optical fibers, operating at a wavelength of 1550 nm, play a key role in this field. It is expected that these lasers will eventually replace many semiconductor data transmission lasers used in Dense Wavelength Division Multiplexing (DWDM) systems according to the ITU frequency grid. Recent years have seen significant progress in ring fiber laser technology, but the field still needs reliable, compact, and cost-effective solutions to compete with the variety of laser diodes available. While existing ring fiber lasers offer advantages, they also face challenges such as complex designs, expensive semiconductor saturable absorbers, and pulse durations of about 200 femtoseconds (fs). Some ring fiber lasers using non-linear polarization rotation (NPR) for mode-locking are more affordable and achieve shorter pulse durations of around 30 fs. However, these lasers still struggle with issues related to stability and mode-locking consistency. To address these issues, our goal is to develop a ring fiber laser circuit and explore mode-locking

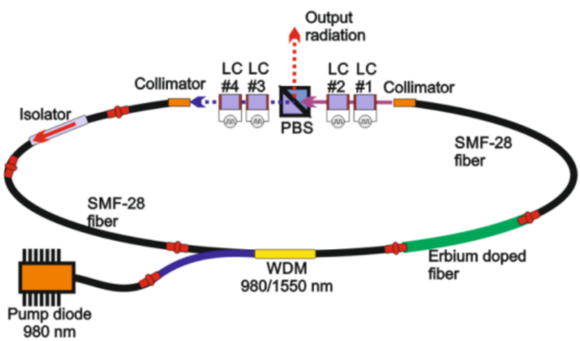

Fig. 1

techniques using liquid-crystal (LC) polarizers. NPR involves the interaction between the polarization of electromagnetic waves and the strength of radiation, where a polarizing beam splitter (PBS) acts as a saturable absorber to stimulate laser pulse generation. Effective mode-locking requires controlling polarization in a non-linear medium. This can be achieved using polarizers or wave plates, which rotate to maintain the necessary polarization state. Precise motorized polarization rotators have been proposed, while mechanical methods such as fiber bending and piezoelectric actuators offer alternative solutions. However, these methods often require prolonged tuning and can result in performance drift. We propose using LC polarizers for electronic control of the NPR mode (Fig.1). LC polarizers offer low-voltage control signals, fast response times, and long-term stability, potentially improving the performance and reliability of ring fiber lasers [1-2].

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α–$LiIO_3$ Single Crystals Doped with some Amino Acids

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Crystals with nonlinear optical properties are widely used in various technologies. In recent years, large-scale works have been done on improving the properties of applicable crystals (lithium iodate, triglycine acetate, TGS) using some substances as dopants [1-4]. Notably, some research groups have reported improvements in the physical properties of several crystals (KDP, ADP, BTCA, ZTC) grown with various amino acid dopants [5-7].

In this study, the effect of doping amino acids L-arginine (L-Arg), L-nitroarginine (L-NNA), L–Histidine (L-His), L-Alanine (L-Ala), and Glycine (Gly) on α-$LiIO_3$ single crystal was presented. The crystals were grown by the method described by Hovhannesyan AA et al [8]. The solution, doped L-His was decomposed. Bulk crystals were grown from solutions doped L-Arg, L-NNA, L-Ala, and Gly and from the pure solution of α-$LiIO_3$.

These grown crystals were studied by single-crystal X-ray diffraction, IR and UV-Vis spectroscopy, and second harmonic generation methods. The XRD data of pure and doped crystals are in good agreement with the reported literature values of pure α-$LiIO_3$ [9], indicating that doping with amino acids does not violate the parameters of the crystal lattice. However, the presence of amino acids in α-$LiIO_3$ crystal can be identified due to IR spectra. From the grown crystals, 1 mm plates were cut with planes perpendicular to the z and y axes, and their UV-VIS spectra were recorded. Studies showed, that the optical quality and physicochemical properties of the α-$LiIO_3$ crystal grown in the presence of amino acids are improved. The obtained experimental data indicated that the second harmonic generation activity of the crystals of α–$LiIO_3$ grown with dopants was higher than that of pure α–$LiIO_3$ (L–Arg and L–NNA (1.5 times), L-Ala (1.58 times), Gly (1.27 times)).

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Quasi-bound states in the continuum in finite asymmetric waveguide gratings

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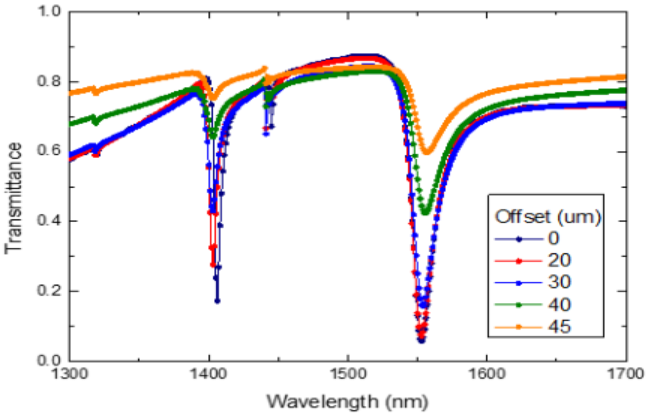
Bound states in the continuum (BICs) offer unique opportunities for studying strong coupling regimes due to their infinite Q-factors and localized mode volumes. However, the experimental realization of true BICs remains challenging. Consequently, researchers frequently employ symmetry-breaking techniques to transform symmetry-protected BICs into quasi-BICs (q-BICs), which exhibit finite yet extremely high Q-factors. This study examines the occurrence of q-BIC within finite all-dielectric asymmetric grating waveguide couplers, focusing on various degrees of asymmetry under normal light incidence. The research aims to identify optimal configurations for achieving the highest quality Q-factor while maintaining maximum efficiency. We analyze asymmetric gratings created by modifying every N-th element of a conventional symmetric grating coupler, exploring the interplay between coupling to waveguide modes and band gap effects induced by Bragg reflection. Our investigation encompasses symmetric, double-period, and triple-period asymmetric grating couplers, all designed to exhibit total transmission extinction at desired wavelengths. To simulate realistic excitation conditions, we employ Gaussian beam illumination in our analysis.
We conduct a comparative analysis between infinite and finite structures, examining how the transition from an idealized infinite model to a practical finite system affects the electromagnetic properties and q-BIC characteristics.



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Ultrabroadband, ultranarrowband and ultrapassband composite polarisation half-wave plates, ultrabroadband composite polarisation pi-rotators and on the quantum-classical analogy

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Composite pulses, which produce ultrabroadband, ultranarrowband and ultrapassband (x,y) rotations by $\theta=\pi$ on the Bloch-Poincaré sphere, are presented. The first class plays a role for design of achromatic polarisation retarders, when the second class corresponds to chromatic polarisation filters. The third class is an assortment of the above two classes. Besides, composite pulses, which produce ultrabroadband z rotations by $\zeta=\pi$ on the same sphere, are presented. These phasal pulses coincide with achromatic polarisation π rotators. On the quantum-classical analogy, we obtain ultrarobust, ultrasensitive and ultrasquare quantum control of a X gate and ultrarobust quantum control of a Z gate.

For instance, our proposed ultrabroadband composite polarization waveplates can operate in the ultrabroad range from ultraviolet to mid infrared, and, importantly, it goes beyond the boundaries of the transparency range of the most commonly used quartz waveplate. We believe that the derivation method can be used to obtain even longer composite waveplates, and the results can be used for the highly transparent waveplate materials like the sapphire, the magnesium fluoride MgF_2, or for the novel materials and metamaterials.

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Solar Cell thin films from hybrid perovskite nanocrystals

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Perovskites, with their unique ABX_3 crystal structure, have emerged as highly promising materials for solar cell applications due to their exceptional light absorption, tunable band gaps, and high charge-carrier mobility. Recent advances in fabrication techniques enable cost-effective production, while power conversion efficiencies of perovskite solar cells (PSCs) now rival those of traditional silicon-based cells.

Ongoing research focuses on optimizing composition through machine learning models, DFT calculations and experimental methods and to enhance stability, reduce toxicity, and improve overall photovoltaic performance. In current project we successfully synthesized and characterized theoretically obtained composite, and were able to achieve strong alignment between theoretical and experimental results of energy band gaps. Moreover, we optimized various steps from synthesis to films: UV treatment and temperature of substrates, spin coating regimes and further steps. Eventually, we obtained simplified procedure of thin film preparation with high adhesion of a substrate and uniform repeatable multilayer film as a result.

Synthesis, Characterization and Liquid Crystalline Phase Formation of MoS_2

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Molybdenum disulfide (MoS2) is one of the most widely used transition metal dichalcogenides, valued for its unique optoelectronic, thermal, mechanical, and chemical properties. MoS_2 has garnered considerable attention for its ability to form liquid crystalline (LC) phase, which is important in designing various small, thin and even flexible devices with tunable parameters [1]. This potential stems from the integration of the self-assembling properties of LCs with the remarkable physicochemical characteristics of MoS_2.

In this study, we focus on the synthesis and characterization of MoS_2. Particularly, CVD method was used for MoS_2 growth followed by the PMMA-assisted transport technique. The crystallographic structure, chemical composition, bond types/hybridizations, absorbance, photoluminescence, morphology, particle size distribution of the synthesized material are characterized using various techniques, including XRD, FTIR-ATR, Raman, UV-Vis, PL spectroscopy, SEM, and DLS technique. Additionally, we study the possibilities of MoS_2 LC formation with careful selection of the solvent and precise control of the sizes and concentrations of the dispersed nanoflakes. The LC phase of the above-mentioned material is examined by polarizing optical microscope. MoS_2 LC will pave the way for new applications in optoelectronics and photonics [2].

Acknowledgments

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Tamm Plasmon Resonance for a Nanolaser Configuration

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The so-called Tamm plasmon resonance can be excited at the interface between a distributed Bragg reflector (DBR) and a thin noble metal film. Such a mode demonstrates both plasmon and cavity properties. Firstly, the Tamm plasmon polariton resonance was theoretically found in 2007 and confirmed experimentally the next year – see references in [1]. It has various applications including photodetectors [2], optical bistable devices [3], and nano- and microlasers [4].

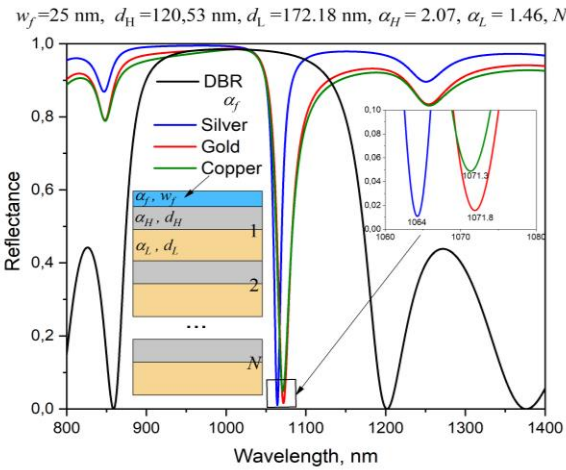

Fig. 1. Reflectance spectra of the BDR-only and the full configuration with a silver, gold, and copper film in the IR

The considered structure is shown in Fig.1, which consists of the noble metal film of thickness wf and refractive index αf, and finite Bragg reflector of N=8 pairs of layers H and L, with α_H, d_H and α_L, d_L parameters, respectively. We use the transfer matrix method (TMM) to study the scattering and absorption of plane electromagnetic wave, incident normally on the noble metal film. In Fig. 1, we present the reflectance versus the IR wavelength for the DBR in the free space and the whole depicted configuration with metal film made of silver, gold, and copper and all other parameters are as indicated. The metal refractive index values are borrowed from experimental data of [5].

The plots demonstrate a sharp resonance in the forbidden zone of DBR (black line), which can be identified as Tamm plasmon mode (TPM). As one can see from the zooms in the TPM vicinity, the deepest resonance belongs to the silver film (because of the lowest losses) and stands at 1064 nm. Note that we have tailored the structure parameters to the Nd:YAG laser crystal emission wavelength band.

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New generation fiber optic gyroscopes

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The work presents research on the operation of a fiber-optic gyroscope. It consists of the following components: a superluminescent laser diode (wavelength 1550 nm), a circulator, a splitter, a phase modulator, and a 500-meter optical fiber coil (fiber type: Panda). Figure 1 illustrates the operation of this gyroscope [1], which meets the average accuracy metrics of existing analogs. However, there are currently active developments and implementations of photonic crystal fibers (PCF) and polarization-maintaining optical fibers (PANDA), which possess a range of attractive properties for use in fiber-optic gyroscopes: fully integrated construction, fiber length around one meter, no need for fiber winding on a spool, and a compact device. PCFs have a complex structure that affects their properties as photonic crystals (PC). Depending on the width of the photonic bandgap, PCFs can be classified as conductors, insulators, semiconductors, or superconductors for electromagnetic waves. Conductors have broad allowed

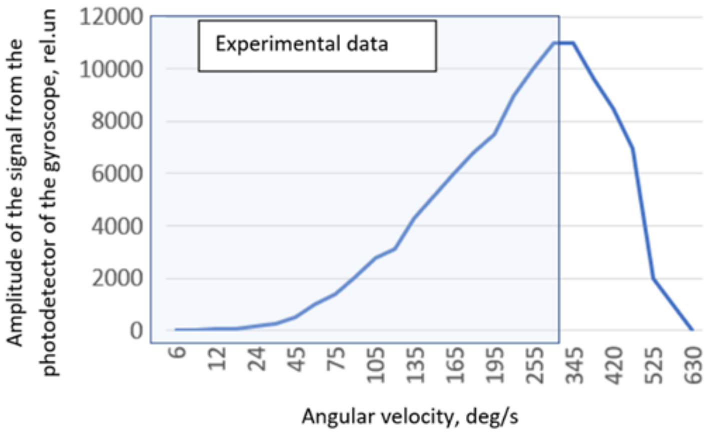

Fig. 1

bands for light propagation with minimal absorption, while insulators have wide forbidden bands and act as ideal mirrors with no light absorption. Semiconductors can selectively reflect photons of certain wavelengths. The hollow core of PCFs and PANDA-type fibers offer advantages over standard optical fibers: operation in a single-mode regime over a broad wavelength range, ability to handle intense radiation, larger mode area, low optical nonlinearity, precise dispersion control, and anomalous dispersion of the waveguide with high steepness through Rayleigh scattering. Additionally, the use of photonic crystal fibers allows for the implementation of a fiber-optic gyroscope based on supercontinuum generation [2]. These studies are being conducted by the team presented in this work.

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Enhancement of Optical Methods and Systems for Object Sensing in Space

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In the field of spatial object sensing, an important task is the investigation of the parameters of both reflected and probing laser radiation. This task is crucial for the development and improvement of technologies used to detect and analyze optical devices. Laser optoelectronic systems are employed to scan the surrounding environment with a laser beam to identify reflective surfaces. This study presents a novel model for investigating the parameters and dynamics of laser radiation, treated as a nonlinear dynamic system. The model facilitates the measurement of physical quantities using nonlinear metrological methods, such as fractal dimension analysis and other topological tools. It is based on the assumption that measured quantities can be represented by interval values and allows for the transition from stationary to random dynamics. The model includes an experimental scheme that outlines various stages and procedures for evaluating measurement results. A key feature of this model is its systemic approach, which enables effective investigation of both stationary and chaotic modes of laser radiation dynamics. This approach allows for the measurement of parameter intervals in different modes, evaluation of their stability, and prediction of time series based on the obtained data. The classification of system dynamics is performed using fractal dimension methods, providing a detailed analysis of laser radiation behavior. The model can be applied both to ensure the stability of laser light parameters and to manage random radiation. The study focuses on a pulsed laser, with the main parameters of radiation including pulse energy, pulse duration, pulse repetition frequency, stability of values, and spectral characteristics. The experimental setup, shown in Figure 1 [1-2], includes an injection system, laser, beam splitters, pulse energy meter, spectral analyzer, pulse duration measurement block, pulse repetition frequency measurement block, and a control, synchronization, and data recording system.

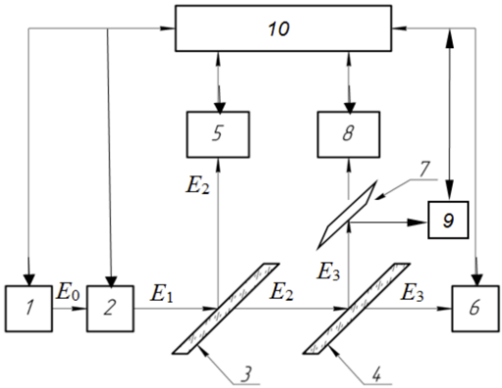

Fig.1. 1 is the injection system; 2 is a laser; 3, 4, 7 are dividing plates; 5 is a pulse energy meter; 6 is a spectrum analyzer; 8 is a pulse duration measuring unit; 9 is a pulse repetition frequency measuring unit; 10 is a system for control, synchronization and recording of the measurement results

This setup provides a comprehensive approach to studying laser radiation parameters and allows for detailed analysis of its characteristics under various experimental conditions.

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On the theory of the Lorenz-Mie phase shifts

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In accordance with the Lorenz-Mie (LM) plane-wave theory for the scattering of light by a homogeneous spherical particle [1], the analytical structure of the total scattering cross section depends on the phase shifts of partial waves with $l \geq 1$, where l is the orbital angular momentum (OAM). The objective in this presentation is to unravel and examine in some detail the salient features of the LM phase shifts associated with the two peculiar [2] values of the OAM, $l = 0$ and $l = -1$. The relevance of such an examination for the studies of the Friedel phase originating in a Fabry-Perot model [3] is discussed. Several facets of the LM phase shifts are investigated under the restrictive constraints of the Rayleigh-Gans approximation [1] and in the index-near-zero [4] limit.

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Optical Properties of Ag-Doped ZnO Films

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Doping ZnO with silver improves its optical and electrical properties [1]. For this purpose, $Zn_{1-x}Ag_xO$ films (x=0.05 and 0.24 at%) are synthesized using e-beam evaporation technique. XRD results confirm that the films are polycrystalline with a typical hexagonal wurtzite structure and do not contain any other impurity or dopant phases. The crystallite size, as determined from XRD spectra, increases from 20 nm to 24 nm with increasing Ag content in the 0.05 and 0.24 at% Ag-doped films. SEM analysis reveals that the grains become more aggregated with increasing Ag concentration. The optical and IR properties of Ag-doped ZnO films are investigated. The value of the optical band gap energy Eg varies from 3.284 eV to 3.267 eV for the 0.05 and 0.24 at%Ag annealed films, respectively. The observed decrease in the optical band gap can be directly attributed to the effect of Ag ion incorporation into the ZnO lattice after annealing.

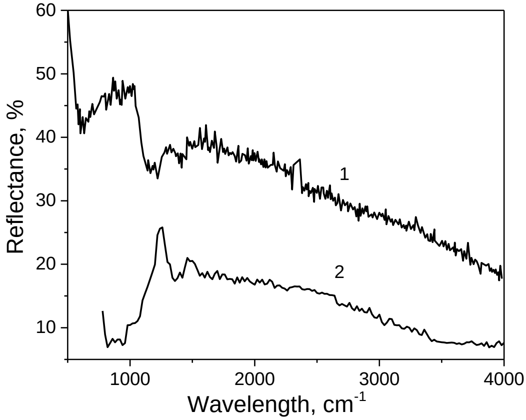

Fig. 1. Infrared reflectivity spectra of 0.05 (1) and 0.24 (2) at. % Ag-doped ZnO films.

The IR reflectivity spectra of the films show that reflectivity decreases with increasing Ag concentration, with the formation of polarons observed in the annealed 0.24 at% Ag-doped ZnO films (Fig. 1).

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Effect of ZnO Nanoparticles on DNA Stability under UV-Irradiation

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The effect of ionizing UV-radiation on the blood erythrocytes was studied using UV-Vis spectra and UV-melting curves on a Lambda 800 UV/VIS spectrometer (Perkin-Elmer). Zinc oxide nanoparticles, as one of the most important metal oxide nanoparticles, are widely used in various fields due to their physical and chemical properties. ZnO NPs have antibacterial and antimicrobial properties and are used to deliver chemotherapeutic agents in the cancer treatment [1]. As the main component of various enzyme systems, zinc takes part in the body's metabolism and plays crucial roles in proteins and nucleic acid synthesis, hematopoiesis, and neurogenesis. ZnO nanoparticles were added to the blood samples, incubated for 24 hours, and then a portion of the blood was irradiated with Medicor 50-60 Hz UV-lamp for 10 minutes. Irradiation was carried out both in the absence and in the presence of ZnO nanoparticles. In the absorption spectra during irradiation, an increase in the absorption intensity in the region of the Soret band at 420 nm was observed, which indicates the hemolysis of erythrocytes and the release of hemoglobin. DNA from blood samples was isolated using GenElute™ Blood Genomic DNA Kit. DNA samples isolated from intact blood and irradiated blood were used as controls. The stability of DNA molecules was studied using UV-thermal melting. Melting experiments were carried out at 260 nm, with a heating rate of 0.25^{o}C/min 25-95^{o}C temperature interval, using 10 mm thermostatic quartz cuvettes. From the obtained DNA melting curves, the melting temperature T_m and melting range ΔT were calculated [2]. For control DNA, T_m was 7.2^{o}C and ΔT was 9.75^{o}C. DNA isolated from irradiated blood samples had worse characteristics: a decrease in T_m and an increase in ΔT were observed. The presence of nanoparticles in blood samples contributed to sensitivity to UV-irradiation.

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Hyperspectral imaging with Fourier transform

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Hyperspectral imaging (HSI) is a spectral sensing technique that captures hundreds of contiguous narrowband images in the visible and infrared regions of the electromagnetic spectrum. Existing HSI systems have disadvantages, such as low speed, high cost and complex structure [1]. One of the methods to increase the speed is to reduce the sampling rate or increase the number of sampling channels. However, the large amount of data still prevents further speed improvements. This problem can be solved by using single-pixel imaging methods [2]. High spectral resolution has been achieved due to the high performance of the single-detector fibre spectrometer, but problems with light acquisition, time scanning and other technical limitations still exist.

As an alternative method of spectral imaging, Fourier transform spectral imaging (FTSI) technology has the advantages of high detection sensitivity and light throughput. Current FTSI methods use a single detector to scan a single spot or acquire images one at a time through an array of detectors [3].

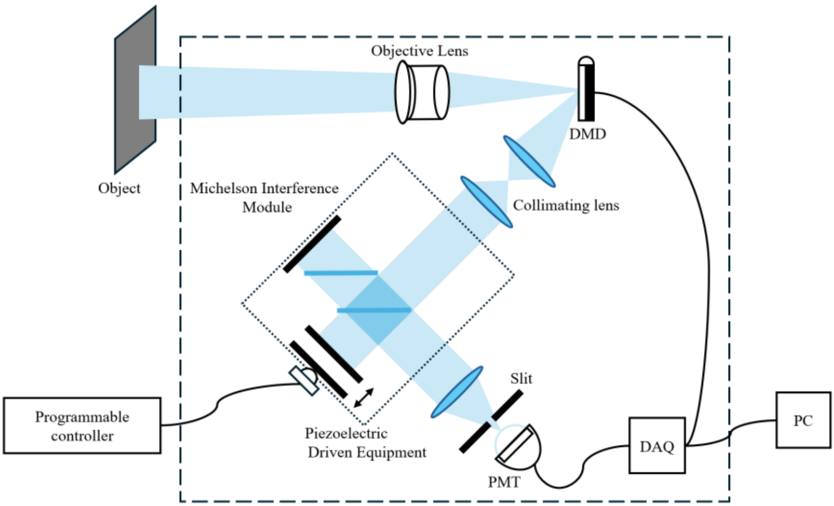

Fig. 1. Proposed setup of the Fourier transform hyperspectral imaging system

The proposed setup is shown in the figure 1, consisting of a digital micromirror device (DMD), collimating lens, Michelson interference module, photomultiplier tube (PMT), data acquisition device (DAQ), and personal computer (PC). The spectra were obtained by calculating the inverse Fourier transform of the collected data.

Thus, FTSI has higher sensitivity and better light throughput than traditional methods, resulting in improved signal quality, especially in low-light conditions, while achieving high spectral resolution.

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Temperature measurements using Bragg sensor

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Over past few decades, fiber-optic sensing has established itself as an innovative and versatile measurement technology for numerous physical parameters such as temperature, strain, displacement, angular velocity, field intensity, etc . Due to their inherent advantages, fiber optic sensors have found wide use ranging from industrial, scientific and navigation applications to healthcare. Being chemically inert, immune to external electric and magnetic fields, capable of remote operation this type of sensors show great prospects for development of novel biomedical instrumentation, allowing multiplexed disturbed sensing in real time.

A simple fiber optic temperature sensor system that utilizes reflective Bragg element as a sensing head has been proposed. The main advantage of the proposed approach relies on the use of widely available low-cost telecommunication devices, such as a DFB laser light source and commonly used fiber optics components. Another important advantage of the sensor system is the measurement technique that doesn't require optical spectrometer or other precise optical measurements, such as interferometry. It is shown that by implementing various Bragg structures as the sensing element it is possible to alter optical response, thus achieving required characteristics of the sensor. Calculations for Bragg structures are presented for both narrow range sensor that can find medical use and wide range temperature sensor with $\Delta T \sim 200$ °C as well as general overview and operation principle of the proposed temperature measurement system.

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Features of the operation of an acoustoplasma magnetron

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Acoustoplasma magnetrons (APM) were developed and patented in our Institute (IAPP) and can be used for various purposes. The report discusses experiments on the use of APM for the deposition of thin films. APM has the properties of both magnetron and glow discharges. Firstly, the cathode of such a discharge works in the same way as in a conventional magnetron, but in addition, similar to a glow discharge, the discharge has a positive column. In APM, the distance between the anode and cathode must be large enough to form a positive column of discharge with acoustoplasma. This leads to an increase in the anode voltage, compared to a conventional magnetron. Secondly, the deposited substrate is either located close to the anode or is electrically connected directly to the anode. Therefore, electrons and negative ions bombard the substrate with energy sufficient to knock atoms out of the substrate, and the substrate and the deposited layer are etched. Because of this, on the one hand, the coating process slows down, but on the other hand various coating defects that weaken adhesion to the substrate surface will be etched more easily in the discharge than defect-free parts. By changing the discharge current, pressure, and type of buffer gas, it is possible to control the rate of such etching. Thirdly, the spraying mode can be changed so much that instead of a dense coating we get a porous coating, and different coatings can be obtained in one technological process sequentially. Fourthly, it is possible to spray oxides and other compositions with variable stoichiometry. For example, it is possible to spray NiOx, where x can be greater, less, or equal to one.

The spraying of various metals (Ag, Al, Cu, Ge, Si, W, Zn) and metal oxides (TiO_2,NiO_x,Ni_2O_3,CsI,ZnO) was studied. The main goal of this cycle of works is the creation of a new generation of solar cells.

Fraunhofer diffraction on a slit when light passes from a material medium into a vacuum

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In continuation of our series of works on Fraunhofer diffraction on a slit when light passes from a vacuum into a material medium, this article examines the inverse problem: when light diffracts from a material medium into a vacuum. Some features of Fraunhofer diffraction are revealed in the case when the medium from which the light falls on the slit is optically isotropic and homogeneous.

Study of the influence of the stress-strain state of the interferometer block on its X-ray topographic pattern

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This work examines the effect of mechanical damage to the X-ray interferometer block on its X-ray diffraction pattern. An explanation is given for the origin of the contrast caused by imperfections in the crystal structure of the interferometer block that arise when it is mechanically damaged.

It has been proven both theoretically and experimentally that the curvature of interference fringes in a moiré topogram is the result of scratches applied to the surface of the crystal block of the X-ray interferometer. The dependence of the period of moiré patterns on the density of dislocation and their movement has been determined. The average value of the dislocation density near the scratch center is calculated. It is shown that the period of the moiré pattern is inversely proportional to the dislocation density.

It has been experimentally proven that a change in the moiré pattern also occurs when the crystal contains dislocations generated as a result of a scratch applied to the surface of the X-ray interferometer crystalline block. The geometric parameters of the scratch applied to the surface of the interferometer crystal block are determined. The scratch depth and the length of the dislocation group are calculated.

Modeling and simulation of the heat propagation processes occurring in a nanoscale thermoelectric sensor of a single-photon detector

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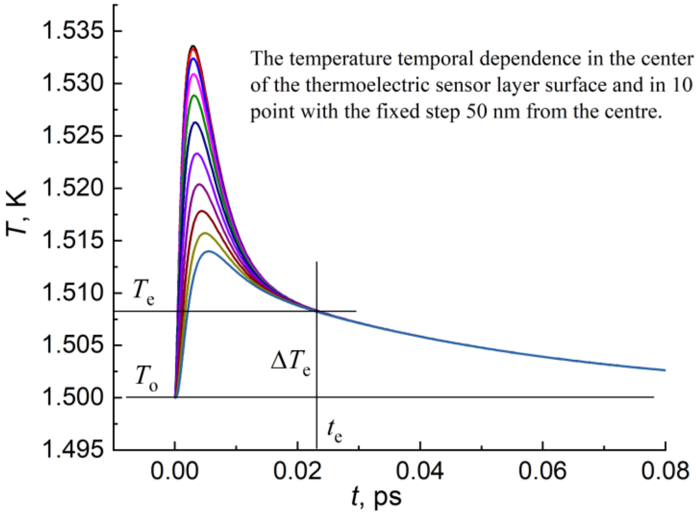
We present the results of modeling and simulation of the heat propagation processes occurring in a nanoscale W/$La_{0.99}Ce_{0.01}B_6$/Mo/Al_2O_3 thermoelectric sensor of a single-photon detector. The sensor has a surface area of 1μm × 1μm, with layer thicknesses of 15, 10, 10, and 100 nm respectively for absorber, thermoelectric layer, heat sink, and substrate are considered. Calculations were performed using the three-dimensional matrix method based on the equation of heat propagation from a limited volume. The temperature temporal dependences of different areas of the sensor were investigated. The parameters T_e and t_e, as shown in the figure, represent temperature equalization levels of 1 and 0.1 mK, respectively, measured at the center of the surface of all layers and at 10 points with a fixed step of 50 nm from the center to the edge were determined. The features and patterns of heat propagation in the thermoelectric sensor at operating temperature T_o of 0.5, 0.8, 1, 1.2, and 1.5 K after absorption of photons with an energy of 0.8, 1.65, 3.1, and 7.1 eV were revealed. The parameter $\Delta T_e = T_e - T_o$ is also calculated. The obtained results show that the parameters T_e, ΔT_e and t_e have close values for the absorber and thermoelectric layer surfaces, as well as the heat sink and substrate. These parameters are significantly higher for the absorber and thermoelectric layer surfaces and increase with increasing energy of the absorbed photon for the surfaces of all layers. The dependence of the considered parameters on the operating temperature is complex. The following pattern has the most general character. The parameters ΔT_e and t_e decrease with increasing operating temperature. The obtained patterns will be used to optimize the design of the thermoelectric sensor.



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The temperature temporal dependence in the center of the thermoelectric sensor layer surface and in 10 point with the fixed step 50 nm from the centre.
T_e
T_o
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0.00
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0.08
t, ps

Synchrotron radiation extension for PIConGPU

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The poster presents an extension for the Particle-in-Cell (PIC) simulation code, incorporating Quantum Electrodynamics effects to enhance the simulation of plasma phenomena. PIConGPU, a highly scalable and open-source 3D PIC code, is employed to model complex interactions in plasma physics. The implemented algorithm approximates synchrotron radiation by calculating photon emission probabilities. Future applications include studying betatron radiation and electron bunch cooling in laser wakefield accelerators. This work aims to provide a comprehensive toolkit for simulating and analyzing high-energy plasma interactions, contributing to advancements in small electron accelerators.

Pattern Recognition Model Based on Topological Analysis

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The topic "Pattern Recognition Model Based on Topological Analysis" is promising in the field of computer vision, but there are several challenges at the start of the research. First, one key problem is how to represent the data. Traditional machine learning methods for pattern recognition use pixel information or geometric features of objects. However, topological analysis focuses on topological features like the number of connected components or holes in an object. This can be hard to understand and model because these features are global and don't change with small changes in the object.

The second problem is choosing the right metrics and algorithms for topological analysis. Tools like persistent homology are powerful for understanding data structure, but integrating them with machine learning models requires new ways to process this information. Specifically, converting complex topological data into input for neural networks or other models needs special algorithms that can include topological features during training.

The third issue is interpreting the results. Topological analysis, especially persistent homology, often produces complex visual outputs (like barcodes and diagrams) that are hard to understand without deep knowledge of topology. This makes it difficult to evaluate the model's effectiveness and choose the best parameters for its operation.

In summary, the main challenges include integrating topological analysis with machine learning methods, selecting the right algorithms, and interpreting the results, all of which require further research and the development of new approaches to solve these problems.

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Design, development and optimization of a homemade non-contact photolithography system

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The significance of scientific studies in the field of optics at micron scale and related devices such as Diffractive Optical Elements (DOEs), as well as interdisciplinary studies in the field of biology and its devices like microchannels, has highlighted the importance of designing an adjustable optical setup for constructing the aforementioned devices. Various processes exist for creating these micron-scale elements. In the Microfluidics Laboratory at IASBS university in Zanjan, microchannels for scientific research were being created; however, the optical setup in use was very rudimentary and error-prone. Therefore, a new design for creating an adjustable setup with higher precision was developed. The following section outlines the work carried out.

Machine Learning-Based Optimization of Programmable Quantum All Logic Elements

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In this work, we explore the application of mathematical optimization methods, enhanced by machine learning principles[1] to determine the necessary parameters for accurately modeling the behavior of all quantum logic elements for qutrits[2]. These methods efficiently identified optimal configurations, significantly reducing theoretical calculation time and improving the reliability of the quantum system.

Particular attention was given to issues of stability and implementation accuracy. We analyzed the impact of various factors, such as decoherence processes, on the performance of our qutrit quantum gates.

The results of our research demonstrate that the proposed approach to implementing simple logic elements in a programmable quantum system with three inputs and three outputs holds promise for the further development of quantum computing, especially in systems that work with qutrits. The integration of mathematical optimization methods into the development process has significantly enhanced the efficiency and accuracy of these quantum systems.

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Dispersion Properties of Magneto-Photonic Crystals

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Magneto-photonic crystals (MPCs) are artificial structures that are periodically arranged unit cells composed of magnetic and non-magnetic materials, creating a photonic crystal with built-in magneto-optical effects [1].

Along with the properties inherent in conventional PCs, these structures have additional optical and magneto-optical properties which considerably expand their functionality. Kerr effect, Faraday rotation and optical nonlinearity can be enhanced in MPCs due to light localization within magnetic multilayer.

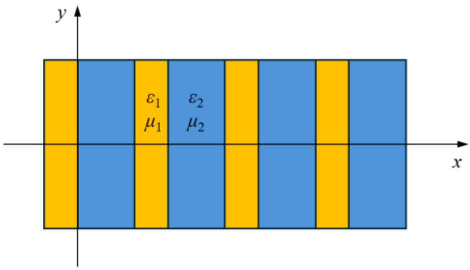

Fig. 1. Structure of a 1D magnetophotonic crystal [2]

One-dimensional crystals can be described using the Abel transfer matrix method, but this method cannot be applied in general case for anisotropic multilayer structures because of mode coupling. However, this is possible in special cases, namely, in two-dimensional model of wave propagation in periodic layered media. Such an approach makes it possible to simplify significantly the analysis of physical phenomena in complex layered media with various combinations of gyrotropic and isotropic elements.

The matrix equation (Eq. 1) described in the article [2] allows to find the characteristic (dispersion) equation for determining the unknown longitudinal wave number β for a wave propagating along gyrotropic layers (along the Oy axis) and the Floquet-Bloch wave number K.

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix}\begin{pmatrix} a_n \\ b_n \end{pmatrix} = e^{-iKL}\begin{pmatrix} a_n \\ b_n \end{pmatrix} \tag{1}$$

The phase factor e^{-iKL} is the eigenvalue of the ABCD transfer-matrix, which is determined from the characteristic equation:

$$e^{-iKL} = \frac{1}{2}\left(A+D\right) \pm i\sqrt{1-\left[\frac{1}{2}\left(A+D\right)\right]^2}. \tag{2}$$

The unknown real values of the roots of the characteristic equation have such form for TM polarization of radiation:

$$K_{TM}\left(\beta\right) = \frac{1}{L}\arccos\left\{\cos\xi_2 b\cos\xi_1 a - \frac{1}{2}\left[\begin{matrix} \frac{\xi_1}{\xi_2}\frac{\mu_{\perp 2}}{\mu_{\perp 1}} + \frac{\xi_2}{\xi_1}\frac{\mu_{\perp 1}}{\mu_{\perp 2}} + \\ + \frac{\beta^2}{\xi_1\xi_2}\frac{\mu_{\perp 2}}{\mu_{\perp 1}}\left(\frac{\mu_{a1}}{\mu_1} - \frac{\mu_{\perp 1}}{\mu_{\perp 2}}\frac{\mu_{a2}}{\mu_2}\right)^2 \end{matrix}\right]\sin\xi_2 b\sin\xi_1 a\right\}. \tag{3}$$

Using the permutation duality principle, the solutions of TE wave propagation in a gyrotropic MPC were found:

$$K_{TE}\left(\beta\right) = \frac{1}{L}\arccos\left\{\cos\xi_2 b\cos\xi_1 a - \frac{1}{2}\left[\begin{matrix} \frac{\xi_1}{\xi_2}\frac{\varepsilon_{\perp 2}}{\varepsilon_{\perp 1}} + \frac{\xi_2}{\xi_1}\frac{\varepsilon_{\perp 1}}{\varepsilon_{\perp 2}} + \\ + \frac{\beta^2}{\xi_1\xi_2}\frac{\varepsilon_{\perp 2}}{\varepsilon_{\perp 1}}\left(\frac{\varepsilon_{a1}}{\varepsilon_1} - \frac{\varepsilon_{\perp 1}}{\varepsilon_{\perp 2}}\frac{\varepsilon_{a2}}{\varepsilon_2}\right)^2 \end{matrix}\right]\sin\xi_2 b\sin\xi_1 a\right\}. \tag{4}$$

Thus, this paper presents solutions to the dispersion equations for both TM- and TE-polarizations, which are suitable for analyzing of dispersion properties of the wide range of MPCs with different material parameters: two isotropic layers on the crystal period, one isotropic layer with another anisotropic layer, two gyroelectric or gyromagnetic layers, or a combination of both, and two gyrotropic layers.

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Photonic crystal nanosensors

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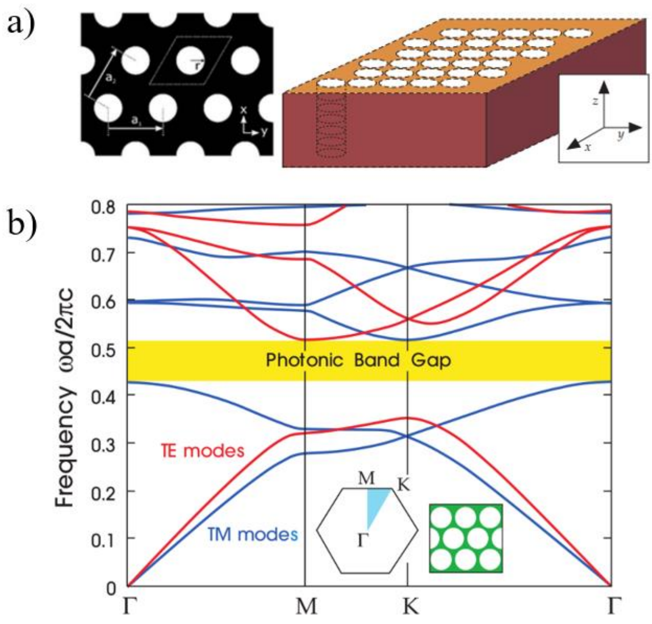
The use of photonic crystals (PCs) as a basis for sensor fabrication is a promising area of nanosensing development due to their larger Q-factor and wider range of applications than traditional sensors and the use of established technologies used for manufacturing CMOS devices.



An example of the structure of a photonic crystal (a) and its photonic band structure [2]

By their nature, photonic crystals are nanostructures with a periodic change in refractive index. This structural feature leads to constructive and destructive superposition of light waves, prohibiting the propagation of some wavelengths and changing the propagation of others. Common technologies for the manufacture of PCs include e-beam lithography, reactive-ion etching, focused ion-beam technology, nano-imprint lithography and material processing using a high energy femtosecond laser pulse [1].

Photonic crystals can be adapted to measure a variety of quantities, including refractive index, nanoparticle presence, optical-mechanical and temperature parameters. Refractive index measurements use the change in resonant wavelength to detect changes in liquids or gases, which is achieved due to the small mode volume and strong optical confinement of nanobeam cavities. Nanoparticle sensors use functionalised surfaces or optical forces to capture particles such as proteins or gold nanoparticles, providing ultra-sensitive detection suitable for clinical diagnostics. In opto-mechanical sensors, the interaction between optical fields and mechanical motion allows for accurate detection of nanoscale displacements, forces or accelerations using such configurations. Temperature sensors use the thermo-optical effect and thermal expansion in photonic structures to detect temperature changes. Thus, the use of nanosensors based on photonic crystals is perspective for biomedical, environmental and industrial applications due to their high sensitivity, compactness and versatility [3].

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Raman Spectroscopy Investigation of Phase Change Material $Ge_2Sb_2Te_5$

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Raman spectroscopy is a valuable tool for identifying crystalline forms. It offers sampling flexibility and can monitor changes in both chemistry and crystallography during phase transitions [1]. The GeTe-Sb_2Te_3 pseudo-binary system includes materials that undergo phase transitions with distinct characteristics. Under external excitations, such as classical heating, laser heating, or electric fields, these materials experience phase shifts (from crystalline to amorphous or vice versa), altering their physicochemical properties [2]. Among various phase-change materials (PCMs), the stoichiometric composition $Ge_2Sb_2Te_5$ (GST) is considered one of the optimal compositions within the pseudo-binary GeTe-Sb_2Te_3 line for data storage devices. GST exhibits high read and write speeds, scalability, and enhanced data retention [3]. This work presents the fabrication of $Ge_2Sb_2Te_5$ films using magnetron sputtering and investigates their structural evolution under classical heating and laser irradiation via Raman scattering. The vibrational modes of GST molecules under temperature and laser irradiation gradients show that the as-deposited amorphous GST transitions first into a metastable cubic phase (*fcc*) and then into a hexagonal crystalline phase (*hcp*).

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