METANANO SUMMER SCHOOL ON NANOPHOTONICS AND ADVANCED MATERIALS

Qingdao, China
August 16 – August 18, 2023

BOOK OF ABSTRACTS

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Metanano Summer School on Nanophotonics and Advanced Materials

Faculty of Physics of ITMO University invites you to participate in METANANO Summer School on Nanophotonics and Advanced Materials which will be held on 16-18 August 2023 in Qingdao, China (offline format).

The school will provide a platform for researchers, students, and industry professionals to come together and learn about the latest advancements in the field of nanophotonics and advanced materials. The program will consist of lectures, hands-on workshops, and poster sessions, covering a wide range of topics such as:

- All-dielectric nanophotonics
- Advanced materials for photonics
- Chiral and bianisotropic metasurfaces
- Perovskites nanophotonics
- Bound states in the continuum
- Nano lasers
- Advanced nanofabrication techniques
- Mie-Tronics
- Wireless power transfer
- Microwave metamaterials

Summer school is an excellent opportunity to network with peers and establish new collaborations with leading experts in the field of nanophotonics and advanced materials.

Organizers

Andrey Bogdanov

ITMO University

Harbin Engineering University

Sergey Makarov

ITMO University

Harbin Engineering University

Mingzhao Song

Harbin Engineering University

Invited Lectures

Day 1

Aug 16th, 8:30 AM – 17:30 AM (GMT+8)

Nonlinear and Chiral Resonant Metaphotonics

Time 09:30-10:00

Yu. S. Kivshar[1,2]
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In metaphotonics, resonances play a pivotal role in enhancing nonlinear effects. Optical properties of metaphotonic structures, whether composed of individual nanoparticles or metasurfaces, are determined by the geometry of their units (meta-atoms) and material properties. Metallic nanostructures can host a variety of resonances, ranging from local surface plasmon resonances in individual nanoantennas to nonlocal lattice modes in plasmonic metasurfaces. Compared to low efficiencies and losses in metallic structures, dielectric metasurfaces and nanoantennas provide an attractive low-loss platform for nonlinear metaphotonics. The main building blocks of dielectric metastructures are dielectric nanoparticles supporting Mie resonances. Dielectric nanostructured surfaces can also host optical bound states in the continuum (BICs), observed as quasi-BICs, with dramatically large quality factors (Q factors) from several hundred to tens of thousands. For nonlinear nanostructures, the phase matching is not applicable, and the frequency conversion efficiency is determined by the resonant characteristics such as coupling efficiency and mode Q factor. It was demonstrated recently that quasi-BICs with very large Q factors can boost the generation of the third harmonics by several orders of magnitude enabling ultrafast self-action effects and high-harmonic generation in the non-perturbative regime. Here, we review the recent advances in nonlinear and chiral metaphotonics of nanoparticles and metasurfaces empowered by optical resonances. In particular, we demonstrate a giant enhancement of the second-harmonic signal generated from silicon metasurfaces at guided-mode lattice resonances and quasi-bound states in the continuum.

Keywords:
Nanoplasmonics, BIC, SERS

Time-varying metasurfaces for extreme control of electromagnetic waves

Time 10:30-11:00

Xuchen Wang
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Conventional metamaterials, limited to engineering solely in 3D space, have constraints in achieving complex control over electromagnetic waves. However, by introducing "time" as an additional degree of engineering freedom, new opportunities emerge to unlock the full potential of metamaterials. In this talk, we will explore the transformative capabilities of time-varying material properties in achieving unparalleled wave control. Through temporal and spatiotemporal modulation, we will demonstrate how this approach revolutionizes metamaterials, enabling strong nonreciprocity, perfect wave combining, the generation of momentum bandgap, and other exotic wave effects.

Keywords:
Metasurfaces, Time-modulation, Space-time modulation, Photonic time crystals.

Principle and Consequence of Topological Charge Manipulation

Time 11:00-11:30

C. Peng[1,2]
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Keywords: BIC, UGR, Topological charges

In recent years, topological photonics has attracted much attention owing to its great potential in promoting the performance of photonic devices that benefit many applications such as optical communication, computing, and sensing. In this lecture, we focus on a platform of photonic crystals slab and indicate that the bound states in the continuum (BICs) in such a system are essentially topological defects: the integer windings of polarization directions in momentum space. As a conserved quantity, the topological charge last and continuously evolves with varying parameters, only if it drops out of the continuum, or annihilates with an opposite charge. The evolution of topological charge leads to a series of novel phenomena, broadening fundamental physics's horizon and boosting applications in many areas. Specifically, the radiation from photonic crystals has been investigated from the perspective of topological charges. A novel class of resonances, namely, merging BIC is introduced. By merging a set of topological charges, a perfect storm upon polarization far-field is created which modifies the scaling rules of energy radiation in the Brillouin zone center. The merging BICs are proved to be topologically robust to out-of-plane scatterings, and the Q factor up to $4.9{\times}10^5$ has been directly observed, which is 12 times higher than ordinary designs. By adopting the BICs to suppress the out-of-plane radiation, while combining with lateral heterostructure boundary to reduce side-leakage of energy, we demonstrate a new type of miniaturized BIC in a finite-sized photonic crystal. A Q factor over 1 million has been observed from the experiment, with a modal volume as small as 3.57 μm^3

Thermo-optical Bistability in Resonant Photonic Structures

Time 11:30-12:00

M. I. Petrov
ITMO University, Faculty of Physics, St. Petersburg 197101, Russia

Keywords: optical heating, nonlinearity, bistability, bound states in the continuum

Recently, all-dielectric thermonanophotonics emerged as a novel platform for optically controlled nanoscale heat management and optical modulation [1,2,3]. In this work, we will report on theoretical and experimental findings on thermally activated nonlinearities in high-Q resonant all-dielectric systems. We will provide general theoretical consideration of optimal heating of subwavelength nonlinear resonators and discuss the general limitation and requirement for reaching the bistable regime [4]. We will also report on the experimental demonstration of thermo-optical bistability in silicon metasurface enabled by the excitation of bound-states in the continuum (BIC). We show that the nonlinear response of the metasurface and, in particular, the hysteresis parameters can be finely controlled and tuned by the excitation conditions owing to the specific properties of BIC modes. We also propose a concept of nonlinear critical coupling for reaching the maximal opening hysteresis loop. All that makes all-dielectric metasurfaces a promising platform for flat-optical logic elements.

[1] Adv. Opt. Photon. 13, 1–92 (2021). [2] Optics Express. 29, 37128–37139 (2021). [3] Optics Letters. 47, 1992–1995 (2022). [4] Nanophotonics. 11, 3981–3991 (2022).

Bound states in the continuum in photonics

Time 14:00-14:30

M. V. Rybin[1,2]
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[2]Qingdao Innovation and Development Center of Harbin Engineering University, Qingdao 266404, China

Keywords: BIC, supercavity modes, quasi-BIC

In this talk, I will speak on the subject of bound states in the continuum (BIC), including basic problems and tasks related to applications. I start with introduction to BIC and general questions on BIC robustness on structural disorder and supercavity modes in a subwavelength dielectric particle. Finally, I turn to the lasing empowered by BIC modes and switchable structures with BIC.

Surface Waves in Photonics

Time 14:30-15:00

Andrei V. Lavrinenko
Department of Electric and Photonics Engineering, Technical University of Denmark, Ørsteds Plads, Building 345A, DK-2800 Kgs. Lyngby, Denmark

Surface waves typically propagates along an interface of two dissimilar media. In difference with acoustic surface waves, which constitute a base for various devices readily available on the market, photonic surface waves (except surface plasmon-polaritons) are still the topic of the lab research. I will give an overview of a wide variety of surface waves has been investigated in numerous material and structure settings, their excitation and characterization methods and address existing and potential applications.

Keywords: Surface waves, Photonics

Historical and conceptual overview: nonlinear metamaterials

Time 15:00-15:30

M. Lapine
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[2]ITMO University, Saint Petersburg, 197101 Russia
[3]Harbin Engineering University, Harbin 150001, China

With this lecture, I will provide a conceptual and somewhat historical overview regarding the development and progress in the area of nonlinear metamaterials. Particular attention will be offered to the design and implementation of nonlinearity, which can be achieved at the level of individual structural elements as well as using their mutual interaction. For example, one of the important highlights in nonlinear magnetic metamaterial development, is the conversion of microscopic electric or electronic nonlinearity, which is the source mechanism at the level of individual elements, into macroscopic magnetic nonlinearity, which can be amazingly strong. Another interesting possibility is the use of various types of mechanical feedback, whereby by a genuinely designed interaction between electromagnetic and mechanical properties, linear as such, leads to the emergence of exceptionally strong nonlinearity and curious nonlinear phenomena, designed, once again, either at the level of individual structural elements, or their interaction in an array. I will also discuss the routes towards efficient tunability, and towards non-resonant nonlinear effects for the optical range. Finally, I will point out some implications of spatial dispersion for nonlinear effects.

Discrete calculations were funded by Russian Science Foundation (grant no. 22-11-00153).

Keywords: Metamaterials, nonlinear optics, tunability

Electromagnetic Superscattering

Time 15:30-16:00

P. Ginzburg
Tel Aviv University, Israel

Electromagnetic scattering bounds on subwavelength structures play an important role in estimating antenna performances, radio frequency identification tags, and other wireless communication devices. Numerous fundamental and practical restrictions have been found and led to the formulation of Chu-Harrington, Geyi, and other limits, which provide estimates on scattering efficiencies. An appealing approach to increase a scattering cross section is accommodating several spectrally overlapping resonances within a structure. Electromagnetic scattering on compact structures is well approximated by a multipole series, where lower orders are typically sufficient for convergence. The maximal possible scattering into a single multipole is called a channel limit. In many cases, a dipole single channel limit (the maximal scattering cross-section, which a small resonant lossless dipole can approach) is considered. In this case, $3\lambda^2/(2\pi)$, where λ is free space wavelength. Compact subwavelength structures bypassing the single channel limit are called superscatterers. Several strategies to design superscatterers with the aid of generic optimization will be discussed and their state-of-the-art performances will be shown experimentally. A new tight superradiant criterion to assess superscattering will be formulated.

Keywords: Superscattering, Electromagnetic Theory, Microwaves, Antennas

Day 2

Aug 17th, 8:30 AM – 17:30 AM (GMT+8)

Metasurfaces for controlling light

Time 8:30-9:00

Lei Zhou
Department of Physics, Fudan University, Shanghai 200433, China

Metasurfaces are ultra-thin metamaterials composed by artificial planar meta-atoms arranged in some specific macroscopic orders, which exhibit extraordinary capabilities to control light waves. In this talk, after briefly reviewing the historical developments of metasurfaces, I will present several recent examples of using metasurfaces to control light. In the first part, I will describe how to design high-efficiency plasmonic metasurfaces to convert propagating waves to surface waves with tailored wave-fronts, in both terahertz (THz) and infrared regimes. In the second part, I will present several dielectric metasurfaces that can control THz waves in the desired way.

Keywords: Metasurfaces, Surface waves

Lattice plasmons: generation and applications

Time 09:00-09:30

Wenxin Wang
Harbin Engineering University, Qingdao, 266500

Plasmonic lattices that support surface lattice resonances (SLRs) have emerged as an exciting platform for investigating light–matter interactions at the nanoscale and enabling a diverse range of applications. Here, we propose a facile strategy for SLRs generation, and explore their interactions with quantum emitters from weak coupling regime as room temperature ASE and nanolasing, to strong coupling regime with obvious Rabi splitting.

Keywords: Plasmonics, Surface Lattice Resnonances

Multifunctional and efficient thermal management materials and devices

Time 09:30-11:00

Rujun Ma
School of Materials Science and Engineering, Nankai University, Tianjin, China

Nowdays, the increasing integration of electronic devices leads to more and more prominent thermal failure problems, and the traditional cooling technology can no longer meet the cooling needs of electronic devices. Here we focus on three aspects to achieve thermal management effects with maximum efficiency:

1. Efficient transfer of heat from working electronic devices through efficient, environmentally friendly, miniaturized solid-state refrigeration devices based on the electrocaloric effect to keep the electronic devices in the optimal operating temperature range and maintain their efficient operation.
2. The transferred part of the heat is converted into electrical energy using highly reliable, environmentally friendly, noiseless high-performance thermoelectric devices to achieve waste heat recycling.
3. The unused heat is quickly dissipated through zero-energy, environmentally friendly, and easy-to-process radiative cooling devices to further reduce the device temperature. The three research aspects are closely integrated and complementary; electrocaloric cooling and radiative cooling provide a greater temperature difference between the hot and cold ends of the thermoelectric devices, which can convert more heat into electricity and provide some of the electrical energy needed for cooling the electrocaloric devices; radiative cooling accelerates heat transfer and improves the efficiency of electrocaloric cooling.

Keywords: Thermal management, Solid-state cooling, Electrocaloric effect, Radiative cooling, Thermoelectric

Advancements in Halide Perovskite Photovoltaic Solar Cells

S. I. Seok
Qingdao Department of Energy and Chemical Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan. Korea

Time 10:30-11:00

Keywords: Perovskites, Solar Cells

Over the past decade, halide perovskite photovoltaic solar cells (PSCs) have garnered significant attention, achieving power conversion efficiencies (PCEs) of up to 26%. This progress has been driven by optimization in device architecture, uniform thin film deposition processes, and material composition. Our research team, pioneers in the field, introduced a groundbreaking bi-layer structure consisting of a nano-structured photoelectrode and a perovskite thin film. Furthermore, we implemented solvent engineering and intramolecular exchange processes to impede rapid crystallization between organic cations and PbI2, leading to uniform perovskite thin film deposition. Additionally, we successfully stabilized the □-phase of formamidinium lead iodide (FAPbI3) by manipulating the perovskite material's chemical composition. In this presentation, I will provide a concise overview of the birth of halide perovskite photovoltaics and discuss our remarkable advancements in the field.

Device Analysis and Large ZnSe Nanocrystals and for Blue QLED

Haizheng Zhong
School of Materials Science & Engineering, Beijing Institute of Technology, Beijing, China

Time 11:00-11:30

Keywords: LEDs, ZnSe, Machine Learning

With the rapid improvements in both of the external quantum efficiency and operating lifetimes of QLEDs, it approaches to the gate of industrialization for flat display applications. Since blue QLED is known to be one of the most important remaining difficult, it has been of great interests to develop the materials and device for OLEDs. In the past three years, we have tried to remove the bastion of blue QLEDs. In this talk, I will introduce our recent progress in the colloidal synthesis large sized ZnSe nanocrystals with pure blue emission as well the introduction of machine learning methodology in device analysis. Large-sized ZnSe nanocrystals with an emission peak of 455-475 nm are synthesized with a general strategy of reactivity-controlled epitaxial growth (RCEG) was developed through sequential injection of high-reactivity and low-reactivity Zn and Se precursors. We further fabricated stable, large-sized ZnSe/ZnS core-shell nanocrystals with photoluminescence quantum yields up to 60%. Very recently, we build up a machine learning assisted methodology to predict the operational stability of blue QLEDs by analyzing the measurements of over 200 devices. By developing a convolutional neural network (CNN) model, the methodology is able to predict the operation lifetime of QLED.

Functionalization of carbon nanoparticles

Time 11:30-12:00

E.V. Ushakova
International Research and Education Center for Physics of Nanostructures, ITMO University 197101, Russia

Keywords: Nanoparticles, Spectroscopy, Energy Level Structure, Hybrid Nanomaterials

Chemically synthesized carbon dots have attracted a lot of attention as an eco-friendly and cost-efficient light-emitting material. To expand the field of their applications, carbon dots can be functionalized for specific task by a control of the chemical and physical properties. Our group developed several methods for functionalization of the surface, including the implementation of carbodiimide chemistry to bound carbon dots with chiral molecules or plasmon nanoparticles, and the use of a seed-growth method to change the chemistry of the carbon dot surface. The functionalization of the surface allows us to control the energy level structure by changing the type of the surface groups together with increasing of the oxidation state of the surface. The bonding with plasmonic nanoparticles allows increase of photoluminescence quantum yield for both green and yellow emissive carbon nanoparticles. For biomedical applications, one of the most relevant directions of functionalization is the development of multimodal nanolabels for both therapy and diagnostics. For that, we have developed two paths for introducing chirality in carbon dots: one-pot synthesis in the presence of chiral molecules and covalent bonding of chiral molecules to carbon dot surface. The latter approach is performed by carbodiimide chemistry with L-/D-cysteine. The functionalization of carbon dots synthesized from citric acid and ethylenediamine with cysteine results in the emergence of the signal in the $n-\pi$ optical transition of carbon dots in the blue spectral region together with the increase in the photoluminescence quantum yield. The developed method also works for carbon dots with optical transitions in the green, yellow, and red spectral regions. The change in circular dichroism signal is due to the interaction of the chiral molecule with the optical center within the carbon dot resulting in the hybridization of lower-energy levels of chiral molecules aggregates at the surface.
This work was financially supported by the Russian Science Foundation (RSF22-13-00294).

High-Performance See-Through Power Windows

Time 14:00-14:30

Chang-Zhi Li
Department of Polymer Science and Engineering, Zhejiang University, Hangzhou 310027, P. R. China

Keywords: n-Doping, Interfacial layer, Solar cell, Semitransparent

Thin-film solar cells made with polymer and perovskite absorbers represent a transformative technology with great potentials for high-throughput manufacturing at very low cost. In this talk, we will discuss the integrative approach of combining molecular design, interface and device to access high-performance polymer and perovskite solar cells, including the results of champion organic solar minimodules made in lab that have been published in the "Solar Cell Efficiency Table" by Prof. Martin Green (59th, 60th, 61st and 62nd editions), as well as our efforts in fabricating inverted perovskite solar cells with the certified efficiency over 26%.

Specific emphasis will be placed on the development of See-through power windows via a new design of semitransparent organic solar cells (ST-OSCs), which allows for the efficient utilization of spectrum-engineered solar photons from the visible to infrared range with both energy generation and saving features. Model analysis indicated that the installation of these see-through power windows worldwide would contribute to the carbon neutrality of society.

Ultrathin Flexible Organic Solar Cells

Time 14:30-15:00

Wenchao Huang[1,2]
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[2]*State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, Wuhan Universtiy of Technology, Wuhan 430070, China*

Keywords: Solar cells, Ultrathin devices

Flexible organic solar cells (OSCs) with high power conversion efficiency (PCE) and excellent mechanical properties are considered a promising power source for wearable electronic devices. However, simultaneously achieving high efficiency and robust mechanical stability is still challenging because highly crystalline or aggregated microstructures that are thought to be critical for enabling efficient device operation render the active layer brittle. In this study, we demonstrate 3-μm-thick ultra-flexible OSCs utilizing a ternary strategy that can achieve an efficiency of over 17%. The use of a mixed acceptor can improve exciton separation and optimizes the blend morphology with more amorphous regions, thus producing a more efficient and mechanically robust device. The ultrathin device exhibits a negligible degradation in its device performance after the cyclic bending test. Ultralightweight and ultra-flexible photovoltaic devices that can be conformably adhered to complex curved surfaces are considered promising future power sources for wearable electronic systems.

Advanced laser technologies for nanopatterning of halide perovskites

Time 15:00-15:30

A. A. Kuchmizhak[1,2]
[1]Pacific Quantum Center, Far Eastern Federal University, Vladivostok, Russia
[2]Institute of Automation and Control Processes, Far Eastern Branch, Russian Academy of Science, 5 Radio Str., Vladivostok 690041, Russia

Keywords: Halide perovskites, Laser nanopatterning, Nanostructures, Femtosecond laser pulses

Exceptional optoelectronic properties combined with inexpensive fabrication and facile bandgap tunability put halide perovskites among the most promising emerging materials for modern light-current technologies. Moreover, perovskites hold promise for nanophotonics, where diverse passive and active optically resonant nanostructures are highly demanded. At the same time, common lithography-based fabrication technologies are often poorly applicable for fabrication of high-quality nanostructures from halide perovskite. This lecture intends to survey recent progress on precise nanostructuring of halide perovskites using state-of-the art laser technologies that recently have appeared as a promising alternative to the common nanofabrication strategies. Special emphasis will be given to fundamentals of the interaction of pulsed laser radiation with perovskite material, methods for optimization of the processing conditions as well as applications of the laser-patterned perovskite designs for nanophotonics.

Terahertz Pulse Time-Domain Holography: Computational Tool for Broadband Single-Cycle Wavefront Assessment

Time 15:30-16:00

N. Petrov[1,2]
[1]*Qingdao Innovation and Development Center of Harbin Engineering University, Qingdao 266404, China*
[2]*School of Physics and Engineering, ITMO University, St. Petersburg 197101, Russia*

Keywords: digital holography, terahertz radiation, vortex beams, phase imaging

This talk discusses the technique of terahertz pulse time-domain holography and its applications in computational metrology. Terahertz pulse time-domain holography allows for the analysis of spatio-temporal and spatio-spectral evolution of terahertz wave trains during their propagation and interaction with obstacles. The talk highlights the two main categories of applications for pulsed terahertz radiation, namely objects inspection/material characterization and wavefront sensing. The focus is on the latter category, which involves broadband beam shaping, investigation of spatio-temporal couplings, and study of the structure of generated terahertz fields. The talk presents an alternative approach to studying the propagation dynamics of terahertz wavefronts, which is based on the measurement of the broadband wavefront in one transverse plane and its numerical propagation along the optical axis using digital holography. The technique combines experimental setup schemes for wavefront registration, mathematical models for diffraction calculation, numerical data processing techniques, and specific tools for data representation and analysis. The talk also discusses specific case studies, including the propagation dynamics of THz Gauss-Bessel beams and the spatio-temporal and spectral structures of wave packets consisting of broadband with a uniformly topological charge beams.

Poster Session

Day 1

Aug 16th, 8:30 AM – 17:30 AM (GMT+8)

Experimental demonstration of superdirective spherical dielectric antenna

Poster ID: 01P

R. Gaponenko, A. A. Shcherbakov
School of Physics and Engineering, ITMO University, 197101, Saint-Petersburg, Russia

Keywords: Dielectric resonator antenna, superdirectivity, experimental measurements.

The use of ceramics with a high refractive index and low losses can significantly reduce the physical size of antennas while maintaining their overall high radiation efficiency. This work theoretically and experimentally demonstrates the possibility of obtaining effective superdirectional radiation using a dielectric antenna smaller than a wavelength. The high directivity of such antennas is associated with the constructive interference of individual electric and magnetic modes of an open resonator in a given direction at certain frequencies. The experimentally measured radiation patterns coincide with the theoretically calculated ones, and the antenna directivity at the resonant frequency exceeds the fundamental Kildal limit, which confirms that the antenna is superdirective. The proposed antenna concept can be scaled to other frequency ranges.

This work was performed with financial support of the Russian Science Foundation (Project No.22-11-00153)

Nonlinear Static Analysis Of Origami-based Structure

Poster ID: 03P

Sanaullah[1], Luo Ani[1], Liu Heping[1]
[1]College of Mechanical and Electrical Engineering, Harbin Engineering University, Harbin, 150001, China

Keywords: Origami, Bar hinge model, Lagrange method, Modified Newton method.

The nonlinear static form of the origami-based bar hinge structure has been formulated based on the Lagrangian method in which a nodal coordinate vector is taken as a variable. The nonlinear equilibrium equation is used to derive the tangent stiffness matrix. To solve the nonlinear static equation, the modified Newton method is implemented as a solver in which a line search algorithm is used that guarantees the fast convergence of the result to the stable equilibrium configuration. Two numerical examples are given that prove the accuracy and efficiency of the developed method. Results show that the developed principles are capable of simulating the origami-based structure into folded form by capturing the large deformation of the structure under the small load as well as the large load. The defined method is not limited to the sheet pattern type models but can be useful to any kind of origami model which is based on the bar hinge elements. Based on the Lagrangian method, the dynamic analysis of the origami-based model can be analyzed by considering the damping coefficient, kinetic energy, and mass of the elements.

Flame and Smoke Detection Using Deep Learning

Poster ID: 05R

Wasiq Ali[1], Muhammad Ubaid[2], Saad Anjum[2], Ahmad Asim[2]
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[2]Department of Electrical and Computer Engineering COMSATS University Islamabad, Attock 43600, Pakistan

This study proposes deep learning based neural computing to detect fires using a combination of closed-circuit television cameras, YOLOv5 object detection, a Raspberry Pi fitted with a Global System for Mobiles (GSM) module, and a cellular network. The cameras would be connected to the Raspberry Pi using a cellular network.To develop the algorithm, we collected numerous datasets containing images taken in various environments and then categorized the photographs showing smoke and fire. Following that, we have annotated particular areas of interest within the images associated with smoke and fire.The system has been constructed to monitor fires in instant time and deliver text messages warnings to the authenticated person. In addition, the system will determine the fire's location using the GPS coordinates obtained from the GSM module. The system then make use of these coordinates at some point. So the proposed system can significantly improved the efficiency of fire detection and response, which, in turn, has the potential to contribute to the preservation of both lives and property.
This work is supported by the National Grassroots ICT Research Initiative 2022-23 Pakistan (Grant No: NGIRI 2023-20871).

Keywords: Smoke detection, Deep learning algorithm,CCTV camera.

Spoof Surface Plasmons based Terahertz Meta- Sensor

Poster ID: 07P

Ruchi Bhati, Anil K. Malik
Photonics and Metamaterials Laboratory, Chaudhary Charan Singh University, Meerut, 250004, India

Sensors are a vital part of modern technology due to the extensive variety of applications in various fields such as imaging, medicine, food quality control, and agriculture. Corrugated metal structure-based metasurfaces reinforce spoof surface plasmons (SSPs) at THz frequency similar to the surface plasmon polaritons (SPPs) for visible radiation. The spoof surface plasmon modes strongly confine electromagnetic fields at the surface boundary of the metals, which offer a highly sensitive surface to any change in the surrounding dielectric environment of the sensing device. We report a spoof surface plasmons-based metamaterial THz sensor that shows two very sharp resonances. The novel THz meta-sensor incorporates Square Split Ring Resonator (SSRR) and + type grooved resonator in the transmission geometry. Strong field confinement and surface current distributions are obtained for both resonance modes. We investigate our metasurface for sensing several pesticides such as Imidacloprid, N, N-Diethyldithiocarbamate sodium salt trihydrate, Daminozide, N, N-Diethyldithiocarbamate sodium salt hydrate, and Dicofol. A significant high sensitivity is observed for both resonant modes. The proposed device is a compact planner and easy to realize, which can be used as highly efficient THz biosensors. The functionality of our sensor can be extended to other frequency regimes by scaling its dimensions.
This work is supported by CSIR-MHRD, Government of India(File no. 09/113/(0029)-EMR-I.

Keywords: Metamaterials, Terahertz, Senosor, Spoof Surface plasmons, Pesticides

Hydrogel-enabled thermally modulated varifocal metalens

Poster ID: 09R

Naeem Ullah[1], Ata Ur Rahman Khalid[2], Shahid Iqbal[3], Xiaoqing Tian[1]
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[2]Nanophotonics Research Center, Shenzhen Key Laboratory of Micro-Scale Optical Information Technology and Institute of Microscale Optoelectronics, Shenzhen University, Shenzhen 518060, China
[3]School of Electronics and Information Engineering, Shenzhen University, Shenzhen 518060, China

Abstract: In this work, the thermoresponsive hydrogel based metasurface is used as a thermally modulated varifocal metalens in the visible frequency regime. The metasurface is comprised of plasmonic resonators embedded on the top of hydrogel and dipped in aqueous solution. Full phase coverage (0-2π) with constant amplitude is accomplished by tailoring the structural dimensions of Au nanobrick. The phase transition of hydrogel from the hydrophobic state (collapsed state) to hydrophilic state (swollen state) triggered by lowering the local critical solution temperature (LCST) temperature, characteristically modulate the position-dependent phase dysconnectivity; as a result, it could be used for dynamic beam focusing and modulation functionality. These tunable optical components based on the non-toxic and biocompatible metasurfaces can be useful for a variety of applications in integrated optics, biomedical sciences, or wearable consumer electronics.

This work is supported by the National Natural Science Foundation of China (Grant No: 62250410369)

Keywords:
Metasurfaces,
Metalens,
Reconfigurable,
Integrated Optics

Evaluation of Specific Absorption Rate in human arm Model at 190 kHz for metasurface-based wireless power system

Poster ID: 11M

Altana Tsyrinova[1], Pavel Smirnov[1], Georgii Baranov[1] Alexander Zolotarev[1], Polina Kapitanova[1]
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Keywords: Wireless Power Transfer, Specific Absorption Rate, Metasurface-Based Resonator

A one-to-many wireless power transfer (WPT) system normally uses a large transmitting resonator to accommodate multiple receiving resonators. The power transmission is performed via the near magnetic field, while the electric field is required be strongly confined to provide the safety of a WPT system for living objects. Under the safety here one need to understand the human exposure limits, regulated by the International Commission on Non-Ionizing Radiation Protection that describes allowable electric and magnetic field intensities a well as specific absorption rate (SAR) in tissues.

Here we report on the numerical study of the near electromagnetic field distributions of one-to-many WPT systems and evaluation of SAR in human tissues. The one-to-many WPT system is implemented as a chessboard with lightened chess figures [1], [2]. The metasurface-based transmitting resonator is integrated into the chessboard to provide a quasi-uniform magnetic field distribution capable of wireless charging of 32 receivers by means of magnetic resonant coupling. Each chess piece consists of an energy receiver and polymer matrix chess figures with encapsulated halide perovskite nanocrystals, exhibiting intensity-dependent photoluminescent quantum yield.

To study the near electric and magnetic field distributions and evaluation of SAR in human tissues we create a model of metasurface-based transmitting resonator in the CST Microwave Studio with a human arm. The obtained results are compared to the similar chess board one-to-many WPT system based on a traditional transmitting coil. Both implementations of transmitting resonators are safe for human tissues. But the metasurface-based resonator provides lower electric field and SAR in comparison to the traditional coil transmitting resonator which is beneficial for application.

This work was supported by the Russian Science Foundation project No. 21-79-30038, https://rscf.ru/en/project/21-79-30038/

[1] Smirnov P., Baranov G., Filimonova T., Tsyrinova A., Rakhmatullin A., Song M., Zelenkov L., Danilovskiy E., Makarov S., Kapitanova P. One-to-Many Wireless Power Transfer Systems Using Metasurface-Inspired Resonators // Wireless Power Week, WPW 2022 - 2022, pp. 690-693
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Photothermal Heating for Phase Change Materials Based Integrated photonics

Poster ID: 13P

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Keywords: Photothermal, Phase Change Materials, Plasmonics

Opto-thermal heating represents a promising approach for enhancing light modulation and data storage in Phase Change Materials (PCM) based integrated photonics. While PCMs rely on the changes induced in optical properties by changes in temperature, their utility can be enhanced through the use of opto-thermal means for the change and bring us closer to an all-optical platform. In this poster, we demonstrate an opto-thermal mechanism to induce a phase change in PCM-based integrated photonic components. The results show that the optically induced heating of PCMs enables reversible optical switching with high modulation depth and low energy consumption. This work opens up a new path toward the development of all-optical, compact, and energy-efficient photonic devices for information processing and storage.

Topological features of quasi-BICs in maximum chiral metasurfaces

Poster ID: 15P

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Maximum chiral metasurfaces selectively interact with circularly polarized light. Their design is greatly facilitated by the concept of photonic quasi-bound states in the continuum (quasi-BICs) relying on symmetry breaking perturbations. While most attention has been paid to the case of normal light incidence, comprehensive analysis of the chiral quasi-BIC properties with respect to obliquely incident waves reveals intriguing topological features and clarifies the potential of maximum chiral metasurfaces for such important applications as laser generation and vortex beam shaping.

The work is supported by the Russian Science Foundation (project 23-42-00091, https://rscf.ru/project/23-42-00091/).

Keywords: BIC, chiral metasurface, topology

High-Q collective modes in chains of subwavelength resonators with simultaneous electric dipole and magnetic dipole responses

Poster ID: 17P

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In this work we study collective modes in infinite and finite one-dimensional arrays of subwavelength resonators supporting magnetic dipole (MD) and electric dipole (ED) types of responses simultaneously. We show that the presence of two responses of different types for a single resonator in an infinite chain can modify the behavior of one of the dispersion curves from monotonic to non-monotonic. In turn, the non-monotonic dispersion leads to the external coupling of the modes of the corresponding finite chain. This results in the formation of the collective mode with highly suppressed radiative losses at certain optimal distance between individual resonators in the chain. We show that by fine tuning the MD and ED resonant frequencies, the optimal distance can be tuned to the values feasible for realistic optical resonant structures. Experimental investigation of the prototype of the resonant chain in the microwave spectral range have confirmed the main theoretical findings.

This research was supported by Priority 2030 Federal Academic Leadership Program.

Keywords: external coupling, avoided resonance crossing, band-edge modes, dielectric resonators, nanophotonics, microwave prototyping

Topological states and flat bands in multimode photonic waveguide lattices

Poster ID: 19R

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Keywords: topological edge states, subwavelength grating waveguides, asymmetric coupling, flat bands

Photonic structures with topologically nontrivial bands are usually designed by arranging simple meta-atoms, ideally, single-mode ones, in a carefully designed photonic lattice with symmetry that guarantees the emergence of topological states. Here we investigate an alternative option that does not require complex lattice geometry but instead relies on the tuning of the parameters of the individual meta-atoms to achieve the degeneracy of the modes with different symmetry. As an illustrative example, we consider a one-dimensional array of equidistant identical periodic nanophotonic waveguides supporting degenerate modes with strongly asymmetric near-field profiles, which gives rise to the coupling modulation. Using this concept, we experimentally realize topological edge states in an array of silicon subwavelength grating waveguides at telecom wavelengths. Exploiting the hybrid nature of the topological mode, we implement its coherent control by adjusting the phase between the degenerate modes and demonstrating selective excitation of bulk or edge states. The resulting field distribution is imaged via third harmonic generation showing the localization of topological modes as a function of the relative phase of the excitations. Our results highlight the impact of engineered accidental degeneracies on the formation of topological phases, extending the opportunities stemming from topological nanophotonic systems. This work was done with financial support from the Russian Science Foundation, Project No.22-72-10047.

Optical Properties of Gold Nanoparticles Assemblies at Liquid-Liquid Interfaces for Raman Applications

Poster ID: 23R

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Keywords:
Self-assembly, Gold Nanoparticles, Liquid-Liquid Interfaces, Optical Properties, Raman Enchancing Susbtrates, SERS

Nanooptics is an emerging field in nanotechnology, which combines nanosized objects and unique light-matter interaction properties at nanoscale. One of the most promising nanoobjects suitable for nanooptics are metal nanoparticles (NPs), which possess Localized Surface Plasmon Resonance (LSPR). And the most attractive strategy, which can bring a significant shift in the area of optics production (especially for filtering and mirroring applications), is based on large-scale self-assembly of metallic NPs with tunable optical response on various substrates[1] and interfaces.[2]

Recently, we have developed a novel, scalable and simple method to obtain highly stable continuous gold nanoparticle (AuNPs) films at various liquid|liquid interfaces (LLIs).[3] Formation of such nanofilms requires only vigorous shaking of aqueous phase containing AuNPs with organic phase containing special organic species. The method allows creating both sub- and multilayer self-healing films. Investigated optical responses – both extinction and reflection – of nanofilms in situ with stepwise increasing of AuNPs concentration showed intriguing and non-linear behavior of assemblies with accumulating AuNPs. We propose that this effect is caused by morphological changes occurred in the film settled at LLI: 2D closed-packed films transfers into 3D thick layer. It may be utilized for further development of liquid filters and mirrors.

The current activities are focused on application of such assemblies to Raman scattering as an enhancing substrates. Control over particles morphology and assemblies morphology allows achieving high enhancing factors 5-fold higher than for a regular Raman spectroscopy.

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Dielectric media effect on the optical transitions in semiconductor nanocrystals

Poster ID: 25B

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Keywords: Semiconductor nanocrystals, boundary conditions, effective mass method

Semiconductor nanocrystals (NCs) – spherical quantum dots in colloidal solution or in dielectric matrix – have a long history of research and developing applications in photonics and optoelectronics. The optical transitions in small NCs are determined by the quantum size energy levels of electrons and holes. In the simplest model these levels can be calculated within the effective mass method assuming vanishing of the envelope functions on the NC surface. However, this simplest model does not allow to fully take into account the influence of different dielectric surrounding that comes not only from the large difference between the dielectric constants but also between the effective masses inside NC and in the surrounding media. We focus first of all on the effective mass difference effect and show that it can be taken into account with the help of the general boundary conditions (GBC) on the envelope function.
The GBC guarantee the vanishing of the normal component of the probability flux density at the NC surface however describe the nonvanishing probability to find the electron at the surface. The GBC contain the single parameter A characterizing the length of the surface region - the same for all energy levels and independent on the NC radius a. We find the analytical expression for the length A relating it with the characteristics of the surrounding media – the height of the potential barrier U and the effective mass m_B in the barrier. We show that the effective mass method with GBC is applicable for $A \ll a$ realizing for large U and m_B where the method with the standard boundary conditions does not work. We show that if the effective mass inside the NC $m_A \ll m_B$, the ground state energy level is determined by U and m_B solely and does not depend on m_A while all excited electron states are determind by m_A. Thus, the dielectric media modifies significantly the energy of both interband and intraband optical transitions.
The work is supported by the Russian Science Foundation grant No 23-12-00300

Strongly subradiant single-photon modes in square arrays of quantum emitters

Poster ID: 27P

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Keywords: two-level atoms, 2D lattices, subradiant states

This work is devoted to the study of collective single-photon modes in 2D arrays of quantum emitters. In a square lattice of N two-level atoms, for the lattice constant $\sim 0.3\lambda$, particularly long-living states are obtained. The occurrence of such subradiant states is determined either by the flatband region of the lattice dispersion, or by the mechanism of destructive interference ensured by a square geometry of a finite lattice. Depending from the type of the state, their lifetime is proportional to N^3 or N^5. In addition, we explore narrow peaks of scattering by such lattices with vector Bessel beams. Such long-lived collective states may find potential applications in nanophotonics and quantum optics.
This work was performed with financial support of the Russian Science Foundation (Project No.21-72-10107)

Decoration of Keplerate-type Polyoxometalate With Photosensitizers and Self-Assembling Agents to Production of Template-Based Hybrid Materials

Poster ID: 29M

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Keywords: Material science, hybrid materials, polyoxometalates

Design of the modern smart-materials with optical response needs supramolecular approach to build hierarchical structures or individual ensembles used for photocatalytic application or biosensing. Here, we report about template-based synthetic route to formation of desired supramolecular shell, composed of organic scaffold and fluorescent dyes, onto the surface of the nanoscale polyoxometalate (POM) Mo132. Using of appropriate alkoxysilane linker allows for gradual termination of POM surface with amino groups followed with anchoring of them by the NHS-ester of different dyes or fatty acid: eosin Y, fluorescein, porphyrin, BODIPY and stearic acid. Due to conjugation with POM, the photoinduced charge transfer band appears and photocatalytic "ping-pong" mechanism can be realized to controlled oxidation of different substrates. In the case of POM with grafted stearic acid, the self-assembling behavior occur forming hollow nanovesicles which can be loaded with guest molecules (like, an ionic dyes). Thus, found synthetic approach has promising potential to design of different photoactive smart-materials from solution chemistry.

This work is supported with Russian Science Foundation #21-73-00311.

SERS-active substrates based on AgNPs@c-Si plasmonic structures for triphenylmethane dye diagnostics

Poster ID: 31P

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Keywords: AgNPs, Si, LSPR, SERS, TPM dye

The study of optical and plasmonic properties of structures is an important step in the development of substrates for surface-enhanced Raman scattering (SERS). In this work, structures based on (1) a disordered self-organized array of hemispherical Ag nanoparticles (AgNPs) on a $Si0_2$@c-Si and (2) embedded AgNPs in c-Si are studied step by step. A simple and reproducible method has been proposed, which consists of the chemical reduction of Ag ions from solution and annealing at 350^{o}C and 1000^{o}C to create structures (1) and (2), respectively. Numerical calculations of the scattering, absorption, and extinction cross-sections are used to determine the positions of the localized surface plasmon resonance (LSPR) multipoles. The reflectance spectra from the structures (1) and (2) were experimentally obtained and the positions of the LSPR were determined, which agrees with the numerical calculations. The splitting of the LSPR dipole is found in the reflection spectra from the structures (1) at oblique angles of incidence for p-polarization of light, which indicates the he prolate shape of hemispherical AgNPs. Finally, SERS shows reliable detection of 10^{-7} M (crystal violet) and 10^{-5} M (methyl orange) with the enhanced factor 10^5 and the relative standard deviation of signal $\sim$ 10 %. These studies suggest that such structures are promising candidates for detecting triphenylmethane dyes.

This work was supported by Ministry of Science and Higher Education of the Russian Federation (Project 0040-2019-0012).

Mechanical scanning probe lithography of 2D perovskites for fabrication of planar polaritonic cavities

Poster ID: 33B

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Keywords: Exciton-polaritons, Planar polaritonic cavities, perovskites, mechanical scanning probe lithography

Exciton-polaritons are unique quasiparticles that possess hybrid properties of both an exciton and a photon. They offer promising avenues for realizing strongly nonlinear systems and inversion-free lasers through Bose-Einstein polariton condensation. However, the practical implementation of polariton systems is still limited by the challenges of temperature operation and the costly fabrication techniques required for both semiconductor materials and photon cavities.

Among the potential solutions, photonic sturctures based on 2D perovskites emerge as a highly promising platforms for achieving strong light-matter coupling. These materials support room-temperature exciton states with significant oscillator strength and, simultaneously, enable the fabrication of planar photon cavities with high field localization due to their elevated refractive index.

In this study, we present an affordable mechanical scanning probe lithography method, tailored for research purposes, to realize room-temperature exciton-polariton systems based on the 2D perovskite $(PEA)_2PbI_4$, featuring a Rabi splitting exceeding 200 meV. Through precise control of the lithography parameters, we can broadly adjust the exciton-polariton dispersion and, importantly, vary the radiative coupling of polaritonic modes with the free space.

These findings offer a versatile approach to fabricating planar, high-quality perovskite-based photonic cavities, supporting the strong light-matter coupling regime. This advancement paves the way for the development of on-chip all-optical active and nonlinear polaritonic devices.

This research was supported by Priority 2030 Federal Academic Leadership Program.

Development of the modification technique for Hollow Core Microstructured Optical Waveguides by Quantum Dots and hybrid organic/inorganic tip membrane

Poster ID: 35M

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Keywords: Hollow core microstructured optical waveguides, Layer-by-Layer assembly, Quantum Dots, Waveguide modification

Hollow core microstructured optical waveguides (HC-MOW) have shown themselves to be a promising object for the research in the field of optical fibers and their modifications [1-3]. In this work we present new approach for modification technology of such objects, that can be used in addition with existing technique of Layer-by-Layer assembly and extended on other types of fibers and waveguides. We show how HC-MOWs could be modified by Quantum dots (QDs) and polyelectrolyte of Polyethylenimine (PEI) to form nanoscale layers on the inner walls of a waveguides. Such modification results in the overall drop in transmission level and its red shift. Further thermal treatment of the modified HC-MOW by QDs results in transmission increase and blue shift. Furthermore, we show a technique for a hybrid tip modification, where organic membrane and nanolayers of dielectric mirrors are deposited. Our study shows that such modification of tip automatically results in the similar spectral behavior due to the heating of the waveguides during mirrors deposition. Our results demonstrate possibility to improve existing technique of Layer-by-Layer deposition of nanoscale layers, modify HC-MOWs and alter its spectral properties.

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Experimental and theoretical demonstration of the high value of the rhenium diselenide refractive index in the near infrared range.

Poster ID: 37P

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Keywords: Dichalcogenides, back focal plane microscopy, high refractive index

Rhenium diselenide corresponds to the family of transition metal dichalcogenides (TMD). The optical properties of these materials have been extensively studied in the recent years. In this work, we put forward a hypothesis about the high value of the rhenium diselenide ($ReSe_2$) refractive index in the near infrared range. At the first step, this hypothesis was tested using the density functional theory. Obtained results showed that the $ReSe_2$ refractive index is characterized by record value exceeding 5. At the next step, we used experimental methods to confirm the theoretical r esult. Due to the uniaxial anisotropy of TMD materials, ellipsometric techniques is usually required for precise characterization of the dielectric permittivity tensor. In the case of the rhenium dichalcogenides, the situation is more complicated, becaus of the biaxial optical anisotropy of these compounds. In our work as an alternative method we suggest the angle-resolved reflection spectroscopy to measure all components of the dielectric permittivity tensor of an anisotropic crystal. We also demonstrated the good agreement between the experimental data and the predictions of the density functional theory. In conclusion, we showed that the combination of the large refractive index and giant optical anisotropy makes $ReSe_2$ a very promising material for all-dielectric nanophotonics applications in the near-infrared frequency range.

This work was was performed with financial support of the Russian Science Foundation (Project No. 21-12-00218).

Slot-die coating for bright green perovskite light-emitting chemical cell fabrication

Poster ID: 39P

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Keywords: Halide perovskite, Slot-die coating, Light-emitting chemical cell, Film morphology

Halide perovskites demonstrate properties well suitable for light-emitting device fabrication. However, micro and macro defects in perovskite film are crucial for device operation. Optimization of fabrication techniques can improve device properties. In this work, we use the scalable slot-die coating method at ambient conditions together with hot air drying to produce perovskite light-emitting chemical cells. We compare it with the spin-coating fabrication method and study film morphology and optical properties of obtained films. Turned out that annealing of the film after deposition on a hot plate leads to higher PLQY and longer Shockley-Read-Hole lifetime, but worse morphology of the film. On the contrary, hor air drying of the film during deposition leads to better morphology and worse photoluminescence. Besides slot-die coating is faster and demonstrates better results for device fabrication. We achieve 8100 cd m^{-2} and 2900 cd m^{-2} luminance at 5 V bias with InGa and Al top electrode correspondingly.

The impact of gamma rays on MAPbI3 perovskite films and solar cells

Poster ID: 41R

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Keywords: Perovskites, MAPbI3, Radiation hardness, Photoluminesence

Perovskites and devices based on them continue to attract a vast attention from material research society. Recent findings in this field showed that perovskite solar cells has a remarkably high stability under gamma irradiation. Depending on perovskite composition, various effects were discovered under effect of gamma rays. In this work, we studied the radiation hardness of methyl ammonium lead iodide (MAPbI3), a traditional material used as a light absorbing layer in perovskite solar cells. It was found that moderate doses up to 1kGy improve the quality of perovskite layer by neutralizing existing defects. Further increase in gamma dose up to 10kGy leads to gradual degradation of MAPbI3 layer in films and full stack solar cells. This was shown by measurement of steady state PL, TRPV and extracting ideality factors from solar cell characteristics. Our findings help to estimate the gamma dose threshold for solar cells and other devices based on perovskite material at which it can normally operate in highly radiative environments.

Light Control of the Dynamic Behavior of Localized Chiral Structures in Nanomotor-Doped Liquid Crystals

Poster ID: 43P

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Keywords: Liquid Crystals, Chiral Nanomotors, Light Control

Recently, the optomolecular approach has been proposed to create light-induced dynamic localized structures in frustrated chiral nematic liquid crystals under continuous ultraviolet Gaussian light illumination with attractive low powers.

The interaction between the twisting of the liquid-crystalline supramolecular structure and the diffusion of chiral molecular nanomotors creates a continuous, regular and unidirectional rotation of symmetry-broken liquid crystal structures under nonequilibrium light illumination conditions. The structure size increases with the power of the recording Gaussian beam, while the rotation period growths non-linearly with the pattern diameter.

However, with a significant increase in the diameter of such structures the rotation movement becomes unstable with slowing down or stopping completely. To get around these limitations, an approach has been found to optimize the spatiotemporal characteristics of the Gaussian beam, which makes it possible to regenerate the rotation of a supramolecular pattern. This extends the light-controllable dynamic behavior of the symmetry-broken structures towards rotation periods of tens of minutes.

Thermally-Induced Mechanical Tuning Of The Second Harmonic Generation In Pnipam Microgels Modified With Au And Si Nanoparticles

Poster ID: 45P

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Keywords: second harmonic generation, pNIPAM, thermally responsive polymer

Mechanically tunable optical platforms sensitive to external stimuli possess the huge potential for smart devices. These systems adjust phase or frequency of optical fields due to mechanical changes in their structure. Most of nonlinear optical signal such as second harmonic generation (SHG) are determined by the fabrication and cannot be tuned. Nevertheless, integration of temperature responsive materials such as poly(N-isopropylacrylamide) (pNIPAM) make these systems automatically driven. By incorporating stimuli-responsive materials, the process of reconfiguring optical signals in these nanoscale systems can be automated. These materials exhibit reversible phase transitions, such as shrinking or swelling, at specific temperatures, which are usually around 32-33°C. The hydrophobic shrunk state is characterized by a reduced volume, while the hydrophilic swollen state has a larger diameter.

This study investigates the temperature-dependent reversible mechanical transformations of thermally sensitive pNIPAM microspheres modified with silicon (pNIPAM@Si) and both silicon and gold nanoparticles (pNIPAM@Si@Au) through SHG signal switching. The SHG process is explored theoretically and experimentally, depending on the applied temperature and pNIPAM phase. The results show that the SHG is enhanced in the shrunk state for both systems. The amplification for pNIPAM@Si is seven times, while for pNIPAM@Si@Au, it exceeds 32 times. These SHG changes are reversible and reproducible during multiple cycles. This effect can be explained by electrical-field-induced second harmonic (E-FISH) contribution and hot spot reconfiguration through phase transition. The obtained results can be used for smart automatic temperature-sensitive detectors, robotic devices or tunable optical metasurfaces.

The work is supported by the Russian Science Foundation (project 21-75-10044).

Microfluidics for high precision synthesis of $CsPbBr_3$ perovskite for advanced optical applications

Poster ID: 49P

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Keywords: Inorganic Perovskite, Microfluidics, Microfluidic Synthesis, Perovskite Synthesis, Droplet Microfluidics, Lasing, Upconversion in Perovskites

Halide perovskite structures of submicrometer sizes have become outstanding tools for various applications in photonics. However, despite the high potential of perovskites, their stable, scalable, and reproducible synthesis with a fine control over the size of the resulting structures (a narrow size distribution) is still challenging. In this work, we report on the synthesis of all-inorganic lead halide perovskites *via* droplet microfluidics, where a formed droplet acts as a sealed microreactor for perovskites' nucleation and growth. For synthesis, we use two systems with different carrier fluids (either fluorinated oil or distilled water). The developed microfluidic system enables the fabrication of perovskite particles with sizes ranging from nanometers to submicrometers with a narrow size distribution, which depends on temperature and hydrophilic-lipophilic balance. Using the advantages of this synthesis method, we obtain optically resonant submicrometer cuboid particles. We study their lasing properties upon two-photon nonlinear excitation on a metallic substrate and reveal a significant reduction of the lasing threshold down to around 230 μJ/cm^2 when the pump wavelength λ corresponds to the first-order Mie resonance of the particle (at λ = 950 nm for the particle dimensions 440 × 640 × 710 nm^3). Our results can be useful for the development of infrared laser beam visualizers and nonlinear imaging.

This work was supported by the Ministry of Science and Higher Education of the Russian Federation (Project 075-15-2021-58).

Evaluating Carbon Dots for Microelement Detection in Biological Media

Poster ID: 51P

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Keywords: Carbon Dots, Fluorescence Lifetime, Quenching Mechanism, Metal Ions Sensor

Microelements in the bloodstream, such as ferrous (Fe^{2+}) and ferric (Fe^{3+}) and cobalt (Co^{2+}) ions, play a critical role in physiological functions. Fe^{2+}, Fe^{3+} are present in hemoglobin and helps distribute oxygen, while Co^{2+} is essential for metabolic processes and the normal functioning of the nervous system. The detection of these metal ions is important for health monitoring. CDs have shown promise in metal ion detection due to their low photobleaching and water solubility. Among a variety of optical sensing techniques, fluorescence intensity and lifetime decay measurements are used to monitor the response of CDs to metal ions. This study examined the optosensory properties of CDs and found that they are sensitive to Fe^{2+}, Fe^{3+} and Co^{2+}, but less sensitive to metal ions such as Na^{2+}, Ca^{2+}, Mn^{2+}, Mg^{2+}, Zn^{2+} and Ni^{2+}. These results can be used to develop a mechanism for the selective detection of Fe^{2+}, Fe^{3+} and Co^{2+} in medical diagnostics.

This work was performed with financial support of the Russian Science Foundation (Project No. 21-75-10044).

Instrument-free detection of nucleic acids via gene-targeted four-way-junction sensor coupled with magnetic nanoparticles

Poster ID: 53P

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Keywords: nucleic acid detection, four-way-junction sensor, nanoparticle aggregation, instrument-free analysis

The detection of nucleic acid (genomic DNA, rRNA, microRNA) is critical for the diagnosis of various diseases and timely treatment. PCR tests and molecular genetics are the gold standards in the detection of these nucleic acids, both in the cure of bacterial and viral diseases and for genomic and oncological treatment protocols. However, it usually requires expensive equipment and skilled personnel. Smart DNA nanosensors with four-way junction can be used as an alternative to classical methods and offer a cost-effective and easy-to-use diagnostic process. In this study, we developed a four-way junction hybridization sensor to detect the model HigA1 gene responsible for antibiotic resistance in *M.tuberculosis*. The probe has sensitivity up to 100 genomic equivalents (GE) due to its "long" analytebinding way and increased specificity due to its "short" complementary way (up to single nucleotide polymorphism (SNP)). Moreover, rapid visible aggregation on a streptavidin substrate once the analyte was added was observed. This aggregation was easily detectable by the naked eye. Additionally, dynamic light scattering (DLS) analysis showed a substantial shift in the size range of the complexes formed. Results demonstrate the potential of DNA nanosensors for visually detecting specific analytes, or SNPs for developing affordable and efficient diagnostic methods.

The authors are grateful to ITMO University. We also thank the Ministry of education and science of the Russian federation No FSER-2022-0009 and Priority 2030 program

Fast fabrication of microscale broadband radiation sources and their applications

Poster ID: 55P

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Keywords: Hybrid nanoparticles, broadband photoluminescence, laser-induced fabrication

Nowadays the development of miniature system components has become a major challenge in the field of photonics. To achieve this, highly efficient nanoscale white light sources are needed, and gold or silicon nanoparticles are commonly used. However, the efficiency of these sources is hindered by heating losses in the metal and the indirect-gap structure of silicon, respectively. To overcome this issue, combinations of metal and dielectrics have been proposed to significantly increase the local electric field. However, current methods of hybrid nanoparticle fabrication have a high cost and labour intensiveness, and do not allow to produce particles on a large scale or with precise control over deposition. This work is devoted to the realization of the method of synthesis of metal-dielectric nanoparticles based on laser-induced dewetting of a thin bi-layer film. The project involves studying the linear and nonlinear responses of the nanoparticles based on their material composition and demonstrating their functionality as sources of broadband radiation. The key advantage of the developed structures is their wide optical range of emission (from 400 to 950 nm), making them suitable for various applications. The Russian Science Foundation (project no. 322104) supported this work.

Decision Tree-based Gradient Boosting for the Rational Selection of Polymeric Hole-Transport Materials for Perovskite Solar Cells

Poster ID: 57R

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Keywords: Perovksite Solar Cells, Hole-Transport Materials, Gradient Boosting, Decision Tree

Over the past few years, there has been a great deal of interest in researching perovskite solar cells. These devices have gained attention due to their high efficiency, easy photoactive layer fabrication using solution-based techniques, potential for upscaling using printing methods, and low expected energy production costs. It is important to consider the material used for hole-transport layer (HTL) as it affects the stability and efficiency of perovskite solar cells. Our recent research has shown that using a double HTL consisting of polytriarylamine and metal oxide in the highest oxidation state can enable stable performance of perovskite solar cells for over 4500 hours. Building on this success, we have compared a set of 46 conjugated polymers with various chemical structures using the same double HTL approach. We investigated the stability of perovskite solar cells under constant light illumination and formulated several empirical rules for the design of the perfect polymeric HTL. Additionally, the study of cross-sections of fresh and aged devices with six exemplary materials using scanning electron microscopy revealed significant changes in the bulk of perovskite for unstable devices. In addition, we applied machine learning for the first time to reveal potential HTLs among conjugated polymers. By fitting collected data using decision tree-based gradient boosting, we were able to select rational polymeric hole-transport materials for perovskite solar cells.

Nonlinear Optical Properties of $CsPbBr_3$ and $Cs_3Cu_2Br_5$ Perovskite Quantum Dot Organic Glasses

Poster ID: 59M

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Keywords: Halide perovskite, quantum dots, nonlinear optical properties, reverse saturable absorption (RSA), self-focusing effects.

This study explores how halide perovskite materials, specifically $Cs_3Cu_2Br_5$ and $CsPbBr_3$ quantum dots (QDs), can enhance nonlinear optical (NLO) properties in organic glasses. $Cs_3Cu_2Br_5$ /PMMA organic glasses demonstrate reverse saturable absorption (RSA) and self-focusing effects, surpassing lead-containing perovskites in optical limiting (OL) performance. The integration of $CsPbBr_3$ QDs into PMMA also leads to excellent OL performance with RSA characteristics. These findings suggest promising applications for these perovskite materials in advanced photonic devices and laser protection. Additionally, $CsPbBr_3$/PMMA organic glasses possess fascinating optical properties, including nonlinear effects and light transmission control, making them suitable for a variety of applications such as all-optical switching systems, optical component protection, and frequency conversion.

Ultra-wide range quantitative detection of pesticides exploiting the agglomeration and aggregation of gold nanoparticles

Poster ID: 61P

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Colloidal gold nanoparticles (AuNPs) display exceptional optical properties, excellent chemical stability, and easy bioconjugation, making them a promising platform for Surface-Enhanced Raman Spectroscopy (SERS)-driven applications. However, their propensity to aggregate creates a significant challenge for their broader use in biosafety-related fields. In our study, we focused on mitigating this issue by investigating and optimizing sodium chloride (NaCl) induced charge-based AuNPs agglomeration. We observed that this approach could expand the detection range of chlorpyrifos (CPF), a widely used pesticide, creating a bell-curve response. Our results showed that this method could detect CPF residues in solvents at concentrations as low as 9 ppb, providing a wider detection range from 9 ppb to 1000 ppm. In addition, we developed a simple and fast swab technique to collect CPF residues from cucumber surfaces, enabling CPF detection down to 0.1 ppm/cm^2. Furthermore, we utilized an unsupervised principal component analysis (PCA) model to differentiate cucumbers containing organic phosphorus pesticides from those with CPF, achieving reliable discrimination with a Q^2 value greater than 0.96. Overall, our methodology utilises the issues associated with nanoparticle aggregation, significantly widening the detection range of harmful substances. This could potentially contribute to advancements in biosafety detection, underlining the potential of colloidal AuNPs as effective tools in this sector.

Keywords: SERS, pesticide, gold nanoparticle, agglomeration, aggregation, swab technique, principal component analysis

Semitransparent Perovskite Solar Cell with double electron transport layer and ITO/Ag as top electrode

Poster ID: 63P

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In this work double electron transport layer (ETL) of PCBM/ZnO (or SnO_2) was used to achieve efficient working semitransparent Perovskite Solar Cell (PSC). Such layer provides excellent charge transport properties, and usage of oxides leads to better protection of perovskite layer while top transparent electrode (ITO) is sputtered. To achieve better transparency and conductivity special pattern of metal (Ag) was thermally evaporated, therefore the structure of final device was ITO/PTAA/PK/PCBM/ZnO/ITO/Ag (pattern). Active layer in this work was perovskite (PK) of the following structure: $MAPb(I_{0.9}Br_{0.1})_3$. PK solution was prepared in modified solvent which allowed to avoid antisolvent step while spin-coating process. The cell with ETL of PCBM/BCP was used as reference with average efficiency of 17%-18%. Working and not shunted device was obtained with high V_{oc} of $\sim$ 1.1 V, however, fill factor and J_{sc} were quite low and work with optimization of ITO sputtering is to be done. Such devices are planned to be used in tandem structure with CIGS cell to overcome Shockley-Queisser limit. This work is supported by the Russian Science Foundation (Grant N 23-73-00060).

Keywords: Perovskite, Solar Cells, Semitransparent, Double ETL

Temperature dependence of photo-induced phase segregation in bromide-rich mixed halide perovskites

Poster ID: 65P

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Keywords: Halide perovskite, phase segregation, temperature dependent photoluminescence

Organo-inorgatic mixed halide perovskites such as $MAPbBr_xI_{3-x}$ undergo phase segregation, expressed as spectral red-shifting of photoluminescence spectra under illumination. The origin of low energy luminescence related to iodine-rich domains formation due to anion segregation. Such domains create favorable band for induced carrier funneling into them. Despite phase segregation process is vital for mixed halide perovskite based optoelectronic devices, the exact mechanism is not well-understood. In this study, we investigate the temperature dependence of halide segregation in bromide-enrich mixed halide perovskites through low-temperature photoluminescence spectroscopy. To obtain a comprehensive understanding of segregation processes, especially in its initial stages, the low-temperature temporal photoluminescence spectroscopy were studied for two bromide-rich mixed halide perovskites $MAPbBr_2I$ and $MAPbBr_{2.5}I_{0.5}$. Here we demonstrate the formation of temporary and intermediate peaks during the segregation process in bromide-rich perovskites, related to halide composition of these domains. Besides intermediate stages perovskite phase transition from orthorhombic to tetragonal phase was captured for bromide-rich organo-inorgatic mixed halide perovskites. To complement the phase segregation study, temperature dependance of time-resolved photoluminescence spectroscopy was provided. Which allows estimating the change in the radiative and non-radiative lifetimes for the host perovskite peak and a segregated one depending on temperature.

This work was supported by Priority 2030 Federal Academic Leadership Program.

Day 2

Aug 16th, 8:30 AM – 17:30 AM (GMT+8)

Numerical investigation of charge carriers dynamics in a semiconductor with two Schottky contact.

Poster ID: 02P

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Keywords: Scharfetter-Gummel discretization, metal-semiconductor-metal, Newton method, Gummel iteration

We have calculated the charge carriers density inside a n-type micro-crystal semiconductor that is sandwiched between two Schottky contact. We used drift diffusion equations and finite difference method and utilized Scharfetter-Gummel discretization technique. To solve the discrete system of equations we implemented the Newton method by calculation of Jacobian using analytical form of Poisson's equation and discrete form of continuity equations. We proposed an strategy to achieve convergence at non-equilibrium case when the Schottky barrier at both contact is high. The proposed strategy is based on calculation of Jacobian matrix's element by using a proper numerical derivative and using of several initial Gummel iteration prior to the Newton iteration. While Newton iteration is sensitive to the numerical derivative at high Schotkky barrier, having source terms in the continuity equations eliminates this sensitivity. Moreover, we suggested a method for assessment of trap state density by measuring potential of a sharp reduction in current density.
This research is supported by Priority 2030 Federal Academic Leadership Program.

Polarization Insensitive Frequency Multiplexed Terahertz Digital Coding Metasurface for Independent Control of Reflected Waves

Poster ID: 04R

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Keywords: Digital coding metasurface, Frequency multiplexed, Polarization insensitive, Propagating waves controlling, Multi-mode OAM beams, Surface waves generation and controlling

Independent control of electromagnetic (EM) waves by metasurfaces for multiple tasks are highly desired and is still the hot topic of research. Here we present a polarization insensitive frequency multiplexed coding metasurface to control the reflected Terahertz waves in the two operating bands independently. Firstly, a coding meta-atom is designed and optimized to provide sixteen distinct independent discrete phases at two different frequencies. These meta-atoms are then distributed with distinct coding sequences in the two-dimensional spatial plane to realize various bi-functional metasurfaces. As a proof of the concept various full structures are designed and simulated to realize a number of bifunctionalities including anomalous reflection/beam shaping, beam steering/ multi-mode orbital angular momentum (OAM) beam generation and propagating wave to surface wave (PW-SW) conversion/ beam steering in the lower and higher (f_l/f_h) Terahertz band, respectively. We believe that the proposed ideas have potential applications in the polarization insensitive multispectral control of EM waves in the Terahertz band to design multitask meta-devices.

A MACA-based Energy-Efficient MAC Protocol Using Q-Learning Technique for Underwater Acoustic Sensor Network

Poster ID: 06P

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One of the major challenge in underwater acoustic wireless sensor networks (UWASNs) is designing the energy efficient medium access control (MAC) protocol. Because in UWASNs, all nodes are battery-operated and replacing these batteries every time is a crucial problem in UWASNs. Various challenges such as, high error rate, long propagation latency and low bandwidth also affect the designing of MAC protocols in UWASNs. In this research, a MACA-based energy-efficient MAC protocol using the Qlearning technique is proposed for UWASNs. Our opted protocol decreases collisions while retaining better energy efficiency. The ability of the sensor Rx nodes to avoid collisions in the absence of any previous interference knowledge, which eliminates the requirement for further indicating, is a crucial component of the suggested technique. Compared to other MAC protocols, simulation results demonstrate that our opted MAC protocol performs significantly better in terms of throughput, end-to-end delay, and energy consumption

Keywords: Medium access control (MAC), Collisions, Energy Efficiency, Q-learning technique, underwater acoustic sensor networks.

G-quadruplex chemiluminescent sensor for the detection of specific nucleic acid sequences of pathogenic microorganisms

Poster ID: 08M

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Efficient point-of-care (POC) molecular diagnostic techniques have the potential to revolutionize healthcare by providing a rapid and accurate diagnosis of infectious diseases. In this study, we propose the design of a peroxidase -like DNA-nanomachines (PxDm) that can selectively hybridize with specific analytes and produce readable outputs. We have chosen *S.aureus*, a pathogen responsible for a number of nosocomial infections, as the target analyte. For detection, we selected a specific gene that is constitutively expressed. The PxDm was equipped with three long analyte binding arms to tightly bind and unwind analytes. Only when all arms bind the analyte a G-quadruplex (G-4) structure is assembled. This structure can form a complex with hemin, which exhibits peroxidase activity. In the presence of the G-4/hemin complex, the chemiluminescence (CL) of luminol molecules, activated by hydrogen peroxide, is enhanced. We evaluated the CL kinetics for several minutes, comparing them with the background signal using a photon counting head. The results indicate that *S.aureus* was recognized with high selectivity and sensitivity up to zeptoM concentrations in a quartz cuvette. In the future, this system may become a full-fledged lab-on-a-chip for the detection of marker-sequenced nucleic acids. The PxDm has several advantages over traditional diagnostic techniques, including its ability to detect analytes at ambient temperatures and its high selectivity and sensitivity.
The authors are grateful to ITMO University. We also thank the Ministry of education and science of the Russian federation No FSER-2022-0009 and Priority 2030 program.

Keywords: peroxidase-like DNA-nanomachines (PxDm), G-quadruplex (G-4) structure, hemin, peroxidase activity, chemiluminescence (CL), affordable POC diagnostics

Metal-doped luminescent carbon dots as nanoprobes for bioimaging

Poster ID: 10R

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Luminescent carbon dots (CDs) are promising nanomaterial with a photoluminescence (PL) tunable from deep blue to near infrared spectral range. CDs are biologically compatible, low toxic, and can prospectively serve as luminescent nanoprobes for biomedical applications, such as drug-delivery, imaging, sensing, etc. Doping of CDs with metals makes it possible to expand the scope of their application and create a multimodal nanoprobe for bioimaging. In this work, we developed CDs doped with manganese (Mn-CDs) with emission in the range of 450-650 nm from various precursors: o-phenylenediamine or citric acid and formamide. We also registered magnetic resonance (MR) images and investigated relaxation performances of Mn-CDs in vitro. It was found, that Mn-CDs have an ability to reduce both longitudinal (T1) and transverse (T2) relaxation time of protons (T1 and T2) by up to 6.4% and 42.3%, respectively, while the concentration of the metal was 2.5 μmol/L. Thus, the developed Mn-CDs are suitable for use and future research as dual modal nanoprobes for luminescent and MR bioimaging.
This work is supported by the Russian Science Foundation (RSF) grant No. 22-73-00090, https://rscf.ru/project/22-73-00090/.

Keywords: carbon dots, luminescent bioimaging, MRI, contrast agents

The effects of lanthanum ions substitution on properties and effective absorption bandwidth (EAB) of zinc ferrite

Poster ID: 12R

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A comprehensive study was conducted to examine the effect of lanthanum (La^{3+}) ions substitution on zinc ferrite crystallography parameters, microstructure, and related physical properties. In this work, Lanthanum-doped zinc ferrite series were prepared by co-precipitation method. Rietveld refinement method combined with Raman spectra analysis reveal that all compositions are only crystallized into zinc ferrite ($ZnFe_2O_4$) after high-temperature treatment at 1000 °C for 5 h. La^{3+} ions preferentially reside in BO_6 sub-lattice, which corresponds to the expanding unit cell and octahedral volume of $ZnFe_2O_4$. The elongation of cation-anion bonds at the BO_6 sub-lattice (0.02Å) and the movement of oxygen toward the AO_4 sub-lattice play an important role in weakening super-exchange interaction (SE) between sub-lattices and raising the frustration of magnetic structure as confirmed by the electron density (ED) mapping analysis. The particle size of the sample was decreased from 1400 nm for x = 0.01 to 600 nm for x = 0.04. These factors were found to cause the decrease of the magnetization values (M_s and M_r) and the increase of field coercivity due to the increase of La^{3+} ions substitution. The substitution of La^{3+} ions are found effective to improve the microwave absorbing (MA) ability of zinc ferrite. The substitution of La^{3+} ions in the composition of x = 0.04 affected the full coverage of the EAB across the entire X-band frequency range, making it an excellent microwave absorbing materials (MAMs) candidate.

Keywords: Zinc ferrite, Lanthanum substitution, Electron density mapping, magnetic properties, microwave absorbing ability

Different scaling laws for Q factor of resonances related to bound states in the continuum

Poster ID: 14P

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We investigate the scaling behavior of resonances associated with bound states in the continuum (BIC) in metasurface comprising circular rods with holes. Through numerical simulations and analytical calculations, we examine the dependence of the quality factor (Q-factor) of resonances on the dimensionless asymmetry parameter for various metasurface configurations. The Q-factor scaling laws reveal both known dependencies, such as $Q \propto \alpha^{-2}$, as well as new ones, including $Q \propto \alpha^{-4}$ and less than two power law $Q \propto \alpha^{-1.75}$. Our analysis reveals that BIC has *dominant* and asymmetry-*induced* multipole terms. Depending on the radiation properties of the induced multipoles and their amplitude in of vanishing asymmetry. Our article provides the effective Hamiltonian approach in studying these phenomena. We expect that our results will open up the possibility of creating photonic structures applicable to the required problem of studying the strong and weak dependence of the quality factor on the asymmetry parameter with respect to the usual quadratic law.

This work was supported by Russian Science Foundation (21-19-00677).

Keywords: resonant waveguide, integrated photonics, magneto-induced non-reciprocity, phase shifter, photonic crystal

Bound states in the continuum: stability against structural disorder

Poster ID: 16P

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In this work, we investigate the stability of accidental and symmetry-protected bound states in the continuum (BIC) against structural disorder. BICs are resonances with infinite radiative quality factor (Q) and although the infinite Q-factor of BIC is a mathematical abstraction, high-quality supercavity modes (quasi-BIC) formed by the BIC mechanism can be excited into the resonator. Here we consider a two-layer resonator formed by dielectric cylinders. The results show that the symmetry-protected bound states in the continuum are more resistant to fluctuations in the distance between the layers, while accidental BIC is more resistant to fluctuations along the period. With an increase in the degree of disorder, the localization of the electromagnetic field is observed, which leads to a decrease in the effective length of the resonator. It should be noted that starting from 60 periods, the effective length of the resonator remains the same with an increase in the number of periods. Also, we investigate the dependence of the Q-factor on the structural disorder in symmetric and asymmetric array of blocks. The results show that in an asymmetric system, the Q-factor is resistant to the introduction of structural disorder.

This work is supported by the Russian Science Foundation (Grant N21-19-00677).

Keywords: bound states in the continuum; metasurface; spatial localization; structural disorder

Anapole: Nonradiating State in All-Dielectric Metasurface

Poster ID: 18P

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The light scattering properties of the dielectric metasurface offer low loss and give access to the electric and magnetic moments simultaneously. The high-index material (such as Si, Ge, and TiO_2) requirement enhances the optimum performance of the device. This also allows the manipulation of exceptionally strong and tunable resonances formed due to the constructive or destructive interference of various multipoles. The Cartesian multipolar decomposition provides the view of toroidal multipole along with the family of electric and magnetic multipole moments. The destructive interference of the electric multipole family with their toroidal counterparts, in the case of Si nanoresonator, gives rise to the non-radiating states called “Anapole”. In our recent study, we have shown the formation of pseudo and hybrid anapole states in a single nanodisk which may find exciting applications in sensing, spectroscopy, switching, and optical nonlinearity.

Keywords: Dielectrics, Multipole decomposition, Anapole

Symmetry-Protected Bound States in the Continuum in All-Dielectric Metasurfaces

Poster ID: 20P

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This research presents a study on the formation of symmetry-protected bound states in the continuum (BICs) in the all-dielectric nanoresonator. The asymmetry in the nanoresonator is obtained by either breaking the out-of-plane symmetry or the in-plane symmetry of the design that turns the ideal BICs into quasi-BICs. These states exhibit as Fano resonance and electromagnetically induced transparency (EIT) in the transmittance spectrum. We obtained high-quality factor resonances through eigenmode analysis and full wave finite element method numerical simulation. These resonances are made tunable by integrating the asymmetric nanoresonator with the monolayer graphene for switching applications.

Keywords: Metasurfaces, Bound states in the continuum, Fano resonances, EIT, Graphene

Exceptional points enhance sensing with a bilayer metasurface

Poster ID: 22P

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Exceptional points (EPs), non-Hermitian degeneracies where eigenvalues of a system and their corresponding eigenvectors simultaneously coalesce, possess higher sensitivity to sufficiently small perturbations than conventional degeneracies known as diabolic points. Here, we use two orthogonally oriented split-ring resonators (SRRs) and vanadium dioxide whose conductivity changes with temperature to tune a bilayer metasurface in a precise and controlled manner to exceptional points in polarization space at a certain conductivity. The system features two sensing schemes to achieve high-sensitivity sensing of temperature and refractive index in the terahertz (THz) range. Our work of EPs-enhanced sensitivity paves the way for multifunctional sensors with unprecedented sensitivity based on metasurfaces.
This work is supported by the National Natural Science Foundation of China (62275061, 62175049); Natural Science Foundation of Heilongjiang Province (ZD2020F002); Harbin Engineering University (B13015); Fundamental Research Funds for the Central Universities (3072021CFT2501, 3072022CF2505, 3072022TS2509).

Keywords: non-Hermitian, metasurface, exceptional point, high sensitivity sensing

High-Harmonic Generation from Halide Perovskites Metasurfaces

Poster ID: 24P

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Keywords: Halide Perovskite, Metasurfaces, High-Harmonic Generation

Outstanding properties of halide perovskites find their application in optoelectronics. At the same time, a relatively high refractive index provides the opportunity to support Mie resonances in the visible and near IR frequency ranges on the micro- and nanoscale, which can enhance several effects. Additionally, halide perovskites demonstrate strong nonlinear properties contributed to multiphoton absorption and subsequent photoluminescence, and high harmonic generation. The generation of high harmonics gained significant attention due to its potential applications as a source of extreme UV and soft X-rays. Employment of the resonant structures allowed efficient high harmonics generation on the nanoscale. Although halide perovskites demonstrate nonlinear behavior, including high harmonic generation, the metaphotonic approach has not been employed yet. Herein, we have developed and fabricated halide perovskite metasurface for generation third and fifth harmonics. We observed a two-order enhancement of fifth harmonics from the metasurface as compared to unpatterned perovskite film. Our work paves the way towards the study of efficient high-harmonic generation in resonant dielectric structures based on halide perovskites. The work was supported by the Ministry of Science and Higher Education of the Russian Federation (agreement 075-15-2021-589)

Magnetic field-induced non-reciprocity in silicon waveguides with strong transverse electric field rotation

Poster ID: 26P

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Keywords: resonant waveguide, integrated photonics, magneto-induced non-reciprocity, phase shifter, photonic crystal

For governing light signals in modern photonics, non-reciprocal devices are of high importance. Magneto-optical effects are often responsible for non-reciprocity, but implementing non-codirectional magnetic fields on chips is difficult. It is convenient to apply the external magnetic field in the direction normal to the chip plane (Voigt geometry), which leads to modes with in-plane electric field transverse rotation. Here we propose studying resonant magnetic-material-free silicon waveguides that support such modes. These nanostructures are based on standard 220nm commercially available SOI wafers. The serpentine folding of waveguides allows them to be used as on-chip phase shifters as well as on-chip optical isolators.

This work was supported by Russian Science Foundation (21-19-00677).

Methods of calculation of Exceptional Points in dielectric rings

Poster ID: 28P

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Keywords: Dielectric ring, Exceptional point, Resonant state expansion, Temporal-coupling mode theory

In photonics, most systems are non-Hermitian due to radiation into free space, but at the same time, the non-Hermitian systems opens up new effects, such as bound state in the continuum and exceptional points, which can be observed in dielectric rings. This work demonstrates methods for calculating exceptional points in dielectric rings, such as the temporal coupling mode theory and resonant state expansion. Subsequently, all three methods (Comsol Multiphysics, Resonant State Expansion and Temporal Coupling Mode Theory) will be compared and outline the benefits of each method.

This research was supported by Priority 2030 Federal Academic Leadership Program and the Foundation for the Advancement of Theoretical Physics and Mathematics “BASIS” (Russia).

Exploring Evolutionary algorithm for designing and optimizing nanophotonic devices

Poster ID: 30R

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An array of opportunities for creating novel technologies using tetra hertz frequency bands had remained largely unexplored and undeveloped for a considerable period of time. Since the last few years many simulation methods and optimization techniques have been proposed and devised to open up frontier of research in manipulating the light wave due to its diverse range of applications, e.g. optical pulse delay and optical switching. Opposite power flow in core and clad of plasmonic waveguide can make it a potential candidate to exhibit slow light phenomenon. In this paper we have explored trapping modes in lossy plasmonic waveguides via two approaches: spatial and temporal, using evolutionary algorithm. Furthermore, optimized structures of 2D photonic crystal with maximum band gap at specific packing factors is also calculated using COMSOL and MATLAB.

Keywords: trapping modes, optimized, plasmonic, photonic crystals

Optical Spintronics

Poster ID: 32P

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In our work we introduce basic concepts of spintronics into photonic world. We introduce optical spin current, an analog of electronic spin current in photonics, and show that it is possible to transfer electromagnetic spin without transfer of the energy. We show that it is possible to create optical spin diode - a device, in which spin angular momentum (SAM) can be transferred only in one direction. It is noteworthy that such a diode does not require the breaking of electromagnetic reciprocity. We present full quantum calculations of the interaction of two lambda atoms via the photonic system of the optical spin diode and show that due to the directional nature of photonic SAM transfer , the transfer of angular momentum between the atoms is also directional.

Keywords: Spintronics, Chirality, Diode, Photonics, Spin Angular Momentum

Optical torque empowered by the harmonic generation

Poster ID: 34R

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Optically induced mechanical torque driving rotation of small objects requires the presence of absorption or breaking cylindrical symmetry of a scatterer. A spherical nonabsorbing particle cannot rotate due to the conservation of the angular momentum of light upon scattering. Here, we suggest a novel physical mechanism for the angular momentum transfer to nonabsorbing particles via nonlinear light scattering. The breaking of symmetry occurs at the microscopic level manifested in nonlinear negative optical torque due to the excitation of resonant states at the harmonic frequency with higher projection of angular momentum. The proposed physical mechanism can be verified with resonant dielectric nanostructures, and we suggest some specific realizations.

Keywords: Optical torque, second harmonic generation, symmetry, angular momentum of light

Linear and Nonlinear Optical chirality driven by Quasi-Bound States in the Continuum

Poster ID: 36P

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Keywords: BIC, Chirality, Metasurfaces, Harmonic Generation

We show how one can shape quasi-bound states in the continuum (quasi-BICs) of dielectric metasurfaces to provide maximum linear-optical chirality. We also consider how such quasi-BICs can empower chiral nonlinear-optical processes. By simulations we demonstrate second and third harmonic generations with high chiral responses: arbitrarily polarized pumping waves generate circularly polarized harmonic and circular polarized pumping waves provide giant harmonic circular dichroism.

The work of A.A. and M.G. is supported by the Russian Science Foundation (project 23-42-00091, https://rscf.ru/project/23-42-00091/). Y.K. acknowledges a support from the Australian Research Council (grant DP210101292) and International Technology Center Indo-Pacific (ITC IPAC) via the Army Research Office (contract No. FA520921P0034).

Raman Lasing in Nanoresonator Supporting Quasi Bound State in the Continuum

Poster ID: 38P

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Keywords: Raman lasing, nonlinear nanophotonics, quasi-BIC, low threshold

The creation of nanoscale lasing devices is an actively developing branch of nanophotonics. Recent progress in the fabrication of semiconductor nanostructures has allowed operating with high-Q optical resonators which is crucial for performance of nanolasers. However, most of the existing configurations require either cryogenic operation temperatures or large pump powers and realization of low-threshold efficient nanoscale laser is still challenging. In this work, we provide a configuration of the gallium phosphide nanolaser involving stimulated Raman emission as the main operating principle. Implementation of the quasi-BICs concept along with the azimuthally polarized excitation empowers low lasing threshold. We apply a simple analytical model to optimize the geometrical parameters of the optical resonator and verify it with the rigorous full-wave numerical analysis. For a cylindrical nanoparticle with the diameter of about 0.95λ the found lasing threshold is approximately 21 mW, which corresponds to the low-input regime of the continuous wave laser. The provided configuration is, to the best of our knowledge, the very first prototype of the low-threshold Raman laser with all the dimensions smaller than the operational wavelength.

Flat-imprinting for Optical gain enhancement of CdSe/CdZnS nanoplatelets thin films

Poster ID: 40P

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Keywords: Flat-imprinting, Stamping, Gain enhancement, Nanoplatelets

The work describes the application of flat-imprinting method to thin films based on CdSe/CdZnS nanoplatelets. The quasi-two-dimensional structure of the nanoplatelets causes lower Auger recombination rate. The delocalization of charge carriers in the plane of the nanoplatelets ensures the coexistence of several excitons and reduces the probability of exciton-exciton annihilation. To create thin NPL films, spin-coating and oriented self-assembling methods were used. The use of a flat stamps in the modification of the surface led to a decrease in the film thickness, and in samples with significant inhomogeneity, also to a decrease in the surface roughness. The size of the stamps, which is smaller than the samples, made it possible to evaluate the difference in the roughness and thickness of the nanoplatelets film. The success of surface modification has been proven by atomic force microscopy. The imprinting mode of the spin-coated samples consisted in the application of 500 kg for 5 minutes. Despite a slight improvement in surface quality - from Rms 4 nm to Rms 3 nm and a decrease in thickness by an average of 30 nm, a significant improvement in luminosity characteristics was detected. The Sample after stamping process showed the effect of amplified spontaneous emission at a threshold power of 65 μW, which was absent initially. The results of optical measurements by the variable stripe length method confirmed the enhancement of photoluminescence and the decrease in the thresholds of amplified spontaneous emission. Under 600 μJ/cm^2 fluence, the modal gain increased by a factor of 12.7 from 22 cm^{-1} to 280 cm^{-1} for the initial and imprinted regions, respectively. The combination of unique characteristics and novel approaches to modifying nanoplatelets layers makes them a suitable material for LED applications due to their high optical gain. The proposed method of surface modification can be used as an additional stage in the design of Side-emitting LEDs.

Exciton-polariton lasing in perovskite Mie-resonant nanocuboids

Poster ID: 42P

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Keywords: Nanolasers, Perovskite, Polariton lasing, Mie resonances

Compact laser sources are highly demanded as key building blocks for integrated nanophotonics. One of the main limitations for the development of deeply subwavelength nanolaser is increased lasing thresholds and, as a consequence, overheating. In this work we exploit the accumulation of exciton-polaritons within a one Mie-mode state enhanced due to mirror-like effect to achieve a single mode lasing at 532 nm from an ultra-small (≈0.37 λ) perovskite nanocuboid on a metal-dielectric substrate. The polaritonic nature of lasing from 0D nanocavity is proven based on both experimental and analytical comparison with 1D and 2D waveguiding systems. As a result, we achieve a record-small perovskite nanolaser with an inversion-free operating regime due to the high exciton binding energy (≈35 meV), refractive index (>2.5 at low temperature), and optimization of polariton condensation, namely, such crucial parameters as intermode free spectral range and phonon spectrum in $CsPbBr_3$. In addition, the chemically synthesized colloidal $CsPbBr_3$ nanolasers can be easily integrated with advanced systems, making them a versatile tool for creating compact optical chips and biosensors.

This research was supported by Priority 2030 Federal Academic Leadership Program.

Highly luminescent material based on defect passivated perovskite $CsPbBr_3$ for laser and LED application

Poster ID: 44P

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Keywords: Perovskites, Defect passivation, Luminescence, Laser, LEDs

Metal halide perovskites ABX_3 are attractive materials for active media applications in lasers, LEDs, and solar cells due to the combination of excellent electronic and optical properties with the advantages of liquid methods for obtaining thin films from solutions. At the same time, the operational and spectral stability of these devices is not sufficient for commercial applications and there is a need to explore strategies to improve the stability of perovskite materials, such as composite engineering and defect passivation. Doping of perovskites with salts of cation B is considered one of the effective methods for passivating defects and creating highly efficient devices based on perovskite. However, the character of passivation is still not clear, since doping with metal ions is accompanied by the introduction of halide ions, which also lead to an improvement in optoelectronic properties. In this work, we studied the optical properties of thin films of a perovskite-polymer composition based on $CsPbBr_3$, and also studied the effect of additional doping of the initial $ZnBr_2$ solution. As a result of measurements, a twofold increase in the photoluminescence quantum yield for films doped with Zn^{2+} in comparison with the initial ones was demonstrated, which indicates higher emission properties. In addition, the study of the dependences of the luminescence intensity on the power of the exciting laser showed that there are fewer nonradiative recombination paths in doped samples. The demonstrated results confirm that doping with $ZnBr_2$ plays an important role in the passivation of defects that enhance nonradiative recombination in $CsPbBr_3$ thin films.
This research was supported by Priority 2030 Federal Academic Leadership Program.

Photoluminescent intensity modulation in hybrid structures based on halide perovskites and phase memory materials

Poster ID: 46P

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Keywords: Active photonics, GST, Luminescence, Perovskites

In this work we have developed and investigated new hybrid GST-perovskite platform for photoluminescent intensity control. We have constructed an analytical model to describe the influence of a GST substrate on perovskite photoluminescence. We have supposed that two main factors affected on electron hole pairs recombination in perovskite layer on GST film are the Purcell effect and the carrier migration and localization on GST-perovskite interface. We have calculated a Purcell factor for GST-perovskite system with two GST phases (amorphous and crystalline) and three halide perovskites (chlorine, bromine, and iodine). After calculations we fabricated GST-perovskite hybrid system and observed perovskite photoluminescence intensity enhancement on crystalline GST compared with amorphous one for three different perovskites mentioned above. Finally, we have experimentally shown the possibility of multiple GST switching under perovskite layer without damaging of latter which makes the system perspective for switchable light sources creation.
This work was supported by the Russian Science Foundation (Project 21-79-10214).

Modulation of Purcell factor with phase change materials

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Poster ID: 48P

Keywords: PCM, LDOS, photoluminescence, Purcell factor

In this work we show modulation of the intensity of spontaneous emission of perovskite by change between amorphous and crystalline phases of phase change materials (PCMs). As PCMs we consider GST and SbSe. As an emitting layer we examine different perovskites, which alter by variation of halogen anion composition (Cl,Br,I). This allows one to tune emission of light in the whole visible range. Considering angular spectrum representation of the Green's function dyadic, we calculate photonic local density of states. Then the Purcell factor is the ratio of obtained photonic LDOS to one for structure without PCM. Varying thicknesses of perovskite and PCM we obtain colormaps of Purcell factor ratio between crystalline and amorphous phases for a number of perovskites.
This work was supported by the Russian Science Foundation (Project 21-79-10214).

Fabrication of Si-based nanoobjects by laser ablation: insights from large-scale atomistic simulation

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Poster ID: 50R

Keywords: Si, nanoparticles, laser ablation

Hybrid metal-silicon nanostructures are key components of multifunctional nanophotonic engineering. One of the promising methods for creation of such structures is laser ablation of Si-based films. This work is devoted to a comprehensive study of the various stages of this procedure for Si, Si-Au and Si-Al nanoparticles: ablation and subsequent solidification of the formed nanoparticles. Based on large-scale atomistic simulation, various fabrication scenarios have been identified that lead to different final states of the formed structures: amorphous, compound and sponge-like nanocrystal structure. The simulation results are discussed in terms of comparison with the available experimental data.

Fabrication of perovskite $CsPbBr_3$ films with high optical gain

Poster ID: 52M

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Keywords:
High-crystallinity, large-grains, optical gain

Nowadays, perovskites based on cesium and lead halide ($CsPbX_3$. X = I, Br, Cl) are a promising class for the manufacture of micro- and nanolasers generating laser radiation in the range of 420-824 nm. Chemically obtained $CsPbX_3$ perovskite single crystals are of high quality and various shapes (cuboids, whiskers nanocrystals, etc.), and have a high level of optical gain (10^3 cm^{-1}). However, polycrystalline thin films of the composition $CsPbX_3$ usually have a morphology with high roughness and a large number of defects, which in turn does not allow them to be used to generate laser radiation, and the value of the optical gain of these films is usually 10^2 cm^{-1}. In this work, we present a new method for fabricating thin films of $CsPbBr_3$ perovskite with large grains based on high-temperature pressure recrystallization, which have a high optical gain (10^4 cm^{-1}). Structural characterization of the obtained films based on atomic force microscopy, scanning electron microscopy, X-ray diffraction confirms the high quality of the films. Decay curves of time-resolved photoluminescence were measured for initial (polycrystalline) $CsPbBr_3$ films and for films after high-temperature recrystallization. The observed curves demonstrate an increase in the decay time for a film with coarse grains (11.5 ns) relative to the initial polycrystalline film (1.34 ns), which, in turn, can be explained by a decrease in the number of deep defects after high-temperature recrystallization. The experimentally obtained measurement data of the optical gain demonstrate an identical dependence – for the initial polycrystalline $CsPbBr_3$ film, the value was 5000 cm^{-1}, while for the film after high-temperature recrystallization, the record value is 12900 cm^{-1}. Based on films with a high optical gain, perovskite microdiscs were fabricated by laser ablation, realizing high-quality laser generation (Q-factor 1800) at a low optical pumping threshold 14μJ cm^{-1}.

This work was supported by the Russian Science Foundation (project 23-72-00031). The work was partially done in ITMO Core Facility Center “Nanotechnologies”.

Anion-assisted Ytterbium and Manganese Ions Doping of 0D and 2D Lead Halide Perovskite Nanostructures

Poster ID: 54P

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Keywords: lead-halide perovskites, lanthanides, manganese, near-infrared region, nanoplatelets, photoluminescence

Lead halide perovskite nanocrystals (NCs) and nanoplatelets (NPls) have attracted significant interest in recent years because of their unique optical properties, such as tunable wavelength, narrow emission, and high photoluminescence quantum yield (PL QY). Metal-ion doping is one of the most efficient approaches to precisely control the electronic and optical properties of perovskite NCs/NPls. For instance, doping with Mn^{2+} and Yb^{3+} ions provide new PL bands at ~620 and 980 nm, respectively, which significantly expands the functionality of perovskite nanostructures. Yb^{3+} doping opens a fundamentally new spectral region for use of perovskite NCs/NPls aiming their use in near-infrared (NIR) lightning and Si-integrated solar concentrators. An important advantage of perovskite NCs/NPls is that the spectral tunability can be easily achieved in the entire visible spectral range by varying the halide composition either during the synthesis or by means of anion-exchange. However, most synthetic strategies need high temperature of a chemical reaction that limits the morphology control of nanostructures. In this report we show that room-temperature anion exchange may be efficiently used for doping of both organic-inorganic and all-inorganic perovskite NCs/NPls. Applying MCl_x (M=Mn, Yb) precursors, we obtained NIR-emitting Yb^{3+}-doped $CsPbCl_xBr_{3-x}$ and $FAPbCl_xBr_{3-x}$ NCs and NPls, as well as Mn^{2+}-doped and Mn^{2+}-Yb^{3+} co-doped $CsPbCl_xBr_{3-x}$ NPls. These nanostructures have high PL QY values and a tunable position of the PL band. In addition, an important advantage of the obtained materials is the presence of PL in various spectral ranges, which can find applications in the fields of optoelectronics and photovoltaics.

Lead-halide Perovskites Nanocrystal Films Application for X-Ray Scintillator Development

Poster ID: 56B

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Keywords: Perovskites, X-ray Scintillator, Film Technologies

Recently, much attention has been paid by researchers to the development of new types of scintillators, one of the most promising being scintillators based on nanocrystals of lead-halide perovskites, due to the high cross section of the interaction of the atoms that make up this compound with X-ray quanta. However, the use of scintillators based on nanocrystals is currently limited by the need to form continuous, uniform, and rather thick films. It is the method of developing the formation of such films that our report is devoted to. In our work we tested 4 methods for the synthesis of colloidal solutions of perovskite nanocrystals based on the hot injection and ligand-assisted reprecipitation (LARP) methods. For the formation of films, a solution of $CsPbBr_3$ synthesized by the LARP method was chosen due to the good optical characteristics and manufacturability of the synthesis method. The application of films by spin-coating, slot-die coating and doctor blade coating has been tested. Spin-coating turned out to be unsuitable for producing thick films. By the other two methods films up to 50 micrometers thick were applied. Their optical and scintillation properties were measured, and their suitability for use as an X-ray detector was proved.

Lead-free germanium perovskites for nonlinear photonics applications

Poster ID: 58M

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Keywords: Nonlinear optics, Perovskites, SHG

Halide perovskite structures are promising materials for various applications in photonics. The most widely used ones are lead-halide perovskites due to the most efficient light conversion, but problems associated with lead toxicity drive our attention to lead-free analogues. Therefore, this project is devoted to the study of lead-free germanium perovskites, and, to be more precise, their nonlinear optical properties. We studied $CsGeI_3$ single crystals and thin films. Measurements of the nonlinear optical properties were carried out both at room temperature and in the low-temperature regime. For thin films, two-photon induced luminescence (2PL) and second harmonic generation (SHG) have been described, and numerical values of the SHG efficiency were obtained. The exciton binding energy in $CsGeI_3$ (16.68 meV) was also calculated from the temperature dependence of the luminescence intensity; the obtained value is similar to the value for $MAPbI_3$. For micron and submicron single particles, 2PL and SHG were also investigated, and in the low-temperature regime (7 K), yet undescribed for $CsGeI_3$ phenomenon of random lasing was discovered. That indicates the material's expanded potential use in light conversion applications. Thus, in this work, we have characterized a relatively easy-to-synthesize material for problems of nonlinear photonics, the distinguishing feature of which is the presence of second-harmonic generation and random lasing at low temperatures.
This work was supported by the Russian Science Foundation (project No. 22-79-00137).

Designing and Characterising High-Q Lithium Niobate Ring Resonators to Enhance the Emission of Erbium Ions

Poster ID: 60R

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Keywords: Nanophotonics, Quantum optics, Lithium Niobate

In this work we demonstrate over 1 million Q-factor ring resonators on a lithium niobate on insulator platform.
Lithium niobate presents opportunities for low-loss electro-optically tunable operation, but is a difficult material to work with, with fabrication imperfections usually limiting the operating characteristics of devices. We discuss considerations that need to be taken into account to design ring resonators for high-Q single mode operation – locking out higher order modes by radiation losses and resonant coupling and minimizing sidewall losses caused by fabrication imperfections.
Such a resonator can be evanescently coupled to erbium ions in calcium tungstate, heterogeneously integrated with the LNOI optical chip. This is a stepping stone to our overarching goal of entangling microwave and telecom photons via transitions in erbium ions.

Comprehensive Understanding of Complex Optical Functionality of Living Biological Sculptures

Poster ID: 62R

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Keywords: Diffractive Phase Interferometry, Optical Phase Unwrapping , Light-Matter Interaction

Probing and understanding the morphological, chemical, and mechanical properties of biological structures is essential to interpret their interaction with desirable light (CW or Broadband) to derive deformability information and parameters associated with multifunctionality. The complex refractive index (RI) of biological cells describes their interaction with light and depends on the concentrations and spatial distribution of a variety of intracellular molecules, correlated to the corresponding biological function. Most biological structures, such as living cells and tissues are transparent due to optical refraction and reflection occuring at the boundary many times within inhomogeneous refractive index distribution. The coherence summation of these events can be expressed as multiple light scattering and optical phase information is lost. Therefore, evaluating the spatial and temporal variations in morphological structures and physical properties of a transparent biological object is almost impossible because the laser beam acquires a distorted wavefront or phase information. It remains a major technological challenge to detect biological features of cellular size with sufficient sensitivity in a complex environment at deep penetration. So, Non-invasive, high-resolution optical imaging of living cells under in vivo conditions is needed to visualize their biological processes. In this context, our own laboratory has developed in-house technology, the Light-Enabled Diffractive Phase Interferometry (DPI) technique along with mathematical modeling using the beam propagation method was utilized for the comprehensive study. Based on this novel concept, the interactions between light and biological matter can be exploited in many circumstances as useful tools in various fields of science and technology. To get most detailed insights into the light matter interaction of the system under investigation, A forward-scattering theoretical model is developed which helps understand our experimental observations. We carried out a systematic study on optical diffraction image of whole blood cells (RBCs) using optical cell models with varied morphology, refractive index (RI), and orientation. Our computational approach that fully utilizes optical angular spectrum information of the blood cell enables us to quantitatively study their morphological and biophysical properties for hematology. In coherent diffractive imaging, the missing phase information is numerically reconstructed by phase unwrapping algorithms, which has been shown to have a unique solution if the oversampling condition is satisfied. Our observations directly demonstrate the coherent manipulation and control of light in these photonic systems and detail understanding of our observation could provide a platform for the development of novel photonic devices for biomimetic technological applications.

Cu_2SnS_3-Based Next-Generation Solar Cell

Poster ID: 64R

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Thin film solar cell (TFSC) technology employing affordable, plentiful, and eco-friendly materials has been developed in response to the demand for cost-effective solar cells. Therefore, it was suggested that Cu_2SnS_3 (CTS), a compound of copper, tin, and sulfur, be studied as a viable alternative to current PV materials. This study aimed to examine the impact of annealing temperature on the purity and crystallinity of CTS material. The solid-state reaction has been used to synthesize a CTS compound powder from elemental powders. In various compositions, Cu, Sn, and S powder were mixed for three hours using mortar-and-pestle and rotational mixing. This was followed by annealing at temperatures between $200°$ and $600°$ degrees Celsius for one hour. XRD studies revealed that the CTS phase was formed between $400°$ and $600°$ Celsius during annealing. However, the process of synthesis does not yet provide pure-phase CTS. The finest quality CTS is produced after annealing at $600°$ Celsius and has a crystallite size of 67.65 nanometers. Diffuse reflectance spectroscopy reveals that the band gap of CTS powder is 1.69 eV, demonstrating that the synthesized CTS is suitable as a solar cell material.

Keywords: CTS Compound, Solar Cell Material, Annealing Temperature, Crystallinity, Energy Bandgap

Determining the position dependence of CDs optical transitions in the red and near-infrared spectral regions

Poster ID: 66B

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Carbon dots (CDs) are luminescent nanomaterials with unique properties which makes them highly promising for biomedical applications. An important task for shifting the emission of carbon dots into the red and near-infrared range is determining the synthesis parameters that influence their optical properties. For such a task, a dataset of carbon dot syntheses is necessary, which can be further explored using machine learning methods. The utilization of these methods is relevant as the development, optimization, and scaling of new materials pose a complex challenge. The aim of this study was to establish the dependencies of the position CDs optical transitions in the red and near-infrared spectral regions based on synthesis parameters. Approximately 300 scientific articles were analyzed, of which 46 were selected for further analysis. Four clusters were statistically identified (KMeans clustering using the elbow method), where the correlation between optical properties and synthesis parameters was pronounced. Furthermore, two samples of red carbon dots were synthesized, and their optical properties were measured. Two equations of multiple linear regression were formulated, and metrics such as R^2, RMSE (root mean square error) and MAE (mean absolute error) were determined. By substituting the quantitative values of the synthesis parameters for the two samples into the obtained equations, it was found that the predicted photoluminescence wavelength of 677 nm for urea-based CDs differed by 47 nm from the experimental value of 630 nm. For citric acid-based CDs, the predicted photoluminescence wavelength of 623 nm closely matched the experimental value of 645 nm. This work was financially supported by the Russian Science Foundation (RSF22-13-00294).

Keywords: Red carbon dots, Machine learning