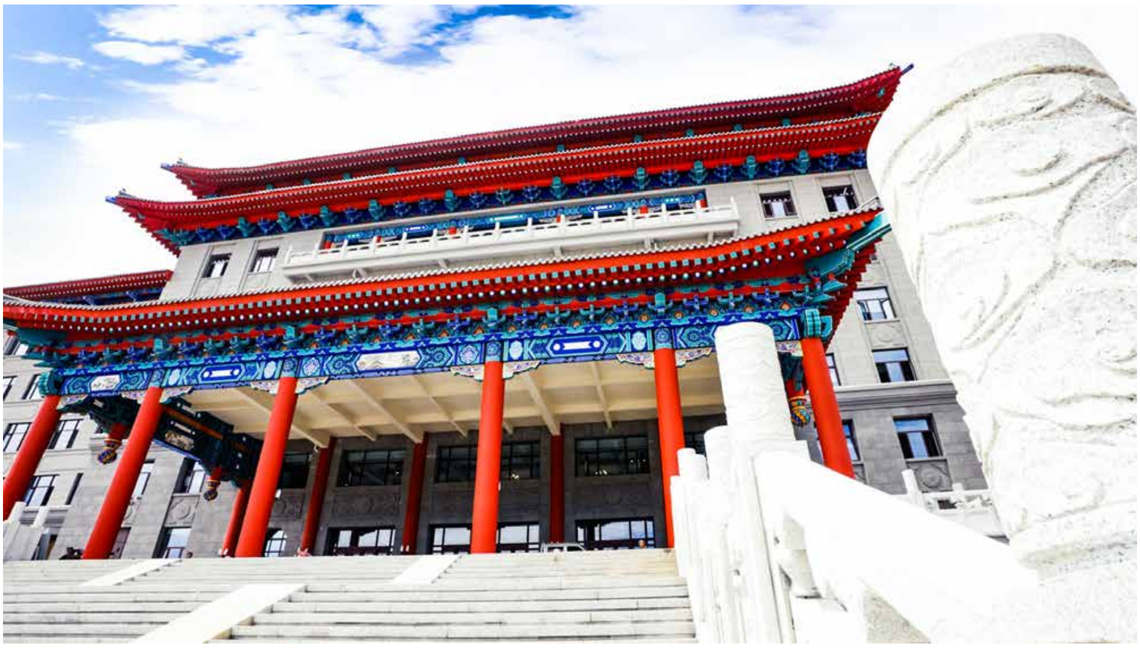
METANANO SUMMER SCHOOL ON NANOPHOTONICS AND ADVANCED MATERIALS



October 13 - October 26, 2024
Qingdao, China

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 13-26 October 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

1 Invited Lectures

1.1 Day 1

Oct 14th, 09:15 AM – 15:30 AM (GMT+8)

Photonic Axion Insulator

Time: 10:30
Keywords: axion, topological insulator, fractional Chern number, braiding

Baile Zhang[1,2].

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In axion electrodynamics, axions interact with electromagnetic fields in a way that can modify Maxwell's equations, through the axion angle θ. While still not observed as elementary particles, axions can exist as quasiparticles in topological crystals, whose quantized axion field can induce half Chern numbers on the surfaces of a three-dimensional crystal. We will discuss how to construct an axion insulator in a photonic crystal and demonstrate its unique topological properties.

Controllable SHG from Lithium Niobate Metasurfaces

Time: 11:00
Keywords: Lithium niobate, Metasurfaces, Second harmonic generation

Mengxin Ren[1].

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Second harmonic generation (SHG), which converts the frequency of a laser □ to twice its frequency 2□, plays a key role in extending spectral coverage of laser sources to wavelengths that are difficult to access by standard laser gain media. As we enter the Nano-era, the SHG at nanoscales with controllable performance is highly desired. Nonlinear metasurfaces have provided us with a revolutionary concept to engineer nonlinear responses from nanoscale. In addition, it also acts as a new platform to realize novel nanoscale SHG light sources. Recently, crystalline lithium niobate thin film on insulators (LNOI) has emerged as an excellent solution for the novel SHG metasurfaces and nonlinear light sources. An SHG conversion efficiency higher than 0.1% has been achieved from LN metasurface framework. How to further tune the SHG performance dynamically has become an urgent problem to address. In this talk, we will present our recent results on the topic of tunable SHG from lithium niobate metasurfaces. Our works offer insights for the development of tunable SHG sources in integrated photonics and nanoscale optical devices.

Optical imaging based on metasurfaces

Time: 11:30
Keywords: Metasurface, Imaging

Shuming Wang[1],

[1]National Laboratory of Solid State Microstructures, School of Physics, Nanjing University, Nanjing 210093, China

Ideal imaging technique simultaneously requires the three-dimensional (3D) high spatial-resolution and the high spectral-resolution. To date, while compact 3D imaging technique and spectrometer have been individually developed, the combination of these techniques has only been realized in cumbersome systems, significantly limiting their practical applications. A long-standing and critical challenge is how to integrate the 3D spatial-resolution and the spectral-resolution into a single nanophotonic device. Herein, based on the precise wavefront control of metasurface and deep-leaning algorithm, we experimentally demonstrate the first ultra-compact spectral light field imaging (SLIM) camera. Owing to the high dispersion of metalens, both the 3D position information and the spectrum can be re-constructed without sacrificing the light throughput. The demonstrated spectral-resolution is as high as 4nm and the spatial-resolution reaches the diffraction limit, enabling the capability of SLIM in precise 3D imaging and material discrimination. Moreover, by using the end-to-end method, the real time facial recognition based on transversely dispersive metalens array has been achieved. By employing an inverse-design method, we demonstrate a pixel-level metasurface-based Bayer-type colour router, with the brightness twice as high as that of a commercial camera.

Singular nanolasers: breaking diffraction limit in dielectrics

Time: 15:00
Keywords: Singular nanolase singularity, moiré nanolasers, twisted lattice nanocavity

Ren-Min Ma[1].

[1]Peking University, China

The pursuit of higher-performance lasers through the localization of optical fields across dimensions such as frequency, time, momentum, or space has been a driving force in laser physics and device development. Notably, the 2023 Nobel Prize in Physics recognized attosecond lasers for their extreme field localization in time, while the 2017 Nobel Prize acknowledged gravitational wave detection made possible by frequency-stable lasers with remarkable field localization in frequency. In the spatial domain, significant progress was made in 2009 with the publication of three seminal articles documenting the first realization of sub-diffraction-limited plasmonic nanolasers. However, the inherent Ohmic loss in plasmonics has posed challenges, including heat generation, increased power consumption, and limitations on device coherence time. The realization of dielectric nanolasers with sub-diffraction-limited field localization was previously considered unattainable. We have now overcome this longstanding challenge by utilizing optical singularities in a dielectric system for lasing. Our approach involves embedding a dielectric bowtie nanoantenna within a twisted lattice nanocavity to create singular dielectric nanolasers. The twisted lattice nanocavity effectively confines the light field to a diffraction-limited spot at its center, where the bowtie nanoantenna is positioned. The bowtie nanoantenna further intensifies the light field at its apices, with the electric field singularity at its tips playing a crucial role. Our analysis, grounded on Maxwell's equations, reveals that the electric field singularity at the apices of the dielectric bowtie nanoantenna arises from momentum divergence. These singularities in dielectric systems facilitate extreme light field compression, achieving a full width at half maximum of approximately 1 nanometer and an ultra-small mode volume of just one-sixth the optical diffraction limit of (□/2n)3. Moreover, the cold cavity quality factor of singular nanolasers, inherited from the twisted lattice nanocavity, can exceed one million. The singular dielectric nanolaser advances the characteristic scale of the laser field to the atomic level, comparable to the scale reached by X-rays. This breakthrough is anticipated to provide a platform for the development of high-performance coherent light sources and innovative imaging tools with atomic-scale resolution for applications in both physical and life sciences. Additionally, these cavities offer valuable opportunities for exploring cavity quantum electrodynamics, as well as nonlinear and quantum optics.

1.2 Day 2

Oct 15th, 08:45 AM – 15:30 AM (GMT+8)

Topological photonic crystals: from nested crystals to disordered photonic alloys

Time: 08:45
Keywords: Photonic crystal, Topology, Disorder

C.T. Chan[1],

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In this talk, we will discuss some new progress on topological aspects of photonic crystals. We first demonstrate the realization of "scalar photonic topological phases" in 3D by constructing a meta-crystal with a nested crystal structure defined by connectivity. The low-frequency band structure closely resembles that of scalar waves. We validate this approach experimentally by creating a meta-crystal that hosts spin-1 Weyl points based on space group considerations. Notably, the topological surface wave states exhibit skyrmion-like electric field distributions, resulting in a continuous band of high-Q surface states within the light cone continuum. This feature allows direct exposure of the topological surface states to air, making these systems highly suitable for practical applications. Our concepts have been experimentally validated. We introduce the new concept of photonic alloys as non-periodic topological materials. Photonic alloys represent a new category of disordered topological materials, offering opportunities for exploring topological materials with adjustable gaps. We show that by combining non-magnetized and magnetized components in a non-periodic 2D photonic crystal configuration, non-trivial topology emerges and associated edge states of these disordered systems can be characterized by the winding of the reflection phase. Our results indicate that the threshold percentages for the system to exhibit topological behavior approach zero in the thermodynamic limit for substitutional alloys, while this threshold remains non-zero for interstitial alloys with a Chern number of 1. Surprisingly, the system manifests non-reciprocal chiral edge states despite a local breakdown of time-reversal symmetry rather than a global one.

Hidden dimension and topological mode shapeshifting enabled by nonlinearity

Time: 09:30
Keywords: non-hermitian, nonlinear, exceptional points, mode shape shifting

Meng Xiao[1,2], Kai Bai[1]

[1]Key Laboratory of Artificial Micro- and Nano-Structures of Ministry of Education and School of Physics and Technology, Wuhan University, Wuhan 430072, China
[2]Wuhan Institute of Quantum Technology, Wuhan 430206, China

The role of nonlinearity in classifying the topology of a system has drawn intense interest recently. Through nonlinear terms, the parameters of a system depend on field intensity. It is easy to imagine situations where the topology of a system changes due to the intensity dependence of some parameters. In this talk, I will discuss two consequences of nonlinearity that make the topology of nonlinear systems fundamentally different from linear ones. In the first part, I show that unstable solutions in nonlinear systems can contribute to hidden dimensions. With the help of these hidden dimensions, some higher-dimensional topological singularities can be realized within lower-dimensional physical systems. In the second part, I demonstrate that nonlinearity can enable topological mode shapeshifting into arbitrarily designed profiles, such as square, isosceles triangular, and sinusoidal waves. These nonlinear topological modes are robust against disorders while remaining uniquely controllable through external sources.

Super-resolution imaging via photo-thermo-optic nonlinearity and laser scanning microscopy

Time: 10:30
Keywords: thermo-optic, scattering, saturation, superlinear, bistability

Shi-Wei Chu[1].

[1]Department of Physics, National Taiwan University, Taipei 10617, Taiwan

In the field of photonics, one major breakthrough in the 21^{st} century is the development of super-resolution microscopy, which has enabled unprecedented resolution down to angstrom level with biological molecules. However, most of the existing super-resolution techniques rely on fluorescence, leveraging its property of switching on/off via spontaneous blinking, stimulated emission, and nonlinear responses. In this tutorial talk, I will present our efforts over the last decade, demonstrating fluorescence-free super-resolution imaging on plasmonics and dielectric meta-atoms. The underlying principle is based on boosting scattering nonlinearity through the combination of Mie resonance and coupled photothermal/thermo-optic effects. The equivalent nonlinear optical indices are enhanced by 1000- to 100000-fold over bulk materials, leading to applications of all-optical switch and label-free super-resolution microscopy. More recently, we uncovered optical bistability in nanosilicon with record-low Q-factor and footprint, featuring in principle unlimited resolution. In addition, the discovery of "displacement resonance" unexpectedly reveals that linear scattering efficiency is maximal when the focus is misaligned, thus showcasing a significant reduction of nonlinear response threshold, sign flip in all-optical switching, and spatial resolution enhancement.

Metasurface Diffractive Optics: From Linear to Nonlinear

Time: 11:00

Guixin Li[1],
[1]Department of Materials Science and Engineering & Institute for Applied Optics and Precision Engineering, Southern University of Science and Technology, Shenzhen 518055, China

Keywords: -

Compared to conventional optical elements, photonic metasurfaces, consisting of arrays of antennas with subwavelength feature size, enable the manipulation of light-matter interaction in a more compact way. Using metasurfaces, the polarization, phase and amplitude of light can be well controlled by engineering the functionalities of the individual meta-atoms and their interactions. Many exotic phenomena in both linear and nonlinear optical regimes, such as wavefront engineering, optical holography, frequency conversion, have been successfully demonstrated. In this talk, I will share our latest progress on these topics.

Anti-disturbance control for dynamic wireless charging system in electric vehicles

Time: 11:30
Keywords: anti-disturbance control, dynamic wireless charging system, electric vehicles.

Zhitao Liu[1].
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Dynamic wireless charging (DWC) systems provide a promising solution to the range anxiety faced by electric vehicles(EV) drivers by enabling continuous charging as EVs travel along specially designed roads. However, DWC systems face multi-source uncertainties including coil mutual inductance changing with EV's motion, leading to significant power fluctuations compared to static wireless charging technology. To ensure a continuous and stable energy supply, advanced anti-disturbance control algorithms have been developed to address these uncertainties. These algorithms incorporate uncertainty estimation, feedforward compensation, nonsmooth disturbance suppression, sensor noise filtering, and online modelling. The methods will be validated through experiments on a DWC platform by maintaining constant output voltage regulation. These benefits significantly improve the availability and stability of DWC systems, thereby alleviating EV range anxiety.

High-efficiency optical field manipulations with metasurfaces

Time: 14:00
Keywords: metasurfaces, far-field, near-field, vectorial optical fields, radiation

Shulin Sun[1].
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Controlling optical fields in a desired manner based on an ultra-compact platform is important for nanophotonics applications. Recently, metasurfaces, a kind of two-dimensional metamaterials consisting of subwavelength microstructures with predefined optical responses arranged in specific sequences, pave up a new way to achieve this goal. Based on Huygens-Fresnel principle, gradient metasurfaces exhibit extraordinary effects for manipulating light, such as anomalous reflection and refraction, flat focusing, meta-holograms, special beam generations, and so on. In this talk, I will introduce our recent works In this direction, including on-chip light controls, vectorial beam generation, multi-function meta-devices.

Kerker superscattering

Time: 14:30
Keywords: superscattering, Kerker effect

Jianshui Li[1], Zhanyuan Zhang[1], Yi Xu[1], Alexander S. Shalin[2], Yuwen Qin[1].
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[2]Moscow Center for Advanced Studies, Moscow, 123592 Russia

Electromagnetic multipoles play an important role in the rapid development of micro and nano optics and offer unique degrees of freedom for tailoring the electromagnetic scattering at the subwavelength scale. The electromagnetic Kerker effect refers to a phenomenon of unidirectional light scattering, arising from the interaction between the induced electric dipole (ED) and magnetic dipole (MD) moments within a scatterer. Notably, both moments are typically constrained by the single-channel scattering limit. Therefore, the total scattering cross section (SCS) at the Kerker condition is also limited, imposing a challenge to achieve super and unidirectional scattering on resonance, simultaneously. Herein, we introduce a concept of Kerker superscattering based on the interaction between super ED and MD scattering that both of their SCSs exceed the single-channel scattering limit. This Kerker superscattering is achieved by utilizing a dielectric resonator coated with a metasurface. Analytical conditions of the Kerker superscattering are derived, which agrees well with full wave simulations. Microwave experiments in frequency and temporal domains are conducted to further consolidate the theoretical results. It is anticipated that the proposed concept can facilitate the development of subwavelength antennas, unidirectional coupler, and Huygens' metasurfaces.

1.3 Day 3

Oct 16th, 08:45 AM – 15:00 AM (GMT+8)

Recent Improvements of Light-Emitting Perovskite Nanocrystals

Time: 08:45
Keywords: -

Andrey L. Rogach[1],

[1]Department of Materials Science and Engineering, and Centre for Functional Photonics City University of Hong Kong, Hong Kong SAR, China

Chemically synthesized metal halide perovskite nanocrystals have emerged as a new class of efficient light emitting materials which are particularly interesting for development of light-emitting diodes (LEDs). Stability of perovskite-based LEDs is still an issue, which can be partially mitigated by proper interface design, such as the use of inter-layer amine terminated carbon dots. As for many other nanocrystals, proper surface passivation is a key to ensure high colloidal stability and processability of perovskites; this can be achieved by employment of multi-amine chelating ligands. To avoid using toxic element lead in perovskites, co-doping of cerium and bismuth into lead-free double perovskite Cs2AgInCl6 nanocrystals is a useful strategy resulting in their improved photoluminescence efficiency. There have been plenty of efforts towards synthesis of core-shell perovskite nanocrystals with anticipated enhanced optical properties and stability; one recent example will be presented here.

High-efficiency optical field manipulations with metasurfaces

Time: 09:30
Keywords: -

Giuseppe Leo[1].

[1]Laboratoire Matériaux et Phénomènes Quantiques, Université Paris Cité and CNRS, France

The generation of structured light dates back to Young's double-slit interference experiment, and for a long time it has been related to the linear superposition of wave fronts. After the broad development of spatial light modulators a few decades ago, this paradigm has been reconducted by the advent of optical metasurfaces. However, the potential of light structuring is even stronger and more fascinating in the nonlinear regime, where the present maturity of nonlinear meta-optics enables to create light harmonics with unprecedented phase, amplitude, polarization and topological complexity. Within this research field, the generation of vortex beams has become an interesting test bed for design and experimental protocols, because of their relevance in both fundamental and applied physics. In this lecture, after an introduction to nonlinear meta-optics, I will focus on our recent results on the generation of second-harmonic vortices with both a uniform dielectric film and an optical metasurface. In the former case we demonstrate spin-to-orbital angular momentum conversion, while in the latter we unravel the generation of high-purity orbital angular momentum with an arbitrary topological charge via a nonlinear meta-hologram. Both results are achieved in AlGaAs-on-insulator platforms.

Electromagnetic Symmetry, Optical Magnetism and Quantum Conductivity for Nanoscale Nonlinear Plasmonics

Time: 10:30
Keywords: Nonlinear optics, plasmonics, nanocavity, optical magnetism, quantum conductivity, molecular electronics

Dangyuan Lei[1].

[1]Department of Materials Science and Engineering, City University of Hong Kong, Kowloon, Hong Kong, 999077, China

In general, symmetric plasmonic nanocavities, such as a pair of two closely spaced metal nanospheres of the same size and constituting material, support only symmetry-allowed bright modes under light illumination. Breaking the cavity symmetry introduces mode hybridization between its bright and dark modes, leading to new plasmon modes like Fano-type resonance modes and bound states in the continuum in a periodic system.

In this talk, I will go on to discuss three "dark" aspects of symmetry-broken plasmonic nanocavities, including 1) light-induced electromagnetic asymmetry for enhancing the surface second-harmonic generation (SHG) of noble metals (Nature Communications 2021, 12, 4326; Nanophotonics 2024, 13, 3337), a mechanism well beyond conventional near-field enhancement strategies, 2) plasmon-induced optical magnetism in an asymmetric nanoparticle dimer-on-mirror cavity as a new second-order nonlinear source (ACS Nano 2017, 11(3), 3067-3080; Laser & Photonics Reviews 2020, 14(9), 200068), and 3) photon-assisted tunneling induced second-order nonlinear optics in conductive molecular nano-junctions (ACS Nano 2018, 12(7), 6492-6503, Nano Letters 2023, 23(12), 5851-5858; Progress in Quantum Electronics 2024, 95, 100517), potentially constituting an entirely new paradigm for single-molecule quantum sensing at the interface of quantum plasmonics, nonlinear optics and molecular electronics.

Semiconductor Cavity Quantum Electrodynamics

Time: 11:00
Keywords: Quantum Dots, Cavity Quantum Electro-

Jin Liu[1],

[1]School of Physics, Sun Yat-sen University, Guangzhou 510275, China

dynamics

Semiconductor quantum emitters, especially epitaxial quantum dots (QDs) with large optical oscillator strength, are one of the most promising candidates for exploring fundamental quantum physics in solid-state and building quantum photonic devices on-chip. However, the deterministic creation and eventual scalability of single QD devices greatly suffer from the random nature of the QDs produced in their self-assembled growth. In this presentation, I will discuss the breakthrough of scalable and deterministic coupled cavity quantum electrodynamic systems (cQED) based on single-photon hyperspectral imaging. With deterministically coupled QD-microcavity systems. We've observed the long-sought-after dynamic resonance fluorescence in cavity quantum electrodynamics and realized quantum photonic devices with state-of-the-art performances, including bright sources of entangled photon pairs, single-photon sources carrying orbital angular momentum and stimulated emission assisted single-photon sources. We finally envision long-distance quantum networks based on telecom band QDs via hybrid integration technology.

Resonant Nanoparticles for All-Optical Nanoscale Heating and Temperature Sensing in Cells

Time: 11:30
Keywords:

M. V. Zyuzin[1].

[1]School of Physics and Engineering, ITMO University, 191002 St. Petersburg, Russia

Temperature control is essential for regulating cellular functions and processes. Uncontrolled temperature rises during treatments like photothermal therapy can disrupt cell metabolism, growth, and survival. To address these challenges, our study focuses on nanostructured materials that enable precise, localized temperature regulation within cells.
The first method we explored leverages optically detected magnetic resonance (ODMR) of nanodiamonds containing nitrogen-vacancy (NV) centers. NV centers exhibit temperature-dependent frequency shifts, enabling accurate temperature monitoring. By integrating gold nanoparticles (Au NPs) as heating agents and NV centers as nanothermometers within a single carrier system, we developed a platform for controlled photoinduced drug delivery and photothermal therapy. Our research revealed that while the concentration and positioning of Au NPs within the carrier influence the required laser power for carrier rupture, the temperature at which the carrier decomposes remains constant.
The second method involves monitoring thermally induced shifts in Raman signals. We investigated optically resonant dielectric nanoparticles, focusing on α-Fe2O3 and silicon (Si)/silicon-gold (Si-Au) nanoparticles, as temperature sensors. Similar to the previous approach, α-Fe2O3 nanoparticles, which generate heat when illuminated, were incorporated into drug carriers, allowing for synchronized drug release and temperature measurement. This system enables precise tracking and control of the temperature at which the drug is released within cells.
We also explored the use of Si and Si-Au nanoparticles in optical hyperthermia. For Si nanoparticles to function effectively as optical heaters, they must have a narrow size distribution to meet critical coupling conditions. However, Si nanoparticles produced by laser ablation often suffer from polydispersity. To overcome this limitation, we created hybrid nanomaterials combining plasmonic Au and dielectric Si structures, resulting in enhanced optical heating and real-time temperature sensing in cellular environments. Our findings demonstrated that these hybrid Si-Au nanoparticles were more effective for optical hyperthermia in biological media.
In conclusion, our study shows that accurate temperature monitoring at the nanoscale can improve the safety and efficacy of modern medical treatments. Further in vivo research is necessary to fully develop and validate these techniques.
This work was supported by the Ministry of Education and Science of Russia (No. 075-15-2023-586).

1.4 Day 4

Oct 17th, 09:00 AM – 15:00 AM (GMT+8)

Functional Nanophotonics with Spectrally Selective Metasurfaces

Time: 09:00
Keywords: Metasurfaces, BIC, biosensing, chirality, van der Waals materials

Andreas Tittl[1],

[1]Chair in Hybrid Nanosystems, Nano-Institute Munich, Faculty of Physics, Ludwig-Maximilians-Universität München, Germany

Metasurfaces composed of sub-wavelength dielectric resonators are a powerful platform for controlling light on the nanoscale, providing significant advantages over their plasmonic counterparts. Photonic bound states in the continuum (BICs) have enabled a new class of spectrally selective metasurfaces supporting precisely tailored ultrasharp resonances, enabling breakthroughs in higher-harmonic generation, strong light-matter coupling, biodetection, and lasing. In this talk, I will present some of our recent concepts for obtaining additional nanophotonic functionalities in BIC-driven systems, including the arrangement of resonators in radial configurations for polarization invariance and greatly reduced metasurface footprints, height-driven BICs for obtaining maximally chiral light-matter interactions, and metasurfaces incorporating van der Waals materials for realizing polaritonic strong coupling. Finally, I will show a new class of dual-gradient metasurfaces, which harness a 2D array of subwavelength nanoresonators with smoothly varying geometry to simultaneously and continuously encode spectral and molecular coupling information within a compact spatial area. These advanced metasurface functionalities open up exciting perspectives for future device applications, especially in ultra-compact and chip-integrated systems.

Metamaterials and effective material parameters: size and shape effects

Time: 11:30
Keywords: -

Mikhail Lapine[1].

[1]School of Mathematical and Physical Sciences, University of Technology Sydney, NSW 2007, Australia

This lecture addresses an important theoretical aspect of metamaterials description: substantial difference between effective medium modelling and actual properties of finite-size samples. The effect owes to discrete structure of practical metamaterials, as opposed to the homogenised treatment assumed in the effective medium treatment. It is well known that effective medium description of metamaterials requires much caution, even for strongly subwavelength systems. Additionally, boundary effects play a dramatic role in finite metamaterial samples with discrete structure, making their observable properties quite different from the predictions of effective medium theory. Small samples, which are only likely to be used in practice, show remarkable deviations and less trivial frequency dependence, but convergence towards the continuous model is rather slow. Several examples and consequences will be shown, as much as the timing permits.

An Algebraic Approach to Light-Matter Interactions

Time: 14:00
Keywords: Light-Matter interactions, Hilbert Space, Conformal Symmetry, T-matrix

Ivan Fernandez-Corbaton[1],

[1]Institute of Nanotechnology, Karlsruhe Institute of Technology, Karlsruhe, Germany

In my lecture, I will explain a theoretical and computational framework for the study and engineering of linear light-matter interactions. The framework is based on the invariance properties of electromagnetism, and it is mathematically formalized in a Hilbert space. The conformally-invariant scalar product of such Hilbert space provides connections to physical quantities, such as the energy or momentum of a given field, or the outcome of measurements. The light-matter interaction is modeled by the polychromatic scattering operator, which establishes a direct connection to a popular computational formalism, the T-matrix. I will illustrate the theory with practical calculations, and explain how the formalism is currently being extended to the quantum and non-linear cases.

Optical Nonlinearities in Resonant Nanostructures and Metasurfaces: From Thermo-Optical Effects to Ultrafast Transient Structures

Time: 15:00
Keywords: Metasurfaces, Metastructures, Thermooptical Nonlinearity, Second-Harmonic Generation, Bound States in the Continuum

Mihail Petrov[1].

[1]The School of Physics and Engineering, ITMO University, 197101 Saint Petersburg, Russia.

In this presentation, we will explore a range of nonlinear optical phenomena facilitated by resonant effects in dielectric and semiconductor nanostructures, as well as metasurfaces. We will begin by examining strong thermo-optical nonlinearities, which can lead to the observation of optical bistability in individual structures with impressively small footprints. Furthermore, we will discuss how thermo-optical bistability can be effectively controlled using bound states in the continuum (BIC) metasurfaces. Next, we will transition to the ultrafast domain, focusing on the generation of non-equilibrium carriers and the rapid modulation of the optical properties of resonant structures. These transient effects can be harnessed to create spatio-temporal optical structures, even within homogeneous semiconductor films. Finally, we will conclude the talk by delving into second harmonic generation in resonant nanostructures, highlighting its significance and potential applications. This work was financially supported by Russian Science Foundation grant № 20-72-10141.

1.5 Day 5

Oct 18th, 08:30 AM – 15:00 AM (GMT+8)

Metalens-Based Imaging

Time: 08:30
Keywords: Metalens, Imaging, High Numerical aperture

Juntao Li[1].

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This study explores subwavelength metasurfaces for manipulating light phase and polarization, featuring attributes like ultralightness, ultra-thinness, and effective optical field modulation. Our focus is on imaging through metalenses. Numerical aperture (NA) in optical imaging is crucial, assessing photon-collection capabilities and finding applications in high-resolution imaging. To overcome traditional lens challenges and bulkiness, we propose a transmissive, polarization-insensitive immersion metalens with adaptive nano-antennas, exhibiting ultra-high NA and high efficiency at 532 nm. These metalenses replace conventional objective lenses, achieving NAs of 1.48 for confocal imaging (300 nm resolution). Furthermore, to address wide-field imaging needs, we have conducted a series of studies base on high NA metalenses, including microprojection imaging based on a polarization-insensitive red-green-blue achromatic metalens doublet, a broadband achromatic flat lens for microscope imaging, a metalens with axial movement for zoom imaging, and a metalens-based stereoscopic microscope.

Meta-optics for topological polarization textures

Time: 09:00
Keywords: Metasurface, polarization encryption, optical skyrmion

Zilan Deng[1], Sicong Wang[1], Xiangping Li[1],

[1]College of Physics & Opto-Electronic engineering, Institute of Photonics Technology, Jinan University, P.R.China

Metasurfaces, composed of arrays of subwavelength artificial atoms, have demonstrated capability of powerful wavefront manipulation. The ultra-thin thickness of metasurfaces offers a new platform for development of integrated planar optics with multifarious functionalities. In this talk, I will present our recent research progress focused on polarization manipulation. Leveraging the flexible polarization control capability, we demonstrate the polarization encryption in arbitrary trajectory covering the full Poincare sphere. In addition, we are able to control the 3D pointing direction of polarization to form topological textures, namely optical skyrmions. We report on the generation of multiple-pi twisted magnetic field skyrmions by using spoof plasmon supported in space-coiling metasurface and demonstrate their robust topologies. Further, we show skyrmion-like structures formed by Poynting vectors are unveiled in the focal region of two pairs of counter-propagating cylindrical vector vortex beams in free space.

Meta-nano structures for sensing and programmable matrix of spectral pixels

Time: 10:30
Keywords: metasurface, sensing, refractive index, phase change materials, programmable, optical lossy cavity, reflective color display, hyperspectral imaging

Sailing He[1,2].

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[2]Department of Electromagnetic Engineering, School of Electrical Engineering, Royal Institute of Technology, Sweden

Some of our recent works on meta-nano structures for sensing and programmable matrix of spectral pixels will be reviewed and presented. First I will present an all-dielectric BIC (bound states in the continuum) metasurface for highly sensitive phase interrogation refractive index sensing. An enhanced surface plasmon resonance biosensor that integrates imaging technology and features dual-parameter interrogation (intensity and phase) with guided mode coupling will also be presented. Next I will present a programmable nanophotonic matrix (like a programmable metasurface) consisting of vanadium dioxide ($VO2$; a phase change material) cavities on pixelated microheaters. The indirect Joule heating of these $VO2$ cavities can result in pronounced spectral modulation with colour changes with an ultrafast modulation rate exceeding 70 kHz, and ensures exceptional endurance even after a million switching cycles. A video-rate nanophotonic colour display by electrically addressing a matrix of 12×12 pixels is demonstrated, as well as a spatiotemporal modulation for spectrum detection. Finally I will present a miniaturized hyperspectral imager using a reconfigurable filter array to tackle the existing trade-off issue between the spectral and spatial resolutions. Utilizing tens of intermediate states of a vanadium dioxide cavity, both high spatial and spectral resolutions are achieved for spectral imaging. Hyperspectral imaging is demonstrated with a frame rate of 4.5 Hz. Some related applications will also be presented.

Extreme light control in low-symmetry phonon-polaritonic materials

Time: 11:15
Keywords: light-matter interaction, shear hyperbolic

Xiang Ni[1].

[1]School of Physics, Central South University, Changsha, China, 410083

/ low-symmetry polaritons

A reduction in crystal symmetry enhances the directionality of optical phonons, leading to increased anisotropy in the material's response. This, in turn, facilitates the emergence of novel polaritonic phenomena, such as hyperbolic polaritons with highly directional propagation, ghost polaritons characterized by complex-valued wavevectors, and shear polaritons exhibiting strongly asymmetric propagation behavior. In this presentation, I will provide an overview of recent advancements in the discovery of phonon polaritons in low-symmetry crystals, including work from our group, emphasizing the critical role of symmetry breaking in shaping polaritonic responses and enabling unique nanoscale light propagation characteristics.

Volumetric Resonator Based On Split Loops For Wireless Power Transfer

Time: 14:00
Keywords: Resonator, Wireless Power Transfer, Rfficiency.

Aigerim Jandaliyeva[1], Andrey Vdovenko[1], Mikhail Siganov[1], Leila Suleiman[1], Pavel Seregin[1], Mikhail Udrov[1], Alena Shchelokova[1], 1.

[1]ITMO University, St. Petersburg, Russia

Traditional wireless power transfer (WPT) methods are limited to 2-D configurations and involve putting the electronic device next to the charging pad. However, this approach limits the mobility of the device during charging. In this work, we have developed and investigated a novel solution that uses a volumetric resonator consisting of a pair of split loops. This resonator can transmit power wirelessly on a room-scale, making charging more convenient and less restrictive. One remarkable feature of this resonator is the magnetic field distributed in the volume with 96% uniformity. This allows us to transfer energy to a receiver anywhere within the resonator's internal volume with fixed efficiency. In other words, the receiver's location inside the resonator has almost no effect on the efficiency of the power transfer. The proposed resonator can be represented as a room, and low-power devices can be charged inside of it.

1.6 Day 6

Oct 20th, 08:45 AM – 12:15 AM (GMT+8)

Effective axion response in photonics and condensed matter

Time: 08:45
Keywords: -

Gao Ke[1],

[1]Shandong University, China

The talk will start with design and synthesis of a series of low band-gap porphyrin-based donor materials in OPV. Then it will be focused on the verification of multi-length scale morphology, which clarifies the direction of device optimization. Then the deep physical mechanism for energy loss will be presented. Finally, it will be focused on the applications of porphyrin based donor materials in different kinds of organic solar cells, such as, tandem cell, ternary cell, flexible cell, semitransparent cell, some of which achieved some record performance. Furthermore, it validates that such class of porphyrin based materials are the best low band-gap donor materials to date.

Directly probing topology with wavefunctions

Time: 09:15
Keywords: Topological photonics, topological phono ics, metamaterials

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Symmetry-protected topology provides a large set of topological phenomena that have attracted tremendous research interest. However, the underlying symmetry that protects the bulk topology often fails at the edge. Examples may include the higher-order and fragile topological insulators, or strong topological insulators with the spontaneous breaking of the time-reversal symmetry due to interaction effects. In these cases, edge states can be gapped and unstable, providing a poor feature of the band topology. In this talk, I show that in many cases, band topology can be probed via the bulk wavefunctions measured in experiments despite that the system is finite. We demonstrate this principle via two different approaches. In the first approach, the bulk Bloch wavefunctions can be extracted from the pump-probe measurements via a revised method based on the singular value decomposition of the pump-probe response tensor. We show that for odd Euler class insulators, the measured bulk Bloch wavefunctions exhibit meronic patterns in the Brillouin zone which can be a direct signature of the Euler class band topology. In the second approach, with the bulk Bloch wavefunctions we can obtain the entanglement entropy of the phononic system which also gives a diagnosis of the band topology. With both approaches going beyond the bulk-edge correspondence, our study may inspire future experimental studies on topological phases.

Nanophotonic control of thermal radiation for infrared application

Time: 09:45
Keywords: Nanophotonics, thermal radiation, infrared

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Control of thermal emission underpins fundamental science as it is related to both heat and infrared (IR) electromagnetic wave transport. Here we present our recent work on using nanophotonic films or structures for controlling thermal emission for infrared applications, including: (1) combining a silica aerogel for thermal insulation and a Ge/ZnS multilayer-based wavelength-selective emitter for simultaneous radiative cooling (high emittance in the 5-8 μm non-atmospheric window) and infrared camouflage (low emittance in the 8-14 μm atmospheric window); (2) demonstrating multispectral camouflage for the visible, mid-infrared (3-5 and 8-14 μm), lasers (1.55 and 10.6 μm) and microwave (8-12 GHz) bands with simultaneous efficient radiative cooling in the non-atmospheric window (5-8 μm); (3) demonstrating a nonvolatile optically reconfigurable mid-IR coding radiative metasurface with independent control of visible scattering properties. This approach constitutes a new route towards thermal emission control and has broad applications in multi-band encryption, IR camouflage, etc.

Effective axion response in photonics and condensed matter

Time: 10:45
Keywords: Axion electrodynamics, metamaterials, nonreciprocity

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Axions are hypothetic particles postulated in high-energy physics long ago. While cosmic axions have not been observed so far, axion fields arise in the effective description of some condensed matter and photonic structures enabling unconventional electromagnetic properties. During the recent years, this has become a topic of active research. In this lecture, I will introduce this field, discuss the origins and theory of effective axion response in metamaterials and, finally, present a recent prediction of our group: novel type of electromagnetic response sharing the same symmetry properties as axion response but distinct from it.

Scattering Evolutions Driven by Geometric Phase

Time: 11:45
Keywords: Mie Scattering, Pancharatnam-Berry Phase, Polarizations.

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Conventional approaches for scattering manipulations largely rely on the technique of field expansions into spherical harmonics (electromagnetic multipoles), which nevertheless is not only non-generic (expansion coefficients depend on the origin position of the coordinate system) but also more descriptive than predictive. Here we explore this classical topic from a different perspective of controlled excitations and interferences of quasi-normal modes (QNMs) supported by the scattering system. Scattered waves are expanded into coherent additions of QNMs, among which the relative amplitudes and phases are crucial factors to architect for scattering manipulations. Relying on the electromagnetic reciprocity, we provide full geometric representations based on the Poincaré sphere for those factors, and discover the hidden geometric phase of QNMs that drives the scattering evolutions. Further synchronous exploitations of the incident polarization-dependent geometric phase and excitation amplitudes enable efficient manipulations of both scattering intensities and polarizations. Continuous geometric phase spanning 2π is directly manifest through scattering variations, even in the rather elementary configuration of an individual particle scattering waves of varying polarizations. It is further revealed previously widely-employed geometric phases of various forms are merely reduced approximations of our new discovery. We have essentially unlocked an extra hidden dimension of scatterings systems, for not only electromagnetic waves but also waves of other forms where geometric phase is generic and ubiquitous. Considering the central role of wave scattering, our discovery will broaden horizons of many disciplines of general wave physics.

2 Posters

Towards optical spin precession

Keywords: Landau–Lifshitz–Gilbert equation, spinning atoms, spinning light

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Electromagnetic fields as well as particles possess energy, momentum, and angular momentum. The total angular momentum of light has, in general, both orbital and spin components. Orbital angular momentum is associated with the phase fronts of light beams. Meanwhile the spin part is associated with the field polarization. Here we discover that the spin of electromagnetic waves can perform precessional motion in an analogous manner to the precessional motion of elementary particles and spinning atoms in an externally applied magnetic field. We identify the physical conditions under which optical spin obeys Landau–Lifshitz–Gilbert equation with zero damping. This finding opens new opportunities towards the realization of novel optical spin devices.

Demonstration of the metamaterial-inspired volumetric resonator with uniform magnetic field distribution for wireless power transfer

Keywords: Efficiency, Near field, Resonator, Uniformity, Wireless power transfer

Aigerim Jandaliyeva[1], Andrey Vdovenko[1], Mikhail Siganov[1]. Leila Suleiman[1]. Pavel Seregin[1]. Mikhail Udrov[1]. Alena Shchelokova[1,2]. Pavel Belov[1,2].

[1]Faculty of Physics, ITMO University, Saint Petersburg, Russian Federation, 197101,
[2]Contributed equally to this work.

This study introduces a volumetric structure consisting of two pairs of strongly coupled split-ring resonators designed to facilitate wireless charging of devices within its internal volume. The resonator's notable feature is its ability to generate a highly uniform magnetic field, achieving up to 90% uniformity across the entire volume. This uniformity ensures stable energy transfer efficiency, regardless of the receiver's position within the resonator. At the same time, the dangerous electric field is confined near the capacitors located at the corners of the split rings, thus ensuring safety in the operating area. The maximum specific absorption rate in 10 grams of tissue (maxSARav.10g) and the impact of electric fields on the arm tissue of a human model placed inside the resonator were assessed and compared following the IEEE C95.1™-2019 guidelines. The resulting values are well below the safety thresholds established by the standard. Both numerical simulations and experimental data demonstrate that the wireless power transfer efficiency can reach up to 60%, with minimal sensitivity to the receiver's spatial location, reassuring users of its high performance. This technology is engineered for easy integration into compact furniture modules or standardized living environments, allowing users to charge devices without sacrificing mobility. This work was performed with financial support of the Russian Science Foundation (Project No. 24-45-02020)

Second Harmonic Generation in Chiral Perovskite Crystals With 2-fold Screw Axis

Keywords: Maximum optical chirality, Perovskite crystals, SHG

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Second harmonic generation (SHG) sensitive to left and right circular polarization opens up possibilities for creating switchable photodetectors and optical modulators for chiral optics. Considerable efforts are being applied to the synthesis of chiral materials lacking an inversion center, characterizing their optical properties, as well as describing them using advanced theoretical methods. In this paper, a newly synthesized chiral perovskite crystals of the C2 symmetry (2-fold screw axis), are considered. Under the undepleted pump approximation, and neglecting reflections from the boundaries, the SHG is modeled in the most general case including all electric-magnetic second-order nonlinear susceptibility tensors and pseudotensors. The obtained analytical results allow reproducing the available experimental data and describing the anomalous SHG circular dichroism of the synthesized materials.

Maximum Optical Chirality of a Planar Metasurface with the Mirror Symmetry Broken by a Substrate

Keywords: Optical Chirality, Dielectric Metasurfaces, BIC, Resonant State Expansion

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Maximum optically chiral metasurfaces resonantly interacting with light of a particular circular polarization – are promising platform for advanced chiral devices. Intrinsic chiral response cannot be achieved in the presence of mirror symmetry planes, including the out-of-plane mirror symmetry inherent to planar metastructures. To resolve this problem, challenging nanolithography techniques are required producing slanted, of variable height or vertically displaced meta-atoms. Formally, the presence of a substrate breaks the out-of-plane mirror symmetry, however, the related chiral effects are usually quite weak. Here we demonstrate how a typical glass-like substrate can induce close to maximum optical chirality of otherwise achiral planar photonic crystal slab. We analyze the substrate driven effect in terms of the resonant state expansion and reveal that its origin is determined by the coupling of states of different spatial parity.

Rewritable structure of an arbitrary topological charge

Keywords: GeSbTe, Optical vortex

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At the end of the last century, Allen and his collaborators discovered that photons possess not only spin but also orbital angular momentum (OAM). Interestingly, OAM is an inherent characteristic of the quantum state of a single photon, providing an additional degree of freedom. A crucial feature of vortex states with different OAM is their orthogonality. This implies that two states with distinct values of l can never be continuously transformed into one another. Therefore, once mixed, they can theoretically be distinguished and separated. The property of orthogonality has been widely utilized in both classical and quantum optical communication and information processing in free space. Many different approaches and devices have been developed to generate twisted photons. However, each method comes with its own significant limitations. For instance, phase plates and metasurfaces necessitate high-precision fabrication and involve complex, multi-step vacuum-based nanofabrication processes. Additionally, spatial light modulators (SLMs) may be cumbersome for microphotonics and photonic integrated circuits. Moreover, SLMs can exhibit noise and drift, which adversely affect the stability of the vortex phase. We propose true two-dimensional structures that operate noiselessly and can be fabricated without the need for costly vacuum nanofabrication equipment. These structures utilize phase change materials (PCM) and are generated by the phase of materials through laser writing technology. PCMs can endure repeated write-erase cycles, allowing for the creation of customizable structures on a single substrate. This capability significantly enhances the variability of the topological charge of the produced vortex, facilitating rapid adjustments to the setup. We utilize the well-established method for generating twisted light, commonly known as the computer-generated hologram (CGH) technique. Following this, we investigate the scattering from the pitch-fork grating using the Born approximation. To validate the topological charge, we implement an astigmatic transformation by incorporating a cylindrical lens function. Ultimately, we fabricate a CGH pattern corresponding to a topological charge of 1 on the GST film using a local heating approach. The local heating was applied using a direct laser writing system. We observe good agreement with theoretical predictions. Additionally, we successfully rewrote the CGH on the same GST substrate, demonstrating an increase in the topological charge of the resultant vortex beam within the same optical setup.

This work was performed with financial support of Priority 2030 Academic Program.

Active Nanophotonic Structures Based on Atomically Thin Semiconductors

Keywords: 2D-TMDs, excitons, tunable nanostructures, meta-waveguides

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Hybrid nanophotonic systems consisting of resonant dielectric nanostructures integrated with single or few layers of transition metal dichalcogenides (2D-TMDs) offer important opportunities for active nanophotonic systems featuring an actively tunable response. While the resonant nanophotonic structures serve to enhance the light-matter interaction in the atomically thin membranes, the 2D-TMDs exhibit tunable excitonic properties. However, the experimental realization and demonstration of active functionalities in such hybrid systems remains challenging.

In this work, we combine 2D-TMDs with resonant photonic nanostructures, namely meta-waveguides and metasurfaces, composed of high-index dielectric nanoparticles. The dependence of the excitonic states on charge carrier density in 2D-TMDs leads to a shift of the central wavelength and to an amplitude modulation of the corresponding optical transitions upon changes of the Fermi level, and thereby to changes in the coupling between the 2D-TMDs and the nanostructure resonances. We experimentally implement such hybrid nanophotonic systems and demonstrate voltage tuning of their transmittance and photoluminescent properties, as well as of their polarization dependence.

Our results show that hybridization with 2D-TMDs can serve as a promising tool for creating tunable and time-variant optical devices at the nanoscale that could find practical applications in optical analog computers and neuromorphic circuits.

Wireless Charging of Electric Kick-Scooters using a Metasurface-Based Resonator Approach

Keywords: Wireless Power Transfer, Micro-mobility, Meta-surfaces, Personal Mobility Devices

Andrey Kuzmichev[1], Polina Terenteva[1], Altana Tsyrinova[1], Sutanu Chatterjee[1], Alexander Zolotarev[1], Pavel Smirnov[1], Polina Kapitanova[1].

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Abstract— Nowadays, the micro-mobility sector is predominantly characterized by the prevalence of electric kick-scooters which have garnered widespread popularity globally due to their advantages in terms of convenience, affordability, and user-friendliness. The integration of Wireless Power Transfer (WPT) technology can play a pivotal role in shaping the framework and implementation of charging infrastructures tailored to accommodate these vehicles in big cities and rural off-grid scenarios.

Here we propose a novel approach for wireless charging of Electric Kick scooters at 6.78 MHz that utilizes a metasurface-based resonator (MBR) as the power transmitting unit and a rectangular spiral coil as the power receiving unit with an air gap of 100 mm between them. Using 3D full-wave field simulations utilizing the Finite Element Method we predict that the WPT system is electromagnetically compatible and safe for use in public places according to the ICNIRP and IEEE standards. We also experimentally verify that RF-RF efficiency of 77% can be achieved through the WPT system when the transmitting and receiving units are perfectly aligned. The tolerance of the power transfer efficiency to axial and in an angular misalignment of the receiving unit with respect to the transmitting one is also measured. We demonstrate that only 10% reduction in power transfer efficiency is observed. This work was performed with financial support of Priority 2030 Academic Program.

Phase change materials as a new path in active photonics

Keywords: Active photonics, phase change materials, perovskite, nonlinear photonics

Artem Sinelnik[1], Olga Kushchenko[1], Daniil Litvinov[1], Mikhail Rybin[1]

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Phase change materials (PCM) are a new class of materials that exhibit a stable, reversible phase transition from an amorphous to a crystalline state and back. When phase changes, such materials dramatically change their optical and electrical properties. In this work, GeSbTe225 material will be considered as the most stable PCM material for active photonics applications. In particular, the linear and nonlinear properties of GST will be discussed, as well as the effect of GST on light-emitting materials. The possibility of using GST in active and switchable optoelectronic devices will also be demonstrated.

This work was performed with financial support of Priority 2030 Academic Program

Light-emitting High-Q off Γ-point Plasmonic-Photonic Bound States in the Continuum in Visible Range

Keywords: BIC, Plasmonic-Photonic modes, Off Γ-Point, Light-emitting

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Bound states in the continuum (BICs) in plasmonic systems are promising for light confinement and enhancement at the subwavelength scale, which is useful for the development of compact lasers, sensors, and light frequency converters. Moreover, off-Γ-point BICs (so-called Friedrich–Wintgen states) would allow an additional degree of freedom for the emission angle. However, high intrinsic losses of metals hinder achieving quality factor (Q) values more than ∼100 level in the visible range for the Friedrich–Wintgen BICs. These Q values become even lower for the cases of additional layers deposition of active materials from the solution. In this work, we reveal off-Γ-point BICs in a hybrid plasmonic-photonic resonant system with a Q-factor exceeding 1000 in the visible range. Namely, we develop an aluminum wave-like two-dimensional (2D) grating coupled to Al_2O_3 2D photonic crystal slab (PCSs) to form a platform for symmetry-protected and off-Γ-point Friedrich-Wintgen

BICs because of zero coupling with the radiation channel. By applying an oriented self-assembled approach to thickness-controllable large-scale coating with CdSe/CdZnS nanoplatelets, we show that such a design can be integrated with semiconductor nanomaterials emitting light at a wavelength around 620 nm and preserving high-Q values of the off-Γ-point BICs. Spectral matching of the leaky off-Γ-point BICs modes with the excitonic band of the nanoplatelets allows us to demonstrate a Q-factor of 708 in photoluminescence, being close to the values reported for lasing modes from BIC-based metasurfaces in visible range. This work was supported by the Ministry of Education and Science of Russia (No. 075-15-2023-586).

Research of stable positions of a dielectric nanoparticle in a hybrid anapole state in optical tweezers

Keywords: Anapole, HAS, Optical Force, Multipole Decomposition

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The existence and effects of the hybrid anapole state on a cylindrical silicon nanoparticle in a linearly polarized Gaussian beam have been described in research. The differences in optical forces and torques arising from a focused Gaussian beam for various wavelength and size parameters of nanoparticles have been observed. For a particle in the hybrid anapole state, a decrease in the longitudinal force that pushes it out of the trap field has been established. In parallel, a number of effects related to the transverse force component were discovered. In an explicit hybrid anapole state, the transverse component has 5 equilibrium points, of which only 2 are stable (and none of these two lie on the optical axis of the beam).

Trapping, antitrapping, and stable points in the focal plane have been observed for particles of different radius close to HAS. Using multipole decomposition, it has been shown that high-order multipole moments are responsible for these effects. It has also been demonstrated that it is possible to sort nanoparticles by size using found effects.

The behavior of a particle during rotation around its own axes was determined. It is revealed that the hybrid anapole is unstable and collapses when the orientation of the particle in space changes. Special equilibrium positions of the particle were found when rotating relative to its own axes for different dimensional parameters of the nanocylinder and the wavelength of the incident field.

AD-C (Automatic Drone-Collector)

Keywords: Science, Electronics, Programming, Drone, MV

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The AD-C project is about to help keeping beaches and water surfaces clean, such as rivers, lakes, bays and etc. This technology is designed to operate autonomously. Thanks to the power station the AD-C can be located anywhere outside, which can be power from solar energy. The software was created to detect floating debris using Machine Vision (MV), collect it and dump it at the desired location.

III-V Integrated Optical Vortex Emitter

Keywords: orbital angular momentum, single photons, vortex combs, microring resonator

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Photons with a helical phase front can carry a discrete, unlimited but quantized amount of orbital angular momentum (OAM). The infinite number of states with different OAMs can greatly increase the capacity of optical communication and information processing in both classical and quantum regimes. To date, the generation of photons carrying OAM relies on the linear or nonlinear process in bulk crystals, which limits both the efficiency and the scalability of the source. Therefore, an on-chip OAM source on a semiconductor chip is yet illusive and highly desirable for integrated photonic technologies. In nanophotonics, the microring resonators sustain whispering gallery modes (WGMs) naturally carrying OAM. The introduction of periodic angular gratings to the WGM resonator collectively scatters the WGMs to the free space, leading to on-chip emissions of optical vortices. These microresonator vortex emitters can benefit from strong light-matter interactions due to the prolonged photon lifetimes and enhanced light intensities. Here, we demonstrate both quantum and classical optical vortex emitters generated on the III-V integrated ring microresonator. The integration of a single quantum dot emitter into an on-chip mircoring resonator enables the generation of single photons in an OAM superposition state, and microring-based vortex combs with each comb line carrying a distinct OAM generate light springs with time-varying orbital angular momenta.

Defect Passivation by Various Bromide Adding and Their Effect on Charge Carrier Dynamics in Perovskite

Keywords: Perovskite, Defect passivation, laser, LED

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Perovskites are known for their "defect tolerance", which allows the use of low-temperature methods to obtain polycrystalline thin films. Although there are defects, most often associated with halogen vacancies (VX), due to the nature of the ionic bonding and the antibonding orbitals. Such defects are formed mainly at the perovskite grain boundaries. Thus, despite the often cited "defect tolerance", nonradiative recombination through defects is the main mechanism of energy loss in perovskites. However, while defects are often considered undesirable in perovskite materials for some applications, their influence in other applications can be beneficial and important. In this work, we demonstrate studying of the optical and transport properties of inorganic perovskite CsPbX3 (where the X position is occupied by Br or a mixed cation of Br, Cl and I) with the addition of CsBr or KBr for defect passivation. Both additives can be incorporated into the perovskite crystal structure and reduce halogen vacancies in the lattice, but the two different compositions demonstrate different optical and transport properties, which critically affects the operation of the devices. Thus, we demonstrate the metrics and analysis of the dynamics of charge carriers in perovskite materials, which is extremely important in the design of various optoelectronic devices based on perovskite.

Ultra-Compact Spectral Modulation and Monocular Polarimetric Metalens for 3D Stereo-imaging

Keywords: Physics, Metasurface, Light-field manipulation

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Metasurfaces, as multifunctional integrated structures, demonstrate enormous potential in the optical domain, offering flexible control over various dimensions such as wavelength, phase, and polarization. To enhance the flexibility of metasurfaces in dispersion control, we modulate the coupling between dual nanorods, breaking the linear relationship between phase and wavelength, and inducing a wideband continuous phase transition effect. This construction enables arbitrary transverse chromatic aberration control across two arbitrary bands within the broadband. The non-uniformity of chromatic aberration allows independent control of the spectrum in the visible and near-infrared bands, with potential applications in atmospheric element detection and cluster component identification. Simultaneously, by realizing full Stokes polarization decoupling based on the metalens, we have developed a polarization-sensitive ultra-compact monocular 3D reconstruction system. This system overcomes the limitations of traditional lens stitching and bulky volume, achieving real-time single-shot snapshots and significantly enhancing imaging resolution. Moreover, the system addresses the information loss associated with circular polarization in traditional polarization 3D technology, simplifying the complex computation of polarization degree. It exhibits high precision in capturing surface texture details of micro-objects. Our approach provides important insights into miniaturized scene reconstruction, surface roughness shape detection, and facial recognition in practical applications.

Magnetic Positioning System with Graphical Feedback for Wireless Charging of Electric Vehicles

Keywords: Wireless Power Transfer, EV Wireless Charging, Sensors, Programming

Sutanu Chatterjee[1], Alexander Zolotarev[1], Polina Terenteva[1], Georgii Baranov[1], Polina Kapitanova[1].

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Wireless charging of electric vehicles (EVs) is gaining prominence globally because it eliminates the need for handling of bulky cables, reduces risks associated with operation in harsh weather conditions and provides a pleasant user experience, all while offering similar power transfer efficiencies compared to wired charging methods. Traditionally, wireless power transfer (WPT) systems are based on the inductive coupling between a transmitter integrated into the charging station and a receiver integrated into an EV. Accurate positioning of the receiver and transmitter is essential in inductively coupled wireless charging systems to achieve high power transfer efficiency, ensure safety, improve user convenience, and enhance the overall reliability of the charging process. This work presents an innovative magnetic positioning system with graphical feedback developed to enhance the precision of positioning in wireless charging systems for EVs. The proposed system consists of three anisotropic magneto-resistive sensors located on three edges of the receiver and three ferrite rod antennas located on three edges of the transmitter. The sensors are able to detect the intensities and directions of magnetic fields generated by ferrite rod antennas and determine the position of the receiver above the transmitter, based on sensor data-processing using an STM32F3 series mixed-signal microcontroller, which correlates the intensities and directions of the magnetic fields with the distance from the center of the transmitter in the horizontal plane. The processed data is displayed via a graphical interface that shows the position of the vehicle's receiver above the transmitter in a real-time manner with an error margin of ±10 mm in both side-to-side and front-to-back horizontal directions. This provides visual feedback to guide a driver during the alignment process, reducing positioning errors. The provided solution is cost-effective and modular and therefore is a significant step forward for the widespread adoption of wireless charging of EVs. This work was performed with financial support of the Russian Science Foundation (Project No.21-79-30038)

Nonlinear orbital angular momentum comb generation

Keywords: Orbital angular momentum, second harmonic generation, comb, optical vortex.

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Over the last decade, free-space optical (FSO) communication has emerged as a promising alternative to fiber optic communication lines. However, one of the main challenges for FSO is maintaining signal stability over long distances due to the atmospheric degradation of the Gaussian beam. To address this, beams with angular orbital momentum (AOM), or vortices, have been proposed. Vortices exhibit a unique intensity structure (doughnut-shaped) and a helical phase, described by exp(il), where is the azimuthal angle and l is the OAM projection onto the propagation direction, also known as topological charge. Despite significant progress, with FSO now capable of transmitting information over distances up to 10 km, it still lags behind classical fiber optic lines in terms of throughput. The primary method for enhancing fiber optic throughput is frequency comb generation, typically involving nonlinear light-matter interactions (such as FWM, SFG, and Kerr comb generation). This approach can increase communication line capacity by several orders of magnitude. Recent advancements have demonstrated devices capable of generating angular momentum combs, using Kerr comb technology with ring resonator defects to produce comb vortices at different wavelengths. In this study, we propose a novel, simpler, and more cost-effective method for vortex comb generation, utilizing second harmonic generation. Our approach is validated both theoretically and experimentally, showcasing the potential for enhanced FSO communication.

Self-assembly of MOF nanoparticles for new photonic devices

Keywords: MOF, Self-assembly, Photonic crystals

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Self-assembly of particles into long-range, three-dimensional, organized superstructures opens perspectives for the design of superstructures for catalysis, photonics, energy or gas storage, and plasmonic sensing. Generally, well-studied nanoparticles such as gold, silicon, or polystyrene are used for such superstructures. Herein, the use of well-shaped nanocrystals of hybrid materials such as metal-organic framework (MOF) can provide new functional properties like lasing or spatially driven second harmonic generation. In this work, we used two MOFs: noncentrosymmetric ZIF-8, which can generate second harmonic, and luminescent UiO-66 with up to 60 % quantum yield. Self-assembly of MOF-based superstructure onto a substrate was prepared by drop casting method. The morphology of the resulting superstructures was examined by SEM. An effect of the surfactant, solvent, and evaporation temperature were also investigated. Next, two types of superstructures are to be analyzed for lasing and second harmonic generation, spatially driven by the difaction of pumping and generated light by the superstructure.

This work was performed with financial support of the Priority 2030 Academic Program.

Bound States in the Continuum: Stability Against Structural Defects

Keywords: bound states in the continuum; metasurfaces; spatial localization; structural defects

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Bound states in the continuum (BIC) are resonances with infinite radiative quality factor (Q-factor) and although the infinite Q-factor of BIC is a mathematical abstraction, high-quality supercavity modes (quasi-BIC) formed by the B IC mechanism can be excited into the resonator. Since in reality we cannot have ideal structures, an important issue is the effect of defects such as structural disorder, geometric disorder, material losses on the Q-factor. Here we consider different types of dielectric resonators and investigate the effect of geometric defects and material losses on their Q-factor. We consider such structures as a bilayer resonator consisting of infinite rods, a one-dimensional structure of blocks, and a chain of dielectric disks. In the case of a bilayer resonator and a chain of disks, we introduce structural disorder along periodicity axis and study the effect of the disorder

degree on the Q-factor of the symmetry protected BIC. In the structure consisting of blocks, we study the effect of random trapezoidal on the Q-factor of BIC. We also study the effect of material losses on the Q-factor of symmetry protected and Fabry-Perot BIC in the bilayer resonator.

This work was performed with financial support of the Russian Science Foundation (Project No. 20-79-10316-П)

Laser-induced Formation of a TiO_2 Nanocoating with a Controlled Phase for Photocatalysis

Keywords: TiO_2, Laser, Photocatalysis

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TiO_2 is a promising material for various practical applications due to its photoactivity, chemical stability, biocompatibility and non-toxicity. The electronic, optical and photocatalytic properties of TiO_2 are closely related to its phase composition. The anatase phase is known for its high photocatalytic activity, while the rutile phase has better thermal stability. A mixture of these phases can possess desirable properties for specific applications. There are various methods for synthesizing TiO_2 structures with a controlled phase, but reducing the number of technological steps remains a challenge. Laser ablation is a promising solution to this problem, as it is a non-contact and precise method that allows the production of pure nanoparticles or thin films without impurities in one step. This study aims to investigate how the parameters of laser radiation influence the phase and morphology of TiO_2 structures and how these characteristics impact the material's performance as a photocatalyst.

This work was performed with financial support of Priority 2030 Academic Program.

Development of optical physically unclonable security labels based on silicon-erbium nanoparticles

Keywords: PUF labels, laser fabrication.

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The development of multilevel physically unclonable security labels can help to efficiently fight counterfeiting. We show a physically unclonable security labels based on nanoparticles consisting of erbium and silicon, produced using the adopted laser ablation technique. In the label each nanoparticle has different inner structure which affects optical responses. The label has five levels of authentication. Spatial arrangement and colors of nanoparticles allows label authentication with computer vision algorithms by microscopic photo. Laboratory methods, in turn, allows verification of the authenticity of the label by far field spectral response, crystallinity of nanoparticle and erbium photoluminescence spectral response.

Acknowledgments: This work was performed with financial support of Priority 2030 Academic Program

Enhancing Signal-to-Noise Ratio in Terahertz Pulsed Time Domain Holography through Raster Scan with Diaphragm-Lens Module

Keywords: Time-domain Holography, Broadband THz fields, Bessel-Gauss beams, SNR, Resolution, Raster scan

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Terahertz Pulsed Time Domain Holography (THz PTDH) is widely used for measuring the spatio-temporal distribution of pulsed THz fields, essential in imaging, examining complex wavefields, and designing metasurfaces and optical components. However, a trade-off exists between signal-to-noise ratio and resolution due to the raster scanning method by the diaphragm in the expanded field. We propose a raster scan approach for THz PTDH applications, replacing the scanning aperture with a module consisting of a conjugated diaphragm and lens that move synchronously. We experimentally investigate the evolution of Bessel-Gauss beams in a low-energy system, based on a femtosecond laser with a pulse energy of approximately a dozen nJ and a repetition rate of tens of MHz, employing the proposed scanning technique. Through numerical simulation, we assess the impact of parameters such as pixel size, diaphragm translation pitch, and scanning plane position on signal gain and resolution within the detection zone for the modified data acquisition method used in THz PTDH.

Holographic microscope based on Pancharatnam-Berry phase optical element

Keywords: Digital holography, Geometric phase, Polarization, Microscopy, Phase retrieval

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A holographic microscope based on a geometric phase lens, which transforms a linearly polarized beam into two beams with right and left circular polarizations, one diverging and the other converging, is introduced. The parallel phase shift method was used to determine the phase distribution. A polarization camera was used to capture four interferograms in a single exposure, each corresponding to different linear projections of waves with right and left circular polarizations. Holograms of a phase object-micrometer were recorded, and the phase delay introduced by the object was reconstructed using the parallel phase shift method. Shown, that this digital holographic microscope, equipped with a geometric phase lens and a polarization camera, allows for precise visualization of surface relief profiles. It can serve as a valuable tool for monitoring the condition of biological samples under external influences.

Temperature-controlled Topological Zigzag Array of Resonators

Keywords: Zigzag Array, Topological Edge State, Temperature Control

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Tunable and switchable systems are the next logical step in the development of topological photonics. In this work, we numerically and experimentally demonstrate a novel method to control topological edge states in a zigzag array of dielectric cylindrical resonators with high dielectric permittivity by applying local heating to the resonator. Spot heating leads to a decrease of resonator's dielectric permittivity, which in turn changes its the resonant frequencies and detunes it from the rest of the system, therefore making the resonator 'fall out' from the array. Numerical simulation and experimental measurement in the microwave frequency range confirm that the properties of the topological edge states in such system can be tuned and controlled by temperature. We hope that the proposed approach to the tuning of the topological edge states can be employed in real devices, such as photonic logical elements.

Inverse Design of Colored Daytime Radiative Coolers Using Deep Neural Networks

Keywords: Nanophotonics, Radiative cooling, Inverse Design, Deep learning, Multilayered structure

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Passive daytime radiative cooling is an eco-friendly and cost-efficient cooling strategy that is achieved by selectively reflecting the solar irradiance and emitting heat to cold background of the universe through the atmospheric window (AW) at infrared wavelengths. The daytime radiative coolers traditionally exhibit a grey or white color due to the requirement of high solar irradiance reflectance. Here, we present a colored daytime radiative cooler (CDRC) that has high reflectance in the NIR, high emissivity in the AW, and the capability to generate subtractive primary colors based on Fabry-Pérot interference using metal-insulator-metal (MIM) structures. The structural parameters of the MIM multilayers are inversely designed using tandem neural networks to achieve cooling powers of 11.2–38.2 W/m2 with on-demand color generation. The proposed CDRCs have potential to be used for cooling thermal sensitive electronic and optoelectronic devices and aesthetic applications.

Fourier Modal Method for Calculating Two-Dimensional Periodic Photonic Crystals with Chiral Inclusions

Keywords: Photonic Crystals, Fourier Modal Method, Factorization Rules, Chirality

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To calculate optical properties of two-dimensionally periodic photonic crystal slabs having inclusions with non-zero macroscopic coefficients of chirality, an enhanced version of the Fourier modal method has been developed, based on the Lifeng Lie factorization rules. This method employs mathematically accurate Fourier transform rules for material equations with coefficients of chirality, expressed as arbitrary 3-by-3 tensors. The transition of the derived expressions for permittivity tensors, magnetic permeability, and chirality coefficients to Lie operators in the absence of chirality is demonstrated. This approach enables accurate calculations even for resonant values of chirality coefficients.

Germanium halide perovskites: synthesis, nanostructuring and nonlinear nanophotonic applications

Keywords: Nonlinear optics, Halide perovskites, Nanomaterials

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Halide perovskites are promising materials that have attracted the attention of researchers due to their outstanding optoelectronic properties. Most of the works devoted to them concern lead halide perovskites, due to their advantages, such as most efficient light conversion. However, recently, the attention of researchers has also been drawn to lead-free perovskites, which are free of problems associated with lead toxicity. Therefore, in recent years lead-free germanium halide perovskites also emerged as a promising class of enviromently-friendly nonlinear optical materials for a variety of applications, particularly in the field of nanophotonics. Previously, researchers demonstrated the high potential of germanium perovskites for up-conversion of infrared light through second harmonic generation. And in this work, we focus on the formation of resonant micro- and nanostructures based on germanium halide perovskites $CsGeI_3$ and $MAGeI_3$, which can efficiently convert near-infrared light to visible both via up-conversion lasing and second harmonic generation mechanisms. Therefore, here we present synthesis methods and nanostructuring techniques used to fabricate high-quality lead-free halide perovskites, as well as modeling and experimental study of their nonlinear optical response. Results of this work pave the way for new optically resonant nanostructures for up-conversion of infrared light.

This work was performed with financial support of Priority 2030 Academic Program.

High-Q two-photon states in atomic metasurfaces

Keywords: Atomic metasurfaces, High-Q modes, 2-photon states

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Suppressing spontaneous emission in ensembles of quantum emitters (atoms) is one of the key challenges in quantum optics and quantum technology. In recent years, significant progress has been made in studying single-photon subradiant states in atomic systems, both in free space and in proximity to nanostructures. However, long-lived entangled two-photon states are still poorly explored. In this work, we consider metasurfaces of two-level atoms in free space, which can support high-Q two-photon states, either scattered or localized. High-Q scattered states are composed of single-photon bound states in continuum or waveguiding states at the edge of the Brillouin zone. Localized states consist of multiple single-photon contributions, some of them lie above the light line, limiting the lifetime of such states.

Experimental investigation of acoustic Kerker effect

Keywords: Kerker effect, experiment, acoustics, directional scattering

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Directional scattering is useful for the wavefront manipulation. In optics resonant directional scattering can be achieved through the Kerker effect. Similar effects can be found in acoustics for coiled-space structures, as their effective refractive index is greater than unity.

In our work, we considered the labyrinthyne metaatom and conducted numerical simulation and experiment to study forward and backward directional scattering, which should meet the Kerker conditions. Numerical simulation was set in Comsol Multiphysics, Pressure Acoustics module. The experiment was carried out in 2-D anechoic chamber for 3D-printed labyrinthine metaatoms. We observed the Kerker effect in both simulation and experiment. Numerical and experimental results showed good agreement.

This work was performed with financial support of Priority 2030 Academic Program.

Directly probing topology with wavefunctions

Keywords: Topological photonics, topological phono ics, metamaterials

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Symmetry-protected topology provides a large set of topological phenomena that have attracted tremendous research interest. However, the underlying symmetry that protects the bulk topology often fails at the edge. Examples may include the higher-order and fragile topological insulators, or strong topological insulators with the spontaneous breaking of the time-reversal symmetry due to interaction effects. In these cases, edge states can be gapped and unstable, providing a poor feature of the band topology. In this talk, I show that in many cases, band topology can be probed via the bulk wavefunctions measured in experiments despite that the system is finite. We demonstrate this principle via two different approaches. In the first approach, the bulk Bloch wavefunctions can be extracted from the pump-probe measurements via a revised method based on the singular value decomposition of the pump-probe response tensor. We show that for odd Euler class insulators, the measured bulk Bloch wavefunctions exhibit meronic patterns in the Brillouin zone which can be a direct signature of the Euler class band topology. In the second approach, with the bulk Bloch wavefunctions we can obtain the entanglement entropy of the phononic system which also gives a diagnosis of the band topology. With both approaches going beyond the bulk-edge correspondence, our study may inspire future experimental studies on topological phases.

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On the Origin of Q Factors in Photonic Crystal Slabs

Keywords: Photonic Crystal Slabs, BIC, Exceptional Points

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Leaky modes are supported in photonic crystal slabs as a type of resonance modes, representing poles of the scattering matrix within the complex-frequency plane. Here, we establish a first principle-based theory to study the complex-frequency band structure governing these leaky modes. The formulation is based on a few dominant bulk Bloch states, in particular, one of which expressed as $|\ _0\rangle$ leads to the non-Hermiticity. This theory yields diverse and intriguing results, encompassing the imaginary parts of leaky mode frequencies, Q factors, bound states in the continuum, exceptional points, far-field polarizations. It is the intricate interplay of bulk Bloch states that reveals remarkable manifestations in the guided-mode resonances of photonic crystal slabs.

High Numerical Aperture Metalens in Terahertz Region

Keywords: Metalenses, Terahertz, High Numerical Aperture

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Terahertz lenses play a pivotal role in terahertz systems, enabling high-resolution biosensing, bioimaging, and the detection of concealed details. Metasurfaces, with their adaptability and compact design, have become a favored choice for crafting terahertz metalenses, overcoming the constraints associated with traditional, bulky refractive lenses. Nevertheless, the diffraction limitations of existing metalens elements have hindered their broader application. To surmount these challenges, a novel silicon-based metalens for the 0.3–0.9 THz frequency band has been proposed. This lens boasts a high numerical aperture and resolution that approaches the diffraction limit, significantly enhancing the potential of terahertz components in nondestructive testing and biomedical imaging applications.

Stability of the Bound States in the Continuum against Material Losses

Keywords: Bound States in the Continuum, Resonant States, Metastruc-

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tures, Dielectric Metasurfaces

Bound states in the continuum (BIC) — resonant states with high quality factors were studied in this work. BIC appear as a special solution of the wave equation: frequencies of BIC reside in the continuum of non-localised states, however the field itself is localised s patially. Theoretically, BIC possess infinite quality factors, but real applications imply different causes limiting a quality factor: structural defects, disorder, material losses etc. Resonant states formed by the same mechanism as BIC yet having finite quality factors by some reason are called quasi-BIC (qBIC). Current work presents that with increasing the tangent of material losses for a resonator, quality factors of qBIC extremely decrease and present an exactly inversely proportional dependence. System of two layers of dielectric rods was studied and both dependence of quality factors on the distance between layers and longitudinal shift are presented. Different types of BIC and qBIC were studied including symmetry-protected BIC, forming of which is caused by the resonator symmetry and destructive interference, and Fabry-Perot BIC, which involve the eponymous resonances between layers and highly depends on structure parameters. Thus, current work unveils the difference between impact of material losses on quality factors of qBIC with different structure parameters of a resonator. This work was supported by the Ministry of Education and Science of Russia (No. 075-15-2023-586).

The effect of rubidium incorporation in perovskite quantum dots and nanocrystals on the dynamics of charge-carrier

Keywords: Perovskites, Nanocrystals, Charge-Carrier Dinamics

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Lead halide perovskites are promising materials for photovoltaics and optoelectronics. Ions that change the chemical composition, crystal structure or passivate the surface are introduced into the usual compositions to enhance their properties. This study focuses on the investigation of rubidium cations inclusion in lecithin covered $CsPbBr_3$ quantum dots and nanocrystals by means of charge-carrier dynamics affecting their properties. According to Goldschmidt's tolerance factor, rubidium can either incorporate into the perovskite crystal lattice or passivate the surface thus differently affecting its properties. This makes the study of such materials especially interesting. Colloidal quantum dots and perovskite nanocrystals with varying ratios of cesium and rubidium were synthesized using the hot injection method. Films were deposited from the solutions using spin-coating method. Optical properties were investigated by the methods of power dependences photoluminescence quantum yield, time-resolved photoluminescence spectroscopy and measurement of amplified spontaneous emission thresholds. These measurements made it possible to determine the mean of rubidium effect on the perovskite crystal lattice and showed the effectiveness of such modification to future applications.
This work was performed with financial support of the Russian Science Foundation (Project No. 21-73-20189)

Metalens based Stereo-microscopic System

Keywords: Stereo-microscop meta-lens

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Stereo-microscopy is an excellent technique for obtaining three-dimensional microscopic images. Stereo microscope is based on parallax effect, using two lenses to image the same object point from different angles to obtain parallax image. However, due to the constraints of the optical path configuration, the numerical aperture is limited to NA=0.2, which limits the resolution of the system. The common front large objective stereo-microscopic system can increase the numerical aperture to about 0.35, but this stereo-microscopic system is twice as expensive as the traditional one, so improving the resolution of the stereo-microscope has become an important topic. Here we demonstrate a high-resolution and low-cost stereo-microscopic system based on a single-layer metalens design with symmetric imaging capabilities and a numerical aperture up to NA=0.4 at an operating wavelength of 532 nm. Our work also demonstrates the results of using a metalens to achieve high-resolution stereo-microscopic imaging of biological samples.

Plasmonic enhancement in Lanthanide-based OLED through Purcell effects

Keywords: OLED, Purcell effect, Purcell factor,

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Photoluminescence, Plasmonic nanoparticles.

Lanthanide-based coordination compounds exhibit narrow emission bands, making them attractive candidates for high color purity organic light-emitting diodes (OLEDs) across the visible and near-infrared spectrum. However, OLEDs employing lanthanide-based emissive layers are hindered by their relatively slow recombination rates (approximately 1 ms). The influence of plasmonic nanoparticles and nanorods on photo- and electroluminescence was studied, as well as the thin film luminescence dependence on solution deposition conditions was investigated. Three highly emissive lanthanide complexes were obtained, their photoluminescence reached 100% in powder and up to 63% in thin film. Optimal deposition conditions were determined. The introduction of gold nanoparticles into the hole-injection layer was shown to only slightly affect the luminescence intensity, while gold nanorods introduction in the emission layer resulted in 50% increase of the OLED performance up to 120% increase of the photoluminescence quantum yield. The enhancement of LED luminescence intensity was also investigated by numerical calculation of the Purcell factor (PF) using "CST Studio" software.

Fig. 1. a) Crosscut of 3D layered model, b) Purcell factor of dipole in presence of three different oriented NRs and c) Dipole directivity with presence of x-oriented NR at wavelength of 475 nm This work was performed with financial support of the Russian Science Foundation (Project No. 21-79-30038).

Simulation and Measurement of Radiation Characteristics of Small Dielectric Resonator Antennas

Keywords: Dielectric resonator antenna, directivity, radio engineering, simulation, experimental measurement.

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The possibility of using the resonance effect in a dielectric resonator for simultaneously obtaining highly efficient and super-directional radiation from antennas smaller than a wavelength has been shown theoretically and experimentally. By optimizing both the dielectric resonator and the emitter, it is possible to increase the efficiency, directivity, or bandwidth of such antennas. High directivity is achieved as a result of the constructive interference of individual electric and magnetic modes of the open resonator in a given direction at certain frequencies. The directivity of the proposed antennas exceeds the theoretical Kildal limit, which indicates super-directional behavior of the antenna radiation.

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

Chiral Light in Twisted Fabry-Perot Cavity

Keywords: Chirality, Farby-Pérot cavity, Handedness-preserving mirror, Photonic crystal

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Fundamental research on the interaction between chiral light and chiral matter is crucial for developing techniques that enable handedness-selective optical detection of chiral organic molecules. An approach to achieving this is through the design of Fabry-Pérot cavities that support eigenmodes with specific electromagnetic handedness, allowing differential interaction with left- and right-handed molecular enantiomers. In this study, we theoretically explore the properties of chiral Fabry-Pérot cavities, using mirrors composed of one-dimensional photonic crystal slabs made from van der Waals As_2S_3— a material known for its exceptionally high in-plane anisotropy.

Leveraging the anisotropy provided by As_2S_3, we design Fabry-Pérot cavities with both constitutional and configurational geometrical chiralities. Our findings reveal that one-dimensional photonic crystal slabs made from anisotropic materials can function as chiral mirrors that preserve a single polarization state upon reflection either as handedness-preserving mirrors that maintain both circular polarizations during reflection.

A cavity constructed using chiral mirrors exhibits constitutional chirality, wherein left- or right-handed electromagnetic modes arise directly from the mirror properties. Conversely, cavities with configurational chirality do not exhibit polarization selectivity and support modes of both handednesses due to the chiral morphology of the overall structure determined by the twist angle between the upper and lower non-chiral anisotropic mirrors.

We demonstrate that in both types of cavities, the electromagnetic field of the eigenmodes can achieve maximum chirality, with a homogeneous intensity distribution that avoids regions of zero intensity. The one-dimensional photonic crystal mirrors employed in these Fabry-Pérot resonators offer a simpler geometry compared to existing designs, and the rotational degree of freedom allows for precise tuning.

The developed chiral Fabry-Pérot cavities can be adjusted to the available technological distance between mirrors through appropriate twisting, making these systems a promising platform for coupling chiral light with chiral matter. This work paves the way for new optical detection methods that can selectively interact with molecular enantiomers, with potential applications in stereochemistry, pharmacology, and molecular biology.

Development of the Hybrid MoM - T-Matrix Method for Simulation and Optimization of Resonant Antennas

Keywords: Numerical analysis, Method of Moment, Scattering, T-matrix method, Antenna Optimization.

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Computational schemes that integrate the Method of Moments (MoM) with the T-matrix method have been developed for the design and optimization of resonant antennas. This approach provides an efficient numerical technique for characterizing dielectric antennas of arbitrary shape under electric dipole excitation. The MoM is employed to address the electromagnetic field integral equations associated with the metallic components, while the T-matrix method, coupled with the invariant imbedding technique, is leveraged for analyzing wave scattering by nonspherical particles. The integration of these methods allows for the construction of a transition matrix that connects piecewise-defined models with those encompassing the entire domain, enhancing both computational efficiency and accuracy.In the realm of resonant dielectric antenna design, this composite computational strategy not only facilitates the rapid determination of resonant frequencies but also substantially reduces the physical size of the antennas. Such miniaturization is crucial for preserving high radiation efficiency within the spatial limitations set by practical applications. This enables the innovation and refinement of antenna designs with enhanced precision and efficiency.

Magnetically tunable bound states in the continuum with arbitrary polarization and intrinsic chirality

Keywords: BICs with arbitrary polarization, intrinsic chiral BICs, magneto-optical effect, chiral emission

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Bound states in the continuum (BICs), which are exotic localized eigenstates embedded in the continuum spectrum and exhibit topological polarization singularities in momentum space, have recently attracted great attention in both fundamental and applied physics. Here, based on a magneto-optical (MO) photonic crystal (PhC) slab placed in external magnetic fields with time-reversal symmetry (TRS) breaking, we theoretically propose magnetically tunable BICs with arbitrary polarization covering the entire Poincaré sphere and efficient off-□ chiral emission of circularly polarized states (C point). More interestingly, by further breaking the in-plane inversion symmetry of the MO PhC slab to generate a pair of C points spawning from the eliminated BICs and tuning the external magnetic field strength to move one C point to the □ point, an at-□ intrinsic chiral BIC exhibits chiral characteristics on both sides of the PhC slab with near-unity circular dichroism exceeding 0.99 and a high-quality factor of 46000 owning to the preserved out-of-plane mirror symmetry can be obtained. Moreover, the chirality of the chiral BICs can be inverted by flipping the magnetic bias. Our work opens an unprecedented avenue to explore the unique topological photonics of BICs with broken TRS and promises multiple applications in chiral-optical effects, structured light, and tunable optical devices.

Topological edge states for lasing using perovskite structures

Keywords: Jackiw-Rebbi states, topological, diffraction gratings, junction

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In this work, we explore the use of topological edge states for lasing in perovskite-based photonic structures, focusing on the realization of Jackiw-Rebbi (JR) states at a topological junction formed between two distinct diffraction gratings. By utilizing the exceptional optical properties of perovskites, we designed a system that supports robust, topologically protected lasing modes at the interface of the gratings. The parameters for achieving JR states were determined through detailed modeling, and the reflection spectra of each individual grating and the junction were analyzed using both COMSOL simulations and the Fourier Modal Method (FMM) implemented in MATLAB. The results confirm the emergence of topological edge states at the junction, demonstrating their potential for stable, low-threshold lasing applications. This study highlights the promising synergy between perovskite materials and topological photonics, paving the way for novel, defect-resistant laser

technologies. Acknowledgments: This work was performed with financial support of Priority 2030 Academic Program

Hybrid Gold-Silicon Sub-Microsponges: Laser Fabrication and Characterization

Keywords: Gold-Silicon Photoluminescence, Hybrid Nanophotonics, Laser Fabrication

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Introducing nanoscale plasmonic inclusions into the crystalline matrix of various semiconductors offers a powerful strategy to amplify nonlinear optical effects in these materials. One example of such hybrid systems is gold-silicon sponge-like particles. These sub-microscale structures represent a multiconnected gold network enveloping a system of polycrystalline silicon grains and possess bright broadband up-conversion photoluminescence in the visible range. In this work, we carry out a comprehensive theoretical and experimental study of these sponges, aiming to shed light on previously unexplored aspects of their formation and optical properties. The obtained results reveal the intriguing relationship between the internal structure and the quantum efficiency of studied particles as well as present the possibility of their fast and controllable laser printing. Altogether, our findings open up wide prospects for the development of silicon-based white-light emitters with enhanced radiation efficiencies.
This work was performed with financial support of the Russian Science Foundation (Project No. 24-72-10075).

Theoretical consideration of a twisted atom

Keywords: Twisted atom, twisted wave, electron transition

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We investigate the twisted state of an atom and the possible effect of such a state on the properties of the photons emitted as a result of an electron transition in that atom. We first propose a framework for describing the twisted atomic state and then explore possible differences in the nuclear recoil effects in the twisted atom compared to those in the plane-wave atom. We conclude that if the initial atomic state is twisted, then the photon distribution is altered. We point out that, in a certain observation scheme, one can detect a feature of this twist in the distribution of the emitted photons, even in zero order in $\frac{m}{M}$. This work was performed with financial support of the Russian Science Foundation (Project No. 24-72-10060)

Accessible, All-Polymer Metasurfaces: Low Effort, High Q

Keywords: Polymeres, BIC, Optical Metasurfaces, Fabrication, Nanophotonics.

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We experimentally demonstrate an all-polymer optical metasurface based on Bound States in the Continuum. Traditional metasurfaces typically demand elaborate multistep procedures associated with nanofabrication—such as metal/dielectric deposition, lift-off, and reactive ion etching. In our approach, we significantly reduce this fabrication burden by using PMMA as the resonator material, eliminating all steps but spin-coating, lithography and development.

This methodology not only greatly simplifies fabrication but also delivers high-quality resonances (up to Q > 500) in the visible spectrum. It further promises advantages such as blending with other materials, greyscale lithography or angled writing.

Selective Perturbation of Eigenfield Enables High-Q Quasi-Bound States in the Continuum in Dielectric Metasurfaces

Keywords: BIC, Perturbation of eigenfields, Dielectric metasurfaces

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Dielectric metasurfaces supporting symmetry-protected bound states in the continuum (SP-BICs) have emerged as an attractive platform for manipulating light–matter interactions on the nanoscale. However, quasi-BIC with a high quality (Q) factor by releasing SP-BIC is still a challenge in practice due to the Q-factor sensitivity to asymmetric parameters and the limited level of fabrication. Here, we present a universal perspective aiming at achieving high-Q-factor quasi-BICs through the efficient perturbation of eigenfields. This approach affords

the flexibility to select scaling laws of the Q-factor, and a larger Q-factor can be obtained under the disturbance of the weak field region for the same asymmetric parameters. Such findings have been extended to classical nanostructures, such as dimeric nanobars, splitting rings, and nanodisks. Finally, square nanodisks embedded with air holes at different positions are used as an example to experimentally confirm our findings. Our method provides a new idea for the release of high-Q-factor quasi-BICs and paves the way for the realization of high-performance optical devices based on a high Q-factor.

Personal Stealth Device Design and Applications

Keywords: Personal, Stealth, Infrared, Multi-band, Mxene, F-P cavity

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In modern combat, various types of light detection technologies are widely used. In order to improve the survival rate of soldiers, it is necessary to design a new type of personal fabric to achieve the function of simultaneous stealth in the VIS, NIR and LWIR bands. This requires spectral modulation of commercial fabrics to achieve high absorption in the VIS-NIR bands to reduce the reflected signals from the environment, and low emissivity in the thermal IR (8-14 μm) range to reduce the thermal radiation signals emitted by the human body itself. In addition to this, it also needs to take into account the flexibility and toughness. Inspired by solar collectors, I chose two options to try to realize this function independently. The first is the Mxene 2D material, which is sprayed onto the fabric, utilizing Mxene's own properties of high absorption in the VIS-NIR and low emission in the thermal IR. The best of the prepared samples was on nylon, which has a hemispherical reflectance of only 5% in the VIS-NIR and an emissivity of only 0.45 in the thermal IR, helping to reduce the radiant temperature of an object at 50°C by about 13°C. The second is an ultra-thin Fabry-Perot film layer plated on fabric, using a resonant cavity for high absorption in the VIS-NIR and metal for low emission in the thermal IR.

Fermi arc and exceptional points in a ring resonator

Keywords: EP, BIC, QNM

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In this work, we report the discovery of EPs in single dielectric ring arising from interaction of radial and azimuthal modes, which depend differently on the height of the ring. Continuing the study of scattering spectra for a very narrow ring, we moved on to the space of three parameters, such as height (h), internal (R_{in}) and external (R_{out}) radii. Riemann surfaces were calculated for the eigenvalues and eigenfunctions of the two interacting modes TE_{012} and TE_{020}. Three-dimensional representation made it possible to detect two EPs in which both eigenvalues and eigenfunctions coincide. The calculation showed that EPs are connected by bulk Fermi arc (a continuous set of parameters $(R_{out} - R_{in})/h$ and R_{in}/R_{out}) along which the frequencies of the two modes coincide, while the half-widths vary. This work was performed with financial support of Priority 2030 Academic Program

Wireless Power Transfer by a Detuned Birdcage Coil with a Dual-Regime Receive System

Keywords: MRI, WPT, resonators, magnetic resonance imaging, wireless power transfer, near field antennas

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In this work, we demonstrate the concept of wireless power transfer by a detuned birdcage coil in a 1.5 T magnetic resonance imaging (MRI) scanner. The birdcage coil is detuned by inductors, while the receive system consists of the loop coil and the two-frequency matching circuit for receiving simultaneously both a wireless power and MR signals. We simulate numerically the distributions of magnetic and electric fields, the specific absorption rate with the human voxel model, and the wireless power transfer efficiency using CST Microwave Studio for different modes of the birdcage coil. The numerical model was verified experimentally. The maximal received power which is limited by the patient safety conditions depends on a position of the receive system within the birdcage coil and the number of modes used. This work was performed with financial support of the Russian Science Foundation (Project No.24-79-10314).

The Dynamics Of Charge Carriers In Cd-Doped $CsPbBr_3$ Quantum Dots and Perovskite Nanocrystals

Keywords: Charge Carriers Dynamics, Quantum

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Dots, Nanocrystals, Perovskite

Lead halide perovskites are a class of semiconductor materials with a perovskite structure that are of great importance in various fields of energy and optoelectronic technologies. In recent years, these structures have begun to attract attention as promising optical materials for the active laser medium. And it is no coincidence: perovskite semiconductors have all the necessary characteristics for a good laser gain medium, including high carrier injection ratio, direct energy band gap and high quantum efficiency. Nevertheless, there are also limitations for their use in laser devices, mainly due to their high level of Auger recombination occurrence, which affects the increase in thresholds of amplified spontaneous emission.
In this work, we study the effects of inclusions of cadmium cations in lecithin-coated $CsPbBr_3$ quantum dots and nanocrystals, since the introduction of these ions into the standard composition significantly changes the characteristics of the material. Doping makes it possible to modify the electronic properties of structures, which in turn might affect the rate of recombination of charge carriers and their mobility and also increases the energy band gap, shifting the luminescence spectrum to the blue region.
To analyze the dynamics of charge carriers, experiments were carried out to study optical properties. The methods used were time-resolved photoluminescence spectroscopy, power dependences photoluminescence quantum yield, measurement of amplified spontaneous emission thresholds. These studies helped evaluate the effect of cadmium on perovskite and demonstrated significant potential for application in future technologies. This work was performed with financial support of Priority 2030 Academic Program

Microlasers Based on GST-Perovskite Hybrid Platform

Keywords: Microlasers, perovskites, PCM, GST.

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Microlasers are actively studied today due to their compactness and the possibility of using them in optoelectronic devices. However, fabrication of such structures of various shapes is often expensive and complex. In this work, a simple and inexpensive two-stage method for fabricating microlasers of any shape (using ring and Fabry-Perot as examples) based on a hybrid GST-perovskite platform is proposed. The structures were fabricated according to the following algorithm. First, a 100 nm thick GST film was deposited on glass substrate using magnetron sputtering. Then the film was partially switched to the crystalline phase by direct laser writing technic (DLW) according to the resonator pattern. After that, the substrate was immersed in a tetramethylammonium hydroxide solution (TMAH or TMAOH) for partial etching of the amorphous GST phase. In this way, ring and Fabry-Perot resonators of various sizes were obtained. Lead-halide perovskite CsPbBr3 was used as an active medium, which was deposited on a substrate with resonators using the centrifugation method. To study the obtained structures, the laser radiation spectra were measured under pulsed laser excitation and the dependences of the spectral behavior on the resonator shape and pumping parameters were investigated. As a result, both single-mode and multimode lasers with central wavelength from 533 to 537 nm, lasing thresholds from 25 uJ/cm^2, and quality factors up to 1400 were obtained. The results of our work are promising for creating coherent light sources of various shapes and configurations.

This work was performed with financial support of the Russian Science Foundation (Project No. 24-72-10038).

Wave scattering calculation for arbitrary shape particles based on scale separation in the Green's function

Keywords: Optics, Scattering, Green's function

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Electromagnetic radiation scattering by small particles is a critical area of study across various fields. The scattering cross-section, influenced by particle size, shape, and refractive index, is essential for characterizing particle properties. In this work, we present a novel approach to modeling scattering processes by solving the Dyson equation for the full Green's function of the system. By employing a scale separation technique, we decou-

ple the behavior of the Green's function within the scatterer from its asymptotic behavior at infinity, leading to a differential equation that can be solved analytically in certain cases or numerically using Finite Element Method (FEM) or Method of Moments (MoM). This decoupling allows efficient solutions of scattering problems for particles of arbitrary shapes and permittivity. We demonstrate the effectiveness of this approach through its application to various types of scatterers. Our work provides a universal framework for analyzing scattering phenomena.
This work was performed with financial support of the Russian Science Foundation (Project No. 21-72-30018)

Arbitrary Shape Transmitter Coils Optimization for One-to-Many Free-Positioning Wireless Power Transfer Systems

Keywords: GA, Optimization, Uniformity, WPT.

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Nowadays, misalignment tolerant wireless power transfer (WPT) systems providing simultaneous power supply to several devices are the subject of intensive research in the field of wireless charging of electronic devices. The critical parameter in such systems is the uniformity of magnetic field generated by a transmitting coil. In this work, we examine the characteristics of the magnetic field distribution of arbitrary shape planar transmitting coils and propose a genetic algorithm (GA) for optimizing their design with the objective of increasing the field uniformity. This study stands out from existing literature by introducing an optimization approach that encompasses not only traditional circular and square coils but also extends to convex polygonal coils. The results of the algorithm are validated experimentally on coils of three various geometries including circular, square, and hexagonal coils. The coefficient of variation of the magnetic field, which serves as a quantitative measure of its uniformity, is found to be 3.6% for circular coil, 5.2% for square, and 5.1% for hexagonal one in a region of interest encompassing a half of the total area of transmitting coil.

This work was performed with financial support of the Russian Science Foundation (Project No. 22-12-00204).

Tunable Perovskite Nanowire Laser based on Surface Acoustic Waves

Keywords: SAW, Perovskite nanowire, Laser

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Laser source as a key part of photonic integrated circuits, is required to be highly efficient and actively tunable. Perovskite nanowires have become a promising candidate for lasers due to their excellent optoelectronic properties, combined with the quantum confinement effect and intrinsic optical cavities. Dynamically changing the cavity of nanowires provides the potential to control light generation based on the modification of photonic modes. Surface acoustic waves (SAW), which are elastic vibrations propagating along the surface of a solid, can be generated on piezoelectric substrates with compact volume. Here we integrate perovskite nanowires on the lithium niobate substrate. By launching SAW with interdigital electrodes, the shape of perovskite nanowires can be changed with hundred-megahertz frequencies, therefore modulating the photonic modes of nanowire lasers. This method provides the possibility to achieve on-chip lasers with high-frequency active modulations for future photonic circuit applications.

Development of far-field wireless power transfer system for IoT and Smart home applications

Keywords: WPT, EMC, IoT, Far-Field

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The paper explores far-field wireless power transfer (WPT) technology for smart home IoT devices. As the WPT system we study an array of transmitters operating in the frequency band and several independent receivers that accept the power to feed IoT devices. The developed system is capable to charge multiple IoT devices located on the flat surface like a wall or a floor at a distance ranging from 0.5 or 2 m from plane of the transmitters. The theoretical model of the far-field WPT system is introduced to analyze accessible power on IoT devices depending on room dimensions and to set demands to transmitters size as well as to electromagnetic field intensity for power management. Also, this model helps to calculate the radiated power density and estimate safety for biological tissues being in a near proximity of the WPT system. Based on analytical estimations a unique design of transmitting and receiving antennae are proposed and numerically optimized to provide low power IoT devices charging on a wall area 1m*2m at a distance 1 m away from the plane of the transmitters. This receiver can be fix inside this area or move within its boundaries. The laboratory prototype of the far-field WPT system is fabricated and studied experimentally in an anechoic chamber. In the safety mode, according to the power density level near the transmitter, the WPT system allows powering a sensor and provide its uninterrupted operation in a 100ms and 1s cycles. The measured transmitter's gain is about 4 dB, the beam is about±60 degrees in frequency range 915....920 MHz. This work was performed with financial support of Megagrant №075-15-2022-1120.

Stable perovskite thin films

Keywords: Perovskite nanocrystals, metal-organic framework.

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Perovskite nanocrystals (PNCs) based on lead halides have exceptional properties: high values of the absorption coefficient and quantum yield of photoluminescence, adjustable band gap. However, due to the ionic structure, halide perovskites are unstable under the influence of external influences such as high temperature, air, and ultraviolet radiation. The objective of this study is to increase the stability of perovskite nanocrystals using the metal-organic framework (MOF). During the experiments, Pb-MOF powder (the metal-organic framework based on lead and trimesic acid ions) was obtained by sonochemical method, from which MAPbBr3 – MOF (MA - methylammonium) films were made in a new one-step method by mixing Pb-MOF powder with a solvent, a perovskite precursor and an ionic liquid. The qualitative composition of composite films was confirmed by X-ray photoelectron spectroscopy, and the average size of nanocrystals and its change over time were measured using transmission electron microscopy methods, and tests for the stability of photoluminescence under the influence of high temperature and ultraviolet radiation were also carried out.

Study of luminescence properties based on defects in 2D materials

Keywords: 2D materials, Hexagonal boron nitride, Single photon emitters

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Single-photon sources in two-dimensional materials not only have the advantage of high brightness and purity, but also achieve high photon extraction efficiency based on their unique atomic-level thickness and are easily coupled to external fields and integrated into optical quantum devices. Among other things, hexagonal boron nitride, whose defects are similar to diamond colour cores with a wide range of defect types, has attracted a great deal of attention as a single-photon source of hexagonal boron nitride with luminescence ranging from the ultraviolet to the near-infrared and the ability to operate at room temperature, but until now, there has not been a method for deterministically generating locatable defects of high purity and high brightness. We obtained high-brightness, positionally controllable defect luminescence by transferring mechanically exfoliated hexagonal boron nitride flakes onto nanopillar arrays. The modulation of defect luminescence by experimental parameters is also discussed, and the stability, pump power and temperature dependence of defect luminescence are characterised by photoluminescence tests.

Chiral Quasi Bound States in the Continuum for Augmented Reality

Keywords: Bound States in the Continuum, Augmented Reality

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Augmented Reality technology enables users to interact with virtual imagines and the real world. The emergence of AR has propelled the development of the next generation of optical devices towards miniaturization, lightweight design, and enhanced light field manipulation capabilities. However, current AR glass still suffer from shortcomings of low efficiency. This work proposes a near-eye display device based on bilayer chiral quasi-BIC (Bound States in the Continuum) nonlocal metasurfaces which can reflect narrow bandwidth RGB light with high efficiency while being able to see the natural environment clearly. At the same time, the geometric phase is introduced to realize oblique emission and reflective focusing. Due to its ability to manipulate narrowband light fields, it can reduce the interaction of metasurfaces and environment light, and has potential applications in the fields of imaging and near-eye display.

Dynamics of bound states in the continuum in non-Hermitian systems

Keywords: Bound states in the continuum, parity-time -symmetric, Q-factor

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Bound states in the continuum (BICs) are peculiar discrete states embedded in the continuous spectrum. Here, the BICs in the optical branch are studied in the Su-Schrieffer-Heeger (SSH) chain. The dynamics of BICs under parity-time (PT)-symmetric perturbation are studied. The results show that each of ordinary BICs always splits into a pair of new type BIC (we call pt-BIC) and lasing threshold mode when a PT-symmetric perturbation is introduced. These PT symmetry-induced BICs are different from ordinary BICs, as they can be excited by an external plane wave but do not radiate, and they carry a reduced Q-factor divergence rate. On the other hand, we investigate how BICs in photonic crystal (PhC) slabs are transformed when a PT-symmetric perturbation is applied. Pt-BICs will arise from each ordinary BIC together with the creation of rings of lasing threshold modes with pt-BICs embedded in these rings. Different from ordinary BICs, the Q-factors divergence rate of pt-BICs are reduced and anisotropic in momentum space. Also, pt-BICs can even appear at off-high symmetry lines of the Brillouin zone. Finally, we further study a PT unbalanced system, especially a purely passive one, and find that a BIC with a divergent radiative Q factor also exists. Meanwhile, merging of two BICs is observed when varying the strength of the differential loss. Different from the ordinary BIC, this loss-induced BIC also can be excited by an external plane wave, although it will not radiate to infinity. The existence of this new type of BICs clearly reveals the new physics arising from the interplay between the BIC and non-Hermitian physics.

Ultrabroadband Infrared Self-Complementary Nanoantennas

Keywords: Plasmonic Antenna, Self-Complementary Antenna, Broadband Constant Input Impedance, Mid-Infrared Range

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We are exploring the possibility of designing nanoantennas that can operate effectively over a wide range of infrared frequencies. To achieve this, we propose using self-complementary nanoantenna structures composed of high-permittivity dielectrics and plasmonic metals. To extend the applicability of Babinet's principle to these materials, we have developed an approach that allows us to design nanoantennas with optimal input impedances near half the vacuum impedance. We have designed several self-complementary silicon-silver nanoantennas with a thickness of 12.7 nanometers that exhibit this behavior over a frequency range from 50 to 300 terahertz. This approach will enable us to create broadband nanoantenna systems that can be used for infrared applications. This work was performed with financial support of Megagrant №075-15-2022-1120

Optomechanical Control of Resonant Objects by Directional Excitation of Surface Plasmons-Polaritons

Keywords: Optical Forces, SPP, Mie Resonances.

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Modern research in quantum optics and life sciences, such as biological research on living cells, as well as the creation of nanostructures in electronics applications, requires precise, non-invasive methods to control the position of nanometre-sized objects in space. Optical tweezers are the simplest and almost non-contact method for mechanical manipulation of such objects. However, precise control of the object's position typically requires focused, high-intensity beams that can damage or destroy the object's structure. One of the most challenging tasks is optical manipulation of resonant objects since they are propelled from high-intensity regions due to large scattering. In this work, we use this feature for optical manipulation and sorting of nanobjects with multipolar response based on the excitation of directional surface plasmon-polaritons at the dielectric-metal interface. This method enables the implementation of an accurate sorting algorithm. The results obtained can be applied to the development of new photonic devices, as well as to the improvement and miniaturisation of diagnostic and biochemical analysis systems.

This work was performed with financial support of Priority 2030 Academic Program.

Metal-Organic Frameworks for Nonlinear Optics and Optical Information Transmission Systems

Keywords: Nonlinear Optics, Metal-organic frameworks, Light modulation, Optical information transmission, Pump-probe experiments.

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In the context of growing demands for data processing speed and efficiency, modern electronics face limitations known as the semiconductor crisis. Insufficient performance, physical constraints of traditional semiconductor materials, and significant cost increases in microprocessor components are driving the scientific community to seek alternative solutions. One such approach is the transition to optical computing, where nonlinear optical materials play a key role. However, existing materials (such as crystals grown by the Czochralski method) have several drawbacks, including complex synthesis processes, difficulties with miniaturization, and insufficient nonlinear optical response. Metal-organic frameworks (MOFs), such as UiO-66 and Co/Ni-based MOFs, represent a promising alternative due to their structural variability and ease of synthesis. These materials demonstrate stable nonlinear optical modulation across a wide wavelength range (from 540 to 800 nm) with a modulation coefficient of up to 25%. Additionally, MOFs exhibit high stability during harmonic generation and are capable of modulating light at ultra-short response times, as evidenced by pump-probe experiments. The high response speed and stability make these materials suitable for optical applications that require high data transmission rates and modulation stability. The use of MOFs positions them as a key solution for the development of eco-friendly and energy-efficient optical computing, capable of overcoming the limitations of semiconductor technologies. This work was performed with financial support of Priority 2030 Academic Program.

Polarization control based on PT-symmetric metasurfaces

Keywords: Exceptional points, PT-symmetric metasurfaces, Polarization control

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Exceptional points, as degenerate points of non-Hermitian parity-time symmetric systems, have many unique physical properties. Due to its flexible control of electromagnetic waves, metasurface is frequently used in the field of nanophotonics. In this talk, we investigate parity time symmetry breaking in polarization space using metasurfaces with anisotropic absorption, whose building blocks consist of two orthogonally orientated meta-atoms with the same resonant frequency but different loss coefficients. This approach is promising for applications in polarimetric imaging, chiral molecule identification, and topological photonics.

Potassium Passivation Enhances the Optical Properties of Perovskite Nanocrystals

Keywords: Charge carrier dynamics, nanocrystals, halide perovskite, surface passivation

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Perovskite materials have already demonstrated their advantages in optoelectronic applications. However, while solar cells with perovskite layers are readily available on the market, their nanocrystals and quantum dots have not yet solved problems in areas like lasing applications, although perovskite LEDs exhibit excellent performance. For example, all nanocrystals share a common issue: surface defects. It is well known that all NC and QD surfaces are passivated by a ligand shell, but this is not always sufficient. Surface defects decrease quantum yield by increasing the non-radiative recombinationrate. This problem can be addressed through dangling bond passivation. In this work, we investigated the dependence of the optical properties of NC/QD on the incorporation of potassium. Potassiumions do not form a perovskite material according to the Goldschmidt tolerance factor when considering lead bromide perovskite. This means that potassium does not incorporate into the perovskite crystalline structure; it remains on the surface and passivates surface defects. This work was performed with financial support of Priority 2030 Academic Program

EPs in a System of Ceramic Resonators in the Microwave Domain

Keywords: Exceptional point, ceramic resonators

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Exceptional points are special states of non-Hermitian systems where both eigenvalues and eigenvectors of two or more resonances coalesce. At these points, the dimension of eigenspace is reduced causing drastic response to small perturbations. Using temporal coupled modes theory, we evaluated effective Hamiltonian describing system of two open ceramic cylinders. Determining the terms of obtained EP we showed that existing of it can be controlled by detuning between resonators. In order to change real part of frequency, we used small nonresonant ceramic cylinder. To tune loses graphite coverage was implemented. Numerical simulation agreed well with the theory confirming our method of tuning system in EP state.

Spin Hall Effect of Electromagnetic Wave Based on Hyperbolic Metasurface

Keywords: Hyperbolic Metasurface, Spin Hall effect, Spin-momentum locking

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In this work, a hyperbolic metasurface is proposed to investigate the spin Hall effect of electromagnetic wave By adjusting the dispersion properties of the metasurface, these phenomena, including unidirectional surface wave propagation and control of spin-momentum locking, are numerically realized. The modulation of surface wave propagation is examined, and the effects of varying geometric parameters on equifrequency contours and wave behavior are analyzed. The results demonstrate that the metasurface design enables precise control of the direction and spin of electromagnetic waves, with potential applications in photonic integrated circuits and advanced optical devices.

Cascaded Metasurfaces Enabling Adaptive Aberration Corrections for Focus Scanning

Keywords: Terahertz, Focus scanning, Aberration correction, Dielectric metasurface.

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Scanning focused light with corrected aberrations holds great importance in high-precision optical systems. However, conventional optical systems, relying on additional dynamical correctors to eliminate scanning aberrations, inevitably result in undesired bulkiness and complexity. In this paper, we propose achieving adaptive aberration corrections coordinated with focus scanning by rotating only two cascaded transmissive metasurfaces. Each metasurface is carefully designed by searching for optimal phase-profile parameters of three coherently worked phase functions, allowing flexible control of both the longitudinal and lateral focal position to scan on any custom-designed curved surfaces. As proof-of-concept, we engineer and fabricate two all-silicon terahertz meta-devices capable of scanning the focal spot with adaptively corrected aberrations. Experimental results demonstrate that the first one dynamically scans the focal spot on a planar surface, achieving an average scanning aberration of 1.18% within the scanning range of ±30°. Meanwhile, the second meta-device scans two focal points on a planar surface and a conical surface with 2.5% and 4.6% scanning aberrations, respectively. Our work pioneers a breakthrough pathway enabling the development of high-precision yet compact optical devices across various practical domains.

Research on Dual-Comb Spectroscopy for On-Site Detection

Keywords: Dual-comb spectroscopy; power amplification; on-site detection

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Dual-Comb Spectroscopy (DCS) is a novel high-performance spectral measurement technique. Its broad spectral range and rapid measurement speed enable it to effectively capture fast changes in airflow, making it a promising laser diagnostic tool for industrial gas detection. In this work, we demonstrate the development and application of a high-power, wide-bandwidth dual-comb spectroscopy system. The system consists of two self-developed optical frequency combs with closely matched repetition frequencies. Power amplification and spectral expansion are achieved using erbium-doped fiber amplifiers and dispersion-compensating fibers. Combined with digital correction modules, we successfully detected the absorption spectra of various gases, which show excellent agreement with simulated spectra from the HITRAN standard database. The spectral resolution reached sub-picometer levels (approximately 0.45 pm). Additionally, we conducted preliminary exploration into the detection of spectra under non-uniform airflow conditions, providing further possibilities for the application of dual-comb spectroscopy in real-world on-site detection scenarios.

Simulation of large-scale achromatic metasurface

Keywords: Metasurfaces, Metalens, Achromatism

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Dispersion is a fundamental optical property that often causes chromatic aberrations in imaging systems. Correcting these aberrations usually involves combining materials with complementary dispersions, adding weight, complexity, and cost. Metasurfaces offer a lightweight and flexible alternative through wavefront control, enabling precise dispersion management via tunable subwavelength structures. However, the limited phase shift achievable by meta-atoms constrains the size of achromatic metalenses, particularly as their diameter increases. In visible light, achromatic metalenses with NA $\geq$ 0.1 typically do not exceed 200 μm in diameter, confining their use to micro- and nano-optics. For broader applications, such as augmented reality, mobile lenses, cameras, and telescopes, larger metalenses on the millimetre or centimetre scale are required. Finite-Difference Time-Domain (FDTD) simulations are essential for exploring large-scale achromatic metasurface designs across various wavelengths, facilitating advancements in metasurface technology and expanding their practical applications.

Application of Bound States in The Continuum

Keywords: BIC, filtering

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Utilizing the unique high Q factor property of BIC, I'm working on researches about filtering and imaging. Designing a multi-channel narrowband filter is useful to improving imaging performance. Also, this method can be used for environmental sensing research. But this work is still ongoing. Next, we will do some experiments to demonstrate it.

Observation of spatiotemporal dynamics for topological surface state with on-demand dispersion

Keywords: Surface state, spatiotemporal dynamics

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Dispersion management in guided wave optics is of vital importance for various applications. Topological photonics opens new horizons for manipulating unidirectional guided waves utilizing edge states. However, the experimental observation of spatiotemporal dynamics for guided waves with on-demand dispersion in topological photonic crystal is an important issue awaiting exploitation. Herein, we experimentally investigate the spatiotemporal properties of topological surface states with on-demand dispersion, where they are supported by a truncated valley photonic crystal with surface modulation. We observe the electromagnetic dynamics of surface states with typical dispersions, where dynamical trapping of an electromagnetic pulse mediated by the unidirectional surface state with flat dispersion and backward beam routing using reversed dispersion properties are achieved in photonic crystal slabs. Both numerical and experimental results substantiate the ultimate dispersion management for the topological surface states, which could pave new ways for the manipulation of electromagnetic waves on the surface of photonic devices.

Surface/Interface Reconstruction of Colloidal Quantum Dots and Their Application in Optoelectronic Devices

Keywords: Surface/interface reconstruction, Quantum dots, Optoelectronic devices

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Colloidal quantum dots (QDs) have garnered widespread attention in the field of optoelectronics due to their unique size and surface effects. This study focuses on the surface modulation techniques of QDs and their impact on optoelectronic device applications. First, we systematically investigated how surface chemical modifications of QDs influence their optical and electrical properties, exploring the regulatory mechanisms of various surface functional groups, ligands, and external environments on quantum dot performance. Next, we examined the application of these modulation techniques in various optoelectronic devices, including light-emitting diodes, solar cells, and photodetectors, etc. Through both experimental and theoretical analyses, we found that optimizing the surface structure of QDs can significantly enhance their luminescence efficiency, photovoltaic conversion efficiency, and charge transport capabilities. Our results demonstrate that surface and interface reconstruction of QDs not only improves the performance of optoelectronic devices but also provides crucial theoretical and technical support for the design of novel optoelectronic materials. Moving forward, we will continue to explore more sophisticated surface modulation strategies to further advance the application and development of QDs in the field of optoelectronics.

Design of Coupled-Resonator Array Antenna for Steering Beam With Extremely High Scanning Rate

Keywords: Coupling, Coupled resonance, Radiation

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An extremely high scanning-rate beam-steering antenna based on coupled resonators is proposed. Coupling resonators in a controlled manner provides a sharp phase variation across a narrow frequency band, which contributes to the extremely high scanning rate. To steer the beam across broadside, alternating positive or negative coupling are employed in the topology. Such a coupled resonator array antenna is modeled and analyzed by coupling matrix technique, which was conventionally used in filter design. To illustrate the proposed technique, two examples with 50 and 100 MHz bandwidths are designed. Experimental validation is also provided for the 50 MHz bandwidth example, which demonstrates that the proposed antenna reaches a high relative scanning rate.