Petersburg Perovskites – 2024

Book of Abstracts

St. Petersburg, Russia
15-17 May, 2024

Petersburg Perovskites – 2024
2nd SPbU Summer School and Conference on Halide Perovskites

The international online summer school and conference is dedicated to the novel photonics material – halide perovskites. At this three-day school, students and young scientists will have the opportunity to hear lectures from the world's leading scientists involved in fundamental research on the physics and chemistry of halide perovskites and their low-dimensional analogues, as well as related technologies and their applications in various fields of optoelectronics and photonics.

The school is held online in Zoom for three days – **May 15-17, 2024**, with school lectures, invited lectures and participant talks.

The school is organized by the Photonics of Crystals laboratory of St. Petersburg State University, Russia (crystal.spbu.ru) and supported by the Ministry of Science and Higher Education of the Russian Federation (Megagrant no. 075-15-2022-1112).

Program committee:

- Constantinos Stoumpos, SPbU and University of Crete (Greece)
- Alexei Emeline, SPbU
- Yury Kapitonov, SPbU

School secretary:

Aleksei Murzin, SPbU (a.murzin@2015.spbu.ru)

Web-site: https://crystal.spbu.ru/conferences/pepe2024.html

School program (Moscow time, GMT+3):

Wednesday, May 15, 2024

9:50-10:00		School opening
10:00-11:00	**Constantinos Stoumpos**, SPbU, Russia	**School talk:** The evolution of perovskites – from $CaTiO_3$ to high-performance semiconductors
11:00-11:30	**Zhijun Ning**, ShanghaiTech University, China	Low dimensional tin perovskite *(invited talk)*
11:30-11:45		Coffee break
11:45-12:00	**Anna Samsonova**, SPbU, Russia	Low-temperature refractive index dispersion in $MAPbI_3$ halide perovskite single crystal
12:00-12:15	**Vasilisa Anikeeva**, Institute of Spectroscopy RAS and HSE, Russia	High-resolution spectroscopy of hybrid perovskites
12:15-12:30	**Anush Badalyan**, A. Alikhanyan National Science Laboratory, Armenia	Proton irradiation effects on $CsPbBr_3$ perovskites thin films
12:30-12:45	**Ilya Martynov**, MIPT, Russia	Conjugated small molecules: A promising hole transport materials in perovskite photovoltaics
12:45-14:00		Lunch
14:00-15:00	**Petr Tolstoy**, SPbU, Russia	**School talk:** NMR of halide perovskites: basic principles and applications
15:00-15:30	**Ivan Zhidkov**, Ural Federal University, Russia	Improving hybrid perovskites stability for solar cells application in space via B-site cation engineering *(invited talk)*
15:30-15:45		Coffee break
15:45-16:15	**Xujie Lu**, Center for High Pressure Science and Technology Advanced Research, China	Pressure-modulated structure-function motifs in two-dimensional halide perovskites and their carrier behavior *(invited talk)*
16:15-16:30	**Matthew Maksimov**, SPbU, Russia	Coherent dynamics of excitons in thin GaAs / AlGaAs quantum well

Thursday, May 16, 2024

10:00-10:30	**Vasilii Belykh**, TU Dortmund, Germany	Coherent spin dynamics of electrons and holes in lead-halide perovskites *(invited talk)*
10:30-11:00	**Dmitry Smirnov**, Ioffe Institute, Russia	The squeezed dark nuclear spin state in lead halide perovskites *(invited talk)*
11:00-11:30	**Jing Zhao**, University of Science and Technology Beijing, China	Reversible mechanically induced photoluminescence changes in hybrid metal halides *(invited talk)*
11:30-11:45		Coffee break
11:45-12:00	**Vladislav P. Bezverkhniy**, LETI, Russia	Investigation of substrates for perovskite quantum dots
12:00-12:15	**Vadim O. Kozlov**, SPbU, Russia	Nonlinear Faraday effect in rare earth doped glasses
12:15-12:30	**Mariia Mamaeva**, SPbU, Russia	Observation of biexciton in $MAPbCl_3$ single crystal
12:30-12:45	**Roman Nazarov**, SPbU, Russia	Optical memory based on photon echo with long-lived spin states in a magnetic field
12:45-14:00		Lunch
14:00-14:30	**Andrey Aleshin**, Ioffe Institute, Russia	Multifunctional structures based on organometallic and inorganic perovskites and their composites *(invited talk)*
14:30-15:30	**Alexei Emeline**, SPbU, Russia	**School talk:** Application of the diffuse reflectance spectroscopy to explore optical behavior of halide perovskites: basic approaches, advantages and problems
15:30-15:45		Coffee break
15:45-16:15	**Weijun Ke**, Wuhan University, China	All-perovskite tandem solar cells *(invited talk)*
16:15-16:30	**Elena A. Bashegurova**, SPbU, Russia	Study of areas of dimensional quantization in GaAs/AlGaAs quantum dots

Friday, May 17, 2024

10:00-10:30	**Aleksandra Furasova**, ITMO University, Russia	Perovskite solar cells for IoT and IoUT applications *(invited talk)*
10:30-11:00	**Alexey Tarasov**, Moscow State University, Russia	Perovskite solar cells stability improvement via efficient surface/bulk passivation and encapsulation *(invited talk)*
11:00-11:30	**Ioannis Paschos**, Westlake University, China	Strong-coupling utilizing 2D organic-inorganic halide perovskite crystals *(invited talk)*
11:30-11:45		Coffee break
11:45-12:00	**Roman S. Kryukov**, LETI, Russia	Optical and electronic properties of carbon quantum dots – organic-inorganic perovskite composite
12:00-12:15	**Alena Yu. Mikheleva**, SPbU, Russia	Phase transition of solid piperidinium lead trihalides
12:15-12:30	**Kamilla M. Konstantinova**, MISIS, Russia	Synthesis and research of perovskite single crystals $CH_3NH_3PbBr_3$ ($MAPbBr_3$)
12:30-12:45	**Ekaterina Deribina**, SPbU, Russia	Helicity resolved spectroscopy of unstrained GaAs/AlGaAs quantum dots
12:45-14:00		Lunch
14:00-15:00	**Yury Kapitonov**, St.Petersburg State University, Russia	**School talk:** Excitons in halide perovskites
15:00-15:15	**Aleksei Murzin**, SPbU, Russia	Energy transfer from the orthorhombic to the tetragonal phase and their coexistence in $MAPbI_3$ halide perovskite single crystal
15:15		School closing

Abstracts

Proton Irradiation Effects on $CsPbBr_3$ Perovskites Thin Films

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

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

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

References

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Helicity Resolved Spectroscopy of unstrained GaAs/AlGaAs Quantum Dots

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In GaAs/AlGaAs quantum dots (QD), the lattice constants of the barriers and the dots are well matched, which makes it possible to maintain nuclear spin polarization longer. This will make it possible to use quantum dots in optical logic devices that use long-lived nuclear spins for information processing.

In this work using temperature-dependent and helicity resolved spectroscopy we studied GaAs/AlGaAs QDs grown by the NFDE method. The system with quantum dots was excited by a right-circular polarization σ^+ 725 nm laser (which corresponds to pumping into a quantum well). It was found that, the degree of circular polarization (DCP) of quantum dots of type A and B is positive and slowly decreases with increasing temperature from 4 K to 120 K (Fig. 1).

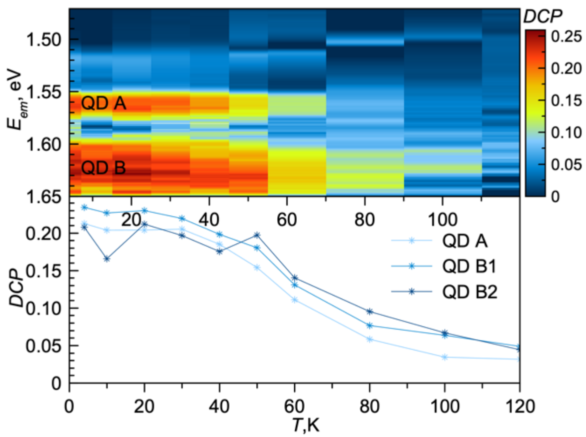

Fig. 1. Degree of polarization (DCP) at different temperatures obtained with 725 nm σ^+ excitation of GaAs/AlGaAs quantum dots (top figure). DCP near the peaks of quantum dots A, B1, B2 at different temperatures (bottom figure).

The work was supported by the Ministry of Science and Higher Education of the Russian Federation (Megagrant no. 075-15-2022-1112) and the Russian Foundation for Basic Research (RFBR 19-52-12046). The work was performed on the equipment of the Resource Center of St. Petersburg State University "Nanophotonics".

Synthesis and research of perovskite single crystals $CH_3NH_3PbBr_3$ ($MAPbBr_3$)

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Halide perovskites are emerging as promising semiconductors for optoelectronic applications due to their resilience against high radiation. This study focuses on the halide perovskite composition $CH_3NH_3PbBr_3$ ($MAPbBr_3$), which has a bandgap of 2.2 eV and is suitable for ionizing radiation detectors because of its high photoluminescence intensity, stability, and radio resistance.

This study focuses on the synthesis and investigation of the optical and photoelectronic characteristics of single crystals of organometallic perovskites. The synthesis involved using a solution of CH_3NH_3Br and $PbBr_2$ salts in dimethylformamide, employing reverse crystallization for crystal growth. The resultant $MAPbBr_3$ single crystals are cubic in shape, measuring 6×6×3 millimeters.

To prepare the crystals for further measurements, ensuring coplanar surfaces were essential. This was achieved through a two-stage machining process. Initially, surfaces were formed by grinding with a fixed abrasive, followed by polishing with abrasive particles suspended in a liquid carrier. Atomic force microscopy confirmed the final surface roughness, achieving an average roughness (R_a) of 42 nm.

The optical properties of the polished $MAPbBr_3$ single crystals were characterized by measuring their absorption and photoluminescence spectra. Upon exposure to ultraviolet light at 350 nm, a visible green photoluminescence was observed at 551 nm.

X-ray diffraction analysis was conducted to ascertain the phase composition of the $MAPbBr_3$ samples. The analysis revealed four dominant diffraction peaks at 15.0°, 30.1°, 45.2°, and 62.6°, corresponding to the 100, 200, 300, and 400 planes of the cubic $MAPbBr_3$ structure.

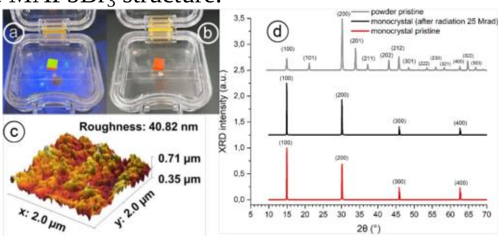

Fig. 1. $CH3NH_3PbBr_3$ monocrystals imaging: a) under UV light b) under visible ambient light; c) surface AFM profile after polishing; d) XRD patterns of crumbled $CH_3NH_3PbBr_3$ monocrystal (grey line), whole monocrystal before radiation (red line) and after radiation (25Mrad) (black line).

Nonlinear Faraday effect in rare earth doped glasses

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In a recent study [1], using the spectroscopy of polarization fluctuation technique (SPF), we discovered fluctuations in the polarization of light transmitted through the medium during resonance probing in the region of forbidden intra-configuration (f-f) transitions of rare earth ions (Nd3+ and Yb3+). The noise was characterized by a flat ("white") spectrum in the frequency range up to 1 GHz and showed no dependence on the magnetic field. The detected polarization noise is interpreted in terms of the structural dynamics of glasses, which was previously observed by various methods, including the Raman scattering technique [2,3] Following the results of [1], it was suggested that rare earth ions are suitable "probes" for observing structural dynamics only in the case of a sufficiently small homogeneous linewidth - by analogy with the giant spin-noise gain in such media [4].

In this regard, it was decided to demonstrate the presence of a nonlinear Faraday effect in previously studied glasses, which manifests itself only in media with a homogeneous linewidth smaller than an inhomogeneous one [5]. For this purpose, a glass sample doped with Nd3+ was used, which demonstrated a bright nonlinear Faraday effect. The possibility of studying the dependence of changes in homogeneous linewidth on temperature is shown. The estimation of the absolute value of the homogeneous linewidth using the nonlinear Faraday effect is discussed The discovery of the nonlinear Faraday effect confirms the hypothesis that the efficiency of observing the structural dynamics of glasses by the SPF method, using probing of rare earth ions, directly depends on the value of the homogeneous linewidth of optical transitions in these ions.

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Low-Temperature Refractive Index Dispersion in $MAPbI_3$ Halide Perovskite Single Crystal

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The refractive index is one of the main optical parameters of any semiconductor media, including halide perovskites. To model devices, such as laser cavities, it is important to know not only the absolute value of the refractive index, but also its spectral behavior -- the dispersion. In this work, the refractive index dispersion *n(E)* in the $MAPbI_3$ ($MA^+ = CH_3NH_3^+$) halide perovskite single crystal is determined in the temperature range from 4 to 88 K by studying the interference of light in a microcavity. It has been shown that in the most practically important transparency region of the material, the dispersion of the refractive index is determined not only by the excitonic transition located nearby, but also by higher-lying interband transitions (Fig. 1).

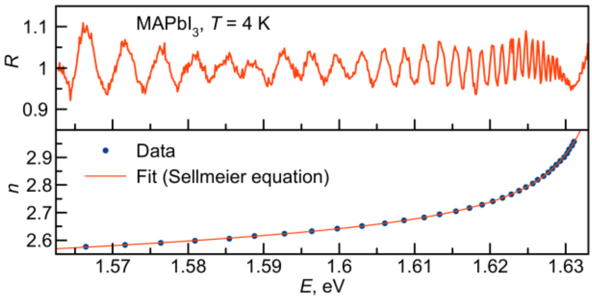

Fig. 1. Reflectivity spectrum of $MAPbI_3$ microcavity (red curve) at 4 K and its refractive index dispersion (dots) fitted by the Sellmeier equation (line).

This research has been supported by the Ministry of Science and Higher Education of the Russian Federation (Megagrant no. 075-15-2022-1112). This work was carried out on the equipment of the SPbU Resource Center "Nanophotonics".

High-resolution spectroscopy of hybrid perovskites

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Exceptional functionality of hybrid metal-organic perovskites $MAPbX_3$ (MA = $CH_3NH_3^+$, X = Br^-, I^-) is due to useful physical properties such as low thermal conductivity, large diffusion lengths, high carrier mobility and long carrier lifetimes, and tunable optical bandgap. Many of these properties are closely related to the features of the phonon spectrum and electron-phonon interaction. In this regard, a comprehensive study of optical spectra and their temperature dependences in a wide frequency range, including the phonon absorption region of the inorganic sublattice [PbX_3], intramolecular vibrations of the methylammonium cation, as well as the region near the edge of the fundamental absorption, seems to be an essential task.

The report presents the absorption and reflection spectra of large $MAPbI_3$ and $MAPbBr_3$ single crystals in the frequency range 20 – 20000 cm^{-1} and temperature range 3 – 330 K, which includes the temperatures of structural phase transitions. The spectra were measured on a Bruker IFS 125HR high-resolution Fourier spectrometer. Several new phonons were detected in the low-temperature reflectance spectra of both samples, the modeling of the obtained spectra allowed us to determine the phonon parameters. The multiphonon absorption spectra were measured in the mid-infrared range (1800 – 12000 cm^{-1}). Below 70 K, a splitting of spectral lines was observed. Presumably, it is associated with a transition to the quantum tunnelling of the $CH_3NH_3^+$ cation.

The absorption coefficient near the fundamental absorption edge of $MAPbI_3$ was estimated. The value turned out to be almost three orders of magnitude lower than the value obtained on thin films. This may be due to the fact that the films have scattering losses, for example, at grain boundaries, and they were not taken into account.

All phase transitions, two in $MAPbI_3$ and three in $MAPbBr_3$, were observed in phonon, multiphonon, and fundamental absorption edge spectra.

The work was supported by the Russian Science Foundation (Grant No.19-72-10132П).

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Study of areas of dimensional quantization in GaAs/AlGaAs quantum dots

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Main aim of this work was to determine the nature of the emission bands in the photoluminescence of a GaAs/AlGaAs heterostructure with QDs.

A sample containing QDs was grown according to recipe described in [1]. After conducting all the experiments, it can be said which peaks belong to which structure on the microphotoluminescence (µPL) graph of sample (Fig. 1).

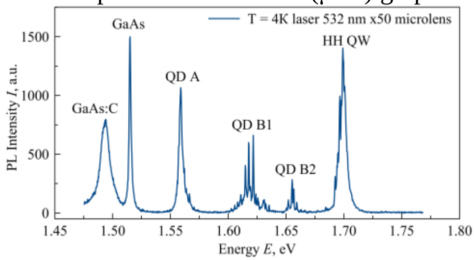

Fig. 1. µPL emission spectrum of single QD, T = 4 K, laser 532 nm, 50x microlens.

The µPL emission spectrum revealed the following bands: emission from carbon contamination in GaAs, emission from the three-dimensional GaAs layer, bands related to QDs A, QDs B1 and QDs B2, heavy-hole excitons in the quantum well (QW). The emission bands of all three QDs consist of individual peaks. Scanning the sample along the x-axis crystal direction with a laser spot, showed correlation between emission from three types of QDs and anti-correlation of said emissions with QW emission.

As a result, the nature of the PL emission bands in the GaAs/AlGaAs semiconductor with QDs was determined. The analysis conducted indicated a region of separation between the QW and QDs. The lowest energy emitting QDs A were identified as nanoholes filled with GaAs. QDs B1 and QDs B2 are smaller quantum-sized structures inside or at the boundary of the nanohole.

This work was carried out on the equipment of the SPbU Resource Center "Nanophotonics". This work was supported by the Ministry of Science and Higher Education of the Russian Federation (Megagrant no. 075-15-2022-1112).

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Investigation of substrates for perovskite quantum dots

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Perovskite materials are promising materials for solar energy and optoelectronics due to their outstanding photovoltaic properties. Their main disadvantage is low stability to the influence of various environmental factors. Therefore, currently there are searches and studies of various perovskite materials, their shapes and composites [1-3].

In this work, the properties of CsPbI3 perovskite quantum dots on various substrates (porous silicon (por-Si), ordinary glass, FTO and ITO) were investigated.

Quantum dots were synthesized by hot injection. They were deposited on substrates by spin-coating.

Porous silicon substrates were selected with different crystallographic orientations: (100), (111), and technological parameters: time and current of electrochemical etching. The obtained samples were studied with deposited quantum dots were studied using IR Fourier spectroscopy, photoluminescence spectroscopy, spectrophotometry and AFM. Some substrates were heat treated at 200^{0}C for 24 hours and were exposed to various charged particles. Thus, various properties of different substrate/QD systems are investigated and various factors affecting their stability are evaluated.

The research results showed that the FTO/QD system retained photoluminescence for 24 hours after manufacture. Por-Si/QD systems and FTO/QD system showed photoluminescence degradation, glass/QD and ITO/QD systems showed greater degradation according to photoluminescence spectroscopy data. It is worth noting that the effects of temperature and irradiation led to the absence of photoluminescence.

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Multifunctional structures based on organometallic and inorganic perovskites and their composites

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The latest achievements in the development of optoelectronic device structures based on organometallic and inorganic perovskites, as well as their combinations with semiconductor polymers and graphene nanoparticles, are considered. The efficiency of solar cells based on organometallic perovskites reached 26.1% in 2024 [1], the external quantum efficiency of LEDs based on inorganic perovskite nanocrystals reached 27.5%, and the mobility of charge carriers in field-effect transistors exceeded 10 cm2/Vs. There has been rapid progress in the development of monolithic organometallic perovskite/c-Si tandem solar cells, which have now reached ~33.9% efficiency [1]. Memristors based on composites of organometallic perovskites with polymers and inorganic nanoparticles are designed as RRAM memory cells based on the resistive random access switching (RRS) effect. Further steps related to scaling such device structures.

A new direction in the area under consideration is the development of multifunctional optoelectronic devices (MFDs) based on organometallic and inorganic nanocrystals of perovskite materials, as well as their composites [2-4]. Some examples of such MFDs combining the functions of light-emitting solar cells, light-emitting field-effect transistors (LE-FETs), thermally sensitive memristors with the RRS effect based on perovskites are considered. Thus, LE-FET combines the switching functions of a FET and emitting LEDs. It has been shown that the introduction of nanocrystals of inorganic perovskites CsPbI3 and CsPbBr3 into the matrix of semiconductor soluble polymers (PPO, MEH-PPV) reduces the hysteresis of the current-voltage characteristics of LE-FET, increases the mobility of charge carriers, as well as the stability of device designs [5]. Memristors with the RRS effect based on films of organometallic perovskites with graphene oxide flakes introduced into such a matrix have been demonstrated to simulate artificial synapses in a wide temperature range [6,7].

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Optical and electronic properties of carbon quantum dots – organic-inorganic perovskite composite

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We describe a method of obtaining carbon quantum dots – organic-inorganic perovskite composites. The carbon quantum dots (CQDs) were obtained from L-Lysine using microwave-assisted synthesis based on a route [1]. An approach of obtaining dry CQDs powder is presented. Optical and electrical characteristics of CQDs+MAPbBr3 film were investigated in order to understand the effect of CQDs on perovskite properties (Fig. 1.). The possible mechanism of charge carrier transport in such composites is discussed.

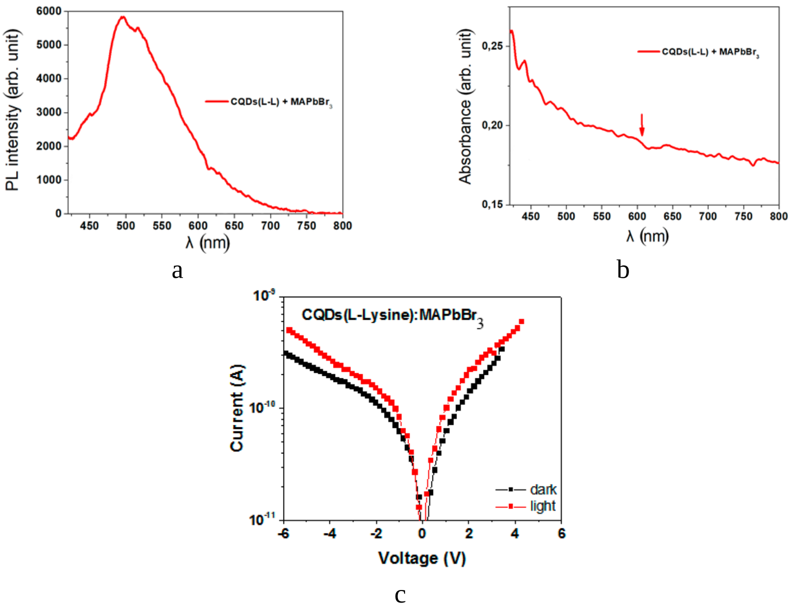

Fig. 1. PL (a) and absorption (b) spectras of CQDs+MAPbBr3 films; current-voltage characteristics of CQDs+MAPbBr3 film under dark (black line) and under light (red light) in semi-logarithmic scale (c)

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Coherent dynamics of excitons in thin GaAs / AlGaAs quantum well

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As of today, spontaneous photon echo is a promising nonlinear phenomenon for creation of advanced solid-state storage systems [1] ought to revolutionize current quantum memory technologies and encourage development of practical quantum computers and networks [2].

The current study investigates spontaneous two-pulse photon echo from exciton and trion ensembles in a thin 14 nm GaAs / AlGaAs MBE-grown quantum well. Spectral and polarimetric measurements of the photon echo signal confirm the excitonic origin of studied excitation. Decay time is measured for both light-hole and heavy-hole excitons (Fig. 1).

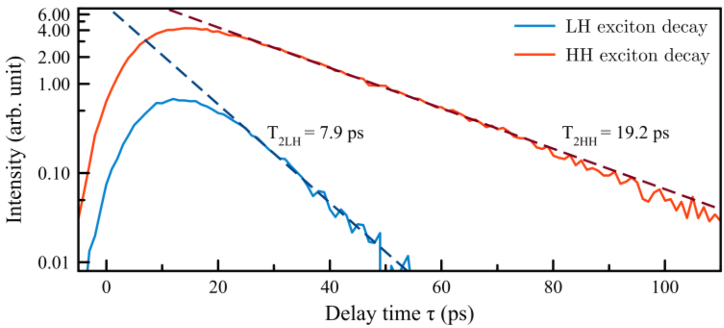

Fig. 1. Decay of photon echo signal from LH and HH exciton

Obtained experimental results demonstrate a presence of robust exciton resonance and a formation of spontaneous photon echo signal in thin GaAs / AlGaAs quantum well on picosecond time scale. 19 ps dephasing time proposes the material as auspicious for future use in information photonics.

Acknowledgments: This research has been supported by the Ministry of Science and Higher Education of the Russian Federation (Megagrant no. 075-15-2022-1112) and carried out on the equipment of the SPbU Resource Center "Nanophotonics"

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Observation of biexciton in $MAPbCl_3$ single crystal

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Halide perovskites are known for their superior optoelectronic properties, but the study of their fundamental properties and subsequent applications are often limited by the high defect density in polycrystalline thin films. This study focuses on 3D halide perovskite crystals, which facilitate the observation of subtle photophysical effects due to their reduced defect density.

In halide perovskites, biexcitons are usually observed in the low-dimensional samples, although the presence of biexciton has been reported for $MAPbBr_3$ single crystal[1]. In this work, the presence of biexciton in $MAPbCl_3$ has been assumed based on the exciton-biexciton population dynamics and the observation of zero degree of circular polarisation. The biexcitons are observed in the luminescence spectra pumped by a pulsed laser below T = 33 K and the binding energy E_{bXX}=11.5 meV. The detection of biexcitons in 3D halide perovskites has promising implications for improving the efficiency of optoelectronic devices and enhancing our understanding of many-body interactions in 3D photonic crystals.

This work was carried out on the equipment of the SPbU Resource Center "Nanophotonics". This work was supported by the Ministry of Science and Higher Education of the Russian Federation (Megagrant no. 075-15-2022-1112).

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Conjugated Small Molecules: A Promising Hole Transport Materials in Perovskite Photovoltaics

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Perovskite solar cells (PSCs) are evolving rapidly, with potential to rival silicon cells. The focus is on new Hole Transport Materials for PSCs, which should match the perovskite energy level, have high conductivity and hole mobility, form a smooth, pinhole-free film, show stability, and be cost-effective. Studies indicate that the high charge mobility of Conjugated Small Molecules (CSMs) is due to ordered molecular packing.

Two new materials, based on a TPA core, were developed and tested as Hole Transport Layers (HTLs) in perovskite solar cells. The addition of the triisopropylsilyl side chain to TPA resulted in unique structural features and favorable properties. The conjugated small molecules, TPA-t and TPA-t EH, have a low HOMO energy level, which aligns well with the energy levels of $MAPbI_3$, leading to reduced energy losses and increased Open Circuit Voltage (V_{OC}) up to 1.1 V. These materials also exhibit excellent hole mobility and high charge extraction efficiency, with short-circuit currents of J_{SC} = 23.3 mA/cm^2. However, a lower fill factor may be due to trap-assisted recombination and suboptimal morphology. Despite these issues, PSCs with TPA-t as the HTL achieve a 17.4% efficiency without doping, comparable to devices using the traditional PTAA HTL. With the benefits of conjugated small molecules over polymers, these CSMs show promise for use in perovskite solar cells.

In short, designing and modifying TPA-based materials with a triisopropylsilyl side chain is a promising way to create innovative hole transporting materials.

The research was supported of the Russian Science Foundation project № 23-73-01279. (https://rscf.ru/project/23-73-01279)

Phase Transition of Solid Piperidinium Lead Trihalides

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In recent years hybrid halide perovskites have gained much attention because of potential application to production of solid solar cells and light sources. However, some issues regarding the crystal structure of new-synthesized hybrid perovskites materials and the influence of external factors on it are still under consideration.

In this study the phenomenon of phase transition in $PiPPbBr_3$, $PiPPbI_3$ was investigated by means of FTIR spectroscopy and thermal XRD methods. Data analysis showed the same indicators in both cases that could be related to possible phase change. According to previous studies, $PiPPbI_3$ transition could be correlated with cation symmetry change from «chair» to «boat» forms. But there is not such transformation for $PiPPbBr_3$ perovskite [1]. In general, the proposed explanation of observed phenomenon [1] is not in exact accordance with IR and XRD data obtained. Hence the findings described above require extra studied in order to be confirmed.

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Energy Transfer from the Orthorhombic to the Tetragonal Phase and Their Coexistence in $MAPbI_3$ Halide Perovskite Single Crystal

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Halide perovskites hold significant promise in the field of light-emitting devices due to their high photoluminescence (PL) efficiency and tunable bandgap across the visible range. Structural phase transitions in them often significantly change the optical properties of the material. This can become both an obstacle and a method for functionalizing the material, which determines the need for their study. In this work, we investigated the optical properties of a halide perovskite single crystal $MAPbI_3$ (MA = CH_3NH_3) during the phase transition between the tetragonal and orthorhombic phases.

The temperature dependence of the energy position of the resonance of the reflection spectra showed a sharp phase transition between the orthorhombic and tetragonal phases in a narrow temperature range (ΔT ~ 5 K) around the phase transition temperature $T_{ph} \approx 162$ K. This behavior is consistent with the results of temperature-dependent X-ray and neutron diffraction studies [1] on $MAPbI_3$ single crystals, and also indicate a small volume of inclusions of the tetragonal phase in the bulk of the crystal at $T < T_{ph}$. However, the temperature dependence of the PL spectra demonstrated the presence of two peaks, the energy position of which corresponds to luminescence from the orthorhombic and tetragonal phases over a wide temperature range (120–162 K). A possible explanation is the presence of a one-way channel for energy transfer from the bulk orthorhombic phase to low-volume inclusions of the tetragonal phase with a smaller bandgap. This conclusion was confirmed in experiments using photoluminescence excitation spectroscopy methods carried out in this work.

This research has been supported by the Ministry of Science and Higher Education of the Russian Federation (Megagrant no. 075-15-2022-1112). This work was carried out on the equipment of the SPbU Resource Center "Nanophotonics"

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Optical memory based on photon echo with long-lived spin states in a magnetic field

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As of today, work is underway to study fundamentally new methods of working with information; a possible solution is storing and processing information in the form of light. The photon echo effect (PE) is a possible foundation for an optical computer because it allows light to be stored. There are two known ways to increase information storage time: using three-pulse excitation, forming a stimulated photon echo (SPE); application of magnetic field. Combining these conditions is a non-trivial experimental task and has not been previously implemented.

The result of the study was the discovery of a long-lived SPE regime in an external magnetic field. The coherence storage time, which characterizes the storage times of optical information, in SPE in a field is 10 times increased compared to the ordinary mode in the absence of a field (Fig. 1). A theoretical explanation for the observed effect is proposed through the Larmor precession of the exciton spin, connecting "light" and "dark" excitons. The open effect could lead to an increase in the number of systems suitable for optical storage and processing of information.

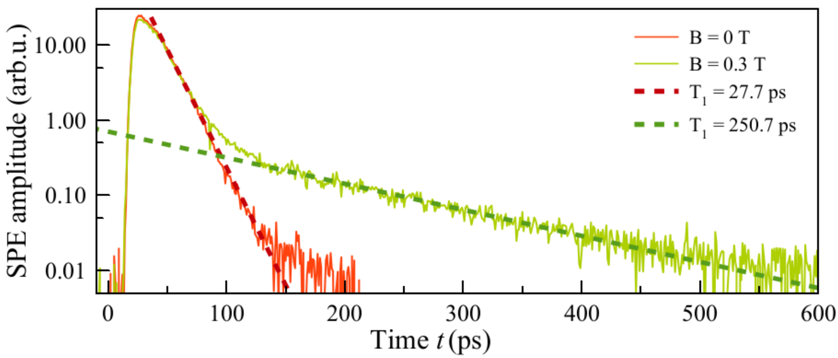

Fig. 1. Decay of SPE in a magnetic field and in its absence.

Acknowledgments:

This research has been supported by the Ministry of Science and Higher Education of the Russian Federation (Megagrant no. 075-15-2022-1112) and carried out on the equipment of the SPbU Resource Center "Nanophotonics"