BOOK of ABSTRACTS

7th International Symposium

«OPTICS & ITS APPLICATIONS»

20 - 24 September, 2019
Yerevan - Ashtarak, Armenia

International Symposium

« OPTICS & ITS APPLICATIONS »

20 - 24 September, 2019
Yerevan - Ashtarak, Armenia

Symposium information & Book of abstracts

Edited by Narine Gevorgyan and Astghik Kuzanyan

YEREVAN

2019

Միջազգային սիմպոզիում

« ՕՊՏԻԿԱՆ ԵՎ ՆՐԱ ԿԻՐԱՌՈՒԹՅՈՒՆՆԵՐԸ »

20 - 24 սեպտեմբեր, 2019
Երևան - Աշտարակ, Հայաստան

Տեղեկություն սիմպոզիումի վերաբերյալ և զեկուցումների թեզերը

Նաիրնե Գևորգյանի և Աստղիկ Կուզանյանի խմբագրությամբ

ԵՐԵՎԱՆ

2019

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The book includes the abstracts of reports submitted to the International Symposium «Optics & its Applications» (OPTICS-2019). Abstracts printed as presented by authors.

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Astghik Kuzanyan (IPR, Armenia)

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- ✓ IPR Armenia OSA Student Chapter
- ✓ Yerevan State Univ. OSA Student Chapter
- ✓ EPS Artsakh Young Minds
- ✓ Univ. of Trento SPIE Student Chapter

Topics:

- *Optical properties of nanostructures*
- *Strong field optics*
- *Quantum optics*
- *Biophotonics*
- *Laser spectroscopy*
- *Nonlinear & ultrafast optics*
- *Photonics & fiber optics*
- *Silicon photonics*
- *Singular optics and its applications*
- *Mathematical methods in optics*

Program highlights:

- Invited plenary talks and sectional presentations
- Professional development lecture
- Student presentations
- Student chapters presentations
- Presentations of scientific organizations and societies
- Lab tours (AANL)
- Social events

Presentations of scientific centers & societies

H. Sarkisyan: **Russian-Armenian University**

G. Buniatyan: **LT-Pyrkal**

A. Papoyan: **Institute for Physical Research, of NAS Armenia**

A. Kutuzyan: **Ultrafast Optics and Photonics Laboratory, YSU**

H. Mkrtchyan: **Yerevan Young Minds**

D. Sampson: **SPIE**

T. Chalyan: **B-Phot**

M. Bojan: **Laser Spectroscopy Optics Lab, INFLPR Magurele**

L. Ionel: **Nonlinear Optics and Photonics Lab, INFLPR Magurele**

D. Blaschke: **NICA, JINR Dubna**

Student chapters poster presentations

EPS Artsakh Young Minds, Armenia

EPS Yerevan Young Minds, Armenia

OSA IPR Armenia Chapter, Armenia

OSA Yerevan State Univ. Chapter, Armenia

SPIE Yerevan State Univ. Chapter, Armenia

SPIE Univ. of Trento Chapter, Italy

SPIE Bauman Moscow State Technical Univ. Chapter, Russia

SPIE Institute of Radiophysics and Electronics Chapter, Ukraine

Symposium Venue

20 September

LT-PYRKAL
21 Shopron Str., Yerevan, 0090, Armenia

21 September

Russian-Armenian University
123 Hovsep Emin str., Yerevan, 0051, Armenia

22 September

Yerevan State University
1 Alex Manoogian str., Yerevan, 0025, Armenia

23 September

Yerevan State University
1 Alex Manoogian str., Yerevan, 0025, Armenia

24 September

A. **Alikhanyan National Laboratory, Armenia**
2 Alikhanian Brothers St., 0036, Armenia

Acknowledgement

Thanks for generous support to all sponsors!!!!

The Abdus Salam International Centre for Theoretical Physics (ICTP)

IAEA

OSA The Optical Society | 100 Since 1916

THORLABS

State Committee of Science RA

EPS European Physical Society

ICO International Commission for Optics / CIO Commission Internationale d'Optique

Uniwersytet Wrocławski

RUSSIAN-ARMENIAN UNIVERSITY

LT-PYRKAL

SPIE. STUDENT CHAPTER YEREVAN STATE UNIVERSITY

Yerevan State University 1919

National Academy of Sciences of Armenia Institute for Physical Research

NATIONAL LABORATORY

EPS

Invited Lecturer

Prof. Petra Rudolf

Invited by EPS Yerevan & Artsakh Young Minds

President of EPS
University of Groningen, The Netherlands

Biography

Petra Rudolf was born in Germany but moved to Italy for her last high school years. She studied Physics at the University of Rome, specialising in Solid State Physics. In 1987 she joined the National Surface Science laboratory in Trieste for 5 years, interrupted by 2 extended periods at Bell Labs, USA, where she worked on the newly discovered fullerenes.

In 1993 she moved to the University of Namur, where she received her PhD and quickly progressed to lecturer and senior lecturer before taking up the Chair in Experimental Solid State Physics at the University in Groningen in 2003.

2014-2018 she was Director of the Graduate School of Science and Engineering. Her main research interests concern molecular motors, graphene, organic thin films and inorganic-organic hybrids. She has (co)authored 247 peer-reviewed research publications and 32 book chapters and given 91 invited talks at national and international conferences.

She was President of the Belgian Physical Society (2000/01) and elected Fellow of the IoP (2001), Lid van verdienst of the Dutch Physical Society (2006), Fellow of the APS (2010) and member of the German National Academy for Science and Engineering (2016), and President of the EPS (starting April 2019). Her work on molecular motors earned the 2007 Descartes Prize of the European Commission. In 2013 she was knighted by H.M. Queen Beatrix of the Netherlands.

A PhD is not enough ... - how to prepare for a career in academia

The first step after the PhD towards a permanent job in academia is a temporary one, namely becoming a postdoctoral research fellow. I shall discuss what a young researcher needs to achieve in her/his postdoctoral period and what consequently s/he has to consider in making his/her choice where to go (place, topic, type of supervisor,...).

After one or two postdoc appointments it will be time to go for the second step, a tenure track assistant professorship. Now not only the scientific productivity is an important criterion, but the selection committee will want to know about teaching experience, whether the candidate has been the daily supervisor of bachelor’s, master’s and PhD students and if s/he has ever attracted any funding, done any outreach or done anything to serve/influence the community in his/her field. They might also like it if the candidate has already been distinguished with a prize. I shall give tips on what a young researcher at the PhD and postdoc level can do to acquire experience and skills in all these areas.

In the last part of my talk I shall discuss how to prepare for the application for a tenure track assistant professorship, what is important in the negotiation if chosen and what to pay attention to in the first months on the job.

For extra info I recommend two books:
“Survival Skills for Scientists” by Federico Rosei and Tudor Johnston
“A PhD is not enough” by Peter J. Feibelman if you want to spend part of your career in the USA.
And a good guide for grant proposal writing:
“Art of Grantmanship” by Jack Kraicer, on https://www.hfsp.org/node/5761 gives an outline of what to do from 1 year before the deadline until the actual grant proposal submission

SPIE

Invited Lecturer

SPIE. STUDENT CHAPTER
YEREVAN STATE UNIVERSITY

Prof. David D. Sampson

SPIE Visiting Lecturer invited by OSA YSU Student chapter

University of Surrey,
Guildford, Surrey, GU2 7XH,
United Kingdom

Biography

David Sampson is the Vice-Provost, Research & Innovation, at the University of Surrey, United Kingdom and until recently head, Optical+Biomedical Engineering Laboratory, Department of Electrical, Electronic & Computer Engineering, University of Western Australia. He is active in the global optics & photonics community, as immediate-past elected Director of the SPIE – The International Society for Optics & Photonics (2017-2019), chair of the SPIE Publications Committee, and 2020 general chair of the OSA Biophotonics Congress and co-chair of the Gordon Conference on Optics and Photonics in Biology and Medicine. He is a fellow of IEEE, OSA, and SPIE. He has conducted research for nearly thirty years in photonics, optics, and microscopy, with applications in communications and biomedicine. He is an authority in optical coherence tomography, its implementation in endoscopes and needles, extensions such as elastography, angio- and lymphangiography and polarisation-sensitive contrast, and translational medical applications in burns, airways and cancer. He has wider interests in open research, support for early career researchers and the research-to-innovation pipeline.

Extending contrast in optical coherence tomography: opportunities in tissue imaging

Micro-imaging of biological tissue with optical coherence tomography brings with it the advantage of not needing an exogenous label – making in vivo imaging straightforward. But it often brings with it a contrast/resolution dilemma – we do not have the contrast or resolution at the imaging field of view necessary for a given application. Do we push for higher resolution to reveal those blurred structures? Achieving high resolution is technically demanding and involves at least a reduction in the axial depth range and quite possibly the sacrifice of field of view in all three spatial dimensions. An alternative to improved contrast through improved resolution is to use a source of contrast alternative to backscattering? Once we have volumetric imaging data, we have many options to choose from: attenuation versus depth, various polarisation contrasts, such as birefringence or optic axis orientation, mechanical properties, such as stiffness or viscoelasticity, and motion, to deduce fluid flow, usually blood, but also lymph. Indeed, some of these mechanisms enable us to probe sub-resolution, or even sub-wavelength structures, albeit with an imaging resolution much lower than this. Ultimately, though, we would prefer to "have our cake and eat it too" – high resolution combined with alternative sources of contrast in combination, and over large fields of view provide the best case scenario. In this talk, I will consider these options, highlighting examples of different resolutions and contrast mechanisms, and attempt to shed light on this intriguing trade-off.

OSA

Invited Lecturers

Prof. Chauvet Mathieu

OSA Traveling Lecturer invited by OSA IPR Student chapter

FEMTO-ST institute, University of Bourgogne Franche-Comté, 15B avenue des montboucons, 25000 Besançon, France

Biography

Mathieu Chauvet is currently Professor at the University of Bourgogne Franche-Comté in France. He graduated from the national engineering school of Brest (E.N.I.Br.) in 1990 and received the Ph. D. degree in electronics from Université de Bretagne in 1994 on nonlinear semiconductor photorefractive waveguides applied to optical telecommunications. He then spent 4 years as a researcher in the physics department at University of Arkansas (USA) in the group of Pr. Greg Salamo on optical spatial solitons and on the epitaxial growth and characterization of III-V semiconductors structures. In 1998, he accepted an Associate Professor position at the University of Franche-Comté and is since carrying out his research in the optics department of the FEMTO-ST institute. His work focuses on nonlinear optical phenomena and devices.

Mathieu Chauvet has over 80 refereed publications and is author or co-author of 140 communications in conferences.

Spatial optical solitons: Fundamentals and Applications

Spatial solitons or more generally self-trapped beams consist of spatially confined waves propagating without change of their transverse profile. Among the different nonlinear media allowing such behavior, we will first depict the versatility of low power photorefractive spatial solitons to realize proof of concepts and illustrate potential applications. Secondly, the recent experimental demonstration of a self-trapped wave, so-called plasmon-soliton, taking advantage of both the plasmonic and the Kerr effects will be presented.

Prof. Ebrahim Karimi

OSA Traveling Lecturer invited by OSA YSU Student chapter

University of Ottawa, 463, Advance Research Complex (ARC) Ottawa, ON K1N 6N5, CANADA

Biography

Prof. Ebrahim Karimi is a Canada Research Chair in Structured Light at the University of Ottawa, a visiting professor at the Max Planck Institute for the Science of Light in Erlangen—Germany and Institute for Advanced Studies in Basic Sciences (IASBS). Prof. Karimi received numerous awards, such as Ontario’s Early Research Award in 2018, Young Researcher of the year in Faculty of Science in 2018, and he is a Fellow of The Optical Society (OSA), a member of the Global Young Academy (GYA), a Fellow the Max Planck Institute, and a Fellow of the NRC-uOttawa Joint Centre for Extreme Photonics. He is also an associate Editor of Optics Express, and New Journal of Physics.

Structured Photons – Their Application in Quantum Photonics

Photons, the quanta of light, possess several different degrees of freedom, e.g. frequency, polarization, spatial and temporal modes, which can be used as platforms for quantum information applications. Polarization, corresponding to the vectorial nature of light, is bi-dimensional, and thus can represent ‘0’ and ‘1’ in the digital world. Unlike, polarization, transverse and temporal modes would provide an unbonded vector space and could be used to extend the alphabet beyond the ‘0’ and ‘1’s to any arbitrary integer numbers. Photons in superposition states of these different of degrees of freedom is known as Structured Photons. In the classical regime, structured light has found tremendous applications; e.g. overcoming the diffraction limit (STED microscopy), for optical spanners, communication multiplexing, and generating non-trivial 3D topologies such as Möbius and Knots. In the quantum domain, structured photons may be used to realise higher-dimensional states, and thus are used for quantum communication, computation and simulations.

The recent progress, challenges and applications of structured photons in modern photonics will be the subject of my talk. Stability and dynamics of two- and three-dimensional polarisation topologies, at the classical domain, will be presented. Finally, I will present their applications in high-dimensional quantum key distribution, quantum hacking, and simulating complex quantum system.

Plenary Speakers

Ani Aprahamian

University of Notre Dame, USA
A. Alikhanyan National Laboratory, Armenia

Armenia Stepping Into the Future at A. Alikhanyan National Laboratory of Armenia

The national laboratory of Armenia is named after its founder Artom Alikhanyan. It was traditionally a laboratory to study high energy phenomena in the cosmos as well as the laboratory. It was known until recently as Yerevan Physics Institute (YerPhi). The transformation of YerPhi to a that of a national laboratory happened in 2011 by expanding its mission beyond being a regional center of excellence in high energy physics, nuclear physics, and astrophysics, to include applications of nuclear science various aspects of Armenia's economy. Some of the new initiatives include applications of nuclear science to to medicine while others include technological advances in detector development, evolution of big data algorithms in quantum computing, and artificial intelligence.

The new developments include the transformation of the AANL campus to a modern 21st century hub for innovation with the help of architects from Harvard University in USA. Leveraging the opportunities created by a rapidly changing and growing country and the vitality of the young Armenian generation, the campus has the potential to become a hub for innovation and knowledge production and to foster productive relationships between various international entities.

This talk will discuss some of the present, and future initiatives of AANL under the leadership of the new director, Prof. A. Aprahamian.

David Blaschke

Uni. of Wroclaw, Poland
JINR Dubna, Russia
MEPhI, Russia

Fundamental Physics with Strong Laser Fields

This lecture gives a short introduction to the status of modern high intensity laser facilities like the European Extreme Light Infrastructure (ELI) and their potential to investigate fundamental physics of the QED vacuum structure in the superstrong, time-dependent electric fields of the focal spot of counter-propagating laser fields. Besides birefringence and the Hawking-Unruh radiation effect it is the Schwinger effect of vacuum pair creation that is considered in great detail. A kinetic equation for the electron-positron pair distribution function with a non-Markovian Schwinger source term is derived and its properties are discussed. Particularly interesting are the Markovian and the low-density limits. The influence of the pulse shape, frequency and field strength of the laser field on the pair production rate are studied. Consequences for the particle production in the initial state of ultrarelativistic heavy-ion collisions with the superstrong fields of color flux-tubes are given and lessons for the phenomenology are given.

Vidar Gudmundsson

University of Iceland, Iceland

Elecron-photonic transport: Interplay of shape and interactions

In the talk we present a model of electron transport through a nanoscale system in a GaAs heterostructure placed in a three-dimensional far-infrared (FIR) photon cavity. The two-dimensional electron system (the central system) is weakly coupled to external leads. Both the leads and the central system are in a constant perpendicular magnetic field. The transport is described by a non-Markovian generalized master equation in a many-body Fock-space in the transient time regime, and by a Markovian master equation in the Liouville-space of transitions for the long time evolution towards a steady state. We use a stepwise exact numerical diagonalization and a truncation scheme to describe the Coulomb interaction of the electrons, together with the para- and diamagnetic parts of the electron photon interactions. We show that this is necessary in order to account for the effects of the shape of the systems and the polarization of the single photon mode in the cavity.

We show that effects of a Rabi resonance between two two-electron states in the system can be seen in the transport current, and by changing the polarization of the photon field in a system with two parallel quantum dots we observe the normal Rabi oscillations caused by the paramagnetic part of the interactions, and another resonance mainly caused by the diamagnetic interaction [1].

We observe vacuum electroluminescence for one- and two- electron ground states in the system, and can again switch between the effect caused by the para- or the diamagnetic parts of the electron-photon interactions by changing the polarization of the cavity mode [2].

Several further effects are presented which are caused by the interplay of the geometry of the system, the interactions, and the polarization of the photon field [3-4].

Recently, we have reviewed our results and methodology for both continuous and lattice models described by the generalized master equations [5].

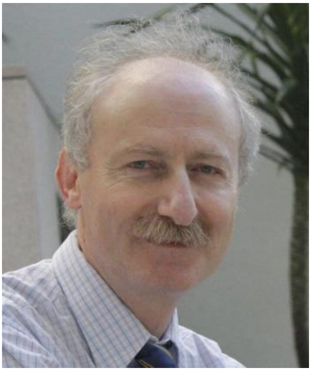
[1] Coupled collective and Rabi oscillations triggered by electron transport through a photon cavity, Vidar Gudmundsson, Anna Sitek, Pei-yi Lin, Nzar Rauf Abdullah, Chi-Shung Tang, and Andrei Manolescu, ACS Photonics 2, 930 (2015), (arXiv:1502.06242).

[2] Electroluminescence caused by the transport of interacting electrons through parallel quantum dots in a photon cavity, Vidar Gudmundsson, Nzar Rauf Abdullah, Anna Sitek, Hsi-Sheng Goan, Chi-Shung Tang, and Andrei Manolescu, Annalen der Physik 530, 1700334 (2018), (arXiv:1706.03483).

[3] Coexisting spin and Rabi-oscillations at intermediate time in electron transport through a photon cavity, Vidar Gudmundsson, Hallmann Gestsson, Nzar Rauf Abdullah, Chi-Shung Tang, Andrei Manolescu, and Valeriu Moldoveanu, Beilstein Journal of Nanotechnology 10, 606 (2019), (arXiv:1809.06930).

[4] Cavity-photon induced high order transitions between ground states of quantum dots, Vidar Gudmundsson, Nzar Rauf Abdullah, Chi-Shung Tang, Andrei Manolescu, and Valeriu Moldoveanu, Annalen der Physik 531, 1900306 (2019), (arXiv:1905.10883).

[5] Generalized master equation approach to time-dependent many-body transport, Valeriu Moldoveanu, Andrei Manolescu, and Vidar Gudmundsson, Entropy 21, 731 (2019), (arXiv:1908.00354).



Gagik Gurzadyan

State Key Laboratory of Fine Chemicals, Institute of Artificial Photosynthesis, Dalian University of Technology, 116024 Dalian, China

Ultrafast Laser Spectroscopy: Upper Excited States of Molecules

Methods of ultrafast laser spectroscopy are applied for studying various photoreactions from upper excited electronic states, i.e. violating Kasha-Vavilov rule:

i) singlet fission from upper excited vibrational and electronic states of rubrene molecular single crystal [1, 2]

ii) excitation wavelength (photon energy) dependent singlet fission in perylene dimers in solution [3]

ii) enhanced fluorescence from high lying excited electronic states S_2 and ultrafast relaxation dynamics in tetraphenylporphyrin/SURMOF (Surface Mounted Metal Organic Framework) [4, 5].

Briefly will also be introduced the methods of ultrafast laser spectroscopy.

[1] Ma, L., Galstyan G., Zhang, K. et al. *J. Chem. Phys*. 2013, *138*, 184508.
[2] Ma, L., Zhang K., Kloc Ch. et al. *Phys. Rev. B* 2013, *87*, 201203(R).
[3] Ni, W., Gurzadyan, G. G., Zhao, J. et al *J. Phys. Chem. Lett.* 2019, *10*, 2428-2433.
[4] Li, X., Gong, C., Gurzadyan, G. G. et al. *J. Phys. Chem. C* 2018, *122*, 50-61.
[5] Li, X., Gurzadyan, G. G., Gelin, M. F. et al. *J. Phys. Chem. C* 2018, *122*, 23321−23328.

Avinash C. Pandey

Nanotechnology Application Centre, University of Allahabad, Allahabad 211002, INDIA

Natural Chronometers: AMS Facility at IUAC

IUAC being an Inter-University Centre, the first in the country, has its main user-base coming from the Universities. The Pelletron-LINAC user base currently has 300 plus faculty members from 111 universities and 63 colleges from the entire length and breadth of the country. In addition, there is participation from the IITs and 90 other national/international research institutions. Considering all accelerator facilities, it is nearly 160 Universities, 85 Colleges and 100 other National/International laboratories. The research activities at the Centre are in the areas of Nuclear reactions (transfer, fusion and fission) near Coulomb barrier, High spin spectroscopy, Spectroscopy of highly charged ions, Interaction of swift heavy ions with materials, Characterization and Modification of Materials, Device fabrication, Radiation Biology, Accelerator Mass Spectrometry etc.

To cater to the need of the researcher from multidisciplinary areas, the development of a compact light source facility to produce THz radiation is in progress at IUAC. The FEL based THz radiation source of IUAC will be the first FEL based high intensity, coherent THz source of the country. The unique feature of the THz radiation produced from IUAC's machine are (a) the radiation frequency is completely tunable in the range of 0.18 to 3 THz (b) the intense electric field of the THz radiation can be varied from a few to few hundreds of kV/cm and (c) the pulse duration of the THz radiation will be very narrow (~ a few hundreds of femtosecond). For the frequency of 3 THz, the no. of photons produced within a few hundreds of fs is estimated to be ~ 10 14 with photon energy of 12.4 meV.

Inter University Accelerator Centre has also set up a national facility for geochronology supported by Ministry of Earth Sciences, Govt. of India. The facility is unique of its kind in the country to provide latest and exclusive instrumentation for the geochronology related studies as well as various other applications. The equipment like LA-HR-ICPMS, FE-SEM, XRF, XRD and sample preparation laboratories instruments have been installed in addition to 500kV based 14C Accelerator Mass Spectrometry (AMS) dating facility. A High resolution Secondary Ion Mass Spectrometer (HR-SIMS) shall be soon installed. A new Ion Accelerator for other heavier isotopes AMS is also being planned as part of Geochronology facility. The Cosmogenic radioactive isotopes can be used as a natural clock, running on a constant speed, to provide the age information of the various natural processes.

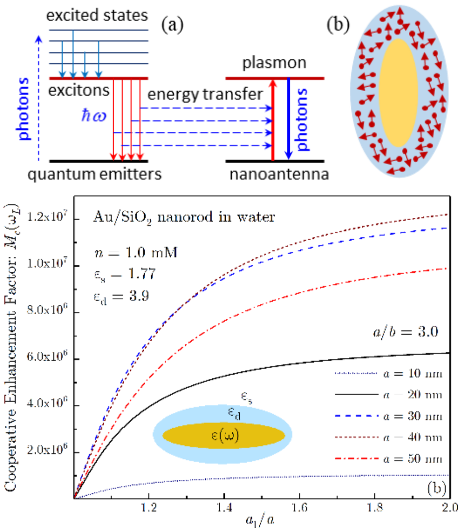
The talk shall give an overview of scientific issues that can be pursued with such a facility in country.

Tigran Shahbazyan

Department of Physics,
Jackson State University,
Jackson, MS 39157 USA

Cooperative emission of light mediated by energy transfer to plasmonic antenna

Spontaneous emission by an ensemble of QEs can be greatly accelerated through electromagnetic correlations between QEs. A common example of cooperative emission is Dicke superradiance of QEs in a common radiation field leading to emergence of collective states radiating at a rate proportional to full ensemble size [1]. In the presence of plasmonic structure, QEs' correlations are enhanced due to resonant Mie scattering while, at the same time, Ohmic losses in metal suppress correlations for QEs near the metal surface [2]. Thus, plasmon-enhanced superradiance hinges on delicate interplay between QEs' direct coupling, plasmon-enhanced radiative coupling, and metal losses.



Here we describe another mechanism of cooperative spontaneous emission by an ensemble of excited QEs based on cooperative energy transfer (CET) to a plasmonic antenna (see Fig.1). If the emission frequencies of excited QEs lie within plasmon spectral band, the plasmonic correlations between QEs lead to emergence of a collective state that transfers its energy at a rate $\gamma_{et}^{c} = \sum_i \gamma_{et}^{i}$, where γ_{et}^{i} are individual QE-plasmon ET rates determined by the plasmon local density of states (LDOS) at the QE positions [3]. Then, if radiation efficiency of the plasmonic antenna is sufficiently high, this energy is radiated away at the same rate γ_{et} it is being received from the QE ensemble [4]. Note that the CET mechanism is insensitive to natural variations of QEs' frequencies caused, e.g., by direct dipole interactions or, in the case of QDs, by their size variations, if QEs' frequencies stay within a broad plasmon band. Furthermore, the power spectrum retains the plasmon resonance lineshape and, therefore, is also largely independent of the QEs frequency variations within the ensemble (see Fig. 1).

Figure 1. Upper panel: (a) Schematics of CET to a plasmonic resonator. (b) Schematics of QEs near Au nanorod with major and minor semiaxis a and b. Lower panel: Enhancement factor for power spectrum of QEs distributed at concentration n within dielectric shell of a core-shell gold nanonorod with outer major semiaxis a_1.

[1] R. H. Dicke. Phys. Rev. 93, 99 (1954).
[2] V. N. Pustovit and T. V. Shahbazyan. Phys. Rev. Lett., 102, 077401 (2009).
[3] T. V. Shahbazyan. Phys. Rev. Lett., 117, 207401 (2016).
[4] T. V. Shahbazyan, Phys. Rev. B 99, 125143 (2019)

Ivan Shelykh

University of Iceland, Iceland

Regime of strong light-matter coupling and developments in polaritonics

Cavity polaritons are hybrid light- matter excitations arising in planar semiconductor microcavities when excitonic transition is brought to the resonance with cavity mode and coupling strength exceeds characteristic broadenings in the system. Being composite particles, polaritons inherit the properties of both light and matter. They possess extremely small effective mass (4 orders of magnitude less then the mass of a free electron) and in the same time strongly interact with each other. This makes polariton system an ideal candidate for the observation of the quantum collective phenomena at surprisingly high temperatures. In the talk we will give an overview of the development of the polariton physics and present some recent results on polariton lattices and their topological properties.

Invited speakers

Vardan Apinyan

Institute of Low Temperature and Structure Research, Polish Academy of Sciences, Poland

Ultraviolet absorption spectrum in the bilayer graphene structure

We have calculated the optical properties in the bilayer graphene with strong excitonic interaction effects. The presented work is based on the solutions for the excitonic gap parameter, chemical potential and the exact Fermi energy in the BLG, given in a series of our previous works [1,2]. We show how the inclusion of the excitonic effects will modify and shift the optical absorption spectrum toward the UV range of the light spectrum. We have calculated the absorption coefficient, refractive index, dielectric response functions and the electron energy loss spectrum for different interlayer Coulomb interaction regimes and for different temperatures. We have shown that all optical properties in the interacting bilayer graphene are strongly related to the behavior of the chemical potential and the exact Fermi level in the BLG which are not the same for the bilayer, even at the zero temperature limit. Since the growing experimental interests in the optical properties of the graphene-based materials and heterostructures, the correct understanding of the interaction effects and their leading renormalizations on different physical quantities in the system presented here is straightforward for correct estimation of the measured optical properties.

[1] V. Apinyan, T.K. Kopeć, Phys. Scripta 91 (095801) (2016).
[2] V. Apinyan, T.K. Kopeć, Physica E 95 (2018) 108.

Mihaela Bojan

National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania

Terahertz spectroscopy: A non-destructive and powerful tool for the characterization of materials

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A wide variety of detection methods are involved in explosive detection including X-rays, infrared, THz, microwave, gamma-rays, etc. THz waves can penetrate through many dielectric materials, such as clothing, paper, plastics, leather, wood and ceramics.

Lately, THz electromagnetic field was implemented in molecular spectroscopy systems based on Time-Domain method. Using this method in spectroscopy, investigated substances present unique molecular spectra. Thus, Terahertz-Time Domain Spectroscopy systems (THz-TDS) allow obtaining different spectral responses of the investigated material comparing to classical spectroscopy.

The necessity to develop a versatile tool in the fight against unexpected threat has helped to the development of THz domain. The THz spectral domain (0.1-10 THz) contains information about molecular vibration spectra. It completes the already accepted spectral ranges used in spectroscopy and, particularly, for compounds detection based on X, gamma, UV visible or IR radiations. Having the properties of “seeing” behind the dielectric substances but being non-ionizing, THz radiation has more and more applications. Due to the property to penetrate non-metallic and dielectric objects, and using non-ionizing radiations (the THz radiation), the THz systems could become a sensible (from point of view of security or forbidden substances) objects.

THz waves are transmitted through a large scale of materials, excepting metals or polar medium (for example the most annoying is water). In this manner, THz radiation became an interesting tool to search behind the opaque things: clothes, envelopes, packages, etc. which is an important property for defense and security industry. Having a THz-TDS system, we developed studies and we report here the following groups od results:

In this lecture, I will present our original results, obtained with this spectroscopic system.

We have built a database which contains some relatively common substances from the category of hazardous ones having capabilities for use as explosives. Out of them we present in this paper Hexametilen - tetraamina ($C_6H_{12}N_4$), picric acid ($C_6H_3N3O_7$), ammonium oxalate ($(NH_4)_2C_2O_4$), ammonium nitrate (NH_4NO_3). We show also in our database some transmission spectra for a firecracker as well as for several types of carbon: graphite, active carbon, .s.o. The transmission spectra of the tested sample where realized at the maximum resolution of 2048 point of measurements. Using this data base, we have established an algorithm for measuring procedures for hyperspectral imaging. We created a low spatial resolution image of the studied object (using a raster scanning procedure), but with a medium spectral resolution that we compared it with the database spectra. With all the data we can create a 3D hyperspectral image cube of the analyzed object

Also, another set of our reported results having applications in food industry, was the building of a data base of transmission/ absorption spectra for a set of five food dyes, E 102-Tartrazine, E 110-Sunset Yellow, E 122-Azorubine, E 124-Red Ponceanu, E 155-Brun HT.

Alexei Chizhov

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Spontaneous emission spectrum of a two-level atom in a parabolic mirror

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We investigate spectral properties of the spontaneous decay of a two-level atom in a parabolic mirror. We consider the case when the atom is located at the focus of the parabola and its dipole moment is oriented along the mirror symmetry axis. It is shown that the spatial behavior of the atomic spectrum reveals the strong interference in the vicinity of the atom and has undepleted component around the symmetry axis far away from the atom. We also find that the maxima of the spectrum line-shape exhibits the certain frequency shifts with respect to the atomic resonance frequency.

Fabrice Devaux

FEMTO-ST Institute, France

Quantum imaging in photon counting regime: a proven tool for measurement of quantum features of light

In the field of quantum optics, imaging started with single-point detectors scanning image planes to reconstruct quantum spatial features of light. At the early 2000's the emergence of commercially available Electron Multiplying Charge-Coupled Devices (EMCCD) detectors arrays, that are sensitive to single photons, have tremendously enlarged the perspective of quantum imaging. From the first use of EMCCD for quantum imaging up to now, this device has become a proven and essential tool for future applications of quantum imaging to massive parallel processing of quantum information.Based on his experience and activities, regarding the use of EMCCD cameras in quantum imaging, the author will present the method and advantages of using EMCCD cameras in single-photon counting mode.

Dmitry Efimov

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Strong-field physics with many-electron atoms

Advances in studies of strong and short laser field interaction with atoms and molecules yielded in establishing of Attosecond Science. Presently one can generate light with duration of tens of attoseconds and monitor the internal processes in matter within an attosecond-scale resolution. Essentially, during the light-matter interaction electrons are released and then are driven by the laser field; some of them can rescatter with the parent ion leading to the emission of photons, change of its own momentum and shaking the ion. Obviously, strong-field interaction incorporates not solely the valence electron, but rather the whole electronic shell of an atom or a molecule. This is clearly seen already from the early 90s experiments on atomic ionization that revealed an effect of non-sequential double ionization, i. e. total number of produced double ions could not be explained by independent releases of electrons. The many-electrons effects manifest themselves in both momenta of freed electrons and spectra of emitted light. But the treatment of such data is complicated due to the lack of efficient theoretical models. For their development one needs to perform quantum many-particle simulations that are extremely computationally demanding. This is why calculating of such a complex system evolution and revealing the role of each electron is a challenging task. We review the current progress in research of many-electron effects carried out with use of the recent two- and three- electrons numerical models.

Laura Ionel

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Spatio-temporal analysis of non-collinear femtosecond pulses combination

Non-collinear coherent combining (NCCC) of ultrashort pulses is investigated in the presence of symmetrical variation of the angle made by the laser beams propagation trajectory and the x-axis (α°) in order to determine the optimum conditions to generate higher intensity in the focal region. For this, a 2D model of the electromagnetic field (EMF) distribution in the focal region of the coherently combined pulses have been elaborated using a commercial software that implements the finite difference time domain (FDTD) method for solving Maxwell equations. The sources are Gaussian both in space and in time. The numerical simulations have been done by varying symmetrically the laser beam propagation angle α in the range of 25°-65° with 5° step. A detailed study concerning the intensity evolution of the EMF distribution in the focal area has been performed under the α variation conditions in air, at 2, 5, 10 and 20 cycles pulse duration. The simulation results obtained by this study are presented and discussed. The research is supported by the Romanian Authority for Scientific Research and Innovation, Project LAPLAS VI and by the national project PNCDI III 5/5.1/ELI-RO_2017_16 (“SIMULATE”) under the financial support of Institute for Atomic Physics - IFA.

Ekaterina Koroteeva

Lomonosov Moscow State University, Russia

Infrared imaging in fluid dynamics: from impinging jets to human perspiration flows

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Infrared thermography (IRT) is a versatile optical tool that provides temperature distribution maps of observed surfaces via detecting their naturally emitted radiation within a certain infrared (IR) spectral band. High resolution and temperature sensitivity of commercially available thermal cameras have made IRT a powerful technique for a numerous amount of applications in many areas of technology, medicine, and science.

The IR data acquisition and analysis depend on the optical properties of a studied object. Objects in a gaseous or liquid state usually have large, wavelength-dependent IR light penetration depth. That imposes significant challenges for quantitative IRT in fields like fluid mechanics.

This presentation provides an overview of the ongoing research at the Laboratory of Plasma/Fluid Dynamics and Flow Visualization at Moscow State University, Faculty of Physics, concerning the development of IRT-based non-destructive techniques for quantitative analysis of fluid dynamic processes. The research is focused on exploiting high temporal resolution and fast thermal response of modern photon detectors that allow for effective time-resolved visualization of near-wall flow field behavior. We show that the presented methodology can be applied to a wide range of fluid dynamic problems: starting from laminar-turbulent transmission in liquid boundary layers (relevant for jet cooling engineering applications) to sweat droplets formation and evaporation (relevant for applications in psychophysiology related to non-contact monitoring of human psycho-emotional states).

The study is supported by the Russian Science Foundation (grant number 19-79-00162).

Claude Leroy

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Sub-Doppler spectroscopy using nano-cells

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We present the physics of the nano-cells and some of its applications among which the important one is the possibility to obtain atomic sub-Doppler spectra simply due to the intrinsic nature by construction of a nano-cell.

After a brief reminder of the properties of a nano-cell, we describe the parameters relevant to describe parallel and perpendicular flights to the laser beam and explain which atoms contribute to the spectrum (⊥) or not (//).

Then we present experimental spectra obtained in the Institute for Physical Research of Ashtarak, Armenia using a nano-cell and compare these spectra with the theoretical ones calculated in the Laboratoire Interdisciplinaire Carnot of UBFC, France (Fig. 1).

In order to make clear the relevance of using such type of cells in order to produce sub-Doppler spectra we make a final comparison with experimental spectra obtained in cm-size cells (Fig. 2).

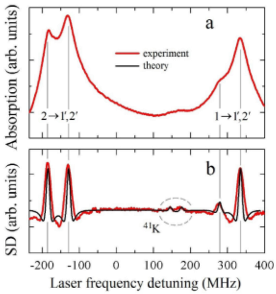

Fig. 1. Experimental and theoretical D1 line spectra of ^{39}K and ^{41}K. Transitions are described on the right side.

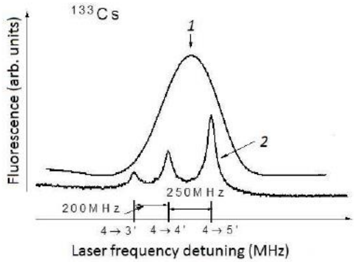

Fig. 2. ^{133}Cs - Spectra obtained with : 1 - $L = 3$ cm, 2 - $L = \lambda = 852$ nm.

[1] A. Amiryan, A. Sargsyan, Y. Pashayan-Leroy, C. Leroy, D. Sarkisyan, J. of Mod. Opt., 66 (2018).
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Super-resolved self-referencing digital holographic microscopy

Digital holographic microscopy (DHM) provides quantitative phase contrast and threedimensional (3D) imaging in arbitrary time scales that are suitable to investigate various phenomena, including dynamic behavior of biological specimens. 3D information is obtained by post-processing of the recorded digital holograms through the angular spectrum propagation approach for numerical reconstruction. However, its interferometric nature makes it highly sensitive to un-correlated noises. Self-referencing DHM arrangements provide a compact geometry that are temporally stable against environmental vibrations and suitable for the measurement of dynamic specimens such as cells. In this talk, first, we will present several arrangements for self-referencing DHM, which we have developed. Then, we will explain the major methodologies to increase the lateral resolution in DHM, including micro-sphere assisted and structured illumination methods. We will describe the principles of the methods, their possibilities to be integrated with other optical imaging and detection techniques, along with their sample applications in biology and metrology. For example, we will use the information from the super-resolution DHM to identify thalassemia minor red blood cells and healthy ones. Most of the super-resolved self-referencing methods that we present here have the potential to serve as a bench-top device for cell identification and biomedical measurements.

Sergey Popruzhenko

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Extreme radiation damping in laser-driven plasma at ultrahigh and not so high intensities

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We examine the motion of plasma driven by intense electromagnetic fields under conditions when secondary radiation of the electrons makes a considerable and even dominant impact on the collective plasma dynamics. Such interaction regime can be achieved either under the action of extremely strong electromagnetic fields to be delivered in a foreseeable future by multy-petawatt laser sources or under the action of moderately intense laser pulses which excite collective oscillations with wavelengths comparable to the micro-plasma spatial size. Two corresponding examples are considered in details. First we present a theory and a numerical model of the Inverse Faraday Effect (IFE) driven by the radiation reaction force [1,2] in two regimes (a) when the radiation reaction is described by classical electrodynamics and (b) when quantum corrections to the radiation spectrum play a considerable role. We show that the IFE induced by the extreme radiation damping can lead to the excitation of ultrahigh quasi-static magnetic fields of giga-Gauss strength.

Second, we consider emission of strong terahertz (THz) radiation from a micro-plasma created by tunneling ionization of a gas in intense infrared laser pulses. We show that, in a small plasma of 20 micron size the electrons experience dipole oscillations with the carrier frequency in the THz domain leading to a strong and highly coherent emission. This emission damped by the radiation reaction force leads to an efficient conversion of the kinetic energy stored in the plasma electrons into the energy of electromagnetic waves.

[1] T.V. Liseykina, S.V. Popruzhenko, and A. Macchi, New J. Phys. 18, 072001 (2016).
[2] S.V. Popruzhenko, T.V. Liseykina, and A. Macchi, New J. Phys. 21, 033009 (2019).
[3] T.V. Liseykina and S.V. Popruzhenko, Proposal for a bright single-cycle terahertz source based on gas cells irradiated by two-color laser pulses, submitted.

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Critical Phenomena and the Functional Renormalization Group

Critical opalescence is a common phenomenon, not only in optics, where the sizes of the gas and liquid region start to fluctuate over increasingly large length scales as the critical point is approached. As soon as the density fluctuations become of a size comparable to the wavelength of light the light is scattered and the substance appears cloudy. Theoretically, due to an inherent self-similarity the mathematical description of such phenomena are quite challenging and was finally solved by Ken Wilson's renormalization group method.

In this talk a non-perturbative functional renormalization group approach is reviewed and its application to different physical systems are discussed. Different matter phases with accompanying phase transitions appear very often in various systems whose details, particularly in the vicinity of their criticality, are triggered by quantum and thermal fluctuations. Here, the advantage of the functional renormalization group becomes manifest and the influence of the quantum and thermal and/or density fluctuations on thermodynamical systems are accessible.

To demonstrate the predictive power of this method the findings are confronted to results obtained with mean-field approximations where usually these important fluctuations are ignored.

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Exciton routing and nonlinearity in transition metal dichalcogenide monolayers

We propose a scheme for the spatial exciton energy control and exciton routing in transition metal dichalcogenide (TMD) monolayer which lies on a paraelectric substrate. It relies on the ultrasensitive response of the substrate dielectric permittivity to temperature changes, allowing for spatially inhomogeneous screening of Coulomb interaction in a monolayer. As an example, we consider the heterostructure of TMD and strontium titanate oxide ($SrTiO_3$), where large dielectric screening can be attained (see Fig. 1). We study the impact of substrate temperature on the characteristic electronic features of TMD monolayers such as the particle bandgap and exciton binding energy (see Fig. 2), Bohr radius and exciton-exciton interaction. The combination of particle bandgap and exciton binding energy modulation results in the shift of the exciton resonance energy. Applying local heating, we create spatial patterns with varying exciton resonant energy and an exciton flow towards the energetically lower region of the sample. The details of investigation are available in Ref. [1].

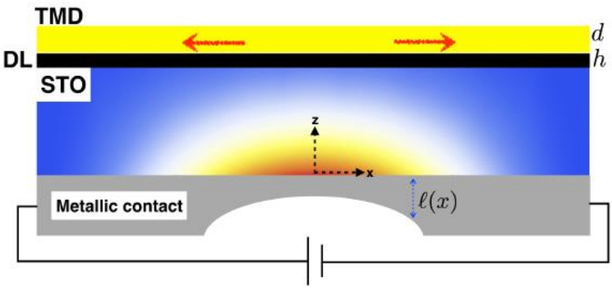

Figure 1: The sketch of monolayer TMD deposited on top of STO substrate. The substrate is inhomogeneously heated from the bottom by Ohmic contact of varying thickness. The color indicates the variation of temperature along STO substrate. In the highly heated region, the substrate permittivity is lower, resulting in strong bandgap renormalization and higher value of exciton resonance energy. The spatially varying landscape of resonance energy routes excitons excited by optical pumping to the lower temperature regions of the sample, allowing to create a controllable current of exciton cloud. The red arrows denote direction of the exciton gas flow.

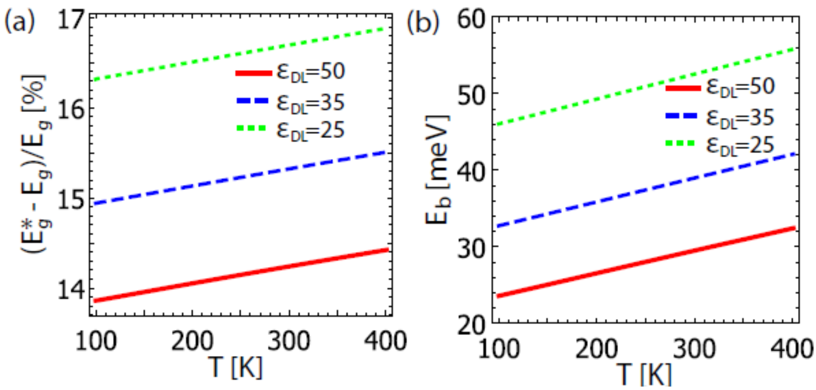

Figure 2: (a) Bandgap dependence on the substrate temperature. For larger values of dead layer permittivity the renormalization is smaller due to the reduced strength of Coulomb interaction. (b) Exciton binding energy as a function of substrate temperature for different values of dead layer permittivity. The modulation of Coulomb interaction strength results in variation of binding energy, while the presence of a dead layer makes the impact of substrate less pronounced.

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Oral Presentations

Microsphere-assisted self-referencing digital holographic microscopy in transmission mode

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In this work, we introduce a self-referencing microsphere-assisted transmission digital holographic microscopy (DHM) system in real-image operating mode. Self-referencing DHM arrangements provide a compact geometry that are temporally stable against environmental vibrations and suitable for the measurement of dynamic specimens such as cells. These advantages may be more pronounced for microsphere-assisted DHM systems. In the real-image mode, unlike the virtual-image mode, the working distance is increased. This, in turn, provides flexibility for insertion of additional elements for enhancement of the image quality, or for other required tasks. The lateral resolution enhancement is similar to the virtual image arrangement and the axial resolution is decoupled from the lateral one. The methodology is discussed theoretically and validated experimentally by conducting DHM experiments on standard microobjects and aggregation of micro-particles. Our results show that, by the assistance of a rather big size 550 μm silica microsphere, a 10× microscope objective can resolve the 3D structure of a compact disk. The arrangement may be useful toward having a compact and inexpensive benchtop high-resolution three-dimensional imaging apparatus.

A potential of optical coherence tomography for the intraoperative diagnostics in neurosurgery of brain gliomas

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An intraoperative diagnosis of brain tumors is one of the most urgent and challenging problem of modern neurosurgery. The most important measure of the effectiveness of treatment is complete tumor resection. This task is not always feasible so consequently often leads to the tumor recurrence. Existing methods of the intraoperative neurodiagnosis of tumors are plagued with limited sensitivity, especially for low-grade gliomas, and, furthermore, still rather expensive. Thus, a development of novel methods for the intraoperative diagnosis of gliomas, aimed to demarcate clear boundaries of tumors, is a topical problem of medicine, physics, and engineering sciences.

Our research, aimed at the study of the ability of optical coherence tomography (OCT) for the intraoperative diagnosis of brain gliomas of different grades, has the goal to observe the differences between OCT signals obtained for ex vivo samples of various types of brain glioma and intact brain tissue. OCT noninvasively provides visualization of the internal structure of biological tissues, as well as information about scattering properties of tissues with higher resolution than conventional ultrasound imaging. We propose a multiple-feature based data analysis that demonstrates promising results in differentiation of tissue classes.

In our experimental study, we have measured OCT signals of a set of ex vivo human glioma small samples, additionally, we have obtained OCT images of ex vivo rat brains with glioblastoma models. Our results highlight the potential of OCT for neurosurgery and oncology, especially, for detection of tumor margins.

The work was supported by the Grant from the Russian Foundation for Basic Research (RFBR), Project # 18-38-00853.

New trend in high resolution atomic spectroscopy: Faraday rotation and Second Derivative of absorption spectra from Nano-cells

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Optical cells containing atomic vapor of alkali metals are widely used in atomic physics, laser spectroscopy, and emerging applications, including chip-scale atomic clocks and optical magnetometry, ultra-narrow optical filters, etc.

For many processes, such as resonant atom-light interaction in the presence of magnetic or electric fields and collisional broadening of spectral lines, frequency resolution of individual optical transitions between the hyperfine sublevels, which can be separated from each other by down to 20 - 50 MHz, is important. Meanwhile inhomogeneous Doppler broadening in alkali vapor cells reaches 400 - 1500 MHz. Sub-Doppler resolution with simple single-beam geometry, providing a linear response of atomic media for transmission, fluorescence, and selective reflection experiments can be attained using optical vapor nano-cells with a thickness of the order of resonant wavelength. Recently we have demonstrated both experimentally and theoretically, Faraday Rotation of optical radiation using a nano-cell (NC) placed up to 0.1 T longitudinal magnetic fields [1]. Having a spectral width of ~ 50 MHz FR resonances are frequency-resolved and despite the large number of transition components this allows one to investigate the behavior of an individual transition in strong magnetic fields. Moreover, we propose a simple data processing technique, which allows retrieval of homogeneous lineshape of individual optical transitions in absorption spectra, which are initially masked by overlapped inhomogeneous spectral profile. The technique is efficient for the spectra of an atomic vapor NC with a vapor column thickness equal to half of the wavelength of the resonant laser radiation. The following procedure is employed. After recording the absorption spectrum with scanning the laser radiation frequency across the resonant region, the second order derivative A''(w) is determined from the raw absorption spectrum A(w). As a result, the transition linewidth in the second derivative spectrum reduces down to ~15

MHz (~ 50-fold narrower as compared with the Doppler broadening) [2]. This allows to separate and to study individual atomic transitions.

[1] A. Amiryan, A. Sargsyan, Y. Pashayan-Leroy, et al., J. Mod. Opt., 66(3), (2019).
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Nanocomposite based photonic crystal sensors of biological and chemical agents

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NEXT Nanotechnology Laboratory
INFN-Laboratori Nazionali Frascati

In this talk I illustrate the first results obtained through the collaboration with Institute of Physics NASU, Kiev Ukraine, Lviv Polytechnic National University Ukraine and Fraunhofer Institute Golm Germany, with the financial support of Emerging Security Challenges Division, Science for Peace and Security Programme, Multi-Year Project 2018-2021. The goal of the project is to develop cheap but effective photonic crystal (PC) structures formed by a periodic distribution of nanoparticles in polymer matrix for highly sensitive detection of chemical and biological agents, for detecting small quantities (10-12-10-14 g) .

The volume PC structures are fabricated using holographic method in original nanocomposites developed by authors.

Main steps are:

(i)theoretical analysis and design;

(ii)fabrication and characterization of label-free sensors;

(iii)functionalization of PC structures with graphene nanoflakes,

(iv)testing of enhancement effects in Raman spectroscopy.

The realization will promote emerging nanotechnologies for early detection of environmental contamination.

Freeform reflector based lab-on-chip for Raman spectroscopy in biochemical analysis

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Vrije University of Brussels, Belgium

For the last two decades, Raman spectroscopy has found widespread use in biological and medical applications thanks to the high specificity for the identification of molecules by means of the vibrational spectrum, which can be treated as its "fingerprint". We aim to bring bulky Raman spectroscopy towards a lab-on-chip (LOC) system that integrates several laboratory functions on a single integrated chip in combination with a freeform segmented reflector. LOC Raman spectroscopy can provide highly specific information about molecules. The Raman spectrum of an unknown substance can be compared against a database of known Raman spectra in order to identify the substance under test. In this study lipid droplets in a microfluidic chip are monitored by using confocal Raman spectrometer based on freeform segmented reflector.

Investigating bound entangled two-qutrit states via the best separable approximation

Ayatola Gabdulin, Aikaterini Mandilara
Nazarbayev University, Kazakhstan

We use the linear programming algorithm introduced in [1] to perform Best Separable Approximation [2] on random sets [3] of density matrices representing bipartite systems of two qutrits. It is known that for this case a small volume of PPT (bound) entangled states exist, and these states form layers on the outer surface of polytope of separable states. We devise a method for estimating from our numerical results the thickness of these layers as well as the percentage of the surface of the separable polytope covered by these. We compare these results with studies in bipartite systems of dimension 12 and we draw preliminary conclusions on the growth of volume of bound entangled bipartite states with the dimension of the Hilbert space.

[1] V. M. Akulin, G. A. Kabatyanski, A. Mandilara, "Essentially entangled component of multipartite mixed quantum states, its properties, and an efficient algorithm for its extraction," Phys. Rev. A 92, 042322 (2015).
[2] M. Lewenstein and A. Sanpera, "Separability and Entanglement of Composite Quantum Systems," Phys.Rev.Lett. 80, 2261-2264 (1998).
[3] K. Zyczkowski, K. A. Penson, I. Nechita and B. Collins, "Generating random density matrices," J. Math. Phys. 52, 062201 (2011).

Point-contact spectroscopy of 122-type iron-based superconductors

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Yanson point-contact (PC) spectroscopy [1] and PC Andreev reflection spectroscopy [1] are the advanced methods of solid state physics. The fundamental purpose of Yanson PC spectroscopy is the direct observation of electron-phonon interaction function and other non-phonon excitations in conductors in the normal state by measuring the nonlinearities of the current-avoltage characteristics (CVC) of PCs at low temperatures. PC Andreev reflection spectroscopy is an effective tool for studying the energy gap in quasiparticle excitations spectrum of superconductors, along with its dependence on temperature and magnetic field including both conventional and, for example, high-temperature and iron-based superconductors.

Here we will present the PC study of KFe_2As_2, $RbFe_2As_2$, CsFe2As2, $_{Ba1-x}NaxFe_2As_2$ and $Ca(Fe_{1-x}Co_x)_2As_2$ single crystals belonging to 122-type iron-based superconductors.

KFe_2As_2 have been investigated by Yanson PC spectroscopy. The PC spectra (or the second derivatives of CVC) of KFe_2As_2 demonstrate a single 20 meV bosonic mode. According to the calculations of electron-phonon interaction and taking into account the specificity of the band structure of KFe_2As_2, a model of indirect exciton excitations is proposed to explain origin of this mode.

The superconducting states in $Ba_{1-x}Na_xFe_2As_2$ (x=0.35) and $Ca(Fe_{1-x}Co_x)_2As_2$ (x=0.04 and 0.1) have been investigated by PC Andreev reflection spectroscopy. The differential resistance spectra (or the first dV/dI derivatives of CVC) of the above-mentioned compounds demonstrate the double minima Andreev reflection structure at the temperatures much lower than the temperature of superconducting transition. The calculations within the Blonder–Tinkham–Klapwijk model gives the reduced superconducting gap 2Δ/kBTc of 3,6±1 for $Ba_{1-x}Na_xFe_2As_2$ (x=0.35), and about 5 -10 for the $Ca(Fe_{1-x}Co_x)_2As_2$ with x=0.04 and 0.1 respectively, what is far above the BCS value 3.52. The dV/dI spectra of KFe_2As_2, show a sharp zero-bias minimum in up to 7K for some PCs on their basis which is likely of the superconducting nature and demonstrates the enhanced more than two times transition temperature in the PC core. With increase of temperature, the magnitude of the minimum gradually decreases and it vanishes at a temperature about 7K, which is in line with its superconducting origin.

The authors thank S. Aswartham and S. Wurmehl (IFW Dresden), Z. Bukowski, M. Babij, and A. Zaleski (INTiBS Wroclaw) for providing the samples.

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Quantum two-state level-crossing models in terms of the Heun functions

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We examine the semiclassical time- dependent quantum two-state problem, with the focus of the analytic description of the non-adiabatic evolution of two-state systems subject to excitation by level-crossing field-configurations. We classify the complete set of the semiclassical time-dependent quantum two-state models solvable in terms of the five function of the Heun class. Then in these infinite classes we identify concrete field configurations that allow level-crossing processes: for example, a model that describes infinite (periodical) crossings of resonance, another one that describes asymmetric resonance crossing with a finite time of process and others. We comprehensively analyze the behavior of the two-state quantum system under these field configurations. Additionally, we discuss used mathematical approaches and new developments in them and also show, that these analytic solutions of the quantum two-state problem might be projected on the relativistic and non-relativistic wave-equations and generate new potentials for the later ones.

A wide range optical magnetometer based on nanocells

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In the past decade, optical nanocells (NC) of about 40 nm to 1 mm thickness in light propagation direction have proven to be efficient spectroscopic tools, allowing to perform linear Doppler-free spectroscopy with a simple one-beam experimental setup. We have recently shown that the derivative of selective reflection (dSR) from NC allows one to record atomic spectra with a about 50 MHz linewidth [1]. The sub-Doppler nature of recorded signals and the linearity with respect to the atomic transitions strength make the NC-based dSR technique an extremely convenient tool for studying the splitting of hyperfine atomic transitions in a longitudinal magnetic field and modification of their transition probabilities [2]. Our theoretical model, based on the articles [3, 4], has shown a very good agreement with the recorded experimental spectra in a wide range of magnetic field variation covering evolution from Zeeman to hyperfine Paschen-Back regime.

Based on these studies, we have explored the feasibility of designing a nanocell-based optical magnetometer having a measurement range of 0.1 – 5.0 kG with a precision of about 1 G. To do so, a Raspberry Pi computer coupled to an Arduino Due board records the Rb D2 line from a NC exposed to the magnetic field to be measured. After fitting the experimental spectrum by minimizing the residuals between experiment and theory, our Mathematica program returns the measured magnetic field value. To demonstrate its efficiency, the magnetometer was used to measure the inhomogeneous magnetic field produced by a permanent neodymium-iron-boron alloy ring magnet at different distances from the cell. The coefficient of variation of the measurements remains under 5% in the magnetic field range of 2 – 0.4 kG. Possible optimization and outlook are addressed.

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Iron-doped Lithium Niobate crystals studied by Raman spectroscopy

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Lithium Niobate ($LiNbO_3$, LN) crystals are widely used among photorefractive materials, due to the versatility of this material for a large number of applications such as; phase-conjugation, holographic storage, frequency doubling, SAW sensors or else electro-optic modulation. However, LN device performance is limited by strong light-induced refractive-index changes inducing optical damage via the photorefractive effect. Photorefractivity of LN crystals can be increased by doping crystal with iron ions.

Raman spectroscopy is a powerful spectroscopic technique providing possibility to obtain information about structural and vibrational properties of a given material.

Iron doped LN crystals of different compositions (from congruent to stoichiometric) were analyzed by time dependent Raman measurements. A positive frequency shift of Raman lines has been detected. After a number of experiments, this time shift was attributed to the photorefractive space charge field via inverse piezoelectric effect. Then, space charge field values were calculated by frequency shift value. The space charge field saturation value in iron doped near stoichiometric LN crystal was found much lower comparing to near congruent ones.

Charge and current densities in P- and T-symmetric models with applications to graphene rings

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In both the field theoretical and condensed matters aspects, among the most interesting topics in quantum field theory is the investigation of the effects induced by gauge field fluxes on the properties of the quantum vacuum. In the present report we have discussed the combined effects from the magnetic flux and boundaries on the VEVs of the fermionic charge and current densities in a two-dimensional circular ring. The examples of graphene nanoriboons and rings have already shown that the edge effects have important consequences on the physical properties of planar systems.

In the problem at hand, for the field operator on the ring edges we have imposed the bag boundary conditions. The distribution of the magnetic flux inside the inner edge can be arbitrary. The boundary separating the ring from the region of the location for the gauge field strength is impenetrable for the fermionic field and the effect of the gauge field is purely topological. It depends on the total flux alone. The latter gives rise the Aharonov-Bohm effect for physical characteristics of the ground state. The consideration is done for both irreducible representations of the Clifford algebra in (2+1) dimensions. In these representations the mass term in the Dirac equation breaks the parity and time-reversal invariances. For the evaluation of the VEVs we have employed the method based on the direct summation over a complete set of fermionic modes in the ring. The eigenvalues of the radial quantum number are quantized by the boundary conditions. The eigenvalue equations for the positive- and negative-energy modes differ by the sign of the energy. The radial current vanishes. The charge and the azimuthal current are decomposed into the boundary-free and boundary-induced contributions. Both these contributions are odd periodic functions of the magnetic flux with the period equal to the flux quantum. An important feature that distinguishes the VEVs of the charge and current densities from the VEV of the energy density, is their finiteness on the ring edges.

The corresponding results are applied to graphene rings with the electronic subsystem described in terms of the effective Dirac theory with the energy gap. If the energy gaps for two valleys of the graphene hexagonal lattice are the same, the charge densities corresponding to the separate valleys cancel each other, whereas the azimuthal current is doubled.

Applying terahertz solid immersion microscopy for sub-wavelength-resolution imaging of soft biological tissues

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Terahertz (THz) radiation attracts considerable attention in biophotonics [1,2]. The methods of THz imaging and spectroscopy yield label-free differentiation between healthy tissues and malignant tumors with different nosology and localization [3–5], sensing of glycated tissues [6], diagnosis of viability [7] and traumatic injuries [8] of tissues. However, some challenging problems are inherent to modern THz optical systems; among them, we notice their low spatial resolution due to relatively large THz wavelengths and diffraction phenomenon [9]. Thus, conventional THz imaging systems are not suitable for studying small-scale heterogeneity of biological tissues, such as microfibrils, individual cells, and cell organelles [1,2].

In our research, we developed a novel modality of THz imaging – i.e. THz solid immersion microscopy [10]. It based on the effect of a reduction in dimensions of the electromagnetic caustic (beam spot), when it is formed in a free space, but at a small distance behind a medium with high refractive index (i.e. in evanescent field volume). We developed an experimental setup, which relies on the proposed principle and uses a backward-wave oscillator [11], as an emitter of continuous-wave THz radiation, and a Golay cell (an opto-acoustic cell) [12], as a detector of THz field intensity. We predicted numerically and demonstrated experimentally that the proposed imaging modality provides an impressive spatial resolution of 0.15λ (λ is an electromagnetic wavelength in a free space), which is beyond the Abbe diffraction limit [13,14]. Finally, we applied the experimental setup to study different types of biological tissues and objects; among them: plant leaf blades [14,15]; tissue spheroids, featuring the diameter of about 300μm and made of chondrocytes for applications in 3D bioprinting of tissues [14,16]; soft biological tissues of the human body ex vivo [14,16]. In our THz images, we observed sub-wavelength scale inhomogeneities of tissues, which correlated with the data of tissue microscopy in the visible range. The observed results highlight a potential of the terahertz solid immersion microscopy in numerous demanding branches of biophotonics, including applications in oncodiagnosis, regenerative medicine and bioprinting technologies.

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Simulation of heat propagation processes in the four-layer detection pixel of the thermoelectric single-photon detector after two photons simultaneous absorption

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We present the results of modeling and simulation of heat propagation processes taking place in $SiO_2/W/CeB_6/W/Al_2O_3$ detection pixel of the thermoelectric single-photon detector after simultaneous absorption of two photons with 0.8 eV energy. The calculations are carried out on the base of the equation of heat distribution from a limited volume using the three-dimensional matrix method for differential equations. The spatiotemporal dependence of the amplitude of the signal appearing on the detection pixel is studied at different α distances between the centers of two hot spots. It is shown that the signal maximum does not change and is equal to the signal from one photon for the calculations when the values α are greater than 0.5 μm. The signal decay time to the background value in case of the presence of the second absorbed photon is significantly longer in comparison with the case of one photon. The results of the calculations show that the detector signal is greater when α is smaller, in case $\alpha < 0.5$ μm. It is shown that the thermoelectric director can distinguish both the cases of absorption of one photon and simultaneous absorption of two photons.

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Highly-Sensitive Nanoscale Optical Switch with Plasmonic Waveguides

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We present a sub-wavelength plasmonic all-optical switch based on the concept of Mach-Zehnder interferometer (MZI). Surface-plasmon polaritons (SPPs) in plasmonic waveguides are capable to confine the electromagnetic energy in the nanoscale region, which provides the possibility to design sub-wavelength all-optical switches. We employ MZI with nanoscale plasmonic waveguides where, ON/OFF states of the switch happens by applying a control waveguide to the structure. The cladding and core of the waveguides are made of dispersive and nondispersive media, respectively. The dispersive media includes metamaterial with positive and negative permittivity and permeability. The control waveguide affects the Kerr nonlinear media in the MZI and SPPs propagation that cause destructive and constructive interferences between up and down branches of the MZI. This structure has the capacity to propagate both transverse electric and transverse magnetic SPPs and is sensitive to the electromagnetic properties of media in the switch structure. Our all-optical switch has applications in biosensors and facilitates multi-frequency switching.

Optical Properties and Application Potential of Fractal Graphene Layers

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Carbon nanostructures and especially graphene are under general attention of international science society due to their unique physical properties and huge application potential. Production of such nanostructures by the most optimal methods is the goal of many studies. In our research large scale fractal graphene layers are obtained by complex method of liquid phase exfoliation and self- organization. Atomic force microscopy (AFM) is used to study the surface properties of formed layers and to assess their thickness. Surface potential of graphene and potential transition between the graphene and substrate is measured by Kelvin probe method. Raman scattering spectra were used for structural analysis and assessment of the level of defects. The influence of twisting deformation between layers on Raman spectra is discussed.

The optical absorption spectra for these layers indicate the presence of an exciton transition along the M-point of symmetry of the Brillouin zone. These spectra of are affected by dielectric confinement effect. In addition, the graphene / $LiNbO_3$ structure is considered as a potential structure for surface acoustic wave (SAW) sensors.

Orientational order in the N_2-Kr alloys

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Using the transmission electron diffraction technique we studied the structure of N_2-Kr solid solutions with the aim to understand how the introduction of impurity particles affects the orientational order of the N2 linear molecules in the solutions. [1]

Observations were carried out in a standard electron-diffraction technique equipped with a helium cryostat (THEED). The deposition regime was chosen in order to obtain random distributions [2]. The samples were grown in situ by depositing gaseous mixtures on polycrystal Al or amorphous C substrate at T=20 K. The error in the lattice parameter measurements was usually 0.1%. The gases were mixed in a special bottle at room temperature, the typical waiting time of up to 5 min at ensured a uniform distribution of the gases. The overall level of impurities in the source nitrogen and krypton gases did not exceed 0.01%. The relative error in the intensity measurements did not exceed 7%.

Information about the orientational order was obtained from the analysis of the concentration dependence of the intensity of diffraction peaks. Based on a comparison between measured and calculated intensity of diffraction lines the orientational order factor η was determined.

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Singlet exciton fission in crystals and molecules

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Singlet exciton fission, or singlet fission (SF) is a spin-allowed process when one molecule is excited to singlet states and it can share its energy with neighboring molecule in the ground state to generate two triplet states [1]. This unique process was observed mostly in organic crystals, solid films and dimeric molecular systems.

As a good candidate for photovoltaic applications to increase efficiency, singlet fission should be faster than competing intramolecular relaxation processes. In our work, SF was observed directly from the upper excited singlet states bypassing the lowest relaxed state S_1. SF is much more efficient and faster than other competing processes: internal conversion, excimer formation, dimer cation formation.

Excited state dynamics in α-perylene single crystal and cofacial perylene dimer solution are studied by use of time-resolved fluorescence and femtosecond transient absorption techniques under different excitation conditions [2-3]. SF was detected from distinct triplet-triplet absorption band in TA spectra and was found to be excitation photon energy (wavelength) dependent.

In perylene dimers, SF was detected directly from upper excited vibrational and electronic states within 100 fs, competed well with vibrational relaxation in S_1 (4.7-7.0 ps) and $S_2 \rightarrow S_1$ internal conversion (380 fs). Excitation to higher energy levels (4.96 eV) leads to higher efficiency of singlet fission.

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The source of polarization entangled pairs of photons and testing Bell's inequality

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Quantum entanglement of photon pairs is of a great importance in the quantum optics and it is used in the fields of quantum cryptography, quantum teleportation and the development of quantum computers. Photons are perfect for a quick, efficient and secure way to transfer information considering the speed of data transfer and almost non existing interaction with its environment. Because of that they have a huge role in the development of quantum communication networks. In this presentation description of an experimental setup for realization of polarization entangled photon pairs of the wavelength of 810 nm will be shown together with the results of the experimental measurements of correlation of polarized states. Also, the experiment confirmed the violation of Bell's inequality in CHSH form of 114 standard deviations from the classical limit. The experiments have been done at the Photonics and quantum optics research unit at the Ruđer Bošković Institute in Zagreb.

The spectronic method for the ultrashort laser pulses manipulation

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For the complete characterization of an optical pulse, both the pulse shape and phase are required. Various methods in contemporary optics provide the complete amplitude and phase characterization of optical pulses on the femtosecond time scale. Among the most popular methods are the frequency-resolved optical grating (FROG) [1] and its modifications, which provide accurate and complete determination of the temporal amplitude and phase by recording high-resolution spectrograms, which are further decoded by means of iterative phase-retrieval procedures.

In order to restore the complex field of the pulse by avoiding the iterative phase-retrieval procedures, full information on the spectral intensity and spectral phase is required. The spectral phase measurement makes it possible to have information on the dispersive characteristic of the medium, as well. One of the most popular and commercialized techniques of spectral phase measurement is multiphoton intrapulse interference phase scan (MIIPS) [2,3].

A novel technique for measuring the spectral phase of an ultrashort pulse is developed based on the dispersive Fourier transformation method, as an alternative to spectral interferometric methods. The pulse spectral phase is measured by transferring the information from the spectral to the temporal domain by stretching the pulse to reach the far field of dispersion. We have implemented the technique through sum-frequency generation by using the laser pulse as a reference and have experimentally demonstrated the direct spectral phase measurement of various amplitude-modulated pulses.

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Self-focusing by bichromatic illumination with Bessel and Gaussian beams in azobenzene liquid crystal

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Simultaneous illumination of the azobenzene liquid crystal medium by 15 mW red non-diffracting Bessel beam at 632.8 nm and weak 0.1-0.25 mW green Gaussian beam at 532 nm has been studied. Experiments showed that the presence of weak green beam in the medium leads to the spreading of the Bessel beam and deflection of the Bessel core in the direction opposite to the location of green Gaussian beam relative to the Bessel beam central maximum. After switching off the green beam, the dynamics of restorat ion of Bessel beam demonstrated the pronounced self-trapping feature of its central core and transient soliton-like propagation with reduced diameter and increased intensity and propagation depth thus forming a waveguiding channel.

The work was supported by International Science and Technology Center, Project A-2130.

Reflectance spectroscopy for the estimation of glycated hemoglobin (HbA1c) for the monitoring of diabetes mellitus (DM): A pilot study

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The main focus of the given study is to research and develop a new noninvasive approach which will help to find out the level of glycated hemoglobin (HbA1c) in diabetic patients in vivo. Conventional way that is used by doctors to evaluate duration of diabetes (HbA1c) is invasive method which mainly is inconvenient for patients. In this perspective our aim is to avoid existed problems by measuring optical spectra of white non-coherent light reflected from skin. The method which is used represents reflectance spectroscopy technique with fiber-optic probe. According to our task for proper analyzation of healthy and diseased human's spectra we employ semi-empirical reflectance model which allows analyzed easily ongoing biochemical and architectural (in case of complications) changes. We carried out an experiment, where nine volunteers participated, three healthy and rest of them with according to specification of problem, three pre-diabetics and three insulin dependent diabetics. The results are quite distinctive. Each of the mentioned group have its own specific reflectance spectrum and it is easy to recognize them individually.

Singlet fission for solar cells

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Here, the most general choice for solar cells is briefly interpreted, given the following types are silicon-based solar cells, dye-sensitized solar cells and perovskite based solar cells. We explore possibilities to increase efficiency of solar cells by using the singlet fission (SF). SF is a process when a photogenerated singlet exciton splits into two dark triplet states, i.e. with one single absorbed photon is possible to generate two excitons.

SF was studied in six-thiophene single crystals and thin films by use of time-resolved fluorescence and femtosecond transient absorption techniques under different excitation conditions. The SF has threshold for six-thiophene thin films: E = 3.02 eV. SF was observed directly from upper excited singlet states within 240 fs, which competes well with internal conversion, charge transfer and intersystem crossing processes.

Gauss-Bessel Beam Formation Via Annihilating Optical Vortices

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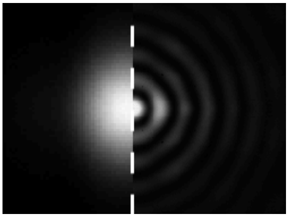
During the last decade the light and its properties are studied for many practical applications and more particularly for sending beams at very long distances. One of the main problems to overcome is to keep the diffraction spreading as low as possible. This phenomenon cannot be avoided, but only minimized. Beam profiles, other than Gaussian, are theoretically and experimentally investigated and the so called "non-diffracting" solutions are proposed. One of them is the so called Bessel beam. A true Bessel beam is an exact solution of the Helmholtz equation with infinite energy and, unfortunately, it cannot be generated experimentally. However, reasonable good approximation in the form of a Gauss-Bessel beam can be experimentally realized using a range of different methods.

This work presents a method for generation of Gauss-Bessel beams using annihilation of optical vortices (OVs). OVs are singularities in the wavefronts with spiral phase profiles containing truly 2-D point phase dislocations. The central singular point has no defined phase leading to zero-intensity, which creates the characteristic toroidal beam cross-section of the OV beam. One of the parameters describing such OVs is the Topological charge (TC) m - an integer number with sign, corresponding to the total phase change $2\pi m$ over the azimuthal coordinate φ. Arithmetics with such OV shows that, if we combine two OVs with opposite TC (e.g. m1=-2, m2=+2) the resulting beam will have no remaining TC (zero TC means no singularity, i.e. no OV), and should recover the original beam profile in the far field. Using Gaussian host beam and relatively low TC ($|m|<10$) encoded and subsequently erased with spatial light modulators, a well formed Gaussian-like bright peak is observed in the far-field. However, when a higher TC (e.g. >20) is initially encoded on the Gaussian background beam and is subsequently annihilated, a distinctive Bessel-like (Gauss-Bessel) beam profile can be observed in the focus of a lens (i.e. in the artificial far field).



Experimental results demonstrating far-field beam intensity distribution after annihilating optical vortices with TCs=1 (left; Gaussian beam) and TCs=48 (Gauss-Bessel beam).

Investigation of the the dependence of the Gauss-Bessel beam properies, on the topological charge as a control parameter, as well as its propagation characteristics are presented in this talk. Moreover the smaller diffraction, compared to a focused Gaussian beam shows great potential for future research.

Poster Presentations

Total Transfer of Population in Multi-Level System by Chirped Frequency

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Transfer of population between two quantum states using the Stark-chirped rapid adiabatic passage (SCRAP) technique is known since decades through the early works [1, 2] and it allows a simple and robust method for a complete population transfer among three states in atoms and molecules. Extension to three-level systems, e.g. double-SCRAP (D-SCRAP) or three-state-SCRAP (T-SCRAP) were theoretically proposed [1,3,4,5] and experimentally demonstrated [3,4]. However, these powerful extensions of SCRAP have been so far mainly investigated numerically. In particular, the sensitivity of the technique with respect to pulse propagation effects, dynamic detuning, and parametric spectral broadening requires a detailed investigation.

In this work, we present a simple implementation population transfer in a five-level atom based on the numerical analysis, using chirped frequency method on a five-level system, considering all the relaxation processes. The proposed models of optical reversible Fredkin gate can serve as a basis for the design of a reversible optical processor operating on the cyclic transfer of atomic populations.

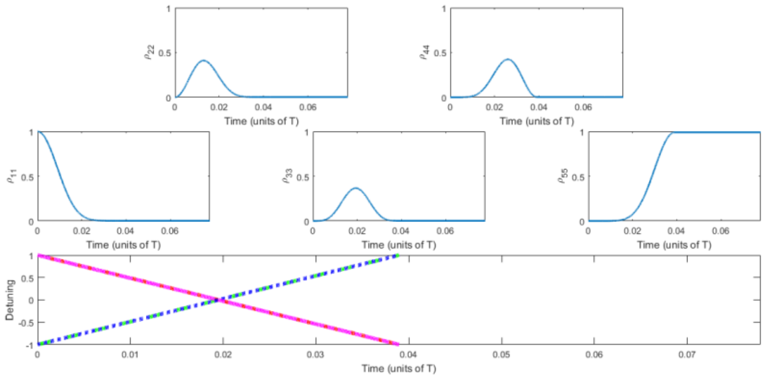

Figure: Total transfer of population for a five-level system using two cw lasers, linearly detuned.

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Experimental Measurement of Goos-Hanchen shift

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In this paper, using coherent and partially coherent optical sources we experimentally measure the Goos-Hanchen shift (GHS) in glass-air interface. Total internal reflection at the interface of a polygonal prism, in which the cord is coated with four metallic stripes is considered. The collimated beam hits both the glass-air and metal-air interfaces, and due to the high absorption of the metallic (silver) parts the beam in such areas is geometrically reflected. However, the air-glass areas possess a physical reflected beam shift. The reflection beam is recorded as an image, and by statistical analysis on the images, the intensity distributions along the strips are obtained. Our experimental results for the GHS are in agreement with predicted values.

Magnetic fields effects in the EoS and the mass of white dwarfs

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White dwarfs are compact stars with a typical mass around one solar mass and the size of the Earth, which counteracts the gravitational pull with the pressure of a degenerate electron gas. The presence of magnetic fields in such objects is well documented, yet there is a debate on its effects in the equations of state and the structure. Motivated by the observation of thermonuclear supernovae that seems to require exploding white-dwarf masses above the Chandrasekhar limit, a series of papers by Das & Mukhopadhyay (2012, 2013) explored the magnetized version of the stellar structure and argued for a substantial increase of the maximum possible mass for large values of the magnetic field. In our work, we consider an electron gas under the action of an external magnetic field and study the effects in the equations of state (EoS) and the mass. The EoS feature a splitting of the pressure in two components, one parallel and the other perpendicular to the magnetic field, which suggests the necessity of using structure equations considering the axial symmetry of the magnetized system. Thus, we compare the mass and radii of magnetized white dwarfs obtained with two different sets of structure equations. First, we solve the standard isotropic Tolman-Oppenheimer-Volkoff (TOV) equations for the parallel and perpendicular pressures independently. Then, we obtain the mass-radii curves using an axially symmetric metric in spherical coordinates, the gamma-metric (Terrero et al., 2019). Our results show that the main effect of the magnetic field anisotropy in white dwarfs structure is to cause a deformation of these objects. Since this effect is only relevant at low densities, it does not affect the maximum values of magnetized white dwarf's masses, which remain under Chandrasekhar limit.

Impurity states in a graphene bilayer in a magnetic field

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The graphene bilayer due to its peculiar band structure can be extensively used for different applications in optoelectronics.

In this work, on the basis of a variational approach, we investigate impurity states in gapped bilayer graphene in a perpendicular magnetic field. The dependencies of the ground state, binding energy and oscillator strength of the impurity electron on the gap value and tight binding parameters, describing the interaction between two layers, have been found. It is shown that these quantities and consequently the optical transitions energies can be tuned by external electric and magnetic fields and by varying the parameters describing the band structure of the system.

This magnetic-field tuning of impurity electron optical transitions energy can be promising for potential applications in optoelectronics.

Three-dimensional tracking of bovine sperm cells to investigate the effect of urea on their motility by inline digital holographic microscope

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This research aims to finding the kinematics characteristics of biological samples which has special importance in biophysics. To do so, we use an experimental method to track bovine sperm cells in three-dimensions as a movable bioparticle under various conditions (various concentrations of urea). By applying digital holographic microscopy, we can both identify the most appropriate condition for increasing the probability of fertility and improve the future breeding of the cows. An increase in the amount of protein in the diet of cows leads to strengthen them. The problem rises where the conversion of extra proteins to urea in their bodies happens. This work is based on applying the image-processing methods and using the obtained information from the analysis of holograms which are recorded by digital holographic microscope that is known as a phase contrast microscope. This research led to wonderful results and demonstrated a reduction both in the motility of the sperm and in the probability of fertility by increasing urea concentrations.

Effect of long-range spreading on two-species reaction-diffusion system

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Two-species reaction diffusion system $A + B \rightarrow A$ and $A + A \rightarrow (\emptyset, A)$ is studied in presence of long-range spreading. In contrast to the usually assumed ordinary short-range diffusion spreading of the reactants, we consider long-range hops, which cause diffusion to become anomalous. Anomalous diffusion properties are common to a broad spectrum of natural phenomena. We use approach based on L´evy distribution to describe transport in such systems. When considering L´evy flights, critical dimension $dc = \sigma$, below which the methods using mean-field techniques fail to predict large-scale behavior of the system, depends on the control parameter for the L´evy flights $0 < \sigma \leq 2$. Perturbation expansion in ε is now performed in the form $\varepsilon = \sigma - d$. Large-scale behavior of the reaction process is studied employing field-theoretic approach. The perturbative renormalization group method is applied in order to determine the time dependence of the density of reacting particles.

A novel detectors based on laser spectroscopy

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The aim of this project is the study of innovative way to develop particle detectors characterized by a low energy threshold (below 100 eV) in a large active volume that could improve the actual standards. Low energy threshold detectors are necessary in many frontier fields of the experimental physics. In particular these are extremely important for probing Dark Matter (DM) possible candidates.

Since we need to focus the energy range between meV and eV, a low energy threshold in a large volume is important for our detector. The active material of the proposed scheme is made of Rare Gas (RG) in the solid phase both undoped and doped with alkali or rare earth atoms. Solid crystals of gases maintained at cryogenic temperature that provide a low interacting environment [1] in order to obtain a low energy threshold detector. These kinds of crystals were proposed in the 50's as unreactive environment for the study of a wide number of atoms and molecules that can be isolated within the solid crystals [2]. This technique called matrix isolation spectroscopy (MIS) as the guest particles are isolated within the crystal that is made of un-reactive material.

In our case, laser spectroscopy used as a precision tool for the measurement of a transition event between two energy levels, when the quantum jump is triggered by an external particle to be detected. These type of crystals small energy releases can be probed exploiting laser-assisted processes that up-convert the low energy release of the incident particle. MIS usually allows for the investigation of vibrational energy levels of the dopants with a high efficiency and without the rotovibrationals degrees of freedom. Doping the crystal with alkali or rare earth atoms introduces sub - eV energy levels. Therefore, in the proposed detector, the intrinsic energy threshold ΔE coincides with the lowest level when the matrix is pumped by a narrow bandwidth laser, providing the lacking ionization energy. The free electrons created inside the matrices when the incident particle is absorbed in the material, can be extracted, and once in vacuum easily detected. Preliminary tests regarding both the large crystals growing and the doped matrices, are currently under development.

Study of photorefractive nonlinear scattering by Z-scan technique in $LiNbO_3$ crystals

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The Z-scan technique is a well-established sensitive method to determine these nonlinearities of optical materials. However, there are the limitations of the Z-scan method for the determination of the NLR and NLA in photorefractive media. These limitations are essentially caused by the presence of nonlinear scattering (NLS) that masks the third-order nonlinear response. Therefore, a modified open-aperture Z-scan setup was used by us to evaluate partial contributions of NLS in the observed transmission attenuation. Our study was undertaken with a cw-excitation at 514.5 nm in nominally pure, Mg- and Zr-doped $LiNbO_3$ crystals. It has been established that the wide-angle photoinduced light scattering represents a dominating contribution to NLS in photorefractive $LiNbO_3$ crystals and gives the significant transmission modulation within the open-aperture Z-scan trace. NLS has a significant magnitude in the undoped, strongly Zr-doped ([Zr]≥2 mol%) and Mg-doped $LiNbO_3$ at the moderate and high light intensities, and at low light intensities in the moderately Zr-doped (0.625 ≤ [Zr] ≤ 1.5 mol%) LiNbO3 crystals. The relation between the NLS coefficient α_{nls}, gain factor Γ (coupling efficiency between the pump and scattered waves) and seed scattering ratio m0 is derived by us. The actual values of these parameters depend on dopant type, concentration and light intensity. They reach extremely high values (α_{nls}=46.1 cm^{-1}, and m_0 = 0.0068) in the moderately Zr-doped $LiNbO_3$ crystals.

Radial Diffractive Acoustical Element

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Diffractive optical elements have been considered for many years due to their usefulness in various application such as optical manipulation. It seems possible to incorporate similar elements to engineer acoustical wavefronts. In this research we use diffractive elements fabricated by acoustical wave sensitive materials to desirably modify the intensity of incident acoustic wave. We used radial diffractive acoustical plates and measured the variations in an amplified wave's intensity along the propagation axis as well as the lateral changes. These elements can be used for several applications including gas mixing and indirect light particle displacement.

Structural properties of Ho-doped lithium niobate thin films

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Different concentration of Ho^{3+}ions doped lithium niobate ($LiNbO_3$) thin films were created by Sol-Gel method on a sapphire substrate of (001) orientation. X-ray rocking curves of $LiNbO_3$:Ho^{3+} thin films show an intense peak of sapphire corresponding to the reflection (006) of the substrate and, at lower angles, the peak of $LiNbO_3$ corresponding to reflection (006). The results confirm that the main volume of the crystalline films is epitaxially oriented with the “c” axis parallel to the substrate normal. It should be noted, that with a decrease of the thickness of the film (the number of layers) the $LiNbO_3$ peak intensity decreases, while its position is practically independent on Ho^{3+} ions concentration.

Structural modifications of obtained thin films were investigated by high resolution X-ray reciprocal space mapping. The reciprocal space maps were collected in the proximity of the symmetric (006) and asymmetric (018) Bragg reflections of the sapphire substrate. The results show that the crystal quality of $LiNbO_3$:Ho^{3+} films is independent on the Ho content or film thickness and that the thin films are in a fully relaxed state with respect to the underlying sapphire substrate. Raman scattering mapping of the surface of the thin films with a back scattering configuration and the use of the laser beam at 532nm confirms that the structure of the $LiNbO_3$:Ho^{3+} thin film is homogeneous across the surface.

Application of magneto-optical signals from Rb D1 line in magnetometry

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Magneto-optical signals from an ensemble of atoms have been used in various scientific fields for measuring magnetic field, one recent example [1]. Signals presented in the current study have the potential of measuring magnetic field on their own or they could be used as a reference signal for calibration of any magnetometer especially for measuring large magnetic field values – over 1000 gauss. A popular way to calibrate or measure non-zero magnetic field is to observe level-crossing signals in alkali vapour for the D2 transition [2]. In the present study we show that also the fluorescence from D1 line of rubidium can be used to measure magnetic field, as it provides expressive signal dependence on external magnetic field. We have observed both experimentally and theoretically two oppositely circularly polarized laser-induced fluorescence (LIF) component dependence on the magnetic field. The exciting electric field **E** is in a $\pi/4$ angle with respect to the magnetic field **B**, and the observation direction is perpendicular to the plane of **E** and **B**. We set this geometry as the main goal of our project is to observe angular-momentum alignment-to-orientation conversion in the ground state of rubidium atoms. Nevertheless, in the fluorescence signal some profound structures at particular magnetic field values appear. The formation of these structures can be attributed to magnetic sub-level scanning in the external magnetic field. When the energy difference between two particular magnetic sub-levels coincides with the set laser frequency, an increase in the fluorescence signal can be observed. The amplitude of the peaks is proportional to the transition probability and the width is proportional to the Doppler broadening. Possible increase of magnetic field resolution can be achieved if Doppler effect is suppressed, for example using nanocells [3]. A. Mozers acknowledges support from ERAF PostDoc Latvia project No. 1.1.1.2/16/117 "Experimental and theoretical signals of ground-state angular momentum alignment-to-orientation conversion by the influence of laser radiation and external magnetic field in atomic alkali metal vapour".

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Investigation of the practical application of silicate glasses containing CdS_xSe_{1-x} nanocrystals

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The experimental results of studying the temperature dependence of the optical transmission spectra of silicate glasses containing CdS_xSe_{1-x} semiconductor nanocrystals in the range of 20-300°C are presented. Measurements show that the temperature dependence of the band-gap energy of CdS_xSe_{1-x} nanocrystals is fairly well described by the Vershin formula. The dependence of the temperature coefficient of a variation in the band-gap energy depending on the nanocrystal size was plotted for various samples. This dependence is a peaked curve. The maximal value of temperature coefficient is approximately twofold larger than the corresponding value for the bulk CdS_xSe_{1-x} semiconductor. The investigation into the temperature dependence of the transmission spectra is aimed at the prospects of using these samples as optical temperature-controlled filters. On the other hand, knowing the shift of the absorption edge, we can determine the variation in temperature. The accuracy of temperature measurement using this method can be one tenth of a degree. This method has an advantage that allows us to determine the temperature-field distribution. Silicate glass containing CdS_xSe_{1-x} nanocrystals is located in regions, where the temperature distribution should be determined, and glass coloration or, more exactly, the value of the absorption edge at each point of the glass determines the temperature distribution of this region.

Visualization of hydrostatic migration of a particle at liquid-liquid interface

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Investigation of phenomena at the liquid-liquid interfaces are useful in biology and engineering. Analytical description of such phenomena is challenging because it often involves nonlinear dynamics. We have shown, both theoretically and experimentally, that a small particle moving along a liquid-liquid interface inside a viscous fluid, is repelled from the interface due to hydroelastic forces. The analysis of the acquired images shows that the elastic disturbance in the interface, produced by the flow field results in the particle-wave coupling.

Copper oxide-based thin films synthesized by different techniques: Morphological, structural, and optical properties

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Copper oxides due to their nontoxicity, availability, low production cost and abundance of the starting materials are of particular interest. In the Cu–O chemical system two compositions are formed for practical use: Cu_2O and CuO. They have found numerous applications in different fields such as electrochromic coatings, catalysis, super capacitors, emitters, gas sensors, photovoltaic devices and solar cells. A wide range of methods are used for deposition of copper oxides thin films, among which varieties of chemical synthesis, thermal evaporation, electro-deposition, laser ablation, and physical sputtering can be distinguished [1-5].

In the present study, properties of copper oxides thin films prepared by thermal evaporation and direct current magnetron sputtering techniques are discussed. The thermal evaporation was realized by vacuum evaporation of copper wire on different substrates with post-deposition annealing of the formed thin films in the muffle furnace (temperature range 200-500° C). Magnetron sputtering was carried out in an argon atmosphere by sputtering a copper target at a voltage of 300 V, and an anode current of 0.4 A with post-deposition annealing of prepared thin films in the temperature range 300-800° C. To analyze the crystalline phase of the prepared thin films their crystalline structures were determined using X-ray diffraction patterns with Cu Kα radiation (λ = 1.5418 Å). The morphology and structure of the prepared films were analysed by the UV-Vis and Raman spectroscopy (RS), XRD, EDX and SEM techniques. The results for the deposited thin films indicated that these methods allow to formation thin films as Cu_2O and CuO phases with a controllable thickness and crystalline phase by changing the deposition time, deposition atmosphere and temperature.

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The investigation of electronic structure and optical properties of YGa_2

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Employing the projector augmented wave (PAW) method [1] with the Generalized Gradient Approximation GGA, we have investigated the electronic and optical properties of YGa_2 compound.

First-principles electronic structure calculations were performed within the framework of density functional theory (DFT) by means of VASP Simulation Package [2]. The exchange-correlation potential of Perdew–Burke–Ernzerhof (PBE) for electron–electron interactions is used [3]. The accuracy for the total energy convergence after the self-consistent calculations has been set at 10^{-8} eV. The tetrahedron method of k-integration has been applied for the self-consistent calculations with the (8; 8; 12) k-mesh of the Brillouin zone, according to the Monkhorst– Pack grid scheme [4].

The optical anisotropy in YGa_2 is analyzed through the optical functions such as refractive indices and static dielectric constants along the principal axes. Our calculated band structure and optical spectra have also been compared.

In addition, we have compared our results with the theoretical results of MgB_2 and AlB_2 [5], which crystalize with the same space group ((AlB2 type structure at NTP, space group P6/mmm)).

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Anisotropic Elastic Properties of Liquid-Crystalline Elastomers

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There exist a large variety of materials that have the same macroscopic symmetry as nematic liquid crystals [1-7], but that cannot flow: they are macroscopically homogeneous anisotropic elastic media with a nonvanishing shear modulus that provides resistance to shear distortions. These materials include nematic liquid crystalline elastomers, polymers and gels. Liquid-crystalline elastomers have wide possibilities of applications from micromechanical systems [8] (e.g., in atomic force microscopes, as valves in microfluidic systems, as artificial muscles in robots) to propulsion systems [9] (inspired by cilia in nature) and active smart surfaces, which can change their properties according to the environment [10].

The general approach to study the properties of the mechanical deformations of anisotropic elastomers is proposed. The stress tensor, the Young modulus and the Poisson ratios for the parallel and perpendicular homogeneous orientations of nematic molecules relative to the axis of external forces influence are obtained by the varying of the free energy of mechanical deformation. It is shown that these constants have the anisotropic character and the experiments for the direct measurement of seven elasticity coefficients entering the free energy expression are proposed. This approach allows us to calculate orientational deformations of anisotropic elastomer in response external stimuli and mechanical deformations due to the reorientation of nematic director.

Thermal influence on the optical properties of a cholesteric-polymer layer-cholesteric system

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Cholesteric liquid crystals have a helicoidal structure which is possible to control by external influences such as electrical field, temperature, hydrodynamic flows, etc. It was known that temperature increase shifts the photonic bandgap into the shortwave range of spectrum due to the high solubility of chiral dopant. It is important to take into account the temperature effect as it can considerably influence on various types of liquid crystalline systems' optical properties such as refractive indexes, transmission spectrum, etc. The tunable photonic bandgap is attractive for tunable laser applications[1].

We have experimentally and theoretically investigated the optical properties of the cholesteric-polymeric layer-cholesteric system, namely the transmission spectrum in different thermal conditions. The presence of the polymeric film between two cholesteric layers generates multiple defect modes inside the photonic bandgap which are very close to each other. This result has been verified also theoretically. Besides, we have followed the optical properties e.g. transmission spectrum of the above-mentioned system when changing the temperature. Temperature gradient also originates flows inside cholesteric-polymer layer-cholesteric three layered system. Mentioned multilayer system can be used for multimode lasing and spectrum shift due to temperature change can expand the possibility to gain lasing peaks with different wavelengths as well.

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Effect of surface roughness on the Goos-Hanchen shift

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By considering an optically denser medium with a flat surface, but with natural roughness instead of abstract geometrical boundary, which leads to mathematical discontinuity on the boundary of two adjacent stratified media, we have thus established the importance of considering physical surfaces; and thus we studied the Goos-Hanchen (GH) effect by ray-optics description to shed light on parts of this effect that have remained ambiguous. We replaced the very thin region of surface roughness by a continuous inhomogeneous intermediary medium. Applying Fermat's principle for the incident light ray, few fundamental questions about GH shift are more convincingly addressed, which are in excellent agreement, even with the most details of the experimental results.

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87.	**Pandey Avinash**	Inter University Accelerator Centre, India
88.	**Pandey Sarita**	Sudha Institute of Environment and Technology, India
89.	**Papoyan Aram**	Institute for Physical Research, Armenia
90.	**Peranic Matej**	Institut Ruđer Bošković, Croatia
91.	**Pashayan Svetlana**	Institute for Physical Research, Armenia
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95.	**Reymers Anna**	Insol, Armenia
96.	**Rudolf Petra**	University of Groningen, The Netherlands
97.	**Sahakyan Mane**	Institute of Low Temperature and Structure Research, Poland
98.	**Sampson David**	University of Surrey, UK
99.	**Sargsyan Maksim**	Yerevan State University, Armenia
100.	**Sarkisyan Hayk**	RAU, Armenia; YSU, Armenia; SPBSTU, Russia
101.	**Sarukhanyan Tatevik**	Yerevan State University, Armenia
102.	**Schäfer Bernd-Jochen**	Justus-Liebig-University Giessen, Germany

103.	**Shahbazyan Tigran**	Jackson State Uni., USA
104.	**Shahnazaryan Vanik**	ITMO University, Russia
105.	**Shelykh Ivan**	University of Iceland, Iceland
106.	**Stepanyan Ararat**	SE Tech, Armenia
107.	**Stepanyan Artem**	Yerevan State University, Armenia
108.	**Sukiasyan Minas**	CANDLE, Armenia
109.	**Tahmasebi Zahra**	Institute for Advanced Studies in Basic Sciences, Iran
110.	**Tsarukyan Lusine**	Institute for Physical Research, Armenia
111.	**Tsverava Mariam**	Ivane Javakhishvili Tbilisi State University, Georgia
112.	**Zhao Tongyu**	Dalian University of Technology, China
113.	**Zhekova Maya**	Sofia University “St. Kliment Ohridski”, Bulgaria

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