Symposium Information
BOOK of ABSTRACTS

1-5 September, 2014
Yerevan - Ashtarak, ARMENIA

ICTP smr2633: OPTICS-2014, 1 - 5 September, 2014, Armenia

ՀԱՅ-ՌՈՒՍԱԿԱՆ (ՍԼԱՎՈՆԱԿԱՆ)
ՀԱՄԱԼՍԱՐԱՆ

Միջազգային սիմպոզիում

«ՕՊՏԻԿԱՆ ԵՎ ՆՐԱ ԿԻՐԱՌՈՒԹՅՈՒՆՆԵՐԸ»

1 - 5 սեպտեմբեր, 2014
Երևան–Աշտարակ, Հայաստան

Տեղեկություն սիմպոզիումի վերաբերյալ և զեկուցումների թեզերը

ԵՐԵՎԱՆ
ՀՌՀ ՀՐԱՏԱՐԱԿՉՈՒԹՅՈՒՆ
2014

ICTP smr2633: OPTICS-2014, 1 - 5 September, 2014, Armenia

РОССИЙСКО-АРМЯНСКИЙ (СЛАВЯНСКИЙ) УНИВЕРСИТЕТ

Международный симпозиум

«ОПТИКА И ЕЕ ПРИЛОЖЕНИЯ»

1 - 5 сентября, 2014
Ереван-Аштарак, Армения

Информация о симпозиуме и Тезисы докладов

ЕРЕВАН
ИЗДАТЕЛЬСТВО РАУ
2014

UDC 535:06

Optics & its Applications: Symposium Information & Book of Abstracts of the 2nd International Symposium (Armenia, 1-5 September, 2014). – Yerevan, 2014 – 190 p.

The book includes the abstracts of reports submitted to the ICTP scientific event smr2633: 2nd International Symposium «Optics & its Applications» (OPTICS-2014). Abstracts printed as presented by authors. Full texts of the reports selected by the Programme Committee of the Symposium will be published in the ADVANCED SCIENCE FOCUS (ASFo).

The Book of Abstracts of the 2nd International Symposium «Optics & its Applications» is issued by decisions of Scientific Council of the Organizing Committee of OPTICS-2014, and Publishing Council of Russian-Armenian University (session of Council, August 11, 2014).

Edited by **Narine Gevorgyan** (RAU, Armenia / ICTP, Italy)

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Foreword

It is our great pleasure and honor to welcome you to the ICTP scientific event in Armenia smr2633: 2nd International Symposium "Optics & its Applications" (OPTICS-2014) in Yerevan-Ashtarak, Armenia, September 1-5, 2014. The OPTICS-2014 is the first official ICTP scientific event in Armenia.

To visit Armenia is like to travel back in history and feel the spirit of more than 30 centuries. Rich with historical churches, monasteries, monuments, and magnificent masonry, this country, the first to adopt Christianity and proclaim it as its state religion in 301 AD, is a unique treasure for those interested in great events. Should your interests lie in nature, the beautiful Armenian Plateau with hidden lakes, including the mysterious Lake Sevan, waterfalls, torrents, rivers, springs, valleys, highlands and rich forests, are evidences of the miracles of nature. The topography of the land and the man-made wonders of a centuries old architecture of churches and monasteries bring to life the history of one of the world's most ancient nation and culture. In addition, the cableway "Wings Tatev" being the world's longest non-stop reverse air tram is located in Armenia.

The objective of this ICTP Symposium in Armenia is to bring together experienced and young scientists working in various areas of optics, to share their ideas and achievements, present their works and to discuss the most recent developments in their areas. This scientific event will provide opportunities for researchers from industrial companies, academic and research institutions to exchange informations and to launch cooperations. It shall attract young scientists of the region to the modern and multifacetted field of optics and its applications and encourage them to start a career as researcher.

The Symposium will host 156 scientists from 29 countries of five continents, namely: Armenia, Australia, Belgium, Cuba, Denmark, Egypt, France, Georgia, Germany, Greece, India, Iran, Italy, Japan, Latvia, Lithuania, Mexico, Moldova, Poland, Russia, Saudi Arabia, South Africa, Switzerland, Turkey, Ukraine, United Kingdom, USA, Uzbekistan and Venezuela.

The International Symposium on OPTICS - 2014 is dedicated to the 50th Anniversary of the Abdus Salam International Center for Theoretical Physics.

On behalf of the organizing committee, we sincerely hope that this symposium meets and eventually exceeds all your expectations and we wish you a wonderful stay in Armenia!

With kind regards,
Direcotrs of OPTICS-2014

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  Institute of Mathematics and High Technologies
- ✓ **Institute for Physical Research of NAS**
- ✓ **LT-PYRKAL**
- ✓ **Armenian ICO TC**
- ✓ **YSU & NAS SPIE Armenian Student Chapter**
- ✓ **Yerevan State University**
  Department of Physics

Co-organizing Student Chapters:
OSA Bauman Moscow State Technical Univ. Chapter, Russia
SPIE Bauman Moscow State Technical Univ. Chapter, Russia

Topics:

- *Optical properties of nanostructures*
- *Quantum optics & information*
- *Singular optics and its applications*
- *Laser spectroscopy*
- *Strong field optics*
- *Nonlinear & ultrafast optics*
- *Photonics & fiber optics*
- *Optics of liquid crystals*
- *Mathematical methods in optics*

Program highlights:

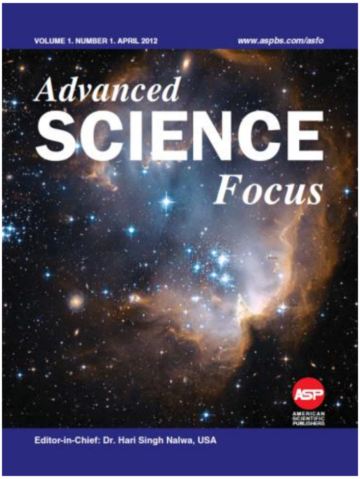
- Invited talks and sectional reports
- Presentations of young scientists (*Special awards from SPIE Armenian Students Chapter for best student presentation*)
- Poster presentations
- Professional development talks
- Presentations of international institutions and societies
- Exhibition
- Lab tours
- Social Programs

The Symposium Program includes: presentations of institutions & societies (30 min), plenary talks (40 min), invited talks (30 min). The program also includes: sectional oral presentations (20 and 15 min), students' presentations (10 min) and poster contributions (posters are accepted up to format A0 (1189mm x 841mm)), proposed by participants and accepted by the Scientific Council of the Organizing Committee.

Proceedings

The Symposium Proceedings will be published in the **ADVANCED SCIENCE FOCUS** (ASFo).

Expected publication: First quarter 2015



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Lab Tours

Institute for Physical Research of NAS

- Optics Laboratory
- Laboratory of Laser Spectroscopy

Russian-Armenian (Slavonic) University

- Laboratory of Photonics & Optoelectronics

Yerevan State University

- Ultrafast Optics Laboratory

LT-PYRKAL

- Laser laboratory
- Laboratory of optics

Exhibition

http://lt-pyrkal.com/en/

http://www.ni.com/

http://www.newport.com/

http://www.bralax.com/

Symposium Venue

Department of General Physics and Quantum Nanostructures
Institute of Mathematics and High Technologies
Russian-Armenian (Slavonic) University
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LT-PYRKAL
21 Shopron Str., Yerevan, 0090, Armenia

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Russian-Armenian (Slavonic) University

Russian-Armenian (Slavonic) University (RAU) is a unique institution in the South Caucasus region being under the joint authority of the Russian Federation and the Republic of Armenia. The decision to establish RAU in Yerevan was taken in 1997 when the RA and RF governments signed the agreement to open a Russian university in Armenia. What followed was a period of firm effort led by two governments. In almost two years the vision of Russian-Armenian University had become a reality. The first intake of students was held in February 1999 for Science of Law, Public and Municipal Administration and Journalism. Since then the University has been constantly growing and encompassing new branches of learning and research. Starting from 2002 scientific centers, institutions and problem research groups have been developing within the university. In the same year RAU offered its first post-graduate course to the students. The reconstruction of the building was ended in 2004. On October 15 of the same year Park of Gratitude was opened at the university as a symbol of the past, present and the future of Russian-Armenian friendship. This very day is considered to be the University Day.

On April 29th, 2005 RAU was accredited by the Ministry of Education of the Russian Federation.

Nowadays RAU offers a wide range of undergraduate and postgraduate programs. There are 20 academic departments and 11 faculties functioning at RAU. Students are trained in 32 Chairs which involve highly qualified specialists. Most of them have Doctor’s or Candidate’s degree. The University offers training in almost all branches of modern science and humanities giving both Bachelor’s (4 years) and Master’s (2 years) degree. Senior students have an opportunity to continue their education in Russia or other countries.

The aim of the university is to prepare highly qualified specialists meeting the demands of the new century and to support them to find jobs corresponding to their knowledge and skills. Professors from the Republic of Armenia and the Russian Federation do their best to make this goal come true.

Since its creation the university has been governed by 2 presidents; the founding president, famous expert in Russian language and literature, Academician Levon Mkrtchyan was followed by Former Prime-Minister of the Republic of Armenia, Doctor of Economic Sciences, Professor, Academician of the Russian Academy of Natural Sciences, member of National Academy of Science of Armenia Armen Darbinyan who has been the president since November 1, 2001.

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National Academy of Sciences of Armenia
Institute for Physical Research

Main scientific directions:

Laser physics and material science, *in particular*:

- *atomic physics, laser spectroscopy*
- *quantum and nonlinear optics, photonics*
- *quantum information, computing and communication*
- *matter wave physics*
- *interaction of radiation with matter*
- *new solid-state lasers, laser materials and schemes*
- *growth and characterization of laser and scintillation crystals*
- *thin film structures for microelectronics and laser technologies*
- *solid state physics, organic ferromagnetism*
- *high-temperature superconductivity*
- *synthesis and characterization of nanomaterials*
- *scientific instrumentation*

Research in these areas is carried out in 12 laboratories:

- Theoretical Physics Laboratory
- Optics Laboratory
- Laboratory of Laser Spectroscopy
- Laboratory of Crystal Growth of Luminescence Materials
  - X-ray Analysis
- Quantum Informatics Laboratory
- Crystal Optics Laboratory
  - γ-Radiation Station
- Solid State Lasers and Spectroscopy Laboratory
  - Coating Facility
- Solid State Physics Laboratory
- Superconducting Detectors’ Physics Laboratory
- Non-Linear Crystals and Elaborations Laboratory
- High-Temperature Superconductivity Laboratory
  - Electron Microscopy and X-ray Microanalysis
- Physics Engineering Laboratory

Some figures

- Founded: **1968**
- Location: **Ashtarak, 25 km north-west from Yerevan**
- Overall campus territory: **700 000 m^2**
- Total number of employees: **174**
- Publications: about 100 per year, including 50 in refereed journals
- Organized conferences: Annual "Laser Physics" International Conference (1996-2011); International "Young Optician School" (2007); International Advanced Research Workshop "Modern Problems in Optics & Photonics" (2009); International Scientific Workshop "Photonics & Micro- and Nano-structured Materials" (2011); International Symposium "Optics and its Applications" (2011); International Advanced School on Frontiers in Optics & Photonics (2012); 2nd International Advanced School on Frontiers in Optics & Photonics (2014); ICTP smr2633: 2nd International Symposium "Optics and its Applications" (2014)
- Education activities: Basic Chair of Quantum and Optical Electronics of the Russian-Armenian (Slavonic) University
- International collaboration: with over 50 leading scientific centers (France, Germany, USA, Italy, UK, Russia, Latvia, Bulgaria, Poland, Japan, Spain, Australia, Switzerland, Croatia, Canada, Taiwan, Greece and others); CNRS International Associated Laboratory (LIA) "IRMAS"

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LT-PYRKAL

General information about LT-PYRKAL cjsc

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LT-PYRKAL Armenian-Greek Closed Joint Venture was established in 1999. According to the founders' aim the Company was established with the capability of carrying out especially complicated projects on Lasers and EO systems. Its main activity is carried out mainly on contractual bases. The infrastructure of the Company is created in a way that provided realization of the practically full cycle of Scientific Research- Laboratory Prototyping-Industrial Production.

One of the main directions of the Company is the growth technology development of active laser crystals and optical crystals. Works are carried out in the direction of development and market promotion of various rare earth doped laser elements on the bases of Fluoride and Oxide host crystals. These works are developed in the following directions: manufacturing of small laser rods with high concentrations aiming at obtaining high energies from small sizes; growth of the laser rods up to 120 mm with small concentrations; search of new crystals for laser and other applications.

Development technology and manufacturing of high-quality acousto-optical and electro-optical Q-switches have been carried out within the Company, together with their control devices with improved characteristics that would be used in modern laser systems requiring simple parameter control. Thus, a powerful acousto-optic fused quartz Q-Switches has been developed at the wavelength of 1.064μm with water-cooled system and control power of 100 W, which has low price and successfully competes with the Western analogs.

The main part of electronic devices with which the Company developments are equipped are also designed and produced within the Company. These are the power supply units for pulsed and CW lasers, Acousto-Optic and Electro-Optic Q-Switch Drivers, automated electronic systems of laser radiation parameter control and monitoring. The indicated devices are equipped with micro-control systems, the software of which has also been developed within LT-PYRKAL.

The Company is constantly accepting orders of leading Western Companies on polarization and laser optics components; these are cavity flowtubes and reflectors of complicated configurations made of doped borosilicate glasses, fused silica, sapphire; lenses, laser mirrors, band-pass filters, prisms, lightguides, substrates, and phase plates.

During past years the Company has developed and manufactured prototypes of intracavity and ring parametric oscillator with wide tunable range in middle IR range, remote system for gas trace components detection in the atmosphere, i.e. LIDAR based on the principle of differential absorption of IR radiation passing through the atmosphere. Among other designs are OPO based eye-safe laser, CW diode pumped Q-switch laser, a range of free running and Q-Switched lamp pumped pulsed solid-state Nd:YAG laser with pulse energy up to 1.5 Joule at 1.06 μm wavelength. Investigations and developments of other laser systems for applied purposes are being carried out.

The Company is regularly participating in International Trade Exhibitions. A wide range of Company products has been presented at the exhibitions: laser crystals doped with various materials, doped and un-doped fluorides, sapphire; optical elements (plain and spherical), band-pass filters; aucousto-optic and electro-optic Q-Switches with their control units; pulse laser power supply units; cavity flowtubes and reflectors of various configurations. Presently around 80 employees are working in the Company.

Faculty of Physics
Yerevan State University

The process of training specialists in the field of physics and mathematics began in YSU in 1922. The establishment of an independent faculty of Physics and Mathematics comprised of separate Chairs of Physics and Mathematics in 1933 was a significant step towards developing physics in Armenia.

To strengthen the development of physics, and in order to provide more new specialists in our republic, the Faculty of Physics was separated from the Physical and Mathematical Faculty in 1959. The first dean of the faculty was NAS RA Academician Norayr Kocharyan.

The staff of the faculty is comprised of highly qualified specialists. Currently NAS RA three Academicians and NAS RA five Associate members, 36 Doctors of Sciences, and more than 80 Candidates of Sciences are involved in the tutoring staff of this faculty.

Starting with 2006-2007 Academic year the specialization (distance learning) of Pedagogue Specialist of Physics is also available.

The scientific-research activities, which are conducted in the laboratories of the faculty, correspond to the present demands of the field. There is also an equipped computer room with modern technologies, which enables students to get acquainted with modern scientific experiments and automated systems of technology management.

Different international grants and many projects, financed by the state budget, testify to the active scientific life at this faculty.

Acknowledgement

Thanks for generous support to all sponsors!!!!

Special Invited Talks: Presentations of International Institutions & Societies

Joseph NIEMELA

- ✓ ICTP
- ✓ ICO
- ✓ International Year of Light

Rene BRUN

- ✓ CERN

David BLASCHKE

- ✓ JINR

Invited Plenary Talks

Sequential quantum measurements

János A. Bergou[1], Edgar Feldman[2], and Mark Hillery[1]

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It is generally assumed that in the process of performing a measurement on a quantum system the state of the system collapses to one of the eigenstates of the physical quantity that is being measured. Recent works, however, are challenging this concept (see, for example [1]). Using the formalism of generalized quantum measurements (POVMs, Positive Operator Valued Measures), in this talk we will show that this so-called collapse postulate is not absolute; there are ways to get around it [2]. In particular, the post-measurement state of the system can be designed with a great deal of flexibility. If one chooses an appropriate figure of merit to characterize further processing of the system after the measurement has been performed, one can even optimize the post-measurement states to maximize the corresponding figure of merit. The ideas will be illustrated on two examples. In the first example multiple observers determine the initial state of a qubit, employing the strategy of unambiguous state discrimination, by performing subsequent observations on the same qubit without revealing the measurement results to each other. In the second example multiple observers determine the initial state of a qubit, but this time employing the strategy of minimum error discrimination, again by performing subsequent observations on the same qubit without revealing the measurement results to each other. State discrimination with minimum error is the prime example for a standard (projective) quantum measurement, so it is even more surprising that the post-measurement states can be designed with some flexibility. In both scenarios we optimize the post-measurement states to maximize the joint probability of success, i.e., the probability that each observer in the sequence will learn the initial state of the quit. Finally, we will show that similar ideas can be applied to telling the past history of a quantum system, conditioned on the outcomes of measurements performed in the present.

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Curl forces and beyond

Michael Berry

H H Wills Physics Laboratory, University of Bristol, UK

Forces depending on position but which are not derivable from a potential, that is, forces with non-zero curl, give rise to dynamics that is not Hamiltonian or Lagrangian, while also being non-dissipative. Noether's theorem does not apply, so the link between symmetries and conservation laws is broken. The physical existence of curl forces has been controversial and the subject of intense debate among engineers. But an example is familiar in optics: force on a dielectric particle in an optical field. Motion under curl forces near optical vortices can be understood in detail, and the full series of 'superadiabatic' correction forces derived, leading to an exact slow manifold in which fast (internal) and slow (external) motion of the particle is separated.

WKB - type approximations in the theory of vacuum particle creation in laser fields

D. Blaschke[1,2], L. Juchnowski[1], A. D. Panferov[3], and S. A. Smolyansky[3]

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The effect of vacuum particle creation in constant fields was predicted just as a tunneling mechanism [1]. It was therefore a natural first step to use the WKB approach for relativistic fields also in extimating pair production rates for the case of fastly varying external fields. Standard references for vacuum electron-positron pair (EPP) creation in spatially homogeneous, periodically time-dependent electric fields are Brezin-Itzykson [2] and Popov [3].

In our contribution, we compare these results with the numerical calculations based on a kinetic equation that follows from the basic equations of motion of strong QED [4]. This approach was used widely for the investigation of EPP creation in strong laser fields in the case of linearly polarized electric fields [5]. This comparison shows that the WKB type approximation is valid only for small adiabaticity parameters $\gamma = E_c\omega / E_0 m \ll 1$, in the range of the validity of the tunneling mechanism. Here, E_c is the Schwinger critical field strength; E_0 and ω are the amplitude and frequency of the laser field, resp. Increasing γ and thus entering the multiphoton regime is accompanied by a catastrophic breakdown of the WKB approximation valid in the tunneling domain. This conclusion is in accordance with the work [6] showing that the non-stationary tunneling problem meets with difficulties manifesting themselves by an irregular dependence of the results on the energy.

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Intense ion beams from relativistic laser-matter interactions, and their development for advanced cancer therapy

Thomas E. Cowan

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The development 20 years ago of ultra-intense lasers of up to Petawatt (10^{15} W) powers, opened a new realm of laser-matter interactions in which the dynamics of the plasma electrons is fully relativistic. This brings with it a new degree of immense complexity, in terms of the highly non-equilibrium conditions in the laser-focus with extremes of electron current density, self-generated fields, rapid ionization, anomalous resistivity effects, and rapid heating. Understanding the fundamental processes in detail, and unraveling their complex interconnections, is one of the grand challenges of modern laser and plasma physics.

The extreme conditions produced in relativistic laser-matter interactions also give rise also to many new and useful secondary radiations and beams, including intense x-rays, multi-MeV gamma-rays, high energy electrons, nuclear reactions, positron generation, short-wavelength harmonic radiation, and intense and energetic beams of protons and ions. The latter are particularly remarkable, in that they exhibit extremely high quality, with transverse emittance one hundred times smaller than conventional RF accelerators. Laser-accelerated proton beams have been produced in broad spectra with up to 100 MeV, which has fueled speculation that these could be used as a new generation of compact ion accelerators for advanced, precision tumor therapy.

The Helmholtz-Zentrum Dresden-Rossendorf and the German National Center for Radiation Research in Oncology-Dresden, OncoRay, have an extensive program of advanced particle-beam therapy research, which is developing new techniques for precision therapy and biologically-individualized and technically-optimized tumor therapy. A major aspect is the development of ultra-intense laser-matter interactions for compact medical ion-accelerators, based on a new generation of compact and efficient, fully diode-pumped ultra-intense petawatt lasers. If successful, this will offer the potential to shrink the size of present, synchrotron-based regional (or national) ion therapy centers, to a clinical scale which could be accommodated in any modern hospital radiation therapy department.

In this talk, a review of the discovery and unique properties of laser-accelerated protons and ions will be presented, together with an overview of the ongoing research to develop these for future application in precision tumor therapy. This will provide an interesting view into the unique cross-disciplinary application of ultra-intense laser-plasma physics into accelerator and medical physics and applications.

Laser-induced spin dynamics in above-threshold ionization

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We investigate the relativistic features of the tunneling ionization dynamics of highly-charged ions in super-strong laser fields. Spin effects arise during the relativistic tunneling ionization process [1]. The spin-resolved ionization probabilities are calculated employing relativistic Coulomb corrected dressed strong field approximation [2], and taking into account the laser field driven electron spin dynamics in the bound state. Even if an electron is very tightly bound to an ionic core, its spin dynamics may still be crucially affected by a laser field of moderate intensity. This effect is beyond the commonly accepted strong field approximation and can be confirmed in a challenging experiment employing collisions of highly charged ions with ultra-strong laser beams.

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Optical Properties of Zn based Ternary Luminescent Semiconductor Nanomaterials

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Luminescent semiconductor nanocrystals are of great interest for their various applications. II-VI compound semiconductors, especially zinc chalcogenides: ZnO, ZnS, ZnSe, ZnTe, are among a typical class of materials that has been intensively investigated. The range of their wide direct band gap provides the possibility to fabricate optoelectronic devices to response to various electromagnetic spectrums. Ternary alloyed nanostructures semiconductors are of prime interest due to their tuneable band gaps with strong promise for augmented multifunctional optoelectronic devices with flexible innovative performance. Alloying and doping have been widely used for band gap engineering and property tuning of these semiconductor nanocrystals, providing novel composition and structure dependent properties. The alloying results in a material with different optical and electronic properties with broad range of emission.

Here, efforts are devoted to synthesize $Zn_{1-x}Cr_xO$ (ZnCrO) and $ZnO_{1-x}S_x$ (ZnOS) ternary alloyed nanostructures using chemical routes such as sol gel and solution combustion methods. The detailed structures of these nanomaterials were studied by scanning electron microscopy, high resolution transmission electron microscopy, X-ray diffraction and micro-Raman spectroscopy which confirm the formation of desired nanostructures. On the other hand, optical absorption, and photoluminescence were employed to probe the fundamentals of optical properties. It was observed that Cr doping affects the luminescence emission from ZnCrO. Random substitution into ZnO matrix causes the formation of interstitial Zn which further induces the non-radiative recombination.The energy band-gap of ZnOS nanocrystals show significant band-gap bowing with varying composition, while photoluminescence studies show high luminescence efficiency. The varying band-gap (2.54 eV - 3.85 eV) of ZnOS ternary nanocrystals suggests them as an excellent choice for white light generation from UV/blue LEDs and conventional discharge light sources.

Secure Communication by Coherence Modulation at the Photon Counting Level

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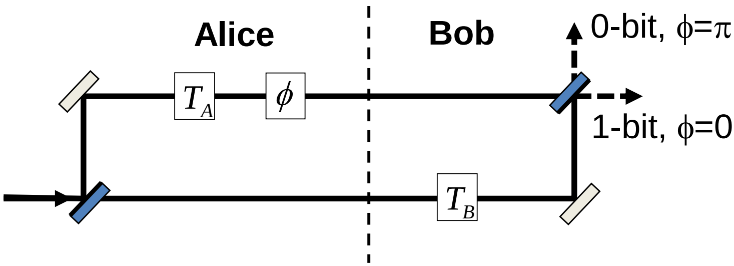
A seminal development in the field of secure communication is that of quantum key distribution, which allows the secure sharing of a common cryptographic key. In this paper we introduce a different way of exploiting properties of photons to make the transmission of a message both highly secure and quantifiably so. Specifically, we show how coherence modulation operating at the photon-counting level allows Alice to transmit a message to Bob in such a way that, assuming ideal devices, Bob can receive the transmission perfectly, whereas Eve, if she intercepts the transmission, can detect very little more than a noisy succession of random 1's and 0's. Furthermore, in tapping into the low-intensity light transmitted by Alice to Bob, Eve quickly betrays her presence.



Coherence modulation at the classical—i.e., high-light or non-photon-counting—level [1] is illustrated in the figure. If time-delays T_A and T_B are equal, Alice can transmit 1's and 0's to Bob by means of phase modulation: with $\phi = 0$, all light exits one output port, signifying a 1-bit; with $\phi = \pi$, all light exits the other port, signifying a 0-bit. If, on the other hand, $|T_A - T_B| >> \tau_c$, where τ_c is the coherence time of the light, there is no interference at the output beam combiner and the light exits both ports in equal amount, leaving the value of ϕ, and therefore the value of the bit, unknown.

For the secure transmission of 1's and 0's, it was proposed in Ref. **Error! Bookmark not defined.** that Alice and Bob sequence their respective time delays through a set of M possible values in synchronism, the specific sequence of values constituting the transmission key. It was originally presumed that Eve, not knowing the key, and therefore, not knowing the correct time delays to use, would be unable to determine ϕ and, therefore, the bit value. Subsequently it was determined that Eve could successfully attack the system and that it was not secure [2].

We show in this paper that if the light is reduced to photon-counting levels, Bob can detect high SNR outputs, whereas Eve, not knowing the time-delay sequence key, operates at low SNRs and quickly betrays her presence to Alice and Bob. The security of the system increases as the number of possible time delays M increases. Details and statistics of a particular attack by Eve are presented.

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Ensemble inequivalence in systems with wave-particle interaction

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We consider the classical wave-particle Hamiltonian in its generalized version, where two modes are assumed to interact with the co-evolving charged particles. The equilibrium statistical mechanics solution of the model can be worked out analytically, both in the canonical and the microcanonical ensembles. The competition between the two modes is shown to yield ensemble inequivalence, at variance with the standard scenario where just one wave is allowed to develop. As a consequence, both temperature jumps and negative specific heat can show up in the microcanonical ensemble. The relevance of these findings for Free Electron Laser applications is discussed.

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Study of atomic transitions of alkali metals in strong magnetic fields with the help optical nanometric-thin cells

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Atoms of Alkali metals (Rb, Cs , K, Na), are widely used for investigations of optical and magneto-optical processes in atomic vapors, as well as for cooling of atoms, for Bose–Einstein condensation, and in a number of other problems, therefore, detailed knowledge of the behavior of atomic levels in external magnetic fields is of a high interest [1].

It is well known that the energy levels of atoms in an external magnetic fields undergo splitting into a large number of a Zeeman sublevels which are strongly frequency shifted. Simultaneously, there are changes in the atomic transition probabilities in an external magnetic field B [1].

The implementation of recently developed technique based on narrowband laser diodes, strong permanent magnets and micro-and nano- thin cells (MTC and NTC) make studies of the atomic transitions behavior in an external strong magnetic field (in the range of 5 kG- 9 kG) simple and robust, and allows one to study behavior of any individual atomic transition of the ^{85}Rb and ^{87}Rb atoms for $D_{1,2}$ lines [2,3].

The technique based on MTC and NTC use can be successfully implemented to study behavior of individual atomic transition of the Cs atoms for D2 line in an external strong magnetic field (in the range of 5 kG- 9 kG) [4,5].

In the case of an external strong magnetic fields decoupling of the electronic total angular momentum J and the nuclear magnetic momentum I occurs and the eigenstates of the Hamiltonian are described in the uncoupled basis of J and I projections (m_J ; m_I) (so called Hyperfine Paschen Back (HPB) regime). Important and striking peculiarities of HPB regime for Cs, Rb and K atoms will be presented.

Theoretical models that are well describing behavior of atomic transitions in strong magnetic fields (HPB regime) will be presented.

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Optical spectroscopy of plasmonic systems

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Surface plasmons are collective electronic excitations in small metal nanostructures which are able to create extremely strong oscillating electric fields on spatial scales well below the diffraction limit. When dye molecules, semiconductor quantum dots, or any optically active systems are placed nearby a plasmonic nanostructure, their optical response can be strongly modified and/or enhanced. We will discuss several examples of plasmonic enhancement of optical transitions including fluorescence, luminescence and energy transfer.

Multimodal microscopy with high resolution spectral focusing CARS

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In this work we describe an approach that extends capabilities of multiphoton microscopes based on dual wavelength output femtosecond laser sources. Coherent Anti-Stokes Raman Scattering (CARS) microscopy with 17 cm^{-1} spectral resolution is experimentally demonstrated. Our approach is based on spectral focusing CARS. For pulse shaping of the pump and Stokes beams we utilize transmission gratings based stretcher. It allows the dispersion of the stretcher to be continuously adjusted in wide range. The best spectral resolution is achieved when the chirp rates in both pump and Stokes beam are matched. The device is automated. Any change in the beam path lengths due to the stretcher adjustment or wavelength tuning is compensated by the delay line. We incorporated into the device a computer controlled beam pointing stabilization system that compensates the beam pointing deviation due to dispersion in the system. High level of automation and computer control makes the operation of the device easy. We present CARS images of several samples that demonstrate high spectral resolution, high contrast and chemical selectivity.

Invited Talks

Cavity quantum electrodynamics in half open cavities

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Traditionally cavity quantum electrodynamics explores the almost resonant interaction between a few cavity modes of the radiation field and elementary material quantum systems. For material two level systems (qubits) the resulting dynamics is described well by the Jaynes-Cummings-Paul model or in the more general case of many two level systems by the Tavis-Cummings model [1]. Numerous features of these models can be described adequately with the help of the dressed-state picture [2]. However, as the number of field modes strongly coupled to elementary material quantum systems increases the dresses-state picture becomes inconvenient for a qualitative and quantitative description of the resulting quantum electrodynamical processes. In particular, this applies to the description of recent experiments in which trapped elementary two level systems are coupled almost resonantly to few-photon radiation fields inside
a parabolic cavity [3].

Motivated by these experiments we discuss characteristic features of almost resonant coupling between a few two level systems and the multimode radiation field inside such half open cavities. For this purpose semiclassical photonic path representations can be used for describing the resulting photonic dynamics inside these cavities. Previously these photonic path representations have been applied successfully to the description of the dynamics of a single photon interacting with a single two level system inside a half open cavity [4]. In this contribution it is demonstrated how these semiclassical path representations can be generalized to the description of the intricate dynamics of multiphoton radiation fields interacting almost resonantly with a few two level systems in such extreme multimode scenarios.

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Geometrical description of Ince-Gaussian cavity modes and other propagation-invariant beams

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Closed form solutions of the paraxial wave equation, such as Hermite- and Laguerre-Gaussian beams, are important for several reasons: they constitute complete bases in terms of which any other paraxial beam can be expanded; they are modes of simple laser cavities composed of concave spherical mirrors; they preserve under propagation their transverse intensity profile up to a scaling. At any transverse plane, the Hermite- and Laguerre-Gaussian cavity modes have simple analytic expressions that are separable, respectively, in Cartesian and polar coordinates. A third such family, the Ince-Gaussian modes, was introduced recently, which is separable in elliptical coordinates. This talk will provide a general description of these families of beams, stressing their connection to the cavities that produce them, as well as to the ray model by using an analog of the Poincaré sphere. This description is surprisingly rich in geometry, and has direct analogues in other areas of physics, particularly in quantum systems described by two-dimensional harmonic oscillators.

Optomechanical effect on the Dicke quantum phase transition and quasi-particle damping in a Bose–Einstein condensate: a new tool to measure weak force

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We make a semi-classical steady state analysis of the influence of mirror motion on the quantum phase transition for an optomechanical Dicke model in the thermodynamic limit. An additional external mechanical pump is shown to modify the critical value of atom–photon coupling needed to observe the quantum phase transition. We further show how to choose the mechanical pump frequency and cavity–laser detuning to produce extremely cold condensates. The present system can be used as a quantum device to measure weak forces.

Voltage and temperature tuning of laser properties using liquid crystals

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Liquid crystals are materials that have excellent electro-optic properties: moderate voltages are able to induce large refractive index changes. This refractive index tunability can be used to actively control laser emission by incorporating liquid crystal material inside the laser cavity. In the first example we have combined Vertical Cavity Surface Emitting Lasers (VCSELs) with a liquid crystal layer in an external cavity. Both chiral and non-chiral nematic liquid crystals have been used. The chiral liquid crystals act as a tunable mirror for the laser emission while the non-chiral liquid crystal is used to tune the external cavity length. Experimental and numerical results show the effect of the liquid crystal layer on the laser threshold and on the wavelength, polarization state and transverse profile of the emitted light. In a second example, laser dye is incorporated inside the liquid crystal material itself to form an optically pumped liquid crystal laser. By inserting this material between two weak reflectors we have obtained voltage tunable Fabry-Perot lasing with high slope efficiency and a tuning range up to 10 nm. In this configuration the laser light is emitted perpendicular to the liquid crystal layer. In a third example we look at numerical simulations of in-plane liquid crystal lasers. Here the laser light is emitted parallel to the surfaces containing the liquid crystal. The accurate modeling of the light generation in such systems is complex because the materials are optically anisotropic and the configuration is two-dimensional with fully two-dimensional variations of the liquid crystal orientation. Therefore we use advanced optical methods based on finite-element calculations of the optical modes in periodic two-dimensional structures. The optical modes in a lying helix configuration are calculated as a proof-of-principle for this simulation method. Interesting observations can be made when looking at the optical modes in these structures. Applying a voltage over the liquid crystal layer results in a shift of the laser emission.

Higher-derivative Lagrangians for Spinoptics

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We suggest to describe a "spinning light" propagation in media by the use of higher-derivative Lagrangians. For this purpose we introduce the "Fermat metric" $g_{ij} = n^2(r)\delta_{ij}$ where $n(r)$ be the refraction index of media, and construct the extrinsic curvatures (rigidity and torsion) of the paths in this curved space. Then we define the Lagrangian of spinning light as a function linear on curvature and torsion. We give the Hamiltonian formulation of this system, calculate curvature and torsion of light trajectories, as well as effective color and spin.

Magnetoelectric effects in local light-matter interactions

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We study the generic dipole interaction of a monochromatic free-space electromagnetic field with a bi-isotropic nanoparticle or a molecule. Contributions associated with the breaking of dual, *P*, and *T* symmetries are responsible for electric-magnetic asymmetry, chirality, and the nonreciprocal magnetoelectric effect, respectively. We calculate absorption rates, radiation forces, and radiation torques for the nanoparticle and introduce novel field characteristics quantifying the transfer of energy, momentum, and angular momentum due to the three symmetry-breaking effects. In particular, we put forward the concept of "magnetoelectric energy density", quantifying the local PT-symmetry of the field. Akin to the "superchiral" light suggested recently for sensitive local probing of molecular chirality [1], here we describe a complex field for sensitive probing of the nonreciprocal magnetoelectric effect in nanoparticles or molecules [2]. This can lead to the discovery of the magnetoelectric effect at the molecular level, as was discussed by Curie and Debye almost a century ago [3].

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Medical Applications of Lasers

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Although lasers are today used by a large variety of professions, one of the most meaningful applications of laser technology has been through its use in medicine. The medical potential of the laser has been explored since its invention. Today, these devices are widely used in almost all fields in medicine for diagnostics and therapeutics. One example is photodynamic therapy which is an antitumor method that uses a nontoxic photosensitizer and visible light to produce cytotoxic reactive oxygen species that destroy malignant cells. This clinical method has now reached the level of being accepted treatment for a number of diseases, among which are several forms of cancer. In this work we report the use of two chlorin e-6 based photosensitizers and its introduction to clinic practice for treatment superficial basal cell carcinoma using photodynamic therapy method. Local treatment was performed for 39 patients with 172 tumors. The presented data show a favorable response, with an overall rate of complete remission of 98.3% and acceptable functional and aesthetic results.

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Knotted vortices in light

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Optical beams propagating in three-dimensional free space are complex scalar fields, and typically contain optical vortices - filaments in 3D space where the intensity is zero. These may be thought of as generalized interference fringes, and topological singularities of phase. Random wave fields, representing optical speckle patterns scattered from rough surfaces, have a tangled skeleton of nodal lines, in which tangles of vortex loops can be knotted and linked, and whose complexity we are beginning to understand. We can also create knots using the using mathematical knot theory to choose correct superpositions of laser modes to have various knotted and linked optical vortex lines.

Detecting the atomic ionization induced by attosecond optical pulses: delay effects in Coulomb systems and their interpretation

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Detecting and measuring attosecond pulses is rather a time-dependent quantum-mechanical problem than a purely optical one, as well as that of using the attosecond pulses as probes for real-time monitoring of electronic motion in atoms and molecules. We start from a brief review of the known attosecond pulse detection techniques, including the Reconstruction of Attosecond Beating by Interference of Two-photon Transitions (RABITT) and the attosecond streaking methods. Then we proceed to quantum mechanical theory of time delays in the detected electron ejection from a short-range and a Coulomb attraction center. It is shown that the attosecond streaking, mostly used in time delay measurements, can be formally described by placing a virtual detector of the arrival time delay at a certain distance from the center of the system. This approach allows derivation of a simple formula for Coulomb-laser coupling that perfectly agrees with the results of numerical solution of the time-dependent Schrödinger equation [1]. Proceeding to two-center molecular systems, we study the dependence of the time delay upon the energy, the angular momentum projection, and the azimuthal quantum number for the ionization of molecular hydrogen ion [2]. We propose a physical interpretation of singularities, arising when the formal expression for the time delay is applied to the ionization of molecular hydrogen. Virtual analogies in the field of low-dimensional quantum systems with tailored potentials are discussed. The work is supported by grant RSCF (14-41-00017).

The work was partially supported by the RFBR, grant No. 14-01-00420

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Pseudospin and conical diffraction in photonic lattices

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Graphene’s Dirac cones appear due to its two inequivalent sublattices and resulting half-integer spin analogue, the ”pseudospin”. In contrast to Dirac fermions in photonic graphene the conical intersections with flat band in Lieb lattice spectrum support eigenstates with integer pseudospin. We study some of the most striking differences displayed by integer and zero pseudospin states: pseudospin-dependent conical diffraction and the generation of higher charged optical vortices. We test our ideas experimentally using light propagation in photonic Lieb lattice femtosecond laser-written in fused silica glass.

Manipulation of hyperfine state populations via the Autler-Townes effect

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In this talk, we shall review the results of our work on interaction of strong coherent light fields with atomic and molecular quantum states. These studies rely on exploitation of the Autler-Townes effect [1], the simplest implementation of which would involve a three-level experiment: two levels coupled by a strong laser field creating two adiabatic (or dressed) states, which are probed by a weak field coupled to a third level to visualize the adiabatic states as typical doublet structures in the probe excitation spectrum.

We shall highlight two particular situations. In the first one, we shall consider Ramsey-type interference a three-level system *g*-*e*-*f* coupled by two laser fields. A strong laser field *P* coupled between the levels *g* and *e* prepares the system in a given adiabatic state, from where the population is transferred to a high lying state *f* using a second, weaker laser field. The excitation spectrum of level *f* yields interference fringes resulting from two excitation pathways to level *f* due to Landau-Zener crossings of adiabatic states. These interference fringes can be exploited to switch the population of level *f* by changing the detuning of the weaker field between the interference maxima and minima.

The second highlight includes consideration of dark state formation (see [2] for definitions) upon interaction of hyperfine level systems with strong laser fields. In this type of experiments, the strong laser field would normally couple two hyperfine manifolds included in states *e* and *f*, yielding a number of adiabatic states. Those are probed by a weak laser field scanned across the resonance with a third state *g*. We show that unequal number of hyperfine sublevels in states *e* and *f* will lead to the formation of dark states, whereas in the case of equal hyperfine structure of *e* and *f* dark states are not formed. Experimental implications of this phenomenon will also be discussed.

We acknowledge the support by the EU FP7 REGPOT project FOTONIKA-LV, the EU FP7 IRSES Project COLIMA, US Office of Naval Research Grant

No. N00014-12-1-0514, and the trilateral project supported by the Latvian, Lithuanian and Taiwanese research councils.

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Chi(2) optical nonlinearities in Silicon

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Nonlinear optics in silicon micro-devices is a novel and extremely promising research field [1]. The possibility to obtain an all-optical data management can be reinforced by its implementation on a CMOS-compatible, all-silicon based optical platform. Until now the worldwide research has been focused on the exploitation of the optical nonlinearities arising from the interaction of intense near infrared (NIR) light-fields with the third-order nonlinear susceptibility $\chi^{(3)}$ of crystalline silicon inside waveguides. The main reason for this choice is a consequence of the inherent crystalline symmetry of silicon itself. Silicon's centro-symmetry (inversion symmetry) prohibits the existence of a bulk dipolar second-order nonlinear susceptibility, $\chi^{(2)}$, leaving room only for surface contributions.

The possibility to exploit second-order nonlinearities in silicon waveguides is challenging, first of all, because of the fact that a lower-order nonlinearity requires less intense pump to drive the waveguiding device into a nonlinear optical regime. Secondly, the $\chi^{(2)}$-based optical generation scheme is much simplified and cheap: in fact, in this case only one pump beam is needed to generate other wavelengths via, for example, second-harmonic-generation (SHG) or spontaneous parametric down conversion (SPDC). It is important to mention here that the natural spectral range of operation for silicon nonlinear optical devices falls within its spectral transparency window, ranging from near-infrared in the case of SHG (λ>1.2 μm), to the mid-infrared (MIR up to ~10 μm) for the SPDC of a NIR (for example 1.54 μm) pump beam.

Here we show that a sizeable second-order nonlinearity at optical wavelengths is induced in a silicon waveguide by using a stressing silicon nitride overlayer [2,3]. We carried out second-harmonic-generation experiments and first-principle calculations, which both yield large values of strain-induced bulk second-order nonlinear susceptibility, up to 40pmV-1 at a wavelength of 2300 nm. We envisage that nonlinear strained silicon could provide a competing platform for a new class of integrated light sources spanning the near- to mid-infrared spectrum from 1.2 to 10 um but as well the development of an integrated silicon optical modulator based on Pockels effect.

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On a charged particle's spin evolution induced by a strong laser

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The dynamics of a charged spin-1/2 particle in a strong monochromatic plane wave background is discussed in the semi-relativistic regime beyond the conventional dipole approximation. Within the semi-classical approach, several examples of deviations of particle's spin evolution from its non-relativistic adiabatic counterpart will be given. Among them we will analyze:

1) A spin-flipping process in a strong circularly polarized monochromatic plane when the spin-flipping transition probability has a resonant form with respect to a laser intensity;

2) Effect of non-linear dependence of a spin precession frequency on a laser intensity and polarization;

3) Appearance of the non-trivial phase of a particle’s wave function during motion in the circularly polarized laser background.

Collective spontaneous emission from ensembles of semiconductor quantum dots

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I will discuss the results of the theoretical modeling of luminescence from ensembles of self-assembled quantum dots (QDs). QDs are artificial semiconductor systems showing many atomic-like properties and allowing one to implement various concepts and procedures known from the traditional atomic quantum optics. Unlike natural atoms, they are affected by size and shape fluctuations and, therefore, show a broad distribution of their optical transition energies, well above the natural emission line width.

Our simulations are based on the Markov Master (Lindblad) equation, describing the interaction of confined carriers with the modes of the electromagnetic field, as well as on the quantum jump method, which allows us to study systems composed of a larger number of dots. I will show that the emission of light from such systems can show the effects of collective interaction of the QDs with the modes of the electromagnetic field. This can lead to experimentally observable enhanced emission from system of QDs in various arrangements [1,2] and to superradiance in the (hypothetical) case of very uniform ensembles. As a result of the inhomogeneity of transition energies, coupling between the dots plays an essential role in collective emission effects. Indeed, formation of delocalized exciton states with different strengths of the coupling to their electromagnetic environment (that is, “darker” and “brighter” ones), which underlies the collective effects in emission, critically depends on the relation between the differences in transition energies in various dots and the coupling between them [3].

In the case of dense ensembles of QDs, our modeling shows [4] that the collective character of the spontaneous emission in the presence of inter-dot coupling can indeed lead to an enhanced emission rate at weak excitation, as observed in the experiment [1]. Our results indicate, however, that the fundamental long-range (dipole) interactions via the common electromagnetic reservoir are not sufficiently strong to account for the experimentally observed effect. However, additional short-range interactions (which may arise due to a combination of tunnel coupling and Coulomb correlations) can indeed lead to faster radiative decay. Under the assumption that additional short range interactions are present, the model reproduces the observed dependence of the decay rate both on the number of emitting dots as well as on the spectral position of the detection. I will comment on the relation between the expected emission properties of a given system under weak and strong excitation (linear response vs. strong inversion regime). I will also discuss the second order correlation function $g^2(\tau)$ of the field emitted by an ensemble of QDs. I will show that signatures of correlated emission can also be found in photon-photon correlations and that the interplay of energy dispersion and coupling affects also this kind of photon statistics.

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Probablility representation of states in quantum mechanics and quantum optics

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New formulation of standard quantum mechanics is presented. It is called the probability representation of quantum mechanics. In this representation, quantum states are identified with fair probability distributions which are used instead of the wave function or density matricies. The relation to other representations used in quantum mechanics and quantum optics as well as in quantum information, where one employes the Wigner function or Husimi and Glauber-Sudarshan quasidistributions is reviewed. The probability distribution is shown to satisfy the quantum evolution equation and the equation for energy levels. These equations are new forms of the Schroedinger (von Neumann) equations related to these equations by integral Radon transform. The probability is the standard optical tomogram, which is measured in quantum optics experiments to reconstruct the Wigner function of photon states. New results like new uncertainty relations and new entropic inequalities obtained by using the probability representation of quantum mechanics and checked recently in quantum optics experiment on homodyne photon detection are discussed. Some problems of quantum mechanics foundations and their relation to classical mechanics, entanglement, and quantum correlations are reviewed.

Spectral Compression – Temporal Lensing and Fourier Conversion in Ultrafast Optics

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The concept of aberration-free time-lens, in view of its applications to ultrafast optics, laser physics and photonics, is presented. The nonlinear-optic process of temporal lensing - spectral compression of ultrashort pulses in dispersive delay line followed by single-mode fiber [1-4] is a temporal analogue of diffracted beam collimation in a light-induced lens. During the dispersive delay, the pulses are stretched and phase modulated, in analogy to beam diffraction. The further compensation of the dispersively accumulated phase-shift by means of a nonlinear process leads to the spectral narrowing: temporal lens "collimates" the radiation in time, and "focuses" the spectrum. The temporal lens, like the spatial one, has more general feature of Fourier transformation (FT), leading to the conversion of temporal information to the spectral domain. The following applications of temporal Kerr lensing are demonstrated [1]: spectral imaging of pulse temporal for direct real-time femtosecond pulse measurements and fine frequency tuning of radiation along with spectral compression [5-10], generation of dark solitons [11], nonlinear-optical filtering of radiation noise [1], the material characterization D-scan technique – in analogy of the Z-scan [12], and the femtosecond pulse undistorted delivery method [13] based on spectral compression. This approach becomes more promising by the use of similariton for inducing parabolic aberration-free temporal lens. Particularly, our recent studies permit us to develop a new method of parabolic temporal lensing / spectral compression and spectrotemporal imaging through phase addition in the sum-frequency generation process [19], instead of self- or cross-modulation by the Kerr effect [5-9]. This improvement provides the method with the two principal advantages: it becomes self-referencing and aberration free [14].

The subjects of this review are the recent experiments, carried out in our Ultrafast Optics Laboratory and supported by the concept of similariton-induced aberration free parabolic temporal lens, with the following key issues: similariton pulse compression, spectral focusing, noise suppression-filtering, chirped CARS, pulse spectro-temporal imaging, self-referencing spectral interferometry, frequency tuning - spectral control of signal etc.

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Tunneling dynamics of two-atom systems

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In this work we expand the description of tunneling of two contact interacting particles and partially fill the analytic gap between noninteracting and infinitely interacting cases for a square potential. We discuss the effect of indistinguishability and inter-particle interaction on system dynamics. The investigation is complemented by discussing the possibilities of entanglement generation in the mentioned systems.

Selective reflection of light by a vapor of alkali molecules

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We report the first observation of selective reflection of light from an interface of a dielectric window and molecular vapor of Rb_2 dimers formed in all-sapphire sealed-off rubidium vapor cell (temperature up to 520 °C, atomic and molecular densities up to 10^{18} and 3×10^{16} cm^{-3}, respectively). The selective reflection signals were recorded on various rovibronic components of $1(X)^1\Sigma^+_g$ – $1(A)^1\Sigma^+_u$ bound-bound electronic transition of Rb_2 by scanning a diode laser frequency in a spectral range of 851 – 854 nm. Only selective reflection signals corresponding to groups of several individual transitions have been recorded, which was attributed to high spectral density, large collisional broadening, and low oscillator strength of individual rovibronic transitions.

Correlations of Rydberg excitations in optically driven atomic ensembles

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Atoms in high-lying Rydberg states strongly interact with each other via long-range potentials [1,2]. These interactions translate into the level shifts of multiple Rydberg excitations which are therefore strongly suppressed. Collection of atoms within a certain "blockade" volume can then accommodate at most a single Rydberg excitation [3,4]. Perhaps counterintuitively, dephasing of atomic polarization increases the steady-state excitation probability of such a Rydberg "superatom". Larger atomic ensembles can accommodate more Rydberg excitations which effectively repel each other. The Rydberg superatoms behave as soft spheres resulting in highly sub-Poissonian probability distribution of the number of excitations. In the finite size one- and two-dimensional systems, the boundary effects mediate quasi-crystallization of Rydberg excitations [5], while the density-density correlations exhibit damped spatial oscillations. Similarly to a single superatom, dephasing and larger atom density lead to stronger density-density correlations of Rydberg excitations [6].

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Photonics technologies for surface processing: The example of cactus epilation

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Nopalea Opuntia cactus is an important food product for some countries whose demand increases in the world for its nutritional properties and reduced water consumption for cultivation. One critical operation that limits the commercialization is the manual removal of thorns. A new method that eliminates the thorns from this product by using laser pulses is presented. The pulse energy and duration were empirically determined, the key criterion being to achieve the highest ablation efficiency while causing minimal damage to the surrounding area. Both Photo-acoustic Induced by Laser Ablation (PILA) and Dynamic Reflectance were used for interactively monitoring the thorn removal process. There were demonstrated the advantages of laser process avoiding the losses caused by manual de-thorning and also the increment of product life.

Adaptive Optics in Non-Linear Microcopy

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Image quality in non-linear microscopy such as two-photon absorption fluorescence is highly dependent on the size and shape of the focal illumination volume. The signal strength is proportional to the square or even cube of the excitation intensity. To achieve the necessary temporal conditions the use of a femtosecond laser is essential. Regarding spatial requirements focusing via the objective lens has to be close to the diffraction limit. However, shortcomings in the instruments' design and construction, mismatches in refractive indices as well as scattering and absorption in the specimens can deteriorate the point spread function (PSF). Adaptive optics is a technique that can overcome some of the above mentioned problems. A wavefront manipulator – most often a deformable mirror - is capable of introducing local phase variations in the illumination beam. Selecting the phase changes (pre- aberrations) in a manner that they are compensating the phase errors along the way to the focal spot will ensure the best possible PSF 1.

Finding the correct settings for the wavefront manipulator can be based on the results of wavefront sensing or on the properties of the obtained microscope images. The former requires additional hardware such as a Shack-Hartman sensor and the possibility to generate a "guide star". In this case one is rewarded with fast and effective correction procedures. In a sensorless setup a quality criterion – for instance the overall fluorescence intensity - for the microscope images has to be defined. Iterative procedures such as "Random Search" or "Phase Diversity" are then carried out until a preset threshold has been reached.

In this paper a system for two-photon excitation and second harmonic generation microscopy in combination with an adaptive optics module will be introduced. Different adaptive optics procedures are discussed and images will be presented that show improvements in the selected feedback metric.

1. for an overview see: "Adaptive Optics for Biological Imaging" ed.: Joel A. Kubby, CRC Press, Boca Raton, 2013

Diagnostics of warm dense matter via optical properties

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Warm dense matter can now been produced readily from radiation with high power lasers like the FLASH in Hamburg or within shock wave experiments. Optical properties, in particular reflectivity, Thomson scattering, inverse bremsstrahlung, absorption and spectral line shapes are investigated since they show specific features due to the plasma environment and can thus serve as diagnostic tools. Spectral lines are shifted and broadened. Thomson scattering shows specific components depending on collective or non-collective behaviour of free charge carriers. Several experiments will be discussed using a consistently developed quantum statistical description.

Within a generalized linear response theory for systems in non-equilibrium a generalized Drude formula [1] is derived. Quantum statistical expressions for the dynamical collision frequency are given in terms of correlation functions. Analytical calculations are performed in the weak coupling region [2]. For evaluations at arbitrary coupling strength we apply MD simulation techniques [3].

Systems from bulk to reduced dimensionality are considered. Spatially resolved collective modes of laser excited electrons in clusters are discussed [4]. Emitted K-spectra of sparsely ionized radiators can be used to determine plasma parameters and fields of target regions beneath the laser created hot plasma layer [5].

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Realization of Kohn's theorem in the ellipsoidal quantum dots

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An electron gas in a strongly oblated ellipsoidal quantum dot with impenetrable walls in the presence of external magnetic field is considered. Influence of the walls of the quantum dot is assumed to be so strong in the direction of the minor axis (the *OZ* axis) that the Coulomb interaction between electrons in this direction can be neglected and considered as two-dimensional, coupled. On the basis of geometric adiabaticity we show that in the case of a few-particle gas a powerful repulsive potential of the quantum dot walls has a parabolic form and localizes the dot in the geometric center of the structure. Due to this fact, conditions occur to implement the generalized Kohn theorem for this system in the presence of external magnetic field.

EMC and optics aplications

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The presentation will show some examples of optics applications in EMC (electromagnetic compatibility) issues. In brief, EMC is the part of knowledge which ensures a collision-free (not interfering) operation of electronic / electrical equipment. Due to the purity in terms of transmission of electromagnetic waves optics is often used just to help comply with the EMC requirements. Two kinds of optics applications will be presented : as the way to provide the purity of test-beds in EMC measurements and second as the way to transmit the information, particularly to eliminate the impact of the environment exposed optical fibers on the content.

The first part will present the use of optics application in the EMC measurements. There will be shown examples of using the probes equipped with fiber optic lines on the test-beds. It will be indicated why it is so important in the EMC measurements to eliminate electromagnetic phenomena and why the optics might be the best approach.

The second part will present examples of systems using optical connection to increase the reliability and immunity to electromagnetic interference.

Based on years of National Institute of Telecommunications EMC Testing Laboratory experience there will be shown some examples of devices using optical control as the solution allowing improvement of EMC parameters. Of particular interest may be the cases of optics applications in devices working in underground mines. Basic data concerning electromagnetic environment in those mines will be presented, and it will be shown why optics "won" against traditional forms of information transfer in that environment.

Laser induced spin-orbit coupling in 2-component ultra-cold atoms

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After reviewing recent most important experimental works on laser induced spin-orbit couplings in trapped ultra-cold multicomponent gases I will present our theoretical study of the effects of the laser induced spin-orbit coupling on the ground states of 2-component alkali fermions loaded in optical lattices. I will discuss effects of unidirectional spin-orbit couplings, those that are experimantally realized already successfully and also effects of Rashba-like spin orbit couplings corresponding to non-Abelian vector potential. For repulsively interacting fermions on ladder-like optical lattice with unidirectional spin-orbit coupling along the ladder legs we identify a Neel state which is separated from rung-singlet and ferromagnetic states by quantum Ising phase transitions. These phase transition lines cross for maximal spin-orbit coupling and a direct Gaussian phase transition between rung-singlet and ferro phases is realized. For the case of Rashba-like spin-orbit coupling, besides the rung singlet phases two distinct striped ferromagnetic phases are formed.

Adiabatic description of spectral and optical characterisitics of axial-symmetric quantum dots

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Within the effective mass approximation an adiabatic description of spheroidal and dumbbell quantum dot models in the regime of strong dimensional quantization is presented using the expansion of the wave function in appropriate sets of single-parameter basis functions. The comparison is given and the peculiarities are considered for spectral and optical characteristics of the models with axially symmetric confining potentials depending on their geometric size making use of the total sets of exact and adiabatic quantum numbers in appropriate analytic approximations.

The eigenvalues and eigenfunctions of the problem, obtained in both analytical and numerical forms, were applied for the analysis of spectral and optical characteristics for ensembles of quantum dots with distributed dimensions of minor semiaxis of spheroidal quantum dots with a parabolic and non-parabolic (Kane) dispersion law in homogeneous electric fields [1–3].

The work is supported by grant RSCF (14-41-00017).

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The BRALAX project – A useful experience for career development of researchers and entrepreneurs in photonics

Luis Ponce

IPN CICATA ALTAMIRA,
BRALAX S de RL MI, Mexico

We report our experience in the development, transfer and commercialization of laser technology. The projects we included in the conference were developed through collaboration between research centers and enterprises in developing country. The Laser Lancet, a compact and low-cost laser device, can take blood samples for analysis without needles, improving and eliminating hazardous waste. The technology of high power, compact and low cost lasers, also served to develop a portable Laser Induced Breakdown Spectroscopy system that uses as pumping source laser pulses in so called "burst mode", which improves the quality of elemental detection in comparison with expensive equipment existing in the market as we show in some case-studies. Finally, we present a new photonic machine to remove Nopalea Opuntia cactus spines, a food product whose demand increases in the world for its nutritional properties and reduced water consumption for cultivation.

Oral Presentations

Design and Developing of a LabVIEW-based LED-Induced Fluorescence Spectroscopy System for Non-destructive Quality Assessment of Horticultural Products

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Over the past several years, the demand for high quality horticultural products has been remarkably increased. Thus, it is important to use non-destructive methods for product quality monitoring. Presently, spectral measuring methods such as fluorescence, transmission, remission and diffuse reflection have been investigated for fruit quality control applications. LED-induced fluorescence spectroscopy has proved its potential for non-destructive detection of some defects in agricultural products, such as tissue browning and bruising. Due to such defects, the changes in the polyphenol and chlorophyll contents are occurred which can be considered as visible marks of decreasing fruit quality. In the present work, a fluorescence spectrometer (spectrofluorometer) controlled by labVIEW software is designed and developed. The spectrometer is able to measure the fluorescence spectra directly from the fruit and vegetable surface in the desired regions. To do so, the spectrometer is equipped with a suitable fiber-optic probe. The hardware solution is based on data acquisition working on the USB platform and controlled by the application running on the PC. In the next step, by applying the fluorescence spectroscopy, the changes in chlorophyll content during shelf life are determined by using spectral analysis in the visible range. In this system the chlorophyll fluorescence is induced by a light emitting diode (LED).

New graphene based III-Nitride Schottky barrier solar cells

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Based on the ability of III-Nitride based materials and their alloys to optimally span the solar spectrum and their superior radiation resistance, solar cells based on p-type InGaN with low indium contents and interfacing with graphene film (G/ InGaN), is proposed to exploit the benefit of transparency and work function tunability of graphene. The G/p-InxGa1-xN performance can be optimized by modifying the work function of graphene and InxGa1-xN properties, accounted for by variation of its In content, doping level, and thickness.

Quasi-spin vector and geometrical optics of inhomogeneous anisotropic media

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We have systematically analyzed the spatial dynamics of the polarization state of light in smoothly inhomogeneous anisotropic media. As a medium of this kind, we have considered a nematic liquid crystal with twist orientation. The analysis is carried out both with use of a system of a coupled equations and the Poincare sphere.

A system of coupled equations has been solved with respect to the Cartesian components of the electric field component using a rotating coordinate system.

Within the limits of the given model the system of the equations describing the behavior of Stokes vector is reduced to the Bloch equations (the Bloch polarization equations), and spatial dynamics of the light polarization state is visually described on Poincare's sphere by means of a quasi-spin vector.

We have shown that, upon propagation of light in this medium, the state of the polarization experiences oscillations the spatial frequency of which depends on the thickness of the specimen. Our analysis also has shown that, at an appropriate choice of the thickness, this twist cell behaves as a broadband half wave plate.

It is necessary to underline, that the considered problem, except purely theoretical, represents also the great interest in respect of technical application for the purpose of creation of broadband achromatic polarization converters.

Study of laser beam wavefront distortion in the systems with corner cube retroreflector

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Resonators comprised corner cube retroreflectors are widely used in lasers working in visible and near IR ranges due to their high axial misalignment stability. High order odd aberrations are compensated after being reflected from corner cube retroreflector [1]. Despite of the fact, that resonators with corner cube retroreflector are stable, they have a big disadvantage. Six independent beams emerge because of the phase shift which is the result of reflection from corner cube retroreflector surfaces. Taking into account polarization states of these beams is also important. A certain polarization rotation can be achieved by means of coating the surfaces of corner cube retroreflector with specific materials [2]. Laser beam wavefront control is one of the most important problems in adaptive optics. It was shown that corner cube retroreflectors may result in the reduction of wavefront distortion. Forms of wavefronts after passing through retroreflectors with different coatings are studied and presented in this research. It was observed that compared with the case of uncoated retroreflector the distribution of beam profile is the best in the case of retroreflector with metallic and dielectric coated surfaces. The coating of surfaces changes the phases of beams, thus merging six independent beams into one. Improvement of beam energy and divergence has also been observed.

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Temperature Effects on Fidelity of Reflectivity from Bragg Mirrors

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A Bragg mirror (or distributed Bragg reflector) is an optical device which is composed of an alternating sequence of multiple layers of two different materials. Each optical layer thickness corresponds to one quarter of the wavelength that provides constructive interference of the reflected waves from the mirror layers. There thus appears a certain range of wavelengths (called the photonic stopband), within which light propagation in the mirror structure is strongly suppressed. It is why Bragg mirrors act as high-quality reflectors, so that they have a wide use in many optical devices, such as resonant cavities and interferometers.

However, in the case of the quantized electromagnetic fields the mirror reflectance, which is just related to intensities of the incident and reflected fields, cannot fully characterize the process of reflection. This is due to the fact that the interaction of the incident electromagnetic field with the mirror materials might cause a significant change in the quantum state of reflected light. Instead, the fidelity of the incident and reflected states of light that shows their quantum closeness may serve as the measure of the reflection efficiency.

The present report is aimed to investigate the influence of the thermal noise on the quantum state of reflected light from the Bragg mirror.

Our theoretical description of quantum properties of the reflected fields is based on the state transformation for dispersive and absorbing four-port devices [1]. The transformation characteristics of the Bragg mirror formed of twelve repeated layer pairs of titanium and silicon dioxides we calculate analytically using the quantum-optical input-output relations for multilayer plates [2]. Taking the incident light field in coherent and Fock states, we show that the fidelity of reflectivity turns out to be strongly dependent on the level of thermal noise and absorption of the mirror.

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Optimisation of supercontinuum generation in all-solid soft glass photonic crystal fibers with flat all-normal dispersion

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Supercontinuum generated with pump pulses at a wavelength close to the zero-dispersion wavelength of the fiber in the anomalous dispersion range based on soliton dynamics are susceptible to laser shot noise. It limits practical use in several applications where time-stable spectra are needed. An alternative approach is supercontinuum generation in a fiber that exhibits only normal dispersion, where soliton formation and broadband noise amplification by modulation instabilities is prohibited.

The all-solid microstructured fiber was engineered to achieve a normal dispersion profile flattened to within -50 to -30 ps/nm/km in the wavelength range of 1100 – 2700 nm. The fiber is made of an in-house synthesized boron-silicate glass (ITME NC21A) and a commercial N-F2 silicate glass using standard stack-and-draw technique. Optimum supercontinuum was generated in a PCF with lattice parameters of d = 2.15 µm – glass inclusion size, $d/\Lambda = 0.91$ – relative inclusion size), core diameter of 2.43 µm and lattice diagonal of 35.61 µm.

Under pumping with 75 fs pulses centered at 1550 nm, the supercontinuum spanning over an octave from 900 – 2300 nm is measured. As a pump source we used Coherent OPA 9800 optical parametric amplifier (OPA).

Numerical analysis of supercontinuum generation was performed using the model based on the numerical solution of the scalar nonlinear propagation equation. In the model we included the frequency-dependent effective mode area and fiber loss, as well as pump laser shot noise. Numerical and experimental results are in a very good agreement, except for the cladding mode peak, which was not reproduced by simulations.

Further improvement of supercontinuum is predicted for photonic crystal fibers with modified structure parameters and another pair of thermally matched soft glasses SF6 and F2.

Simulation of a vacuum-seeded linear laser accelerator

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Classic designs of electron accelerators are typically limited to electric gradients well below 100MV/m and thus require very long setups or suffer large losses through synchrotron radiation. Modern lasers however can deliver 10 GV/m or more [1] and have the potential to shorten the acceleration length by 2 orders of magnitude. While all vacuum-based laser accelerators suffer from the Lawson-Woodward Theorem, which states that a relativistic electron can not gain energy from a plane wave in an infinite vacuum [2, 3], there have been multiple attempts to circumvent this effect: One idea is to control the bounding conditions and construct inverse FELs [4] or use only the ponderomotive acceleration of a circularly polarized wave [5]. Our approach attempts to break the symmetry in electron acceleration by spawning the particles inside the laser pulse via vacuum-seeded e^+e^- pair creation. This design permits energy scaling up to the laser strength a0 squared and produces a high-energy positron jet along with the electrons. In this talk, we will shortly explain the theoretical foundations of charged particle acceleration in a vacuum, discuss the theoretical limits of our approach and show preliminary simulation results obtained with our proprietary plasma- and QED simulation suite PSC.

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Optical shaping of surface metallic micro- and nano-structures on the surface of dielectric materials: prospects of the use of non-diffracting beams

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The technique of optical shaping of surface metallic micro- and nanostructures based on processes of metal atoms adsorption on the surface of a crystalline substrate and simultaneous controllable photo-stimulated desorption of atoms by non-uniform laser beam illumination is presented. The experiments were performed for sodium atoms deposition onto the sapphire substrate. The measured absorption spectra of adsorbed atoms (adatoms), as well as spectra of photo-desorbed atoms are showed to be wide and extended from 400 to 900 nm and peaked near 589 nm of the characteristic position of the yellow doublet of free sodium atom. Due to the wide absorption spectrum of adatoms the 440 nm diode laser beam was used for photo-desorption process. The experiments were performed with evacuated and sealed off sodium cell with sapphire windows. The sapphire substrate was illuminated through the commercial linear mire with a pitch of 10 μm by 440 nm laser beam with $1 W/cm^2$ intensity. This provides the spatial distribution of the illumination intensity over the sapphire surface and optical control of sodium atoms deposition onto the sapphire substrate preventing the nucleation and growth of the granular film in the illuminated areas. Experiments showed that the mire pattern was well reproduced in the sodium deposits thus creating the microstructured metallic film with a few tens nm thickness.

The novel suggestion to use nondiffracting optical beams for high contrast microstructuring of surface metal film is presented. The formation of zeroth order nondiffracting Bessel beam with radial period of concentric rings of 10 μm with the use of an axicon was performed.

The suggested techniques open new perspective of laser structuring of the metal films with arbitrary shape and micrometric resolution. The structured metal films have a number of applications in fast and sensitive photo-detection, high performance photovoltaics, subwavelength metal gratings and polarizers, surface enhanced Raman scattering, surface second harmonic generation etc.

Impact of Structure Factor on Radiation Transfer in Structured Medium

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Radiation transfer theory is widely used for solving scattering problem in different media. Usually it operates with random structures. For structured medium, the wave interference plays a significant role, changing scattering phase functions and static structure factor. Thus, the multiply scattered radiation may obtain a complicated angle distribution. In this case radiation transfer should account the wave interference during multiple scattering. This was done via introducing the rigorously calculated scattering phase functions. In this work, the numerical algorithm, based on FDTD and Monte Carlo simulations, for calculation of the multiple scattered radiation is presented. The calculated phase functions, structure factor and scattered radiance for different structures and wavelength are shown and analyzed.

Adiabatic tracking of molecule production in Bose-Einstein condensates with Kerr terms

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Nonlinear quantum systems are at the heart of modern applications such as non-linear optics and Bose-Einstein condensation [1]. The formation of molecules from ultracold atom gases by external fields are well described by a semiclassical mean-field Gross-Pitaevskii theory [2]. We consider third-order nonlinearities, where $\Omega(t)$ is the Rabi frequency and $\Delta(t)$ is the detuning:

$$ic_{1t} = \left[-\frac{\Delta}{3} + \Lambda_{11}|c_1|^2 + \Lambda_{12}|c_2|^2\right]c_1 + \frac{\Omega}{\sqrt{2}}c_1^* c_2,$$

$$ic_{2t} = \frac{\Omega}{2\sqrt{2}}c_1 c_1 + \left[\frac{\Delta}{3} + \Lambda_{21}|c_1|^2 + \Lambda_{22}|c_2|^2\right]c_2,$$

c_1 and c_2 are the atomic- and molecular-state probability amplitudes, respectively, and Λ_{11}, $\Lambda_{12} = \Lambda_{21}$, Λ_{22} describe atom-atom, atom-molecule and molecule-molecule elastic scatterings. For the initial condition $c_2(t_0) = 0$ we obtain

$$P(t) = 2|c_2|^2 = \tanh^2\left[\int_{t_i}^{t_f} \frac{\Omega(s)}{2} \sin\alpha(s) ds\right].$$

This formula shows that there aren`t solutions leading exactly to a complete transfer for finite pulse areas, which is the same formula for $P(t)$, as in the case without Kerr terms [3].

We propose an efficient and robust adiabatic passage technique for a driven nonlinear quantum two-state system, describing the transfer from an atomic to a molecular Bose-Einstein condensate by external optical fields. We consider the influence of the third-order nonlinearities. The technique is based on the tracking of a desired solution rather than imposing the parameters. The pulse ingredients are obtained by tracking the dynamics derived from a Hamiltonian formulation, in the adiabatic limit. The efficiency of the method is demonstrated in terms of classical phase space (with the underlying fixed points and separatrices). We prove the crucial property that this nonlinear system does not have any solution leading exactly to a complete population transfer. It can only be reached asymptotically for an infinite pulse area. We show that in any case with Kerr terms we have a crossing of separatrix. However, we present that for avoiding from oscillation we need $\Omega_0 >> \Lambda_s$ in order to have a good transfer. We show illustration of the possible behaviors of the system with different parameters.

The proposed method can be applied for other types of nonlinearities or for more complicated problems, such as three-level Λ-systems with stimulated Raman processes.

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Entanglement and Quantum Coherence in Subharmonic Generation Process

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The dynamics of correlation between fluctuations of the number of photons of interacting modes is investigated for the process of intracavity subharmonic generation. It is demonstrated that this correlation strongly depends on the nonlinear mode coupling coefficient. For small values of the coupling coefficient, the correlation between fluctuations of the number of photons is small. With an increase in the coupling coefficient, the correlation increases (the state of subsystems becomes entangled) and, starting from a particular value of the coupling coefficient, starts to decrease with further increase in the coupling coefficient, gradually approaching zero (entanglement of subsystem states decreases). The quantum dynamics of the number of photons, quantum entropy, and Wigner function of the stationary state of the fundamental and subharmonic modes is investigated. It is demonstrated that the dynamics of these quantities also strongly depends on the coupling coefficient of the interacting modes. We show that, for large values of the mode coupling coefficient and long interaction times, the subharmonic mode becomes localized in a two-component state with equal probabilities of finding it in each component. Quantum entropy of this state is smaller than maximum entropy of the two-component state equal to ln2, which suggests that quantum-mechanical interference takes place between the subharmonic mode components.

Heralded source of time bin entangled single photons

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Time-bin entangled single-photons are highly demanded for long distance quantum communication. We propose a highly efficient heralded source of anti-Stokes single-photons entangled in multiple temporal modes (time bins). The source is based on the heralded creation of one atomic spin excitation followed by deterministic conversion of the latter into single anti-Stokes photon delocalized in multi-time-bins. With experimentally verified heralded creation of a single atomic spin excitation the source clearly provides high purity of single-photon states. The waveforms of anti-Stokes temporal modes are controlled by the shape of read laser pulses. A mechanism is suggested to verify experimentally the phase coherence across all time bins.

Modulated optical similaritons and self-similar rogue waves in nonlinear waveguides

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In recent years, the study of rogue waves has gained fundamental significance in nonlinear optical systems, because it opens the possibility of producing high intensity optical beams [1, 2]. We consider the beam propagation through tapered graded-index nonlinear waveguide amplifier which is governed by generalized nonlinear Schrödinger equation (GNLSE) [3]. We proposed a systematic analytical approach to control the dynamical behavior of optical similaritons and rogue waves in tapered graded-index waveguide [4]. A close inspection reveals that for long distance propagation, these waves undergo collapse [3, 4]. By adding a suitable homogeneous background in the expression for widths of the self-similar solutions which is achievable through the modulation of tapering profile, we could avert this situation, and suppress the collapse of these self-similar waves. This modification in width and tapering profiles help us to propagate the self-similar waves quite a distance stably and to control the exponential growth of background in rogue waves.

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Phonon hardening and softening in femtosecond-laser-excited metals

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Many ultrafast structural phenomena in solids at high fluences are related to changes in the phonon frequencies at lower fluences. Here we studied the response of representative phonon modes of Mg and Cu to femtosecond-laser excitation using electronic-temperature-dependent density functional theory. We found softening of some and hardening of other lattice modes, where some modes even showed both behaviors as a function of the excitation strength. We relate the laser-induced changes in the phonon frequencies to changes in the ground-state electronic density of states following atomic displacement patterns in the directions of a phonon eigenmode. Using this relationship we established a general connection between the unexcited electronic structure of a material and the structural response to intense femtosecond-laser excitation.

Cylindrical Plasmonic Microcavity and its Excitation

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Cylindrical plasmonic microcavity structure has been considered. The system consists of a cylindrically curved metallic structure placed above the flat metallic surface, supporting Surface Plasmon Polariton (SPP) propagation, and are separated by dielectric gap. The active coupling between SPP resonant modes and SPP modes propagating over the flat metallic surface has been demonstrated. The excitation efficiency dependence on structure's geometric and electrodynamics parameters of plasmonic microcavity has been investigated. The possibility of controlling (or modulating) resonant SPP modes by varying different parameters such as minimal distance d between cylindrical metallic and flat surfaces, relative permittivity ε_d of the dielectric gap, as well as working wavelengths λ has been demonstrated.

Photodynamic Ability of Silver Nanoparticles in Inducing Cytotoxic Effects in Breast and Lung Cancer Cell Lines

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Cancer is still a major health problem and the use of nanomedicine for cancer treatment has become a new focus area for research. The multifunctional effects of silver nanoparticles (AgNPs) have made these nanostructures potent compounds for biomedical applications. AgNPs were characterised by transmission electron microscopy for size, shape and cellular localisation; UV-visible spectroscopy for absorption properties and Zeta potential for determining their surface charge. Cytotoxicity effects on both MCF-7 breast and A549 lung cancer cell lines were assessed using inverted light microscopy, Trypan blue exclusion assay, Adenosine Triphosphate (ATP) luminescence and Lactate Dehydrogenase (LDH) membrane integrity assays. The cell death mechanism was determined by Annexin-V and Propidium Iodide (PI) flow cytometric analysis. The results showed that AgNPs used during the present study were found to be of spherical shapes, -0.0261 mV surface net charges with average size of 27 nm and were positively identified in both cell lines. Irradiated AgNPs promoted decreased viability and proliferation, increased cytotoxicity and induced programmed cell death through apoptosis. AgNPs exhibited photodynamic activity in both cancer cell lines but MCF-7 cells showing enhanced cytotoxic effects over the A549 cells.

Level crossing models in quantum physics

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The level-crossing is a key concept of the theory of non-adiabatic transitions well appreciated in quantum physics for a long time. Such models, both time-dependent and time-independent, have been widely studied in the context of many physical and chemical phenomena including magnetic resonance, electronic transitions in atomic and molecular collisions, laser-induced atomic dynamics, dynamics of Bose-Einstein condensates, nanophysics, quantum phase transitions, neutrino oscillations, chemical reactions, etc.

We discuss the level-crossing models for which the solution of the quantum time-dependent two-level problem is written in terms of the Heun class of mathematical functions. A useful generic feature of these models is that they suggest processes with more time scales compared with the models described by the hypergeometric equations. A representative example is the case of double crossings, when the time-separation between two crossings and the speed the system crosses a particular resonance point are controlled almost independently, by separate parameters. The same is the case when periodically repeated crossings are discussed: the coupling strength, the period of crossings and the detuning modulation amplitude are described by well identified separate parameters. Analyzing the general case of variable Rabi frequency and frequency detuning, we mention a variety of models with two crossings of the frequency resonance. These models are generated by both real and complex transformations of the independent variable. In general, the resulting detuning functions are asymmetric, the asymmetry being controlled by the parameters of the detuning modulation function. In some cases, however, the asymmetry may be additionally caused by the amplitude modulation function.

Discrete cavity solitons in dissipative photovoltaic photorefractive media

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Light propagation in a coupled optical cavities array in dissipative photovoltaic photorefractive media which has been driven by a pump field is investigated with numerical simulations. It was shown that superposition of appropriate Gaussian beam and plane wave pump field can be used to write and erase of discrete cavity solitons (DCSs) and also, the possibility of moving DCSs by inclination of pump field. We estimate maximum and minimum of velocity for DCSs in this system.

Radiation Reaction: The numerical challenge

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The current and next generation of laser facilities aim to generate peak intensities in the order of 10^{25} W/cm^2, entering a regime where the contribution of the particles' self-fields in laser-plasma interaction can no longer be neglected. The dominating effects of the self-fields are radiation reaction, Compton scattering in the laser field, and electron-positron pair production in the laser field. Our group has developed a numerical module for the Particle-In-Cell (PIC) framework PSC to incorporate these into simulations of the laser-plasma and seeded laser-vacuum interaction under such conditions. We aim to solve a system of extended Vlasov equations similar to the equations presented by Elkina et al. (PR STAB 14, 054401), which can be motivated by a semiclassical expansion of correlation functions arising from Quantum Electrodynamics in a strong external field. In the talk we will focus on the inclusion of Compton scattering. In the regime of relatively low intensities and particle energies solving these equations amounts to including classical radiation reaction. In this regime the PIC method of solving the lowest moments of an expansion of the distribution function into quasi-elements can be applied. However, in the regime of strong quantum radiation this approach fails. We will discuss the implications for the implementation of the self-field effects in a PIC code.

Recent advances in terahertz and thermal imaging

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Terahertz photonics is an emerging field that uses photonics techniques to generate and detect terahertz waves in the spectrum range from 0.1 THz to 10 THz. Photoconductive antenna (PCA) is one of the most popular techniques for such purpose. In this technique, a planar antenna is lithographically patterned on an ultra-fast photoconductive substrate such as low-temperature-grown GaAs (LTG-GaAs). These devices can work both in CW and pulse mode. In CW mode, the operation principle is based on the mixing of two CW infrared lasers in the DC biased fast photoconductive material. Due to the photomixing, a CW photocurrent is generated with the beat frequency in terahertz range. In pulsed mode, however, the absorption of a single femtosecond pulse laser in the photoconductor generates a transient pulse photocurrent. The resultant photocurrent in each case acts as the source of terahertz radiation.

In the terahertz part, we focus on the PCA technique, and introduce different structures that can be used for THz wave generation/detection. We present various simulation results for modeling PCAs made of metallic patterns as the antenna. We also explore new material systems such as graphene to be used in PCAs for increased performance.

Thermal imaging for civil applications using uncooled microbolometers has been attracted attention from many research groups around the globe. Searching for a cheap, sensitive and non-toxic system is still a challenging task. Many suppliers are now providing cameras with thermistors based on Vanadium Oxide (VOx) which is a toxic material, non-compatible with Si technology and needs a separate fabrication line. Other providers are using a-Si which is an amourphous material that results in a high noise level at low frequencies.

Here, in the second part we demonstrate the advances in thermistor and its implementation in bolometer technology.

The radiation from a longitudinal oscillator moving along a circular trajectory

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We investigate the electromagnetic fields and the radiation intensity for a charged particle moving along an arbitrary closed orbit around a dielectric cylinder immersed into a homogeneous medium. These results generalize our previous research in the special case of a circular orbit. For the latter geometry it has been shown that under certain conditions strong narrow peaks appear in the angular distribution of the radiation intensity in the exterior medium. We discuss the influence of the trajectory shift from the circular one on the characteristics of the peaks. As an application of general formulae we consider the radiation from a charged longitudinal oscillator moving along a circular trajectory. It is shown that the presence of oscillations essentially influences the radiation intensity compared with the case of synchrotron radiation.

Stability of periodic waves for the Maxwell-Bloch equations

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We discuss the stability of periodic wave solutions of the coupled Maxwell-Bloch equations. The stability of localized pulses has been also investigated and it was found that 2π - pulses are stable to longitudinal and unstable to transverse perturbations [1]. The problem in studying the stability of the periodic wave is more challenging. Using the language of quantum mechanics, one can say that the study of the stability of the localized pulse is similar to the scattering on a one-dimensional potential that vanishes as $|x| \to \infty$, while the consideration of a band spectrum is necessary for the periodic wave. The bandstructure gives the answer to a question on stability. For simplicity one can use the factorization $\upsilon(\Delta) = F(\Delta)\upsilon(0)$ to derive one equation for the envelope field $E_{\tau\tau} + \beta E + E^3/2 = 0$, where the medium polarization is given by $Nd\int g(\Delta)[u\cos(\omega t - kz + \varphi) - \upsilon\sin(\omega t - kz + \varphi)]d\Delta$, N being the density of active atoms, $g(\Delta)$ is the detuning distribution, $F(\Delta)$ is defined by the norm condition. For each type of the solution there is a determined value β. So, for $\beta = \lambda^2 - 2$ one has $E_0(\tau) = 2dn(\tau, \lambda)$, and with $\beta = 1 - 2\lambda^2$ the solution is given by $E_0(\tau) = 2\lambda cn(\tau, \lambda)$, where $dn(\tau, \lambda)$ and $cn(\tau, \lambda)$ are Jacobi elliptic functions of real elliptic modulus parameter λ. We now adopt a double decomposition whereby each variable is decomposed into the sum of a periodic component and a perturbation component $\psi(\zeta, \tau) = \Psi(\tau)\exp\left[\gamma(\tau/2 + \zeta)\right]$, where $\tau = \Omega_0(t - z/V)$, $\zeta = z\Omega_0 V^{-1}(1 - V/c)$, $\Omega_0 = d\varepsilon/\hbar$, d is a dipole moment, V is the velocity of the wave, $\Delta = (\omega_0 - \omega)/\Omega_0$ is the detuning, ω_0 is the frequency of the transition, ω is the frequency of the wave. One can verify that $\Psi(\tau)$ satisfies the Lamé equation $-\Psi_{\tau\tau} - \lambda^2\left[1 - n(n+1)sn^2(\tau, \lambda)\right]\Psi = E\Psi$, where $E = \mu^{-2} - \lambda^2 - \gamma^2/4$, $\mu^2 = \lambda^{-2}$ for dn-wave and $\mu^2 = 1$ for cn-wave. Thus, the investigation of the stability of a periodic wave is reduced to consideration of a spectrum of the operator at the left-hand side of the equation. Once the facts about the spectrum of the Lamé equation are obtained, we can get the information about the stability of the periodic wave. Therefore, for $n=1$ we get the eigenfunctions dn, cn, sn and the corresponding eigenvalues are given by $E=0$; $1-\lambda^2$; 1. As a result, for the interval $0 \le E \le 1-\lambda^2$ we have the allowed band, further, for $1-\lambda^2 < E < 1$ - the forbidden band. The next band begins from the edge of the Brillouin zone ($E=1$) and corresponds to the continuum spectrum. It is easy see that the cn-wave ($\mu^2 = 1$) is unstable to perturbations from the lowered allowed band. At the bottom of the band one has a maximum of the increment, namely $\gamma = 2\sqrt{1-\lambda^2}$. Further, moving to the edge of this band, one has the decreasing its to zero. At the other hand, the dn-wave ($\mu^2 = \lambda^{-2}$) is stable. If we assume $n=2$, then we have the allowed band for the intervals $0 \le E \le 2+\lambda^2 - 2\sqrt{1-\lambda^2+\lambda^4}$ and $1+3\lambda^2 \le E \le 4$. The continuum spectrum begins from $E = 2+\lambda^2+2\sqrt{1-\lambda^2+\lambda^4}$.

It is shown that one periodic wave is unstable while the other is stable to one-dimensional perturbations. The results are obtained using the formalism of supersymmetric quantum mechanics for one-dimensional periodic potentials [2].

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Simultaneous LIBS and Raman spectroscopy by a single laser pulse

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In this paper, a set-up for simultaneous recording Raman and LIBS, has been designed. By partially focusing the laser pulse on the sample surface, Raman scattering and atomic and ionic emissions from the plasma created on the sample were collected and recorded by an Echelle spectrograph and an ICCD detector. For low laser energy, only Raman signal appears. By increasing the laser energy above the breakdown threshold, LIBS signal is detected. Recorded spectra show a large self-reversal in main calcium lines positions. By increasing the laser energy, intensity of LIBS peaks grows exponentially, even for the self-reversed peaks.

Morphology and Size-dependent Scattering Efficiency in the Photoanode of Nanostructured Solar Cells-Theoretical Calculation

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The dye sensitized solar cell (DSSC) offers the promise of cheap solar energy and has been extensively recognized as promising alternative to conventional silicon solar cells. One of the main features of DSSCs is their nanostructured photoelectrode which provides great surface area for adsorption of dye molecules to capture the incident photons. Although this provides large surface area for dye absorption but small size of nanoparticles will be resulted in low-intensity Rayleigh back-scattering, giving low solar light capture by dye molecules. Consequently, correct optical design, include large surface area for dye adsorption and extensive light scattering, is essential to achieve high light harvesting efficiency with DSSCs. In this study, we demonstrate the strong dependence of light scattering efficiency on the morphology, size and design of photoelectrode structure. Two configurations have been considered in this regard: In the first configuration, the additional porous back-scattering layer used on the top of the common meso-porous film. This design is appropriate for DSSCs in which electron diffusion lengths are longer than the electrode thickness. In another approach, light scatterers are embedded inside mesoporous layer; operating as scattering centers. When the electron diffusion length is shorter than the electrode thickness, embedding diffuse scattering particles in the nanocrystalline paste may yield a better output. Various types of isotropic and anisotropic structures including sphere, hollow-sphere, fibre and hollow-fibres in size range of 100 nm to 900 nm have been considered. The scattering efficiency of these structures has been calculated in both configuration. According to simulation results, hollow structures such as hollow fibres and hollow spheres with thin wall thickness demonstrates much better performance in comparison to filled one. This simulation approach would be useful in the design or optimization of photoelectrode of dye or quantum dot sensitized solar cells. Based on the above results the appropriate range of size and morphology of scattering particles in accordance with the absorption spectrum of sensitizer in nanostructured solar cells can be proposed.

Digital holographic microscopy of optically trapped micro-objects

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Digital holographic microscopy (DHM) provides a noninvasive and quantitative phase contrast imaging that is suitable for high resolving investigations of living cells and their structural deformations. On the other hand, for a large class of micron-sized important objects, in particular living cells and aerosol particles, which require keeping in a liquid or gaseous environment for their normal functionality, their immobilization is a crucial task. Optical trap is an elegant approach to immobilize such samples. Integrated DHM and optical trapping (OT) setup is of particular advantage for quantitative visualization of three dimensional (3D) structures that are trapped by laser beam. Here, we discuss all possible DHM and OT integration configurations including DHM and optical fiber trap integration. To illustrate the capability of the combined setups, several validation experiments have been performed, and the results have been presented and analyzed.

Digital projection moiré as a powerful means of nondestructive analysis of advanced materials

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In this paper digital projection moiré (DPM) method is used to analyze the non-linear behavior of flexible-core sandwich materials. These cores are highly flexible with respect to the face sheets causing localized effects in displacement and stress fields. We compare the results of three-point bending with Finite Element Analysis (FEA) results that are obtained from the ABAQUS finite element model. It has been shown that DPM experimental results are in good agreement with FEA simulations.

Diode Array-Pumped Mid-infrared cw Cr^{2+}:CdSe Laser

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A room-temperature, all-solid-state, broadly tunable laser operation of Cr^{2+}-doped CdSe crystal with diode array pump source was firstly obtained. We used a conduction-cooled, single bar, fiber-coupled diode array to provide an excitation for the Cr^{2+}:CdSe crystal. This cw pump source has output power about 6 W with spectral width (FWHM) <15 nm and central wavelength of 1940 nm, which is close to the absorption maximum of Cr^{2+}:CdSe crystal. We already achieved output of 238 mW at 2.6 mkm, but we plan to reach about 0.5 – 1 W of output power.

Spectral Compression of Femtosecond Pulses: Classic, All-Fiber, and Similaritonic Techniques

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We implement femtosecond pulse spectral compression (SC) through all-fiber and classic techniques by self-phase modulation (SPM), and similaritonic technique by sum-frequency generation (SFG). The SC process [1] in the dispersive delay line followed by a single-mode fiber (SMF) has demonstrated prospective applications to the urgent problems of ultrafast optics [2]. The generation of dark solitons [3], undistorted delivery of femtosecond pulses [4], spectro-temporal imaging [5], effective CARS microscopy [6] through SC are demonstrated.

In our first experiments with the classic scheme, the spectral compressor consisted of a dispersive prism pair and a standard SMF. In this scheme, a 100 fs-pulse first passed through the prism pair gaining a negative chirp, which was afterwards compensated in the SMF through the SPM process. At the output, we had a pulse with a 12.3x SC ratio. In the second experiment with an all-fiber scheme, the prism pair was replaced with a hollow-core fiber (HCF) with anomalous dispersion at our wavelength. For optimal SC, we tuned the laser central wavelength. In this case, the SC ratio was equal to 8.4. In the third experiment with the similaritonic technique, we split the input radiation into low- and high-power parts. The low-power part passed through a prism pair, while the high-power part passed through a standard SMF, generating nonlinear-dispersive similariton with a parabolic phase [7]. Afterwards, the beams were focused on a BBO crystal for SFG, resulting in 23.3x SC.

Concluding, we have implemented femtosecond pulse spectral compression through three different techniques: classic and all-fiber by SPM, and similaritonic by SFG. We have achieved 12.3x, 8.4x, and 23.3x SC ratios for the classic, all-fiber, and SFG techniques, respectively. This work can be further developed by using HCFs with flattened dispersion, as well as by splicing the HCF and SMF.

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Effect of Rashba and Dresselhaus spin-orbit interactions on the polaron properties in wurtzite semiconductor quantum well

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Wide band gap GaN, among other group-III–nitride-based semiconductors, have provoked a lot of interest in the past few years, largely due to the good optical properties as well as great potential in optoelectronics [1]. In contrast to the zinc-blende semiconductors, the existence of hexagonal c axis in wurtzite structures leads to an added intrinsic wurtzite structure inversion asymmetry in addition to the bulk inversion asymmetry [2, 3]. Therefore, their phonon spectra becomes much more complex and the electron spin splittings include both the Dresselhaus effect (cubic in k) and Rashba effect (linear in k) [4].

We study the simultaneous effect of Rashba and Dresselhaus spin-orbit interacttions on the polaron properties in wurtzite semiconductor quantum wells. The linear and cubic contributions of the bulk Dresselhaus spin-orbit (SO) coupling and the effects of phonon confinement on electron–optical-phonon interaction Hamiltonians are taken into account. We found analytical solutions for the polaronic states as well as polaron effective mass within the range of validity of perturbation theory. It is shown that in the electron-phonon interaction and polaron mass correction are both significantly enhanced by the spin-orbit coupling. Both SO coupling terms have the same polaron binding energy, which is higher than that for systems in the absence of SO interaction. The effective mass correction is positive for the upper term and negative for the lower term.

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Acknowledgements

This work was supported by State Committee Science MES RA, Grants No. 13YR-1C0044, 13IE-038, 13-1C196, 13RE-093.

Poster Presentations

Laser spectroscopy of cesium atomic transitions in strong magnetic fields

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It has been demonstrated that the use of so called "λ/2- method" allows one to effectively investigate individual atomic levels of the D_2 line of Cs (with the most complicated spectrum among all alkali metals) in strong magnetic fields in the range of 0.5 kG - 8.5 kG. The method is based on strong narrowing of the absorption spectrum (which provides sub-Doppler resolution) of a cesium filled thin cell with the thickness L equal to a half-wavelength ($L = \lambda/2$) of the laser radiation ($\lambda = 852$ nm) resonant with the D_2 line. In particular, the λ/2 method has allowed us to resolve 16 atomic transitions (in two groups of eight atomic transitions each) and to determine their frequency positions, fixed (within each group) frequency slopes, the probability characteristics of the transitions, and other important characteristics of the hyperfine structure of Cs in the Paschen–Back (HPB) regime.

HPB regime means that in the case of an external strong magnetic fields there is decoupling of the electronic total angular momentum J and the nuclear magnetic momentum I and the atomic system is described in the uncoupled basis of J and I projections (m_J ; m_I). Possible applications are mentioned. Two theoretical models have been implemented. The values of the magnetic field have been indicated at which the models describe the experiment well.

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The polaron properties in a wurtzite nitride cylindrical quantum wire under external electric field

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The interactions between all charge carriers and phonons have an important influence on the electronic and optical properties of low-dimensional polar semiconductors. Due to the anisotropy of wurtzite crystal, the phonon modes and electron-phonon interactions in the wurtzite nitride quantum wires (QWR) are substantially different from those with cubic symmetry. The Raman scattering spectra of wurtzite GaN QWRs has also shown more complicated phonon vibration properties than those in the zinc bland planar and cylindrical heterostructures [1,2]. On the other hand, the polaron effect is one of the important issues affecting the physical properties, such as the electronic self-trapped energy and effective mass, impurity and exciton binding energies, etc., in nanostructures. These effects become more interesting in the presence of external fields.

In this work, the effect of an electric field on the polaron properties in a wurtzite nitride cylindrical QWR embedded in a nonpolar matrix is studied theoretically. In the framework of the effective mass approximation, by using the Lee, Low, and Pines variational method, the analytical expressions for the quasi-one-dimensional Fröhlich polaron self-energy and effective mass are obtained as functions of the wire radius and the strength of the electric field applied perpendicular to the wire axis. A comparative analysis of the confined and interface phonons contribution to polaron self energy and effective mass is presented. The obtained results can be taken into account in the interpretation of optical phenomena related to polaron motion in wurtzite nitride cylindrical QWR and will have significant practical consequences for optoelectronic devices, such as light-emitting diodes, laser diodes and ultraviolet photodetector designs and applications [3,4].

This work was supported by State Committee of Science MES RA, Grants No.13-1C196, 13IE-038, 13RF-093, 13YR-1C0044.

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Investigation of real-time 3D evolution of crystal structure in carbon steels using digital holographic microscopy

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The study of crystal behavior in metallic alloys, specially steels and cast irons has been of great interest to many scientists. In this paper, reflective digital holographic microscopy (rDHM) method is applied for three-dimensional visualization and measurement of deflections in crystal structure of carbon steel. The results demonstrate that digital holography is an effective technique for acquiring non-contact and high precision 3D information of the surface evolution of alloys under stresses.

Laser-induced breakdown spectroscopy for discrimination of healthy and carious teeth

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In this study, laser induced breakdown spectroscopy (LIBS) is used for qualitative analysis and also to investigate the possibility of discrimination of healthy and carious teeth. The technique of laser ablation is receiving increasing attention for applications in dentistry, specifically for the treatment of teeth (e.g. drilling of micro-holes and plaque removal). In the process of ablation a luminous micro-plasma is normally generated which may be exploited for elemental analysis via laser induced breakdown spectroscopy technique. Our results show the presence of some trace elements in teeth including P, Ca, Mg, Zn, K, Sr, C, Na, H, O and the permeability of amalgam (teeth filling materials) elements into dental matrix. The possibility of discrimination of healthy and carious teeth is examined using multivariate statistical analysis called partial least square discriminant analysis (PLS-DA) based on atomic and ionic emission lines of teeth LIBS spectra. Discrimination results are so promising and show the ability of LIBS in classification of healthy and carious teeth using PLS-DA method and its feasibility in clinical applications.

Interband absorption in pyramidal and conical quantum dots

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Problem of linear optical absorption in pyramidal and conical quantum dots has been considered. Calculations conducted based on results of [1], where the analytical expressions for electron wave function of pyramidal and conical quantum dots has been done.

We calculated absorption coefficient, the selection rules and threshold frequency of the dipole approximation.

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Spatially localized structures and oscillons in atomic Bose-Einstein condensates confined in optical lattices

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We consider the problem of formation of small-amplitude spatially localized oscillatory structures for atomic Bose-Einstein condensates confined in two- and three-dimensional optical lattices, respectively. Our approach is based on applying the regions with different signs of atomic effective masses where an atomic system exhibits effective hyperbolic dispersion within the first Brillouin zone. By using the **kp** method we have demonstrated mapping of the initial Gross-Pitaevskii equation on nonlinear Klein-Gordon and/or Ginzburg-Landau-Higgs equations, which is inherent in matter fields within ϕ^4 - field theories. Formation of breatherlike oscillating localized states – atomic oscillons - as well as kink-shaped states have been predicted in this case. Apart from classical field theories atomic field oscillons occurring in finite lattice structures possess a critical number of particles for their formation. The obtained results pave the way to simulating some analogues of fundamental cosmological processes occurring during our Universe`s evolution and to modeling nonlinear hyperbolic metamaterials with condensed matter (atomic) systems.

Wide band-gap II-VI semiconductor compounds: fabrication of nanotemplates and prospects of their application for optoelectronics and photonics

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Wide band-gap II-VI semiconductors are perspective materials to be used as the substrates for nanoporous matrices (NMs) (nanotemplates). The NMs have wide potential for fabrication of the sets of nanowires and nanotubes from various materials, as well as nanodots. These nanostructures are interesting for investigation of electrical and optical contact phenomena between nanotube materials and nanoporous semiconductor matrix. They may be used as high-efficient solar energy cells with nanostructured p-n junction, flat lenses, and elements of complex integrated circuits. The easiest and cost-effective method to obtain NMs is electrochemical etching (ECE), which, however, depends on conductive properties of the substrates.

The conditions of growth for homogeneous ZnSe, ZnS, ZnSSe, ZnCdS and ZnO single crystals with controlled electrical parameters are discussed. Possible application of corresponding substrates for preparation of NMs by ECE using various electrolytes is analyzed. The prospect of using ZnSe and ZnCdS compounds for nanopore arrays obtaining with pore diameter down to 30 nm, as well as ZnO substrates for nanodots or nanopits arrays, are demonstrated. The limitations for producing the similar structures on the basis of ZnS and ZnSSe substrates are also analyzed.

A potential application of NMs is demonstrated through the example of Pt nanotubes grown on nanostructured ZnSe substrates. The results of calculations which show that flat lenses assembled from metalized ZnSe porous structures exhibiting good focusing properties at specific photon energies, are described.

Retrieval of Aerosol Phase Function by Multi-Wavelength Bistatic Lidar

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We developed a multi-wavelength bistatic lidar for retrieval of aerosol phase function in the atmosphere of Zanjan, a city in Northwest Iran (36°40′N, 48°29′E). The lidar consists of two diode lasers of 532 nm and 650 nm wavelengths as transmitters and a digital single-lens reflex (DSLR) camera as a receiver. The irradiance of the two laser lights scattered by atmospheric molecules and aerosols are recorded by the camera at scattering angles between 137 to 179 degrees. Using the inversion algorithm the aerosol phase function is retrieved. This, in turn, determines the dominant type of foreseen aerosols, dust or urban-industrial, in the atmosphere.

Investigation of spectroscopic properties of $LiNbO_3:Ho^{3+}$crystals

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Lithium Niobate (LN) crystals have many applications in integral optics, electro-optical devices, memory devices and holography caused by well thermal and non-linear optical properties. Instead of this, LN crystals doped by rare earth (RE^{3+}) ions give the opportunity to integrate infrared laser radiation and its frequency doubling in the same element. It means, that on the basis of these crystals one can create two-wave and three-wave laser radiation element [1, 2]: Ho^{3+} ion is one of RE^{3+} ions, and its optical properties caused by electronic transitions inside of ground electronic configuration.

On this paper the Stark problem for Ho^{3+} ion ($4f^{10}$ electronic configuration) in $LiNbO_3$ crystal is solved. Main spectroscopic and kinetic parameters induced by inter Stark transitions as well the line strengths of indirect electro-dipole and magnetic dipole transitions, radiative and non-radiative lifetime of levels, cross-sections of transitions etc. are determined.

On the base of analysis of experimental and theoretical data of the main spectroscopic characteristics of $LiNbO_3:Ho^{3+}$ crystals, it has been shown it's perceptivity as a material for optical cooling devices.

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Laser Induced Breakdown Spectroscopy of metal samples with multi-pulse excitation

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A passively Q:Switched Nd:YAG laser capable to work in both single pulse and bust-mode regimes is used as excitation source for Laser Induced Breakdown Spectroscopy (LIBS) of metal samples. In burst mode the laser pulse structure consist in pulse train of two, three or four pulses. The spectra obtained in multi-pulse regime show more intense emission signal in most cases while several lines related to ionic atoms are detected only in multi-pulse regime. In principle the results confirm the advantage of multi-pulse excitation in order to enhance the LIBS resolution.

Intersubband transitions in parabolic quantum well in consideration of the interaction with impurities

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Intersubband transitions in parabolic quantum well are considered taking into account interaction with ionized impurity centers. Calculations are made on the basis of second order of perturbation theory. Matrix element of impurity scattering is obtained using Born approximation with consideration of screening potential. The expression for absorption coefficient is obtained.

Exploring the dynamical Schwinger mechanism with modern laser facilities

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Modern laser facilities like the flagship project ELI (European Extreme Light Infrastructure [1]) provide mankind with unprecedented possibilities to explore the physics of matter and vacuum in extreme external fields and to create high energy densities within smallest space-time volumina. Most spectacular fundamental physics aspects under these conditions include the study of Hawking-Unruh radiation [2] and vacuum pair creation (Schwinger mechanism) [3] in the laboratory.

We give a discussion of the dynamical Schwinger mechanism in strong laser fields in the landscape of wavelengths and field strengths provided by existing and planned laser facilities [4, 5]. Because of the time dependence of the laser fields a kinetic equation approach is developed as the adequate tool for the description of electron-positron pair creation from the vacuum, which can also be applied to similar situations which occur, e.g., in high energy physics (parton production in ultrarelativistic particle collisions from decaying color field flux tubes [6]) and in solid state physics (doublon-hole pair production in Mott insulators by laser irradiation [7]).

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Numerical Calculation of DOS in Nanograting Layers Using Method of Auxiliary Sources

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New materials are required for a new generation of energy converters and coolers. Nanostructuring allows changing material properties so that they satisfy the requirements of a particular energy conversion device. Modern solar cells comprised of semiconductor layers. Photons absorbed in these layers generate an electron hole pair. The $p-n$ junction which is formed by the thin layers separates electrons and holes and forces electrons to run through the load to perform useful work. Conversion efficiency and other parameters strongly depend on charge carrier (electron and hole) mobility in thin layers [1]. Nanograting (NG) fabricated on the surface of thin layer increases carrier mobility and improves the characteristics of solar cells [2]. Nanograting changes material properties. These changes are fully determined by the density of quantum states $\rho(E)$. Changes in itself can be described by introducing geometry factor G such that $\rho(E)=\rho_0(E)/G$ where, $\rho_0(E)$ is density of states in plain layer [3]. To calculate G Schrodinger time-independent equation should be solved in Nanograting geometry. It was one of the goals of the work to solve this problem using numerical methods. There is a full mathematical analogy between quantum billiards and electromagnetic resonators .Therefore, it is reasonable to use the Method of Auxiliary Sources (MAS) for quantum billiard calculation, as it is most efficient numerical approach for solving eigen value problems. It was one of the goals of the project to solve this problem using digital methods. Method of Auxiliary Sources (MAS) has been propoused by Georgian mathematician V. Kupradze [4]. Method was adopted by Georgian scientists for solving eigen value problems related to wave guides with arbitrary cross-section [5, 6]. In the MAS for EM boundary value problems are solved numerically by representing the electromagnetic fields in each domain of the structure by a finite linear combination of fundamental solutions of the relevant field equations, corresponding to sources situated at some distance from the boundaries of each domain. The "auxiliary sources" producing these solutions are chosen to be elementary currents/charges located on fictitious auxiliary surface, usually conforming to the actual surface of the structure. The method only requires points on the auxiliary and actual surfaces, without resorting to the detailed mesh structures as required by other methods. Finally the problem is reduced to linear system of algebraic equations. Solution of which are coefficients of the decomposition. Coefficients should be obtained by solving of the mentioned linear system where one of the coefficients is fixed. It means that the field inside area of interest becomes non-trivial only when the main parameter of the problem is near to eigenvalues and we can easily observe the forming of eigenfunctions. Intensity of the field reaches maximum on eigenvalues. We wrote our program in Fortran code. it contains two files. First part generated digital array analogous to the boundary conditions of quantum billiard and creates 100 auxiliary sources on its basis. The second part of the program sums radiation from the sources and finds wave vector value. In the case of project success, we will be able to change Si properties in such a way that high efficiency solar cells can be prepared from Si material Using interference lithography we fabricate NG on the surface of thin layers to change their electronic properties. Using these techniques, gratings with 10-nm and even sub-10 nm pitch were fabricated.

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Spectral self-compression of Femtosecond pulses

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We numerically and experimentally demonstrate the spectral self-compression of femtosecond pulses in a fiber with anomalous dispersion. The spectral compression process (SC) in a negatively dispersive medium followed by a nonlinear fiber demonstrates prospective applications in ultrafast optics and photonics [1-4]. Recently, the SC implementation directly in a fiber with negative group-velocity dispersion (at the wavelength range $\geq 1.3nm$ for standard silica fibers) was proposed [5]. In this work, we carried out detailed numerical and initial experimental studies on the process of self-SC. In our numerical experiments, we studied the pulse evolution during the propagation through a fiber with anomalous dispersion and low nonlinearity. Simulations were carried out for initial Gaussian, secant-hyperbolic and super-Gaussian pulses. The self-SC of transform-limited pulses takes place when the impact of dispersion exceeds the nonlinearity, i.e. the dispersive length in the fiber is shorter than the nonlinear length ($L_D < L_{NL}$). Roughly, first the dispersion stretches the pulse, and the chirp slope decreases along with the pulse dispersive propagation. Afterwards, the accumulated impact of nonlinear self-phase modulation cancels the dispersion-induced chirp and compresses the spectrum on longer distances. Roughly, first the dispersion stretches the pulse, and afterwards, nonlinear self-phase modulation cancels the dispersion-induced chirp and compresses the spectrum on longer distances. The efficiency of the self-SC process is increasing essentially by slightly +/- chirping the initial pulses: the self-SC ratio is increasing a few times. Our initial experiments on self-SC, for the 100-fs pulses of standard Coherent Verdi V10 – Mira 900F laser system in a hollow-core fiber (ThorLabs HCF-800) with anomalous dispersion, confirmed quantitatively the results of simulations.

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Semiconductor nanospherical heterolayer in radial electrostatic field: spectrum of charge carriers and electrooptical transitions

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The single-particle states in spherical heterostructure, which is placed in the radial static electric field, are considered theoretically. The system under investigation is presented in the form of a spherical nanocomposition core/layer/shell. Source of radial electrostatic field is in the center of the system. Using the WKB (Wentzel-Kramers-Brillouin) method, the analytical expressions for definition of energy spectrum of charge carriers in the quantum well of layer (in the regime of strong quantization) are obtained. The magnitude of this shift is determined by the external field, the geometrical dimensions of the sample, as well as the value of the effective mass of the charge carrier. Particularly, with increasing of external field the position of size-quantization energy levels shifted upward.

The explicit analytical expressions for envelope wave functions of single-particle states in the layer in the presence of radial electric field are obtained also. Depending on the geometrical sizes of the sample for the external field found the corresponding characteristic limit values. When the value of the field is greater than these values, the particle begins to move in the well created in the layer by the external field. External field also leads to spatial separation of opposite charge carriers in the layer. This separation reduces the probability of electron-hole recombination in the layer.

The paper discusses also the interband optical transitions in the presence of a radial electric field. With the increase of the field the intensity of the absorption decreases. This is a consequence of the spatial separation of opposite charge carriers. The paper discusses also the interband optical transitions presence of a radial electric field. With the increasing of external field the intensity of absorption decreases. This is a consequence of the spatial separation of opposite charge carriers. Presence of the field leads to an effective reduction of the bandgap. Accordingly, the shift of the threshold frequencies of absorption in the long wavelength region takes place.

Multiphoton blockade in pulsed regime

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We demonstrate multiphoton blockades (PB) in the pulsed regime by using Kerr nonlinear dissipative resonator driven by a sequence of Gaussian pulses. It is shown that the results obtained for single-photon, two-photon and three-photon blockades in the pulsed excitation regime differ considerably from analogous results obtained for the case of continuous-wave (cw) driving[1]. We strongly demonstrate that for the case of continuous-wave pumping of the Kerr-nonlinear resonator there are fundamental limits on populations of lower photonic number-states (with n=0, 1, 2, 3).

Thus, such detailed comparison demonstrates that PB due to excitation with a suitable photon pulses is realized beyond the fundamental limits established for cw excitations. We analyze photon-number effects and investigate phase-space properties of PB on the base of photon number populations, the second-order correlation functions and the Wigner functions in phase space. Generation of Fock states due to PB in the pulsed regime is analysed in details.

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Composition, optical and electrical properties of lanthanum oxide films

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The La_2O_3 films are promising oxide for integration into future non-volatile memories due to the high dielectric constant (20-27) compared to widely used oxides, such as SiO_2, HfO_2, Al_2O_3, etc. We have studied the composition and optical properties of 40-540 nm thick lanthanum oxide films deposited on n-Si and SiO_2 substrates by e-beam evaporation technique. The oxide films have been found to have high transmission (~ 90 %) in the visible wavelength region with some interference fringes and sharp ultraviolet absorption edge. The energy band gap (5.8-6.2 eV) has been evaluated from the film absorption spectra depending on the film thickness, annealing temperature and film composition. The refractive index of 1.69 at 600 nm was obtained. The dielectric constant, capacitance-voltage and current-voltage characteristics of $Al/La_2O_3/Si$ structures were measured. Negative conductivity has been observed for as-deposited films at 1 kHz in the voltage range 2-4 V. The mechanism of negative conductivity of La_2O_3 films are analyzed and discussed.

Designing 2D optical tweezers array with a single laser beam using 1D defective photonic crystals

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In this work we introduce a 1D photonic crystal with a special graded index defect layer with the structure of $(AB)^4C(AB)^4$. Here, A and B are magnesium fluoride with $n_A = 1.38$ and zinc selenid with $n_B = 2.6$, respectively. C stands for the defect layer. The refractive index distribution function of the proposed defect layer in Cartesian coordinate $(x-y)$ is $n_C = n_0[1 + a[\sin^2(\pi x / x_0)\sin^2(\pi y / y_0)]]$, where n_0 is the background refractive index and x_0, y_0 and a are constants.

Using the transfer matrix method, the properties of the structure is investigated. The results are predictable considering the Bragg condition and destructive interference, which are the origins of the photonic band gap. On the output plane, the irradiance and phase of the incident beam redistribute and 2D optical tweezers array can be generated. We have implemented a $m \times m$ array of optical tweezers. It is possible to change m by changing some parameters of the introduced structure.

The generated optical tweezers array can have different applications in areas of optical trapping, laser beam array, quantum communication, fabricating nanocomposite materials and especially in microfluidic devices. Simultaneous translation of trapped particles, sorting small populations of cells in a lab-on-a-chip environment are some of the introduced tweezers critical applications in biology.

Dynamical Schwinger effect: Properties of the e+e- plasma created from vacuum in strong laser fields

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The topic of our study is particle production in the presence of external fields. We are especially interested in the dynamical Schwinger effect. This phenomenon takes place when fields change with time. The kinetic approach is necessary to fully understand the influence of such time-dependent fields. In the case of QED one can study the distribution function of e+e- pairs (or other charged particles). The study of the dynamical Schwinger effect is becoming increasingly important because of the advent of ELI and XFEL experiments. We started research of particle production in the framework of QED. On the basis of those studies we solved numerically a Boltzmann equation with non-Markovian source term for the e+e- distribution function in a time-dependent external field.

Fiber Delivery of Sub-20 fs Nanojoule Pulses with a Grism-based Dispersive Line

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For femtosecond pulse delivery, a compact stretcher, which consists of a pair of grisms, and large mode area fiber compressor, is proposed and experimented. The delivery of 17.8 fs nanojoule pulse through 2.7 m large mode area fiber, by relevant pre-chirping the pulses at the entrance, is experimentally demonstrated. Pre-dispersing technique for pulse fiber delivery is developed, using large mode area fiber (LMA) and grism line. Simultaneous control of second- and third-order dispersion (SOD and TOD) is realized by a compact grism line. The grism-pair stretcher is composed of two identical grisms each of them being the assembly of a diffraction grating in close contact with a prism. A grism-based stretcher has a negative SOD and its TOD can be set negative too providing suitable conditions for LMA fiber dispersion cancellation at 800 nm. Inside a grism-pair stretcher there exist enough geometrical freedom degrees to adjust the SOD and TOD continuously and simultaneously at desired values. We used also conventional polarization maintaining single mode fiber to compare with LMA. For both fibers we adjusted the distance between the grisms to produce the shortest possible output pulses. Under similar conditions, a standard SMF delivers pulses about 10 fs longer than those delivered by LMA.

Carrier localization, Anderson transitions and stripe formation in hole-doped cuprates

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Understanding the mechanisms of carrier localization and metal-insulator transitions (MITs) in doped semiconductors and insulators remains one of central problems in condensed matter physics. As is well known, the physical properties of the doped copper oxide (cuprate) high-T_c superconductors are very complex and significantly different from those of conventional metals and semiconductors [1-10]. It is widely believed that phenomena of high-T_c superconductivity and MIT in doped cuprates are closely related and the elucidation of the mechanisms of metal-insulator transitions (MITs) in these materials may shed important light on the origin of high-T_c superconductivity [5,7,9]. In this connection, questions concerning mechanisms of the carrier localization and MITs in hole-doped cuprates have received considerable attention for the last two decades [1-9, 11-14]. Despite much theoretical and experimental efforts [2-9, 11-14], the mechanisms of the MITs in the doped cuprates still remain poorly understood. Mott [1] has pointed out that the MIT in these materials is of Anderson type, similar in some respects to that which occurs in silicon doped with boron. However, the questions of the criterion for the Anderson transition and the applicability of the Anderson's theory of MIT to hole-doped cuprates are still not settled [1,5,6,11,12]. Many theoretical works have been carried out so far, but they have not yet reached any conclusive understanding on the quantitative criterion for the Anderson transition (i.e., on the critical value of the ratio V_0/W, where V_0 is a random potential or the disorder parameter, W is the bandwidth of the energy bands of dopants or impurities). Since the magnitude of the random potential V_0 depending on physical parameters of the material and dopants, and on degree of randomness in dopant (or impurity) distribution (e.g. formation of the different clusters of dopants or impurities) remains unknown. Therefore, determination of the possible criteria for the Anderson transition and the possibility of the disorder-induced MITs in the doped cuprates requires further theoretical studies using the new ideas.

In this work, we study theoretically possible mechanisms of carrier localization, metal–insulator transitions (MITs) and stripe formation in hole-doped cuprates. Three distinctly different scenarios are proposed for the carrier localization in three-dimensional (3D) lightly doped cuprates. The binding energies and radii of the extrinsic and intrinsic large (bi)polarons in cuprates are calculated variationally using the continuum model and adiabatic approximation. We have shown that the extrinsic and intrinsic 3D large bipolarons exist in lightly doped cuprates at $\eta = \varepsilon_\infty/\varepsilon_0 < 0.127$ and $\eta < 0.138$, respectively, where $\varepsilon_\infty(\varepsilon_0)$ is the optic (static) dielectric constant. While the optical bipolarons can exist if $\eta < 0.134$ and the Fröhlich coupling constants α are greater than 5.8. The dopant- and carrier-driven inhomogeneities favor the specific charge ordering in the form of a 3D network of carrier-rich and carrier-poor stripes and the formation of different superlattices and in-gap bands of dopants and large polarons. The localized in-gap states develop into metallic states at some critical doping levels. We use the uncertainty relation to obtain the specific conditions for the Anderson and new MITs in cuprates. The applicability limits of these MITs in cuprates are clarified. We argue that the new MITs in the cuprates caused by the strong carrier–defect–phonon and carrier–phonon interactions are accompanied by the formation of a 3D self-organized network of carrier-poor (insulating) and carrier-rich (metallic) stripes, which coexist in a wide range of doping $x \approx 0.02$-0.20, and the suppression of superconductivity observed in underdoped region near the $x = 1/8$ is caused by the formation of insulating stripes on a global scale and by the preponderance of insulating phase compared with the metallic one. Our results are in good agreement with the existing experiments on *La*-based and other cuprates.

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Influence of pump duty cycle on efficiency of green microchip laser

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Green microchip lasers are compact and powerful source of green light (at 532nm wavelength). Cavity of the laser is composed of two plane-parallel components. The first component is an active medium ($Nd^{3+}:YVO_4$) and second component is nonlinear crystal (periodically polled $LiNbO_3$ - PPLN).

This investigation is aimed to find an optimal duty cycle (DC) of pump for the output efficiency. For this purpose output power of the green light was measured versus pump DC for three different microchip lasers in the range of 20-80% with the same pump laser diode. In the experiment pump beam waist, temperature of the cavity and pump peak current were kept constant.

Temperature was set to the optimal phase matching temperature of the PPLN and was kept constant with the precision of 0.1^{o}C. Pump peak current was kept at 1300mA with the precision of 5mA.

In the experiments, output power is higher for higher DC's when peak power is kept constant, which is reasonable result because increasing DC leads to higher average pump power. But in case of efficiency we have quite different picture. One can conclude from the experiments that the efficiency is has a maximum around 50% DC.

In sum, it has been experimentally shown that maximal efficiency of the green microchip laser is obtained at the 50% DC when all other parameters are kept constant.

Spectral compression of randomly modulated pulses

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We report on the study of spectral compression (SC) of randomly modulated optical signals. Recent advance in ultrafast laser physics, photonics and optical communication transfers the noise filtering problem from radio-physics to optics, making urgent the study of interaction and self-interaction of randomly modulated signals. The SC process, based on nonlinear interaction / self-interaction of pulses initially stretched and chirped in a dispersive medium [1], is of special interest from this point of view [2]. Our numerical study is based on the mathematical description of the process through the nonlinear Schrödinger equation, considering the second-order dispersion and Kerr nonlinearity. We use the split-step Fourier method during the numerical solution of equation, with the fast Fourier transform algorithm on the dispersive step. As initial conditions for equation, we use the model of additive noise [3]. The sampling of a large number of realizations (~100) allows us to determine the statistical parameters of the output signals with high precision. The studies are carried out for signals with different coherence time. The results of studies clearly demonstrate the prospects of the SC process for applications in photonics and optical communication for nonlinear noise filtering.

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Thermoelectric single-photon detector for quantum optics applications

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Cryogenic thermoelectric single-photon detectors (TSPD) are one of the emerging techniques for fast single-photon counting. Single-photon detectors are required for research in different areas of modern science, particularly in space astronomy, high energy physics, quantum computing and quantum cryptography.

The principle of operation of the TSPD is simple. Sensor of a TSPD consists of two absorbers and a connecting thermoelectric bridge. When one of the absorbers absorbs a photon, its temperature increases by an amount proportional to the energy of the absorbed photon. The resulting temperature difference between the ends of the thermoelectric bridge δT creates a potential difference ΔU. We can measure ΔU with great precision and thus register an absorbed photon and determine its energy.

The results of modeling of kinetic processes in the TSPD sensor for the cases of 100 and 110 eV photons absorption on various areas of absorber are presented in the present work. The absorber is tungsten, the thermoelectric bridge is $(La,Ce)B_6$. The beginning of the process is very different in the case when the photon is absorbed in the immediate vicinity from the bridge. However, when t=20 ps (t – time after photon absorption), the temperature difference between the ends of the thermoelectric bridge is practically independent from the position of the photon absorption point. At t = 100 ps the signal difference at a photon energy of 100 eV and 110 eV is about 10^{-5} K.

Detection of CO_2 laser radiation in a ferrite

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Properties of ferromagnets, due to the nonlinearity of the magnetic susceptibility of the medium in the low-frequency and microwave electromagnetic fields have been well investigated [1,2]. These phenomena have great practical and scientific value in the areas of signal detection, frequency conversion, etc.

It is well known that there are different ferromagnetic materials transparent within infrared and visible range, which are successfully used for radiation control [2,3]. Particularly there is lot of ferrites, transparent in the far infrared range.

It was also reported about the optical detection, obtained as a result of nonlinear interaction of infrared radiation in transparent ferromagnetic crystals [4].

In this paper we have experimentally investigated the detection ability of far infrared laser radiation in magnetized ferrite, when magnetic field of incident laser radiation excites the magnetic moment of ferrite.

Commercial NM2000 ferrite was used, which has transparency window in the far infrared range. The continuously operated CO_2 laser ($\lambda \sim 10$ μm) with a mechanical modulator chopper was used as a linearly polarized radiation source with CW power approx. 15 W.

The absorption coefficient of ferrite sample in the range $\lambda \sim 10$ μm was $\sim 16 cm^{-1}$.

In the absence of an external magnetic field, detected signal disappears. Signal reaches the maximum value in the region of maximum change of magnetization curve's slope. The reversing of the external magnetic field changes the sign of detected signal.

It should be noted that nonlinear interaction of laser radiation with ferromagnets can find practical application in frequency conversion of laser radiation, recording and storage of information, etc.

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Tuning of Exciton States in a Magnetic Quantum Ring

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We have investigated the exciton states in a CdTe quantum ring in an external magnetic field, containing a single magnetic impurity. We have used the multiband approximation which includes the heavy hole - light hole coupling effects. The electron-hole spin interactions and the s,p-d interactions between the electron, hole and the magnetic impurity are also included. The exciton energy levels and optical transitions are evaluated using the exact diagonalization scheme. We show that due to the spin interactions it is possible to change the bright exciton state into the dark state and vice versa with the help of a magnetic field. We propose a new route to experimentally estimate the s,p-d spin interaction constants.

Light propagation in cycloidal diffractive waveplate placed between crossed polarizers

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The propagation of electromagnetic radiation through a slowly twisting anisotropic medium is described by Jones matrix method. The transmission of light through a twisted nematic liquid crystal is a typical example [1]. We study the system of two cycloidal diffractive waveplate (CDW) with twist orientations in the direction perpendicular to the plate walls [2]. We theoretically study the achromatic CDW with twisted orientation placed between crossed polarizers we also calculate diffraction efficiency of waveplate we also calculate diffraction efficiency of waveplate. Our study proves that there is a strong agreement between our theoretical model and previously done experiments.

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Electromagnetically-induced transparency and modification of group-velocity of light in media of multilevel systems

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Coherent interaction of light signals with quantum systems have been attracting considerable interest for their importance in both fundamental science and practical applications. A prominent example of coherent interactions is electromagnetically induced transparency (EIT) [1], which can be used to eliminate the resonant absorption of a laser beam incident upon a coherently dressed medium with appropriate energy levels. Using EIT techniques, one may greatly slow down the moving optical pulses [2] and even stop them to attain reversible storage and retrieval of light signals [3]. One EIT prototype is a three-level Lambda system driven by a weak probe field and a strong coupling field both in the traveling-wave configuration. Despite a huge number of publications, concerning EIT, study of this effect and of its applications in multilevel systems is limited to only a few works (e.g. [4]). In the present report, we propose a novel scheme of interaction of a five-level system with the field of three laser pulses where the phenomenon of EIT can be observed. We obtain for media of such systems analytical expressions for the susceptibility, linear in the probe field, and study in detail the possibility of light slowing down in these media. We analyse the advantages of proposed scheme as compared to those available in literature. For numerical calculations, we use parameters corresponding to D_2 line of ^{87}Rb. It is shown that obtained results may be employed for repeated storage of optical information.

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Study of growth rate in coiled myelin figures using digital holographic microscopy

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Myelin figures (MFs) are micron-sized cylindrical structures that develop at the interface between water and the concentrated lamellar phase of certain surfactants. Because of minimizing energy the myelin figures come in various forms after formation that are called Coiling. In this paper, we use Digital holographic microscopy (DHM) technique to investigate the coiling phenomenon in MFs. DHM provide three dimensional information on the morphology and growth rate of MFs, by deriving phase information from the interference pattern between light wave passing through the sample and a reference wave. The method yields precise and more reliable values of growth rate of the coiled MFs, with respect to conventional microscopy techniques.

Effect of Interdiffusion on Non-Linear Intraband Light Absorption in Gaussian-Shaped Double Quantum Rings

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Quantum rings (QR) present the opportunity to realize advanced optoelectronic devices, such as photodetectors and lasers due to their unique properties [1]. The potential application in nano-devises has given rise to theoretical investigation and prediction of optoelectronic properties of QRs taking into account the influences of spin-orbit coupling, hydrostatic pressure etc. [2]. Strain-free double quantum ring (SFDQR) solar cells were fabricated by droplet epitaxy in [3]. The shape of the fabricated SFDQRs is very similar to the shape of two shifted Gaussians. Rapid thermal annealing (RTA) was used to improve the optical quality of the solar cells and mainly leads to the interdiffusion of heterostructure compound materials.

In the present work the effects of interdiffusion and variations of Gaussian parameters' values on electronic states and non-linear intraband absorption coefficient in Gaussian-shaped DQR structure are investigated. The obtained results indicate to the opportunity of purposeful manipulation of the optical properties of DQRs by means of RTA and Gaussian parameters.

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Modeling of Radiation Transfer in Partially-Ordered Stratified Media Using Monte Carlo Methods

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This work includes the results of radiation scattering investigation in partially-ordered stratified media. The used method for numerical experiments was based on computational electrodynamics and Monte Carlo simulations. The method allows determining of the differential and integral cross sections and scattering phase functions of stratified layers and scattered radiance. Two different cases were compared: first – Monte Carlo simulations of radiation transfer through double-layer medium using the Henyey-Greenstein scattering function and second – using the real scattering function for group of scatterers. A comparative analysis of the obtained results was done. The significant differences were observed for the considered cases. The experimental set-up and the results of experimental measurements are presented.

Sensing of the sub-surface ordered molecular layers at liquid-metal interface by the coupled waveguide optical modes

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The possibility of the formation of the ordered molecular layers at liquid/metal interface due to coupled waveguide optical modes is considered. These ordered molecular layers changed the optical power transmitted through the conical waveguide which can be detected by photo receiver. The results can be used to investigate the properties of the dielectric thin layers formatted in sub-surface region at liquid/metal interface.

Copper oxides as perspective material for solar cells application

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In search of new and alternative energy sources, solar cells gained a great interest as the most appropriate choice for the creation of clean and efficient energy sources. The high costs of solar cells produced today are determined by cost of used materials, particularly silicon and gallium arsenide. Recently, a special interest of researchers is related with the use of chalcogenide compounds CuIn(Ga)Se2. It is known, that the properties of solar cells based on them strongly depend from the stoichiometric composition, defect chemistry and crystal structure. For this purpose the researchers focused on the development and investigation of new materials. The choice of cooper oxide is driven by the following advantages: widespread in nature, low cost, non-toxicity, high thermal conductivity, high optical absorption coefficient and resistance to overheating [1-3]. They can be prepared with simple methods at very low cost. CuO and Cu_2O are p-type semiconductors with band gaps of ~ 1.5 eV and ~ 2.0 eV, respectively, which are close to the ideal energy gap for solar cells and allows for good solar spectral absorption due to these direct band gaps. However, the efficiency of solar cells based on Cu_2O today is 3.8 %, much lower than the theoretical - 20% [4,5]. In this connection, scientists worldwide are focused on the creating of nanomaterials with controlled size and morphology, among which the copper oxide nanoparticles attract a great interest [1,3,6]. Laser treatment can provide a modification of the synthesized particles, in particular, reducing their size, a change in the structure and phase composition. Thus, the principal possibility is being determined by the surface nanostructuring of laser processed material [7].

In this paper we discuss the results of the surface modification of single crystals and thin films of CuO under the influence of nanosecond pulse of YAG: Nd^{3+} laser at a wavelength of 355 nm in air and in vacuum. Single-crystal CuO samples were coated with a thin film of copper (750nm) by thermal evaporation in a vacuum. The film thickness was measured by stylus profilometer AMBIOS XP-1 with resolution of 1, 5 Å. The surface morphology of obtained samples has been investigated by the scanning electron microscope VEGA TS5130MM and the X-ray microanalysis was performed by the INCA Energy 300 microanalysis system. Electrical conductivity and structural properties have been investigated, calculation of the activation energy was carried out. The results will be used to further search the synthesis conditions and laser treatment of copper oxides thin films with optimal electrical, optical and structural properties for use as photovoltaic material.

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Study of Plasma Intensity enhancement mechanism in collinear configuration of Double pulse Laser-Induced Breakdown Spectroscopy

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Double pulse Laser-Induced Breakdown Spectroscopy (DP-LIBS) technique significantly indicates increasing for plasma intensity of various spectral emission lines Compared to single-pulse scheme. This method are used the various of configurations .In this paper collinear configuration of Double pulse laser induced breakdown spectroscopy was studied on aluminum sample at atmospheric pressure in air. For this configuration, effect of the delay between the two laser pulses on signal enhancement for various spectral lines was investigated and the optimal interval the influence of the delay between the two laser pulses were determined. Moreover, some of the basic hypotheses that is mentioned as the main cause of increase in the radiation intensity such as Change in the mechanism of ablation, ambient pressure reduction and increasing plasma temperature has been studied. Our results demonstrate that the electron temperature and Rate of mass removal for double pulses is higher than that for single pulse of the same total energy.

Induced rotation in a freely suspended 5CB liquid crystal (LC) films by crossed electric fields

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In this paper, the induced rotation by an orthogonal electric current and external electric field in freely suspended liquid crystal (LC) is studied. The LC (4-Cyano-4-n-pentylbiphenyl,5CB) films begin to rotate when the external field and the electric current reach a threshold value. The size and direction of the rotation can be controlled by controlling the size and direction of the electric fields. Moreover, the colored patterns in polarized light illumination experiments in rotating LCs have been investigated.

The electrical field created by the electron in layered cylindrical quantum dots in the presence of uniform magnetic field

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Field created by the electron in quantum dots (QD) is the subject of a detailed research, because these results are directly applied in single-electron transistors. It is important to note that various multipole contributions of electrostatic field created by the electron in QD can be controlled by changing the geometrical parameters of QD, and with the influence of fields. In this work the dipole and quadrupole moments created by the electron in quantum dots with the cylindrical symmetry are investigated. The influence of magnetic field is discussed. Based on the obtained results the potential of the electrostatic field, created by the electron in the system is determined. The dependences of potential on geometric parameters of QD are discussed from the figures, obtained by numerical calculations.

Design and construction of a test instrument based on Hartmann sensor for measuring the figure error of a concave optical surface with large F-number of about 50

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An instrument has been designed and constructed to test a concave optical surface with a radius of curvature and diameter of 10.3 meter and 190mm respectively, using a Hartmann wavefront sensor. The Hartmann mask is consist of an array of 100×100 apertures of 148 µm in diameter that is placed in front of a CMOS chip of a digital SLR camera. Testing of large f-number concave surface is too sensitive to alignment of the optical axes and aperture of the test surface with that of the instrument and Hartmann sensor respectively. A technique is presented to simplify the alignment of the test surface.

Excitonic states and optical properties for quantum dots with different confining potentials

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In this paper we consider different confining potential for quantum nanostructures, especially quantum dots with spherical and cylindrical symmetry. There is a two three models for confining potential: modified Pöschel-Teller, Mors and parabolic potentials. For strong and weak size quantization regimes analytical expressions for the particle energy spectrum and dependencies of effective threshold frequencies of absorption on the geometrical parameters of quantum dot are obtained. And we have considered the boundary conditions for effect of the quantum emission. For the intermediate size quantization regime the problem solved in the framework of variation method. The selection rules corresponding to different transitions between quantum levels are found. The size dispersion distribution of growing quantum dots by the radius by three experimentally realizing distribution functions have been taken into account. Distribution functions of Gauss, Lifshits-Slezov and Erlang have been considered

Formation of large area regular nanostructures by holographic lithography technique

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Advanced technology today is clearly moving towards direction of scaling down things to ever smaller dimensions. Trend once started by IC industry now is expanding into other areas e.g. photonics, MEMS, fluidics, sensors, etc. For that reason there is immense demand for techniques capable of producing nanoscale structures in a cheap and efficient way. Holographic lithography (HL) is emerging as a very promising, powerful and cost effective technique for surface patterning, among them. Off course as all techniques this one has it's limitations too. The biggest is that only periodic patterns can be produced but despite this drawback HL has been shown to be applicable for structuring photonic crystals, nanowires, porous membranes, magnetic dots, etc. In this work 1D and 2D periodic nanosuctures in thin positive and negative tone photoresist layers spin coated on silicon substrates were fabricated employing our custom designed, advanced, fully automated UV holographic lithography system based on Lloyd‘s mirror geometry. Regular structures with periodicities of 200 - 400 nm and with different point lattice symmetries were fabricated and investigated. Possibility to use such structures for refractive index sensing was examined.

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«ОПТИКА И ЕЕ ПРИЛОЖЕНИЯ»

Информация о симпозиуме и Тезисы докладов

Под редакцией Нарине Геворгян

Главный редактор Издательства – **М.Э. Авакян**
Компьютерная верстка – **Н.Т. Геворгян, М.Л. Григорян**

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тел./факс: (+374 10) 27-70-52 (внутр. 112)
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Заказ № 8
Подписано к печати 25.08.2014г.
Формат 60x84 1/16. Бумага офсетная № 1.
Объем 9.4 усл. п.л. Тираж 200 экз.
Отпечатано в типографии: «Пайлун»
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