ARMENIA IN FOCUS SPIE.

Dedicated to the
100th Anniversary of the Optical Society
10th Anniversary of the Armenian SPIE Student Chapter
5th Anniversary of the Armenian Territorial Committee of ICO

Symposium Information & BOOK of ABSTRACTS

4th International Symposium

Optics & its applications

25-28 July, 2016, Yerevan - Ashtarak, Armenia

ՀԱՅ-ՌՈՒՍԱԿԱՆ (ՍԼԱՎՈՆԱԿԱՆ)
ՀԱՄԱԼՍԱՐԱՆ

Միջազգային սիմպոզիում

«ՕՊՏԻԿԱՆ ԵՎ ՆՐԱ ԿԻՐԱՌՈՒԹՅՈՒՆՆԵՐԸ»

25-28 հուլիս, 2016
Երևան, Հայաստան

Տեղեկություն սիմպոզիումի վերաբերյալ և զեկուցումների թեզերը

ԵՐԵՎԱՆ
ՀՌՀ ՀՐԱՏԱՐԱԿՉՈՒԹՅՈՒՆ
2016

РОССИЙСКО-АРМЯНСКИЙ (СЛАВЯНСКИЙ) УНИВЕРСИТЕТ

Международный симпозиум

«ОПТИКА И ЕЕ ПРИЛОЖЕНИЯ»

25-28 июль, 2016
Ереван, Армения

Информация о симпозиуме и Тезисы докладов

ЕРЕВАН
ИЗДАТЕЛЬСТВО РАУ
2016

UDC 535:06

Optics & its Applications: Symposium Information & Book of Abstracts of the Armenia in FOCUS SPIE: 4th International Symposium (Armenia, 25-28 July, 2016). – Yerevan, 2016 – 156 p.

The book includes the abstracts of reports submitted to the Armenia in FOCUS SPIE: 4th International Symposium “Optics & its Applications” (OPTICS-2016). Abstracts printed as presented by authors. Full texts of the reports selected by the Program Committee of the Symposium will be published in the Journal of Nanophotonics Special Section: Optics, Nanophotonics and its Applications.

The Book of Abstracts of the Armenia in FOCUS SPIE: 4th International Symposium «Optics & its Applications» is issued by decisions of Scientific Council of the Organizing Committee of OPTICS-2016, and Publishing Council of Russian-Armenian University (session of Council, July 11, 2016).

Edited by **Narine Gevorgyan** (RAU, Armenia)

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Foreword

It is our great pleasure and honor to welcome you to the Armenia in FOCUS SPIE: 4th International Symposium "Optics & its Applications" (OPTICS-2016) in Yerevan, Armenia, July 25-28, 2016. This event is dedicated to three anniversaries: the 100th anniversary of OSA, the 10th anniversary of the Armenian SPIE Student Chapter, and the 5th Anniversary of the Armenian Territorial Committee of ICO.

Our main organizer is SPIE under the Federation of Optics College and University Students (FOCUS) conference grant, and we proudly mention that this is the second time we can announce: Armenia in FOCUS SPIE!

We gratefully acknowledge this support as well as contributions from other organisations: the Optical Society (OSA), The International Commission for Optics (ICO), the State Committee of Science of the Republic of Armenia (SCS), the Russian-Armenian University (RAU), the Greek-Armenian industrial company LT-Pyrkal, the Institute for Physical Research of the National Academy of Sciences (IPR of NAS), and the University of Wroclaw.

The objective of this 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 a researcher. A special lecture is devoted to the topic of career development.

In this Abstract booklet you shall find not only the information about the invited and contributed talks as well as poster presentations. We give also a short summary on the co-organizing institutions, their history and goals as well as the events which will take place during the Symposium.

The Symposium will host 124 scientists from 19 countries namely: Armenia, Australia, Belarus, Canada, France, Georgia, Germany, India, Iran, Israel, Italy, Latvia, Malaysia, Moldova, Poland, Romania, Russia, Ukraine and USA.

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,
Directors of OPTICS-2016

ORGANIZING COMMITTEE

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LT-Pyrkal, Armenia

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SPbPU, Russia

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Organizing Centers

- ✓ SPIE YSU & NAS student chapter
- ✓ Armenian TC of ICO
- ✓ Russian-Armenian (Slavonic) University
- ✓ Greek-Armenian industrial company LT-PYRKAL
- ✓ Institute for Physical Research of National Academy of Sciences of Armenia
- ✓ Faculty of Physics of Yerevan State University
- ✓ University of Wroclaw

Co-organizing student chapters:

- ✓ OSA YSU & NAS student chapter, Armenia
- ✓ OSA & SPIE Wroclaw Univ. of Technology student chapters, Poland
- ✓ OSA & SPIE BMSTU student chapters, Russia
- ✓ OSA, SPIE & IEEE ITMO University student chapters, Russia

Topics:

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

Program highlights:

- *Invited talks and sectional presentations*
- *Student presentations (Special Prize from OSA for the best student oral presentation)*
- *Student chapter presentations*
- *Professional development lectures*
- *Lab tours*
- *Social events*

The Symposium Program includes: presentations of institutions & societies (10, 30 min), invited talks (30 min). The program also includes: young scientists presentations (10, 15 min); sectional oral presentations (20 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.

Symposium Venue

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

Department of Physics
Yerevan State University
1 Alex Manoogian str., Yerevan, 0025, Armenia

Institute for Physical Research
Ashtarak-2, Ashtarak, 0203, Armenia

Department of General Physics and Quantum Nanostructures
Institute of Mathematics and High Technologies
Russian-Armenian (Slavonic) University
123 Hovsep Emin str., Yerevan, 0051, Armenia

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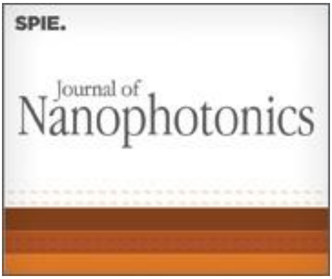
http://rau.am/optics2016/

Proceedings



Selected papers will be published in **the Journal of Nanophotonics Special Section: Optics, Nanophotonics and its Applications**.

Expected publication: 2017

Guest Editors:

David B. Hayrapetyan

Russian-Armenian University, Armenia
Yerevan State University, Armenia

Sergey I. Pokutnyi

National Academy of Sciences of Ukraine, Chuiko Institute of Surface Chemistry, Ukraine

Presentations of International Societies & Institutions

Eugene Arthurs

✓ **SPIE's Role in the Photonic Future**
http://spie.org/

David Blaschke

✓ **University of Wroclaw**
http://uni.wroc.pl/

SPIE student chapters' presentations

1. **Yerevan State Univ. Chapter, Yerevan, Armenia**
   Astghik **Chalyan**
2. **Vidya Jyothi Institute of Technology, Hyderabad Chapter, Hyderabad, India**
   Badrinath **Vadakkapattu**
3. **Univ. of Latvia Chapter, Riga, Latvia**
   Matiss **LACIS**
4. **Wroclaw Univ. of Technology Chapter, Wroclaw, Poland**
   Mateusz **Szatkowski**
5. **Bauman Moscow State Technical Univ. Chapter, Moscow, Russia**
   Irina **Dolganova**
6. **ITMO University student chapters, Saint Petersburg, Russia**
   Daniel **Gomon**
7. **Institute of Radiophysics and Electronics Chapter, Kharkiv, Ukraine**
   Sergii **Poperezhai**
8. **Taras Shevchenko National Univ. of Kyiv Chapter, Kyiv, Ukraine**
   Andrii **Shcherbakov**

SPIE, the international society for optics and photonics, was founded in 1955 to advance light-based technologies.

Serving more than 264,000 constituents from approximately 166 countries, the not-for-profit society advances emerging technologies through interdisciplinary information exchange, continuing education, publications, patent precedent, and career and professional growth.

SPIE annually organizes and sponsors approximately 25 major technical forums, exhibitions, and education programs in North America, Europe, Asia, and the South Pacific.

SPIE provided $4 million in support of education and outreach programs in 2014.

SPIE publishes the SPIE Digital Library, containing more than 415,000 research papers from the Proceedings of SPIE and the Society's 10 scholarly journals with around 18,000 new papers added each year, and more than 215 eBooks from the SPIE Press catalog. The SPIE Press publishes print monographs, tutorial texts, Field Guides, and reference books. SPIE also publishes a wide variety of open access content.

Membership includes Fellows and Senior Member programs. The Society has named more than 1,000 SPIE members as Fellows since 1955, and implemented its Senior Member program in 2008.

The SPIE awards program serves to recognize outstanding contributions from individuals throughout the scientific community.

The SPIE international office is located in Bellingham, Washington and the SPIE Europe office is located in Cardiff, Wales.

INTERNATIONAL COMMISSION FOR OPTICS
COMMISSION INTERNATIONALE d'OPTIQUE

The International Commission for Optics was created in 1947. It is an Affiliated Commission of the International Union of Pure and Applied Physics (IUPAP), and a Scientific Associate of the International Council of Science (ICSU). Its objective is to contribute, on an international basis, to the progress and diffusion of knowledge in the field of optics.

The Commission has three categories of Members: Territorial Committee Members (53 members including two Associate Members), International Organisation members (6 members). The governing body of ICO is its General Assembly, usually held every three years during an ICO Congress that includes an international conference on optics. Between General Assemblies, a Bureau is responsible for the conduct of the Commission. The Bureau consists of the President, the Past-President, the Secretary General and the Associate Secretary, the Treasurer, and fourteen Vice-Presidents, (eight elected) of whom at least two are from industry.

In order to serve and be representative of the optics community worldwide, ICO maintains contacts with its Members and with optical scientists in all countries and welcomes all new contacts. Together with the other societies involved, it contributes to the coordination of international activities in optics such as in particular scientific meetings.

In addition to its Congresses, ICO initiates international topical meetings, and acts as a cosponsor for a number of international scientific meetings organised by other bodies. All the update information on meetings with ICO participation is appearing on the special section at this web site.

ICO has established a Committee for the Regional Development of Optics and has contacts with the International Centre for Theoretical Physics, ICTP, Trieste, Italy in order to find new ways to help to optical scientists and engineers in developing countries, in particular through the exchange of information and through the joint organisation of schools. Under a Proceedings

Donation programme, some libraries in developing countries can receive copies of the proceedings of Conferences with ICO participation.

Schools with ICO participation are of a typical duration two or three weeks, for the main benefit of optical scientists and engineers in non industrialised countries. The contribution of ICO is mainly in the form of support in establishing the programme and finding the appropriate instructors.

A Newsletter covering ICO activities is published four times a year and posted in the ICO webpage. Printed copies of the ICO Newsletter may be obtained from the ICO secretariat as per request.

The board members of ICO Armenian Territorial Committee are

President: **Aram Papoyan** (IPR of NAS)

Vice-Presidents: **Gagik Buniatyan** (LT-PYRKAL)
Levon Mouradian (YSU)

Secretary: **Narine Gevorgyan** (RAU)

Treasurer: **Paytsar Mantashyan** (IPR of NAS)

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 5 Institutes 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 the education either in Russia or in 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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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*
- *ne* [illegible]
- *gr* [illegible] *ls*
- *thi* [illegible] *ies*
- *so* [illegible]
- *high-temperature superconductivity*
- *synthesis and characterization of nanomaterials*
- *scientific instrumentation*

National Academy of Sciences of Armenia
Institute for Physical Research

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 (1996-2015); 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); Series of International Symposiums “Optics and its Applications” (2011, 2014, 2015); Series of International Advanced Schools on Frontiers in Optics & Photonics (2012, 2014, 2016); QuantArm 2014: International Conference and Workshop Quanta and Matter
- 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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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.

Contact information

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University of Wrocław

The University of Wrocław has a rich history of more than three centuries. Founded by Leopold I Habsburg the university evolved from a modest school run by Jesuits into one of the biggest academic institutions in Poland. At the beginning of the 19th century the university had five Faculties: philosophy, catholic theology, evangelical theology, law and medicine. Later it was expanded by numerous sections, laboratories and a natural museum, which exists until today.

After the Second World War a group of Polish professors, formerly from Lvov, started teaching and research activities at the University of Wrocław. Initially they created the Faculties of law and administration, arts, natural sciences, agriculture, veterinary, medicine, mathematics, physics and chemistry. Some of these Faculties were soon transformed into other universities.

Since the beginning of the 20th century, the University of Wrocław produced 9 Nobel Prize winners, such as Theodor Mommsen, Philipp Lenard, Eduard Buchner, Paul Ehrlich, Fritz Haber, Friedrich Bergius, Erwin Schrödinger, Otto Stern and Max Born.

Today, the first and foremost focus of The University of Wrocław is scientific research. Our scholars have numerous links with their fellow researchers from other higher education institutions in Poland and throughout the world. The success of our researchers has been recently recognized by Polish authorities, who significantly increased funding for both equipment and research at our University by 80% compared to previous years.

Like in most countries, in Poland the national quality assessment system is part of a national strategy for improving the quality of education. Every four years the Ministry of Education evaluates faculties of all Polish universities. Last year 9 out of 10 of our Faculties were qualified in the highest category and one was the second highest.

The Academic Incubator of Entrepreneurship is a new unit of the University of Wrocław designed to aid students in starting their own businesses by providing free entrepreneurial advice, organizing conferences, seminars, subsidizing selected investments and offering office space. The Academic Incubator of Entrepreneurship cooperates with the Wrocław Technology Park, a technological centre with laboratories, office space, conference centre and modern multimedia equipment. The objective of the Technology Park is to create conditions for the use of scientific and industrial potential of Wrocław and the region and to stimulate the advanced technologies industry. The University of Wrocław is proud to be one of its shareholders.

Today the University of Wrocław is the largest university in the region and teaches over 40,000 students and around 1300 doctoral students at 10 Faculties. 9000 students graduate from the University every year.

Acknowledgement

Thanks for generous support to all sponsors!!!!

SPIE.

Visiting Lecturer

Optical 3D-Cameras I: physical and information theoretical aspects

Gerd Häusler

Institute of Optics, Information and Photonics,
University of Erlangen-Nuremberg, Germany

We will have a stroll through optical 3D-cameras and optical 3D-metrology, first steps about the limits and the options given by physics and information theory – aiming for the best possible data.
Optical 3D-cameras that work at those limits require much more than a light bulb with a camera or a microscope with a computer appendix.
Optical metrology is:

- more often than not, sophisticated illumination,
- complicated interaction of light with the object,
- transmission of information by a variety of modalities

and eventually storage and computation.
Illumination is the most important feature, as illumination often takes over the major part of the source encoding. Source encoding is extremely important as it reduces the “cost”. “Cost” means literally money, but it means measuring time and complexity as well. There is plethora of ways to illuminate the object, each with high impact on what the “camera” sees. Illumination may be directed or diffuse, structured or homogeneous, coherent or incoherent, polarized or unpolarized... The interaction of light with the object may be coherent or incoherent, nonlinear or linear, there may be diffuse scattering, specular reflection or volume scattering. The transmitted information may be the intensity (yes!), but it is often better to exploit amplitude and phase, as well coherence properties, color, polarization, or even time of flight. The o-e converter may be an array of smart pixels or a simple point detector. The stored signals may look like an image of the object, but a proper optical encoding of the demanded information commonly requires computation for the decoding. The described variety of options can be combined and permuted in abundance, which makes optics such a rich science with new inventions every day, and - another welcome benefit – makes optics complicated and optical experts costly.
This sounds encouraging as well as difficult, and in fact it is. But we can bring some order into the plethora of implementations of optical 3D-sensors, by

looking for the dominant source of noise. It turns out that there are only four different ways of physical signal generation, with different sources of the dominant noise: coherent noise and photon noise. We can put all known sensors into one of these four classes. Understanding the noise limit is quite helpful, as it allows us to decide if a sensor is already working at its physical limit or if it is worth wile to invest better hardware.

We will further discuss the limits and options in terms of uncertainty products: Diffraction-, quantum optics- and information theoretical limits appear as uncertainty products. We know that nature never give presents, but we can bargain with nature via uncertainty products: By accepting, for example, lower lateral resolution we may be recompendated by lower noise, etc.

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Optical 3D-Cameras II: sensors and applications at the limits

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We continue our stroll through 3D-cameras by looking closer at a few paradigm sensors and "hard core" applications. There are hundreds of 3D-sensors at the market, each advertised by "high resolution, ultra-fast, easy handling …". As mentioned, these sensors are based on only four principles of signal generation. From part I of our stroll we will easily understand the common principle and limits in different embodiments.

We start with sensors based on triangulation: these sensors are all limited by coherent noise. Among triangulation sensors we find stereo, laser triangulation, fringe projection, structured illumination microscopy, confocal microscopy. It is interesting that triangulation cannot deliver a single shot 3D-camera with a dense 3D point cloud. We will demonstrate our latest development, the "3D motion picture camera" that acquires up to 300.000 3D-points within each single shot of a

1 Mpix video camera - which is the ultimate information theoretical limit.

We will briefly touch Type II sensors (classical interferometry), where the precision is limited by photon noise. For Type III sensors, the precision is limited only by the surface roughness: white light interferometry ("coherence radar"), time-of-flight sensors and optical coherence tomography ("oct") belong to Type III. Type III sensors can measure nearly all (rough) surfaces, even volume scatterers such as skin or ceramics. The precision does not depend on the working distance or the aperture. These features are unique and extremely useful.

A very modern concept to measure specular surfaces, even free form and strongly curved, is deflectometry (Type IV). Deflectometry is a largely incoherent technique, thus its precision is limited by shot noise, as for classical interferometry. Deflectometry, however, has intrinsic advantages over interferometry: it does not require a reference, which is unique and very helpful, specifically for free form surfaces. The precision of deflectometry can be easily better than 1 nanometer and the dynamic depth range can be 106. The technology is simple and low cost. Deflectometry is easily scalable, for objects such as car windows or microscopic objects. How is this possible? The deep reason is that a sophisticated illumination is performing strong redundancy reduction (encoding). Deflectometry delivers intrinsically the local surface derivative, suppressing the stand-off. Of course (nature never gives presents) there is a drawback: low frequency information about the object is attenuated, which makes an extremely precise calibration necessary to ensure proper decoding.

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Traveling Lecturer

Optical telecommunications at the limit: Can soliton molecules help?

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Telecommunications over optical fibers is immensely successful. The volume of transmitted data grows exponentially, and due to novel data-haungry applications this growth is expected to continue. In binary coding of data, either a light pulse is transmitted within one clock period, or none to represent logical “ones” and “zeroes”. For this format, the data-carrying capacity of existing optical fibers hits a ceiling now, and data formats “beyond binary” are currently investigated, to transmit more than a single bit per clock period. A combination of phase, amplitude, and polarization modulation is used. Moreover, space and/or mode multiplexing are being discussed, but these require special fibers and are incompatible with the existing worldwide fiber network. Economically it seems prudent to pursue technology that works with legacy fibers. The current state will be explained.

So far the fiber’s inherent optical nonlinearity is being avoided. Once one acceopts to exploit it, one can use soliton pulses which possess a unique robustness to perturbations. Solitons are used in a few commercial systems, but they have always been understood to provide a binary format only. We have recently demonstrated that they can be used for a quaternary format, and it is reasonably expected that they can go beyond. The concept makes use of so-called ‘soliton molecules’, bound states of several solitons. Experimental results will be reported, and it will be argued that this scheme may be advantageous in some cases.

Professional development lecture

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How to research

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The professor at the University has duties but, to some extent, he has as well the freedom to choose the area and the kind of his research. This freedom is precious (and rare in most other professions), so he will take care not to waste it. The freedom includes the duty to do something "important" as Einstein said1: the most noble duty of a scientist is, to formulate an important problem. Einstein's words are extremely helpful for the daily life of a scientist (and this includes cosmologists as well as opticists). The researcher should ask himself: "what is the important problem, today, this month, this year?" Apparently, finding really important problems is very difficult. This may explain, as Maslow1 critically observed, why some professors improve their master thesis until they retire. How to overcome that temptation?

One road is to go with Goethes Faust "dass ich erkenne, was die Welt im Innersten zusammenhält" ("Then shall I see, with vision clear, how secret elements cohere") and look for problems that mother nature itself presents. However, the formulation of a hypothesis and the design of an experiment by which that hypothesis can be falsified is quite difficult for questions about the structure of the universe or of matter, as Jim Baggott explains2 in his enthralling book.

Fortunately, along other roads important problems are ubiquitous and easy to find. The first road is to ask about the limits in our area of research, that is optics. The second is the cooperation with appliers of science and technology. We will illustrate these options by several examples of successful optical methods.

There are limits at different levels of hierarchy, e.g.: Physical limits may emerge by diffraction or by noise. Information theoretical limits may be given by encoding or channel capacity. Technical limits may arise by mechanical stability and environment conditions. Asking about the limits of new or already established methods is a challenge and quite fruitful: First, we learn a lot about physics, about information theoretical background and technology, which is fun by itself. Once we understand the limits we can judge existing systems if they are already working at these limits or if and often how

(!) the systems can be improved. We should first ask about the physical limits, then we can decide if a costly improvement of technology might help or not. We should then ask about the information theoretical limits in order to decide if - by proper encoding – the requirements for expensive technology can be reduced. Only after this procedure we should call for better technology. There are many examples that this course of action leads to completely novel methods with less demands of costly technology. Understanding the limits offers the nice adventure to discuss the performance of optical systems exhibited at trade fairs, knowing that the promised specifications are impossible to achieve. Commonly, hidden low pass filters are in play that smooth the results. Such trade offs are possible because limits are quite often given by uncertainty products. Nature does not give any presents1 but we can bargain, sometimes. For example, the depth of field and the lateral resolution are coupled. This is an example to ask if the relation is a really deep, unbeatable: in fact, it is not, in this case. This example encourages us to overcome “limits”, by questioning the assumptions behind their foundation.

We eventually come to the option “academia meets industry”, which includes cooperation with appliers of optical systems, such as in medicine or art conservation. There we find a vast quantitiy of important unsolved problems (metrology, inspection, detection, …) that can be solved with good optical skills and by understanding the limits! This is the road to bring our ideas to the real world and a key to entrepreneurship, which definitely is as satisfying as understanding the limits (but more exhausting).

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Invited Talks

The effects of CdSe/ZnS Core/Shell Colloidal Quantum Dots on performance of Silicon Solar Cell

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The sun emits ultraviolet (UV), visible and infrared light; however silicon-based solar cells mainly absorb visible light. Colloidal quantum dots (CQDs) represent a promising way to increase the efficiency of solar energy harvesting. Herein, we implemented the concept of energy-down-shift (EDS) using CdSe/ZnS core/shell CQDs on a p-type silicon solar cell to absorb more UV light. We used finite difference time domain (FDTD) method to simulate the characteristics of a silicon solar cell covered by CQDs. The employing of green-light emitting CdSe/ZnS core/shell CQDs reduced the surface reflectance and enhanced the power conversion efficiency (PCE). The resultant CQD solar cell provides a 60.10% PCE enhancement.

Dynamical Schwinger process in high-intensity laser fields

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Vacuum particle production by the Sauter-Schwinger effect under action of time-dependent strong fields of different nature possesses a number of general properties which on the qualitative level are independent of the nature of the concrete system. These are, e.g., the existence of the quasiparticle stage of the excitation during the period of the field action, the transient stage of fast oscillations in the period of the external field degradation, the change of symmetry of the system, and the emergence of a strong non-equilibrium out-state. Illustrating examples one can select from condensed matter physics, the physics of stongly correlated systems, the theory of relativistic phase transitions, early cosmology etc. The universal character of such phenomena allows to unify them in the rather general class of field induced phase transitions, a term adopted from the works [1,2,3]. The general foundation for this is the mathematical similarity of the corresponding kinetic equations describing the particle production processes.
In the present report we consider in detail an example from the strong field QED, where the kinetic equation is well known for the linearly polarized, spatially homogeneous, time-dependent external electric field model [4,5]. We discuss also possible experimental manifestations of the strong oscillations of the electron-positron plasma in the transient domain.

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Novel components and devices for mid IR sensors

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Recent progress in development of new low-cost light sources and optical components stimulate rapid development of mid-IR photonic systems. Mid-IR attracts a lot of interest due to potential multitude of attractive applications, e.g. in next generation telecommunications, spectroscopy or food quality control. In particular, the new highly sensitive systems for gas and liquid identification are very attractive for environmental sensor and biochemisty since vibration spectra of most organic molecules are in midIR range.

Most of the commonly used optical materials, such as fused silica glass, cannot be used in the midIR wavelength range due to their high attenuation beyond 2 µm. There are three groups of materials especially suitable for refractive optics components for these wavelengths: single crystal, non-oxide glass and heavy metal oxide glass. In particular, heavy metal oxide glasses can be considered interesting because they offer a compromise between low-cost, relatively simple processing and reasonable transmission in the midIR range. We report on the development of new refractive and diffractive components using hot embossing technique, optical fibers, SLED light sources and MidIR detectors. Their application potential in novel midIR sensor systems is also outlined.

Software for solving boundary value problems in application to waveguide processes

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The algorithms and programs, implemented in Maple and Fortran, for solving the waveguide-type multichannel scattering and eigenvalue problems for systems of the second-order ODEs with continuous or piecewise-continuous and real or complex-valued coefficients on the axis are presented. The results of solving the boundary-value problem by the Kantorovich method, finite element method and matching the fundamental solutions of the system of ODEs at the points of discontinuity of potentials are considered. Algorithms and programs are available from JINRLIB program Library:

KANTBP – a program package for solution of two-dimensional discrete and continuum spectra boundary-value problems in Kantorovich (adiabatic) approach [http://wwwinfo.jinr.ru/programs/jinrlib/kantbp/indexe.html];

KANTBP 4M – program for solving boundary problems of the self-adjoint system of ordinary second order differential equations [http://wwwinfo.jinr.ru/programs/jinrlib/kantbp4m/indexe.html].

The work was supported by the Russian Foundation for Basic Research, grant No. 14-01-00420.

Study of microstructural peculiarities and deformation state of ettringite crystals in Type K cement pastes by FTIR spectroscopy, optical microscopy, combined SEM-EDS, and XRD techniques

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A broad variety of concrete-made constructions such as floor slabs, pavements, roofs, water storage tanks, sewage digesters, reactors, and pumping stations needs a high level of mechanical safety and/or resistance against attack of chemically aggressive waters. Preparation of these constructions from ordinary Portland cement concretes is associated with a *high risk of critical cracking caused by drying shrinkage* of constituent cement paste upon hydration and humidity loss. Therefore, the above specified concrete constructions are prepared with the use of a special type of cements known in literature as Type K shrinkage-compensating or expansive cements. Type K shrinkage-compensating cements are prepared particularly by blending of ordinary Portland cements mainly with powdered ye'elimite (3CaO·3Al2O3·CaSO4) admixture. The hydration reaction of ye'elimite admixture in hydrating Type K cement paste results in formation of an additional amount of the ettringite [Ca6Al2(SO4)3(OH)12·26H2O], one of the main constituent phases both in Portland and Type K cement pastes/concretes. The experimental results reported in literature provide an evidence that namely the ettringite phase is responsible for shrinkage-compensating properties of Type K cement pastes. Therefore, the quantified residual mechanical stresses on ettringite could serve as a good measure of shrinkage-compensating effect of this phase in mature Type K cement pastes. This argumentation stimulates investigations of above residual mechanical stresses as well as microstructural peculiarities of ettringite crystals comprised in mature Type K cement paste.

In this study, with the use of Fourier-transform infrared (FTIR) spectroscopy, combined scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS), optical microscopy, and X-ray diffraction (XRD) techniques, we investigated clustering, microstructural parameters (microstrains and sizes of crystallographic coherent domains), point defects, and the deformation state (residual strain and stress components) of ettringite crystals as well as the cracking of cement paste. The investigation is conducted for a series of samples of mature 1-year aged Type K cement pastes prepared with the water-to-cement mass ratio of 0.35 and relative weight content of the ye’elimite admixture varying in the rang 0-12%.

The most important results of practical interest obtained in this study are associated with determining and technological optimization of the average stress component on ettringite crystals that is responsible for shrinkage-compensating effect in the cement paste matrix. These results were achieved on the bases of combined analysis of FTIR, EDS, and XRD measurements data.

Photon entanglement of nonlinear optical superlattices

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In order to achieve entangled states in Spontaneous Parametric Down Conversion (SPDC) process, we use two-dimensional periodically poled nonlinear optical super-lattices (PPNOS). This work focuses on investigating on the amount of polarization-entanglement between photon pairs in type-II non-collinear SPDC for two-dimensional PPNOS based on LiNbO3. The entanglement of the two photon states is investigated using an appropriate measure called Von-Neumann entropy.

Moreover, the structure for SPDC in PPNOS is studied. The Von-Neumann entropy is considered to measure the entanglement between the photon pairs in SPDC.

We show that the entropy of the system increases linearly with respect to the number of layers. The value of the entropy saturates to the value of 3.5 with 100 eigenvalues.

A self-interfering clock as a "which path" witness

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In Einstein's general theory of relativity, time depends locally on gravity; in standard quantum theory, time is global—all clocks "tick" uniformly. We demonstrate [1] a new tool for investigating time in the overlap of these two theories: a self-interfering clock, comprising two atomic spin states. We prepare the clock in a spatial superposition of quantum wave packets, which evolve coherently along two paths into a stable interference pattern. If we make the clock wave packets "tick" at different rates, to simulate a gravitational time lag, the clock time along each path yields "which path" information, degrading the pattern's visibility. In contrast, in standard interferometry, time cannot yield "which path" information. This proof-of-principle experiment may have implications for the study of time and general relativity and their impact on fundamental effects such as decoherence and the emergence of a classical world.

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Universal local density of states for nanoplasmonic systems: From energy transfer to strong coupling to loss compensation and spasing

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We study local density of states (LDOS) in metal-dielectric composite systems in the frequency range dominated by a localized plasmon mode. By including, in a systematic way, the Ohmic losses, we show that plasmon LDOS is proportional to the local field intensity normalized by the system absorbed power. Explicit formulae are obtained for energy transfer (ET) between quantum emitters and plasmon modes as well as between donors and acceptors situated near a plasmonic nanonostructure. In the latter case, we find that the plasmon-assisted ET rate is proportional to the LDOS product at the donor's and acceptor's positions. For systems with ensemble of QEs coupled to plasmon modes, we use the plasmon LDOS to study the transition to strong coupling regime as well as the loss compensation and spasing in nanoplasmonic systems with gain.

Coupling of localized surface plasmons to epitaxial quantum dots excitons

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Coupling of the resonances with different widths is known to lead to developing of new features that are different from that of both of the participating resonances. According to the theory [1] plexitonic resonances that are the coupled hybrid states of the plasmons localized in metal nanoparticles and the excitons in semiconductor quantum dots (QDs) posses such properties that may be used in chemical and biological sensors with high sensitivity, fast switches, optical delay lines and other devices. In this contribution we report on experimental realization of the coupled plasmon-exciton system.

A stack of five layers of epitaxial InAs QDs were grown on the surface of a gallium arsenide wafer using molecular beam epitaxy. The upper layer of QDs was capped by 3nm-GaAs/3nm-AlAs/4nm-GaAs layer sequence. Then, a thin silver layer was added via physical vapor deposition in a vacuum chamber of Kurt J. Lesker at the residual pressure of 10 7 Torr. After annealing, isolated silver nanoparticles were formed above the layer of buried InAs quantum dots. Optical absorption and fluorescent spectra give clear evidence of the plasmon resonances localized in the silver nanoparticles and their interaction with semiconductor quantum dots.

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Calculating spectral and optical characteristic of quantum dots

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In the effective mass approximation for electronic (hole) states of a spheroidal quantum dot with and without external fields the perturbation theory schemes are constructed in the framework of the Kantorovich and adiabatic methods. The eigenvalues and eigenfunctions of the problem, obtained in both analytical and numerical forms, were applied for the analysis of spectral and optical characteristics of spheroidal quantum dots in homogeneous electric and magnetic fields. Algorithms and programs are available from JINRLIB program Library:

KANTBP – a program package for solution of two-dimensional discrete and continuum spectra boundary-value problems in Kantorovich (adiabatic) approach [http://wwwinfo.jinr.ru/programs/jinrlib/kantbp/indexe.html];

KANTBP 4M – program for solving boundary problems of the self-adjoint system of ordinary second order differential equations [http://wwwinfo.jinr.ru/programs/jinrlib/kantbp4m/indexe.html].

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Oral Presentations

Identification nanostructured composites of poly triazole-amide-imides by microsphere-assisted digital holographic microscopy

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Mirau interferometric objective can be used for common-path reflective digital holographic microscopy (DHM). By placing a glass microsphere within the working distance of a Mirau objective, the effective numerical aperture can be increased leading to an increase in the resolution and lateral magnification of the system. In this paper, we employ the microsphere-assisted DHM to study the surface properties of nanostructured composites of poly triazole-amide-imides (PTAIs). The surface roughness of neat PTAIs sample is very small, while the surface of nanocomposite films of PTAI with 30 wt% MnTiO2 has higher roughness. This is attributed to the introduction of MnTiO2 nanoparticles and formation of nanocomposite. By the use of information extracted from numerical reconstruction of digital holograms, recorded by the microsphere-assisted setup, we have quantified the roughness of the surfaces. The roughness distribution parameter can be used to identify the nanocomposite embedded PTAIs from neat PTAIs. Our results show that microsphere-assisted super-resolved Mirau DHM has the potential to be served as an alternative for expensive surface measurement devices such as atomic force microscopes.

Binding energy of the dielectrically enhanced screened exciton in semiconductor quantum well

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A formalism for the study of the two-dimensional screened exciton states in onesided strong dielectric contrast affected ternary quantum well (QW) system modeled by the two-dimensional Debye-Hückel-type potential is presented. The analytical and numerical analysis depending on the specifics of InSb-based QW is provided. The appropriate density/temperature ratio parameter and QW width correlated ranges have been established for that the screened exciton screening radius as well as the two-dimensional exciton bound state radius and binding energy expressions holds. In particular, the latter's strong enhancement (4÷6 meV) in relation to the unscreened exciton bulk value (0.3÷0.4meV) is received.

SPR based optical biosensors

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Optical sensors are the identification and detection tools to quantify the changes in the properties of the incident light. In the surface plasmon resonance (SPR) sensors, surface plasmons are excited at the boundary of metal-dielectric media. The refractive index changes of the dielectric media alter the conditions of coupling between the incident light and the surface plasmon, which can be detected as a change in the properties of the incident light. SPR sensors can be classified as the angle, wavelength, intensity, phase and polarization modulation based on the characteristics of light and its interaction with surface plasmons.

The SPR based biosensors as a subset of optical sensors are the powerful sensors for the diagnosing of diseases, discovering of new medicaments, delivering drug systems and detecting of pollutants. In general, these sensors are designed to detect specific substance reacts. In order to specify the detection, the biological agents such as DNA, proteins, antibodies and enzymes are used. Commercial type of these sensors, which work based on light intensity detection, have sensitivity in the order of 10^{-6} RIU. Until today, many researches have been done in order to increase the limit of detection (LOD) of these biosensors and the best LOD that is reached is about Pico molar and Femto molar in different cases.

Investigation of electromagnetically induced transparency effect in potassium vapor using a nanometric-thin cell

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We studied the electromagnetically induced transparency (EIT) effect [1] formed in a Λ-system of potassium atoms (4S1/2 → 4P1/2 → 4S1/2, D1 line) with the use of a nanometric-thin cell both experimentally and theoretically. When the coupling laser frequency is resonant with the one of the atomic transition, this allows one to detect EIT-resonance for 39K atoms at L = 770 nm cell thickness. The detuning of the coupling laser frequency from the corresponding atomic transition causes the rapid worsening of EIT-resonance parameters. Due to the small distance between the hyperfine structure ground state levels (~ 462 MHz) in probe laser transmission spectrum it is possible to detect simultaneously EIT and velocity selective optical pumping resonances. The theoretical model is in a good agreement with the recorded experimental results.

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Application of phase-step diffractometry in optical surface testing using a 2D array of reflective disks

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Optical profilometry has been of increasing interest for various applications, especially when high precision and whole-field measurement is concerned. Phase-step diffractometry is proven to acquire nanometre precision together with lower vibrational sensitivity compared with methods based on interferometry. We have utilized phase-step diffractometry in order to provide 3D profile of the optical surfaces. We have coated a 2D array of reflective disks on a thick glass plate, so that placing it above the sample surface creates a 2D array of reflective circular phase-steps. We also suggest a new fringe analysis approach to extract the phase and consequently, the profile of the sample surface. In this approach, we interpret the visibility of the fringes along the radius of the disk as a function of phase. Then, by fitting a cosine curve to the resulting function, the phase value is calculated at different points along the edge of each disk. In this presentation, the basics of phase-step diffractometry is discussed, as well as the results for the profilometry test of an optical flat mirror. The results show that the presented technique can be used as a combination of the two well-known methods of Hartmann and Fizeau interferometry.

Solitonic self-spectral compression of supercontinuum fraction

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Recently, the effect of self-spectral compression (self-SC), a spectral analogue of soliton-effect compression [1-3], has been demonstrated experimentally and analyzed numerically [4]. The self-SC has been observed in a hollow core fiber under combined impact of negative group velocity dispersion (GVD) at 800 nm wavelength and self-phase modulation (SPM). Both the soliton-effect compression and self-SC demand the negative GVD. The solitonic self-SC requires strong GVD and weak SPM [2], while soliton-effect pulse compression requires the weak GVD and strong SPM [1].

We report the self-SC of noisy supercontinum radiation in a standard single-mode fiber. In the experiment, we used laser with amplifier at 1030 nm with 400-fs pulse duration. We generated the supercontinuum in YAG crystal for an effective output at infrared part of spectrum, and cut the spectrum with a longpass filter at 1300 nm to have negative GVD in silica (i.e. the wavelength range above 1300 nm). Thereafter, we coupled the radiation into a 600-m long standard single-mode fiber and optimized the self-SC process by controlling the power with a neutral density filter, resulting in 4.1x self-SC of noisy supercontinuum fraction. We also carried out numerical studies of the process, based on the solution of the nonlinear Schrödinger equation. As the supercontinuum has noisy nature, we numerically examined propagation of randomly modulated pulses in a medium with negative GVD and nonlinearity, using the “signal + noise” model for the pulses. Our studies show that self-SC occurs even for pulses with noisy nature. The process suppresses the noise, resulting in more coherent radiation, and it has periodic nature, evidencing on its solitonic nature.

Concluding, we have experimentally demonstrated 4.1x self-SC of a fraction of noisy supercontinuum spectrum in a 600-m single-mode fiber. Numerical modeling for randomly modulated pulses shows that the process suppresses the noise, according to its solitonic character.

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Confluent Heun functions as terms of solutions of the quantum two-state problem

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Fifteen classes of time-dependent two-state models solvable in terms of the confluent Heun functions are presented. These classes extend over all the known families of 3- and 2-parametric models solvable in terms of the Gauss hypergeometric and the Kummer confluent hypergeometric functions to more general four-parametric classes involving three-parametric detuning modulation functions. The classes suggest a variety of families of field configurations possessing useful properties not covered by the previously known analytic models. In the case of constant detuning the field configurations defined by the derived classes describe excitations of two-state quantum systems by symmetric or asymmetric pulses of controllable width and edge-steepness. The particular classes out of the derived fifteen that provide constant detuning pulses of finite area are identified and the factors controlling the corresponding pulse shapes are discussed in detail. The positions of the pulse edges for the case of step-wise edges are determined. We show that the asymmetry and the peak heights are mostly defined by two of the three parameters of the detuning modulation function, while the pulse width is mainly controlled by the third one, the constant term in the detuning modulation function. It is shown that the pulse width diverges as this parameter goes to infinity. Furthermore, it is shown that rectangular box pulses, as well as infinitely narrow pulses are possible, and the conditions for these to be achieved are obtained. Several examples of such field configurations are mentioned and their basic properties are discussed.

Analyzing the physical field configurations for the general case of variable Rabi frequency and frequency detuning, it is mentioned that the most notable features of the models provided by the derived classes are due to the extra constant term in the detuning modulation function. Due to this term the classes suggest numerous symmetric or asymmetric chirped pulses and a variety of models with two crossings of the frequency resonance. The latter 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. For some classes, however, the asymmetry may be additionally caused by the amplitude modulation function. We present an example of the latter possibility and additionally mention a constant amplitude model with periodically repeated resonance-crossings. Finally, we discuss the excitation of a two-level atom by a pulse of Lorentzian shape with a detuning providing one or two crossings of the resonance. Using series expansions of the solution of the confluent Heun equation in terms of the Kummer regular and the Tricomi irregular hypergeometric functions we derive particular closed form solutions of the two-state problem for this field configuration both for the constant and variable detuning cases. The particular sets of the involved parameters for which these solutions are obtained define curves in the 3D space of the involved parameters belonging to the complete return spectrum of the considered two-state quantum system.

X-ray interferometric temperature gradient moiré fringes in the frame of eikonal approximation

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In the work [1] using eikonal approximation a general formulae has been obtained for the intensity distribution of moiré fringes for an X-ray interferometer containing deformations in all three blocks. In this work is presented application of the eikonal approximation method for the case, when in the mirror block of the interferometer a temperature gradient is applied.

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Photoluminescent properties of the Mn and Yb doped ZnSe crystals

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Photoluminescent (PL) properties of the ZnSe crystal doped with Mn and Yb impurities have been investigated at 300K and 77K. There are PL bands not only at the edge spectral region, but also at visible long-wavelength and infrared regions. The coefficient of the bandgap expansion has been determined from the edge band shift with temperature growth and is equal to 4·10-4 eV/K. PL bands with the 530, 635 nm and 590 nm maxima have been registered. First two bands correspond to the electron transition from conduction band to levels of the CuZn2+ and Cu+ ions respectively [1], but the third band attributes to the intracentered transitions of Mn2+ ion [2]. Complex PL band has been observed in the region of 2 µm, where one of its component quenches with the decrease of the excitation energy and corresponds to the intracentered transition of Cr2+ ion [3]. The PL band with 1660 nm maximum has been registered and is more intense under irradiation with λexc = 532 nm and is attributed to the intracentered transition of Cu2+ ion [1]. Also, there is a new band at 1510 nm under excitation with λexc = 785 nm. It is well known that crystal's radiative capacity increases with temperature drop. However, ZnSe crystal doped simultaneously with Yb and Mn ions shows opposite effect which is manifested in the intensity amplification with temperature growth of the edge band and the band localized near 2 µm excited with the high-energy photons. The presence of ytterbium ions increases the intracentered transitions probability both for the Mn co-doped impurity, and for the Cr and Cu background impurities.

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Integrated Silicon Photonics and microring resonators for biosensing applications

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Silicon Photonics is a tool to face the future challenges in data communications and processing to satisfy the requirements of making the systems smaller, faster and cheaper. One of the most important building blocks in Silicon Photonics is the microring resonator, a circular optical cavity, which enables many different passive and active optical functions [1]. Here, we will describe an application of resonators in the label-free biosensing for real time detection of molecular interactions. In the label-free biosensing approach, the target molecule (analyte) is selectively captured on the surface of the micro-resonator by a bio-recognition agent, immobilized on the surface of the sensor. The trapped molecules form a layer that can be directly measured by quantifying the changes in the effective refractive index of the optical mode of a microring resonator. Since the resonance wavelength depends on the effective refractive index of the mode, a shift in the resonant spectral position is directly linked to a variation in the refractive index, i.e. to the detection of the target molecule. In particular, within the EU project “SYMPHONY” (Grant agreement no: 610580), our aim is to detect hazard cancerogenic Aflatoxin M1 (AFM1) present in milk and dairy products [2]. The sensing device consists of an array of four SiON microring resonators: three have the cladding layer removed and are functionalized for a redundant measurement and one is covered by the cladding (i.e. protected by the liquid) for reference. As a light source is used fiber-coupled to a Vertical Cavity Surface Emitting Laser (VCSEL) operating at 850 nm. Detection is realized with off-chip silicon photodetectors. A microfluidic cell from PDMS is used.

First we assessed the bulk Sensitivity (S) and a Limit of Detection of the system (LOD). The spectral shifts of the resonances were monitored in real-time, while the devices were exposed to glucose-water solutions of various concentrations [3]. For nSiON=1.66, the best sensitivity was obtained S=82 nm/RIU (Refractive Index Units) with a very good reproducibility (error in the order of 1%). This yields a LOD of 1.6×10-6 RIU [4].

We demonstrate a specific detection of AFM1 in buffer solutions, while the non-specific detection of Ochratoxin (OTA) is not occurring.

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Multifunctionality thin films obtained by MAPLE and PLD techniques

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In this paper, we report some results of a comparison between thin films of barium-titanate doped with calcium bariutitanate doped with zinc (BCZT) deposited on platinum and silicon wafer, obtained by pulsed laser deposition (PLD) and matrix-assisted pulsed laser evaporation (MAPLE) using a KrF* laser source. Surface investigations were carried out on atomic force microscopy (AFM) and X-ray diffraction (XRD), these techniques reveals a strong influence of thickness on film surface topography.

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Numerical methods for signal analysis in Optical Coherence Tomography

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Optical coherence tomography (OCT) is one of the widely used and promising noninvasive technique of the medium internal structure reconstruction [1, 2]. It is reported to be effective method for skin tissue diseases diagnosis.

In the present work we use Monte Carlo numerical simulation for study light scattering signal in biomedical samples of skin tissue with nevus at different life-stages. Different life-stages were modeled by sinking nevus down in skin (from epidermis up to derma layer). The results showed a perspective potential for detection different changes of nevus position inside skin tissue.

However, light scattering reduces OCT signal in addition to system imaging noise, thus enhancement of imaging quality using signal processing is a relevant problem for optical coherence tomography.

One of the promising method for reducing noise level in OCT signal is wavelet denoising technique [1, 3]. We applied this method for experimentally obtained OCT images of the test-samples (made from metal wires in scattering nanoparticle water solution). Comparing different wavelet basis and scale coefficients we find three optimal wavelet filters (coif4, sym2 and db3), which afford better denoising result for real OCT imaging samples.

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Morphology induced optical behavior of annealed self-assembled gold nanoparticles

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As reported the gold nanoparticles deposited on dielectric substrates during the high temperature annealing experience drastic morphology evolutions. This report presents an experimental study on the optical absorption spectrum behaviors of the annealed self-assembled gold nanoparticles on glass substrate. The films have been prepared by the centrifuge deposition of gold nanoparticles from a colloidal solution and annealed at the temperature of 500˚C for different time duration (2, 4 and 8 hrs). Annealing for different time durations induces different morphologies. The results show that the surface morphology of these nanostructured films plays a major role in their optical absorption behavior due to plasmon near-field coupling effect. The morphology of the films characterized by scanning electron microscopy (SEM) shows that the 2 hrs annealed gold nanoparticle ensembles are in the most coalescence situation with 0.55 filling fraction and 4 hrs annealed film has lower filling fraction by 0.43. The 8 hrs annealed film has a 65 nm sized islands structure with the 0.16 filling fraction of the gold nanoparticles. The optical absorption properties characterized by UV-visible spectrometry show a broad absorption band for 2 and 4 hrs annealed films that reflect the strong plasmon coupling effect. This coupling effect in the 2 hrs annealed film is stronger than the 4 hrs annealed one. While, the 8 hrs annealed film has the localized surface plasmon absorption with a peak at 560 nm. So, the coupling effect has been eliminated because the nano-islands are completely separated each other. The electronic structures of the films extracted from optical absorption spectra illustrate a quasi-continuous sp band in 2 hrs annealed film and discrete levels in 8 hrs annealed one. This electronic structure affect interband as well as intraband transition behaviors. The optical absorption properties of the annealed gold nanostructured films can make them very useful for many applications such as sensors, solar cells and many other optoelectronic devices.

Structured illumination for high resolution Mirau digital holography

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The spatial resolution of an imaging system is limited by the wavelength of illumination and the numerical aperture (NA) of the system. It has been shown that using structured illumination one can increase the NA synthetically, and surpass the diffraction limit. Here, we demonstrate the use of structured illumination in common-path, off-axis arrangement digital holographic microscopy (DHM). We employed Mirau objective as a compact interferometer for this purpose. A high magnification Mirau objective has low working distances and is substantially expensive. Commonly-used low magnification Mirau objectives, on the other hand, do not have high lateral resolution with respect to their vertical resolution. These limits can be compensated by illuminating the samples by an engineered wavefront. To illustrate the capability of the presented approach we have applied it to detect the fine structure of a digital video disk that cannot be resolved by a conventional DHM system. The improvement in the lateral resolution depends on the pre-defined parameters of the structured illumination, and by varying these parameters lateral resolution and magnification may be adjusted.

Tunable optical radiation formed in crystalline undulator

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The problem of bunch radiation of positrons channeled in a crystal undulator is considered.

Due to the medium polarization there is a energy threshold for the formation of radiation. At the threshold energy of bunch and at the certain spatial period of crystalline undulator the monochromatic beam of optical photons is formed at a zero angle.

Generation of optical radiation in nanotube undulators

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The possibility a tunable optical radiation in nanotubes undulators was investigated. It shows that, at the certain choice of parameters of the problem one can get monochromatic, sufficiently intense and directed radiation in the optical frequency range.

A time-dependent level-crossing model solvable in terms of the Hermite functions

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The concept of the level-crossing is a well appreciated paradigm for a long time after the works by Landau, Zener, Majorana, and Stückelberg. Both time-dependent and time-independent models have been widely studied in the context of different physical phenomena including electronic transitions in atomic and molecular collisions, laser cooling, dynamics of Bose-Einstein condensates, cold atom photo- and magneto- association, etc.

However, the number of known analytic level-crossing models is very limited. In the present contribution we introduce a new one. To derive this model, we consider the models that are solvable in terms of the bi-confluent Heun functions. These are the solutions of the bi-confluent Heun equation, which is one of the four confluent forms of the general Heun equation derived by a coalescence procedure. We have previously shown that there exist five classes of quantum time-dependent two-state models that are solvable in terms of these functions [1,2]. These classes include all the known confluent-hypergeometric level-crossing models. In addition, the derived classes suggest several other interesting models.

We present here a level-crossing model given as

$$U(t)=U_0\,,\;\;\delta_t(t)=\frac{\delta_0}{\sqrt{2t}}+\delta_2\,,\;\;t\in[0,+\infty]\,.$$

To explore the solution for this model we construct an expansion of the involved bi-confluent Heun functions in terms of the Hermite functions. The developed series are terminated thus resulting in two-term solutions. It should be noted that the involved Hermite functions are not polynomials.

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Asymmetric transmission in liquid-crystals of two cholesterics with different pitches and chiralities

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The spectral peculiarities of cholesteric liquid-crystalline (CLC) system of different pitches and chiralities during the diffusion process were experimentally and theoretically demonstrated. The asymmetric transmission phenomenon at different moments of diffusion in mentioned cell was shown, i.e. this CLC structure can work as optical diode in some spectral regions. Chirality of the CLC layers plays a major role in the observed nonreciprocal transmission effect. On the base of the transmittance curves we perform the calculations of ΔTeff= (T1-T2)/(T1+T2) value which shows the effective difference of the transmission spectra from different sides of the CLC system. In case of different chiralities of our CLC system, diffusion passes more slowly and therefore it is possible to conduct more thorough research on long enough period of time, as well as the procedure of "freezing" of certain frequency is more easy when one use cell prepared with this kind of mixture. By “freezing” the desired state of the diffused materials, we can obtain new applications such as: band mirrors; band filters; notch filters; and so on. Beside it, there are some essential features in the dynamics of diffusion between the two CLCs [1].

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Influence of electrical ring resonators metasurface parameters on perfect absorption in terahertz frequency range

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The aim of this research is an investigation of electrical ring resonators metasurface (ERR) parameters influence on perfect absorption and quality factor of absorber in terahertz frequency range. The impact of ERR geometric parameters, ERR layer thickness and spacer layer thickness on the reflection properties was numerically analyzed using finite-difference frequency-domain method. The 5 experimental samples for different ERR geometric parameters at optimal ERR layer thickness and spacer layer thickness were made using photolithography method. It was experimentally obtained the absorption of 99,57% at the frequency of 1,06 THz for TE-polarization and 99,11% at the frequency of 0,4 THz for TM-polarization.

Electronic and optical properties of conical quantum dots ensemble

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In the framework of the adiabatic approximation, the energy states of electron are investigated in the conical quantum dot for three regimes of size quantization: strong, intermediate and weak. For the strong and weak size quantization regimes the analytical expressions are obtained for particle energy spectrum and wave functions. For the strong size quantization regime the correction terms of energy spectrum are calculated by the help of perturbation theory. The obtained results are compared with the numerical ones. The absorption coefficient of the conical quantum dots ensemble are calculated. The dependence of the absorption edge on geometrical parameters of conical quantum dot is obtained. Selection rules are revealed for transitions between levels with different quantum numbers. In particular, it is shown that for the radial quantum number transitions are allowed between the levels with the same quantum numbers, and any transitions between different levels are allowed for the principal quantum number.

Confluent Heun potentials for 1D Schrödinger equation

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We present the potentials for which the one-dimensional Schrödinger equation is exactly solved in terms of the single-confluent Heun functions [1]. A particular attention is paid to the exactly or conditionally integrable sub-potentials the solution for which is reduced to simpler special functions. We show that there are sub-potentials for which each of the two fundamental solutions that compose the general solution of the problem is written in terms of irreducible combinations of hypergeometric functions [2, 3]. Several such potentials are derived with the use of deformed Heun equations [4]. A general approach for derivation of these solutions is the termination of the hypergeometric series expansions of the solutions of the Heun equations.

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Selective reflection of laser radiation from an alkali metal nanocell

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Selective reflection of light from the interface of a dielectric surface and resonant atomic vapor [1] is known to be efficient spectroscopic tool for studies of high-density vapor, atom-surface interaction, etc., and has found numerous applications. Extension of this technique to the case of nanometric-thickness cells with the space between windows of the order of resonant radiation wavelength is promising both for deeper understanding of fundamental processes underlying interaction of laser radiation with atomic system and for new applications such as magnetic-field controlled tunable locking of laser frequency to atomic resonance lines [2]. Meanwhile, as opposed to the case of ordinary cells, theoretical treatment of selective reflection from nanocells is significantly complicated by involvement of additional effects, which has to be taken into account. Preliminary experimental studies demonstrate that the reflection spectrum indeed exhibits dramatic rapid oscillations with thickness L.

We have analyzed possible influence of the concomitant effects inherent to resonant interaction of laser radiation with atoms confined in nanocells on selective reflection spectra aiming at development of an appropriate theoretical model, which will be further verified and elaborated through experimental realization. The following processes are considered: velocity-anisotropic contribution of atoms and velocity-selective optical pumping; coherent Dicke narrowing occurring at $L = (2n+1)\lambda/2$ thickness; and interplay of forward and backward beams (Fabry-Pérot behavior) observed with $L = n\lambda/2$ period. Findings of this work will be used to define conditions of experimental studies using Rb or Cs nanocells with variable thickness.

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Synchrotron radiation from a relativistic charged particle rotating around a cylindrical diffraction grating

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It has considered the radiation from a relativistic charged particle rotating around a cylindrical diffraction grating (formed by metallic strips on a cylindrical surface). The resulting field is a superposition of the synchrotron and Smith-Purcell radiations. The interference between these two sorts of radiations can serve as a mechanism for controlling the spectral-angular characteristics of the synchrotron radiation. Depending on the parameters of the diffraction grating, the interference can enhance or suppress the radiation at a given harmonic.

The modeling of kinetic processes in the ultrafast sensor of thermoelectric single photon detector for UV photons

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Single-photon detectors are required in research in different areas of modern science, particularly in space astronomy, high energy physics, quantum computing and quantum cryptography. The thermoelectric single-photon detector (TSPD) is one of the real competitors to superconducting detectors for single photon detection in a wide range of the electromagnetic spectrum.

The TSPD operation principle is based on photon absorption by absorber as a result of which a temperature gradient is generated on the edges of the sensor. Photon detection becomes possible by measuring the potentials' difference, emerging between the two absorbers.

The results of computer simulation of processes of heat distribution in the multi-layer sensor of thermoelectric detector after UV single photon absorption are presented. The multi-layer sensor consists of a photon absorber (tungsten), which is deposited on the thermoelectric layer (thermoelectric with high figure of merit at helium temperatures) and the latter is deposited on the electrically conductive layer of heat sink. The sensor is located on a dielectric substrate, on which are also set electrical contacts to count the potential difference ΔU, generated between the absorber and the heat sink by the absorbed photon. The calculations were carried out by the matrix method for differential equations, using parameters for the tungsten absorber and thermoelectric thin film layer made of (La, Ce)B6 or CeB6 hexaborides. Changing the thickness of absorber and thermoelectric layer we can modified the count rate and energetic resolution of sensor. According to the results of computer modeling it can be stated that detection of single UV photons and the possibility to define their energy with accuracy no less than 1% is realistic. The count rate exceeding 400 GHz can be achieved.

This work was supported by the RA MES State Committee of Science and Russian Foundation for Basic Research (RF) in the frames of the joint research projects SCS 15RF-018 and RFBR 15-53-05047 accordingly.

Diagnostic device on smartphone basis for obtaining the skin chromophore density distribution maps

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The goal of this scientific research project is to create a method that would allow to use smartphone photo/video camera for creating chromophore concentration maps.

In analytical part is given a concentrated theoretical review about light interaction with human skin as well as the characteristics and possibilities of smartphone cameras.

In methodical part of this research is given schemes and principles of the experiments for finding mobile phone calibration coefficients using color target with known RGB color values in its squares. Specialized light source was made, which consists of light diode ring with 3 different wavelength diodes: blue – with maximum at 460 nm; green – 530 nm; red – 662 nm. The ring has 4 diodes from each color. For analysis of chromophore index (concentration value) in vitro there were created skin chromophore – hemoglobin, melanin, and bilirubin – phantoms, also with added intralipid for creating light scattering effect in phantoms. Melanin phantoms were made of nigrozin, but bilirubin phantoms from carrot juice. A method for in vivo measurements on skin was made.

In results part of this research are smartphone camera correction coefficients, chromophore index values for different concentrations, which were used in experimental results from skin measurements, as well as chromophore maps made from pictures of skin formations.

Multi-spectral fluorescence imaging of skin malignancies

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Most of biological objects contain various types of flourophores. Composition and concentration of these fluorophores affect the shape of fluorescence spectrum of biological object [1]. Thus analyzing the fluorescence spectrum curves one can make conclusions on some properties of investigating substance and differentiate various biological objects. Last three decades many methods employing this feature were developed. Among them multi-spectral and hyper-spectral fluorescence lifetime imaging [2], two-photon fluorescence correlation spectroscopy and imaging [3], scattered–light fluorescence microscopy [4]. Since healthy and pathological tissues contain numerous fluorophores [5], these techniques have been widely employed for diagnosis of skin malignancies.

In present work we propose a novel technique for principal component and linear discriminant analysis of fluorescence imaging data for differentiation of biological objects, and particularly for skin cancer diagnosis. The multi-spectral fluorescence imaging setup includes excitation and detection branches. The excitation branch employs Hg arc lamp and 365 nm narrow-linewidth filter, beam homogenizer, and mechanical chopper, modulating the intensity of UV-excitation. The detection branch uses set of orthogonal bandpass filters and video camera [6, 7]. The central wavelengths of filters transparency windows are λ = 450, 500, 550, and 600 nm and the full width at half maximum of all transparency windows is $\Delta\lambda$=40 nm, which allows to cover wide spectral range. Fluorescence data taken on four central wavelengths forms the four-dimensional principle space. Applying linear discriminant analysis allows to reduce from four-dimensions to one-dimension, and to extract more useful data for differentiation of investigated objects. Described setup was used to study samples of freshly excised BCC and melanomas of the skin. The PCA and LDA of experimental data have shown the ability for differentiating healthy and pathological tissue [8]. We performed mapping of fluorescence images based on PCA and LDA data. Observed results highlight the prospective of the described technique use for medical diagnosis of skin cancers and other malignancies of human body.

Technical realization experimental setup was supported by Russian Foundation for Basic Research project # 14-02-00781. Experimental study of tissue samples in vitro were held thank to support of Russian Scientific Foundation project # 14-15-00758.

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Neutrons diffraction on periodic structures in the presence of external electromagnetic field

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We derive the solution of the Schrödinger equation in the laser field propagating along the direction of constant magnetic field. In the Farri representation, we evaluate the number of quantum transitions and investigate the role of the spin and related effects during the diffraction. We show that the number of quantum transitions is proportional to the fourth power of the number of grating.

On quantum tunneling of inverse power singular potentials

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Is discussed the problem of quantum tunneling through a singular potential, replacing behavior at the singular point by a limiting process: the intermediate, truncated at the point of singularity potential form converge into the original one. Peculiarity of this approach is conservation of probability flow through the point of singularity, and thus its conservation for the whole range of definition. For repulsive potentials we come to a total lack of quantum transparency even in case of a pair of potential barriers which allow a complete transmission at some resonant values of energy for any finite-height barriers.

Also is addressed the problem of resonant tunneling in case of attractive potentials, using the mentioned procedure of regularization. Is shown that except the case of inverse square law of attraction, resonances disappear when the singularity is restored.

Far IR investigations of low energy excitations in $KEr(MoO_4)_2$

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Here we report the systematic investigation of excitation spectra in crystal KEr(MoO4)2. The characteristic feature of rare-earth compounds KR(MoO4)2 (R3+ is a rare-earth ion) is the strong coupling between the electronic excitations of the R3+ ions and phonons. Previous investigations show that the strength of electron-phonon coupling in KR(MoO4)2 can be tuned by a magnetic field [1, 2]. In KEr(MoO4)2 a magnetic field induced structural phase transition has been found at H□4T, T=1.4K.

We investigate KEr(MoO4)2 by means of far-infrared (FIR) spectroscopy using a commercial Fourier-transform infrared spectrometer (Bruker IFS113v) combined with a continuous-field 33-Tesla Bitter magnet. The low temperature FIR study performed in the magnetic fields allowed us to determine energies of electronic excitations as well as lattice vibrations. The obtained frequency-field dependences of electronic excitations show that in this material the phonon energies may coincide with electronic excitations in certain magnetic fields. Also we found complex structure of electronic spectrum in area of CJTE type phase transition.

Additionally in KEr(MoO4)2, the evidence of the non-linear effect induced by a strong coupling between electronic excitations and phonons has been observed in spectra obtained in Voigt configuration (**H** perpendicular to **k**).

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Phase extraction and displacement measurement approaches in phase-step diffractometry

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Phase-step diffractometry is a new technique of phase extraction that has been introduced for several scientific and industrial applications in recent years. Precise measurements of wavelength, thickness and refractive index, surface profilometry and calibration of piezoelectric nanopositioners are some of these applications. There are basically two major phase-extraction approaches in phase-step method, based on calculating either the visibility or the fringe location. Since it is a recent method, it is important to study that different phase-extraction characteristics of phase-step diffractometry. Resolution, sensitivity, repeatability and the effect of several important optical factors such as detector linearity and background intensity are some of the most important properties that need to be investigated. In this presentation, the phase-extraction properties of each of the two major approaches has been studied. Based on the results of these studies, several new phase-extraction approaches has been suggested in order to obtain less noise sensitivity and higher precision.

Cavity solitons synchronization

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Cavity solitons (CSs) are independent and controllable localized light peaks on a low-intensity,homogeneous background and offer a variety of applications from optical memories to all-optical delay lines. The standard configuration is that of an optical cavity containing a nonlinear medium and driven by a stationary holding beam, which provides the energy to the system; both the material sample and the holding beam have a large section. In order to switch ON a CS, a much narrower beam, the address beam, may be coherently superimposed to a broad coherent field, the holding beam. Since CSs have a potential application in signal processing, the response of one CS to a modulation of the holding beam or address beam has recently investigated. Our model is introduced by a full set of Maxwell–Bloch equations valid for describing VCSELs. Two CSs are excited in the injected locked region when the pump current is 20% above threshold. The minimum distance below which CSs begin experiencing mutual interaction is determined. Resonance frequency of the system is estimated. We consider two cavity solitons forced to oscillate by a modulated address beam, so they oscillate sinusoidally in time. Such oscillators can be regarded as self-sustained oscillators. An outstanding feature of this kind of oscillators is their ability to be synchronized. It is illustrated that their oscillations can be synchronized when their interaction is nonsymmetrical. Generally, the interaction between two systems is nonsymmetrical: either one oscillator is more powerful than the other. In this case the frequency of the driven system is pulled towards the frequency of the drive. It means that in our model the modulation amplitude of one CSs must be more strength than the other in order to pull its frequency.

Optical characteristics of graphene films on surfaces with different types of conductivity

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The features of optical properties of grapheme films grown on thin copper Cu (1μm) layer using chemical vapour deposition method were investigated via spectroscopic ellipsometry and nanoscopic measurements. Spectral ellipsometric measurements were performed in λ=250-1000 nm spectral region applying Beattie technique. The azimuth of the restored polarization ψ and the phase shift Δ between p- and s-components of polarization vector were measured at different values of light incidence angle φ from 45o to 75o with step of 5 deg. The ellipsometric parameters ψ and Δ are defined as tan Ψ exp Δ= rp / rs, where rp and rs are the reflection coefficients for the light of p- and s- polarizations. Measurements have been performed consistently for the substrate and for relatively large samples, and modeled by method based on the Fresnel coefficients for multilayer films. Angle variable ellipsometry measurements were performed to analyze the behavior of optical conductivity and dispersion of the complex refractive index. It was observed significant enhancement of the absorption band in the graphene single layer with respect to the bulk graphite due to interaction between exited localized surface plasmon at surface of thin Cu layer and graphene's electrons. Obtained results provide direct evidence of the strong influence of the growing condition and morphology of nanostructure on electronic and optical behaviors of graphene film.

Electric field effect on hot-electron energy-loss rate via LA-phonon scattering in a cylindrical quantum wire

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We have theoretically investigated the influence of an external electric field on the hot-electron energy-loss rate in a cylindrical quantum wire by taking into account the phonon confinement effect. We assume that electrons interact with torsional and dilatational acoustic phonons through deformation potential and with both torsional, dilatational and shear acoustic phonons through piezoelectric potential. Effects of the electric field on magnitude and temperature dependence of the hot-electron energy-loss rate are discussed. The energy-loss rate as a function of wire radius, electric field strength, electron density and electron temperature is obtained. The comparison of our theoretical results for energy-loss rate per electron with the experimental results obtained in the acoustic-phonon scattering regime shows a sufficient agreement.

Optical vortex response to introduced phase objects

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Optical Vortex Scanning Microscope (OVSM) uses focused laser beam with embedded optical vortex to scan the sample. This new scanning method was tested experimentally with simple phase micro-objects. It was shown that our system is sensitive to small phase disturbances which have an impact on both optical vortex position and phase profile. One of the challenges for the OVSM is finding the effective procedures for surface topography reconstruction. We proposed an experimental setup to support the works focused on this problem. The Spatial Light Modulator (SLM) is used as an object generator. SLM allows to generate any phase disturbance with specified value and size, which can be easily introduced into the beam carrying optical vortex. Our system gives an opportunity to measure optical vortex response due to phase modifications introduced by the SLM. We measured optical vortex reaction to simple objects. We tested how object position, size, phase value affects phase distribution around vortex and position of vortex point inside the beam. Phase retrieval algorithm, noise analysis and results of experiments will be presented. These results show the way in which the OVSM should be developed.

Laser assisted fabrication and modification of metal oxides nanostructures

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Recently, there has been a great interest in the nanostructured copper and zinc oxide-based semiconductors. Due to their low cost and abundance, photoconductive, photochemical and antiferromagnetic properties these oxides are among the most attractive active materials for a variety of applications1-4. These nanostructures can be grown using different synthesis techniques, including vapour and liquid phase deposition processes, in which a variety of morphologies can be obtained. Fabrication of nanomaterials with well-defined morphology of structural elements and chemical composition are crucial for achieving their unique properties. In order to fabricate novel nanostructured devices effective methods for generating of nanoparticles (NPs) with desired parameters and assembling of these NPs as specific building blocks into ordered structures are necessary. Several techniques have been reported in literature, describing the assembly of colloidal particles into organized structures, including gravity sedimentation, electrophoretic assembly, spin- or dip-coating, self-assembly and directed self-organization which can provide the transportation of the building blocks to the predetermined sites to produce a nanostructure in a pre-determined way. It should be noted that synthesis of uniform NPs for production of nanostructured materials with new properties or functions is one of the major challenges in nanotechnology.

In this report the results of the laser assisted techniques based on the pulsed laser ablation (LA) in liquid media applied for fabrication of copper and zinc oxide NPs with desired characteristics are presented and a way for assembling of colloidal NPs into nanostructured layers based on laser induced deposition of colloidal NPs on the pre-prepared template is analyzed.

Laser ablation experiments were carried out by focusing of radiation of a Nd:YAG laser (LOTIS TII, LS2134D), operating in a double-pulse mode at 1064 nm (energy 80 mJ/pulse, repetition rate 10 Hz, pulse duration 8 ns), on the surface of the relevant target placed in the cell filled with a liquid (water). For laser-induced modification of the formed NPs the unfocused beam of the second harmonic (wavelength 532 nm) of the same Nd:YAG laser was used. Different optical techniques were applied to investigate the LA process: the optical emission spectroscopy for plasma characterization; fast shadowgraph for cavitation bubble dynamics study; absorption spectroscopy for on-line characterization of NPs in colloidal solutions. The as-prepared NPs were characterized by TEM, SAED, SEM, EDX and XRD. The developed LA technique was shown to be suitable for preparation of particles with desired compositions and morphologies and with sizes in the nanometric range (of 5-30 nm in diameters). The control of stability, size, stoichiometry, crystallinity and chemical composition of the formed particles has been achieved by a proper selection of several experimental parameters such as laser fluence, interpulse delay, a sort of liquid used and post ablation irradiation conditions. The main factors that determine the final composition and morphology of the NPs produced by LA in liquid have been analyzed, including effects of laser ablation parameters.

The preliminary results on constructing of nanostructure arrays from the prepared silver and zinc oxide NPs using the functionalized by the charged polymer substrate and electrophoresis in the corresponding colloidal solution will be also discussed.

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The spectrum and separability of 2-qubit mixed X-states

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The issue of dependence of the entanglement on the spectrum of density matrices of composite systems is studied for the so-called X-states of 2 qubits. It is shown that for an arbitrary spectrum there is 4-parametric family of separable states. The class of absolutely separable X-states, i.e., states remaining separable under the action of the global unitary symmetry transformations of X-matrices, is described. The inequalities in the eigenvalues of X-matrices, defining the absolutely separable X-states, are given.

Enhanced nonlinear light conversion in globular photonic crystals at the band-gap pumping

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The problems of nonlinear process enhancement and high optical harmonic generation are of great importance in optics. Recently, photonic crystals (PCs) [1-3] have attracted considerable interest as prospective media for this purpose. The PC has a structure characterized by a spatially periodic distribution of optical properties, which leads to the appearance of numerous physical effects [4, 5]. These effects allows us employing the PC structures for highly efficient waveguiding [6, 7] nonlinear light conversion, or active media pumping [8, 9].

In this talk, we would consider the results of experimental and theoretical study of the structural light focusing effects in PCs [10]. This effect appears as a result of strong redistribution of electromagnetic field in 2D and 3D PCs at the bang gap-pumping owing to the curvature of its nodes. It leads to strong localization of electromagnetic wave in certain regions of the PC volume and, as a consequence to the enhancement of non-linear optical phenomena [10]. We discuss theoretical background of the structural light focusing effect, the results of numerical simulations, as well as its application for enhanced nonlinear light conversion in artificial opal-based PCs, including generation of second [11, 12] and third [13] harmonics, Raman light scattering [14], and fluorescence.

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Poster Presentations

Resonant circular birefringent transmittance modes in graphene photonic crystals

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A one-dimensional photonic crystal structure containing a single layer graphene sheet is considered. The graphene sheet is embedded between two mirror symmetric Bragg reflectors, and the structure is under the influence of an external magnetic field to induce the gyrotropy of the graphene sheet, and create its circular birefringence properties. Using 4 by 4 transfer matrix method, the circular eigen modes transmittance spectra of the structure are studied for the infrared wavelengths. Moreover, the magneto-optical characteristics including Faraday rotation, ellipticity, and phases of the circular eigen modes at the exit plane of the structure are investigated. The results reveal that for specific conditions of the structure, the resonant circular birefringent transmittance modes are produced in the photonic band gap of the structure. These futures can be potentially utilized in designing the circular transmittance filters based on graphene photonic crystals.

Chirp measurement of ultrashort pulses by the use of train structured by similariton's superposition

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We present a new method of chirp measurement of ultrashort pulses. This method uses nonlinear-dispersion similaritons [1] and their features to obtain the pulses with sinusoidal modulation. Promising results have been obtained for the method, using numerical modeling.

We model an analogue of Shack-Hartmann waveform sensor [2] in the time-frequency domain, which allows to insert spectrally compressed peaks [3] in the signal spectrum. The "distances" between peaks depend on the initial chirp of the signal. Afterwards, the tested pulse initial chirp is recovered by analyzing the dynamics of spectral compression peaks.

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Rashba and Dresselhaus spin-orbit coupling effects on the electronic structure of quantum wires under the influence of in-plane magnetic field

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We have investigated theoretically the simultaneous effect of the Rashba and Dresselhaus spin–orbit interactions on the electronic structure of quantum wires in the presence of magnetic field along the wire. The analytical expression for the electron energy in quasi-one dimensional system is obtained. We have investigated the energy as a function of quantum wire radius, strength of magnetic field, strengths of Rashba and Dresselhaus spin–orbit couplings. We have shown that in the presence of both spin-orbit coupling terms the electron energy doesn't exhibit an angular anisotropy in contrast to the two-dimensional case.

Toroidal quantum dot: Electronic and optical properties

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One electron and exciton states have been considered in the toroidal quantum dot. The convenient coordinate system have been defined and the Schrodinger equation have been written in these coordinates. Electron energy spectrum and wave function dependence on the geometrical parameters have been obtained. The case of flat lower edge of the toroid have been considered. The comparison with the results obtained by numerical methods have been performed. The optical absorption have been considered for both cases of “small” and relatively “large” toroids, when the interaction of an electron and hole is neglected and for the case, when the correlation between the particles was taken into account. Interband and intraband optical transitions have been considered. Absorption edge dependence on the geometrical parameters has been obtained.

X-ray nonlinear Bragg diffraction

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In the work [1] the third order nonlinear dynamical diffraction Takagi's equations are obtained. A numerical method was proposed, the results of numerical calculations and exact solutions both for Laue and Bragg geometries are presented [2,3]. In [4] the time dependent third order nonlinear dynamical diffraction of an X-ray pulse was investigated and the third order nonlinear time dependent dynamical diffraction Takagi's equations are obtained. In this presentation a summary of these works is given from the unique point of view.

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Confined and interface polar optical phonon-limited electron mobility in quantum wires in the presence of perpendicular electric field

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The influence of an electric field on the electron mobility conditioned by confined and interface polar optical phonons for a quasi-one-dimensional cylindrical quantum wire embedded in a dielectric non-polar medium is investigated analytically. It is shown that the inclusion of the polar optical phonon confinement effects is crucial for accurate calculation of the low-field electron mobility in the quantum wire. Taking into account the inelasticity of the electron-polar optical phonon interaction, the electron mobility is derived by a method that was successfully applied in three- and quasi-two-dimensional cases. The contribution of intersubband transitions to electron mobility for the GaAs quantum wire embedded in a glass matrix is estimated. The electron mobility is obtained as a function of the wire radius, applied electric field strength, temperature and the electron concentration.

Electro-absorption in conical quantum dot

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In the framework of the adiabatic approximation, the energy states of electron, as well as the direct light absorption are investigated in conical quantum dot under the external electric field. Analytical expressions for the particle wave function and energy spectrum are obtained. The dependence of the absorption edge on the geometrical parameters of conical quantum dot is obtained. Selection rules are revealed for transitions between levels with different quantum numbers.

Excitonic absorption in gated graphene systems

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Graphene is a single layer of graphite with honeycomb lattice structure. The massless Dirac fermions are presented in graphene; the role of the light velocity *c* here plays the parameter $v_F \approx 10^6$ *cm/s*. Graphene also has been extensively considered as a promising material for nonlinear optical applications [1], since nonlinear quantum electrodynamics effects can be observed in graphene already for fields available in the laboratory. The coherent optical response of graphene systems to laser radiation may reveal many particle correlation effects. In addition to the fundamental interest, the understanding of optical properties of graphene systems may open the way for new applications in nano- and optoelectronics.

Theoretical and experimental investigations on the nonlinear effects induced in graphene system so far have been mainly focused in monolayer graphene. Meanwhile, in the physics of graphene there is growing interest in bilayer and trilayer graphene systems, where the electronic band structures are richer than in monolayer graphene and can be easily manipulated by external fields.

Theoretical and experimental studies have shown that a perpendicular electric field applied to bilayer of graphene modifies its band structure near the K point and may open an energy gap in the electronic spectrum, which is tunable by the gate voltage [2]. The induced gap between the conduction and valence bands could be tuned between zero and midinfrared energies. Also, the magnitude of the gap strongly depends on the number of graphene layers and its stacking order [3].

In this work we investigate excitonic effects in monolayer and bilayer graphene with an opened energy gap.

A substantial band gap in monolayer of graphene can be induced in several ways, e.g., by coupling to substrates, electrical biasing, or nanostructuring [4].

To describe the band structure of graphene systems we use a tight binding approach. In order to take into account the Coulomb interaction, we use second quantized Hamiltonian. We use Hartree- Fock approximation that leads to closed set of equations for the single-particle density matrix.

In the contrast with the standard semiconductor case, in graphene one deals with effective fine structure constant α, and the appearance of bound states strongly depends on the value of α (the choice of dielectric constant κ strongly affects this). For α=0.175 (for the value of dielectric constant χ=12.5) we obtained the maximum of the excitonic peak in monolayer at 4.12R^*. This result is in a good agreement with the exact analytical solution for relativistic 2D hydrogen atom [5].

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Intersubband optical absorption in GaAs parabolic quantum well due to scattering by ionized impurity centers, acoustical and optical phonons

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The intersubband absorption linewidth dependence on well width in GaAs quantum well is calculated. There have been discussed three mechanisms of scattering: carriers scattering by optical (LO), acoustic (LA) phonons and ionized impurity centers (ION). The method which used for calculations is similar to a well-known method of calculating transport mobility. The estimation for absorption coefficient is proposed, based on two-dimensional dynamical conductivity expression. The LO phonon emission process is activated starting from some quantum well (QW) width so it has its impact in absorption linewidth.

Investigation of nanograting structures 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 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 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 . Changes in itself can be described by introducing geometry factor G such that equation (1).

$$\rho(E) = \rho_0(E) / G \qquad (1)$$

where, 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 eigenvalue problems. It was one of the goals of the project to solve this problem using digital methods. MAS have been proposed by Georgian mathematician V. Kupradze [4]. Method was adopted by Georgian scientists for solving eigenvalue 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 Eigen functions. Intensity of the field reaches maximum on eigenvalues. We wrote our program in FORTRAN code. It contains two files.

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Parametrically driven nonlinear oscillator: regimes of selective excitations and quantum statistics of modes

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We discuss new regimes of an optical parametric oscillator combined with an intracavity third-order nonlinear element leading to Kerr photon-photon interaction. On the other side this system can be considered as parametrically driven nonlinear oscillator (PDNO) in which the oscillatory mode is excited through the degenerate down-conversion process [1, 2]. Recent progress in superconducting systems, circuit QED and solid state artificial atoms has opened up new avenues for the design of device configurations based on this system. We investigate PDNO for two cases of excitations: by a frequency-chirped cw driving field or by a train of Gaussian pulses for selective excitations and generation of photon-number states. It is known that for the case of monochromatic pumping there are fundamental limits on populations of photon-number states of PDNR due to dissipation and decoherence. This conclusion restricts the possibilities for realization of the photon blockade due to cw excitations in over transient steady-state regimes. In this report, we demonstrate new various regimes of two-photon excitations of PDNR (frequency-chirped and pulsed excitations) in which the larger photon-number populations of the resonator beyond the cw limits can be created selectively by tuning the frequency of the driving fields The improved populations can be realized by adequately choosing the parameters of the chirp, the detuning and the shape of driving laser pulses. Such selective excitation is associated with two-photon and multiphoton blockades. We also study quantum statistics of modes on the base of the probability distributions of photon numbers, the second-order correlation function of photons as well as the Wigner functions of the cavity mode.

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Exciton spectroscopy of spatially separated electrons and holes in the dielectric quantum dots

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It is shown that the inclusion in the potential energy of an exciton of spatially separated electrons and holes (hole moves in the amount of quantum dots (QDs), and the electron is localized on a spherical surface section (QD - dielectric matrix)) centrifugal energy gives rise to the surface in the zone of quasi-stationary exciton states states that with increasing radius QD moving in a steady state. The mechanisms of formation of the spectra of interband and intraband absorption (emission) of light in nanosystems containing QDs Al2O3, placed in a matrix of vacuum oil. It is shown that electron transitions in the area of the surface exciton states cause significant absorption in the visible and near infrared wavelengths, and cause the experimentally observed a significant blurring of the absorption edge.

Spectron's phase peculiarities: numerical study

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The spectron pulse, which images its spectrum, is known as a one shaped in the "far zone of dispersion" in the temporal analogy of Fraunhofer diffraction [1-3]. The spectron shaping is known in its applications as dispersive Fourier transformation (DFT) [4-6] or in real-time Fourier transformation [7-10]. DFT, maps the spectrum of an optical pulse to a temporal waveform due to chromatic dispersion, thus allowing a single-pixel photodetector to capture the spectrum at a scan rate significantly beyond what is possible with conventional space-domain spectrometers.

The objective of our research is the study of spectron's phase pecularities, to find optimal conditions under which the DFT method works for the phase also i.e. the conditions under which the phase of spectron pulse images the spectral phase, along with amplitude. In our numerical studies, we have examined three different cases. In the first case, we have taken two-peak pulses by summing Gaussian / super Gaussian pulses with various amplitudes and time shifts. In the second case, we have given phase to the spectrum of the initial pulse, such as sine or cosine, with various amplitudes and frequencies. We have examined also the case of initially self-phase modulated pulse (e.g. Gaussian) in the entrance of dispersive medium. The research has shown that in the first case of two-peak pulses the requested dispersion for the phase-mimicking is the same as for the amplitude. We have also found that the spectron pulse intensity minimums are decreasing when the peak values of intensity of initial pulse are close to equal. In the second case, we have found that for the phase-mimicking the request of dispersion is less strict than for the amplitude. The opposite of that has been observed for pulses with strong self-modulation.

The results of our studies on the spectron's phase peculiarities can be prospective for a pulse spectral phase temporal imaging and measurement [11], and for femtosecond pulse complete characterization, alternatively to spectral interferometry.

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Numeric modelling of photophysical properties of hybrid gold nanoparticles

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The model to describe active plasmonic spherical nanostructures allowing modeling the linear optical properties was proposed. Scattering and absorption cross sections, the near field distribution, changes in the radiative and nonradiative spontaneous decay rates, changes in the quantum yield of CAP luminescence, the total change in the luminescence was calculated. The analysis of the results shows that mechanisms of changings in the linear optical properties can be explained with the plasmon-exciton interaction. Extinction and luminescence spectra were determined. Good agreement between theory and experiment indicates that the proposed model is able to explain linear optical properties of hybrid gold structure and the structures of same types.

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Optical properties of double-gated silicon nanowire FETs

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The optical properties of an array of silicon nanowire p^+-p-p^+ field-effect transistors are investigated. Thicknesses of front and buried oxide layers are 8 nm and 145 nm, NW length and thickness are 20 μm and 250 nm, correspondingly. The concentration of acceptors (boron) in both substrate and NW is 10^{15} cm^{-3} and in p^+ source and drain regions 10^{19} cm^{-3}. The peculiarities of source-drain photocurrent over a wide spectrum range are analyzed. It is shown that the absorbance of p-Si NW shifts to the short wavelength region compared with bulk silicon. The photocurrent reaches increased values in the UV range of the spectrum at 300K. Light and dark current-voltage characteristics and spectral dependences are measured at room temperature. The spectral photoresponse of Si NW FET structures is measured using monochromator YM-2. For the irradiation, we used incandescent lamps, positioned at 15 cm from the structure. NW samples are investigated in the wavelength range 0.25-0.6 at irradiation density 1.1 W/cm^2 and 1.6 W/cm^2, respectively. The effect of spectral shift in Si NW was explained as follows.

• The NW width (250 nm) limits absorption of the long-wave photons.

• As opposed to bulk silicon, the energy gap of the Si NWs increases while the NW size decreases.

• Internal quantum yield for Si increases and becomes 2-3 at quantum energy $h\nu \geq 3$eV.

• The color of the emitted light is determined by the choice of the nanoparticle (quantum dot, NW) characteristic size L, since $h\nu = E_g+E_e+E_h$, where E_g is the semiconductor bandgap energy, and the electron and hole confinement energies, E_e and E_h, respectively, become larger while decreasing. As absorption and radiation are conjugating processes then the shift of the absorption spectra to the short-wave range can also be related to this fact. With decreasing size, the short-wave photons can be more effectively absorbed in SiNWs.

Therefore, Si NW FETs can be successfully used as UV photodetectors.

Calculation of characteristics of 2D Metal-semiconductor Field Effect Transistor

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Metal-semiconductor field-effect transistors (MESFET) are regarded as one of the most widespread and prospective semiconductor devises. The 2D Schottky contact structures with modulated inversion layer have the widest application, inasmuch as it is possible to construct devices with very high electron mobility and frequency parameters [1,2]. The speed and the best operating parameters are achieved by minimizing the geometrical sizes of the constructions. The decrease of the sizes leads to the size quantum effects and changes all parameters of the devices. There are various experimental studies on the topic. Particularly, in [3], experimental data of MESFET transistors with 3D-metall and 2D-semiconductor structures are presented. The theoretical calculations reported in literature do not include the nonlinear function between drafting velocity and field intensity. The objectives of the current study is to modulate the working characteristics of 2D MESFET transistors in order to create devices with predictable parameters.

The first part of the study refers to the calculations of characteristics of 2D Schottky contact. For that purpose we solved the Laplace equation by using the mathematical method of conformal mapping. The second part refers to the calculations of the parameters of MESFET transistors. We have not done any significant approximations. In calculations, we consider the nonlinear function between drifting velocity and field intensity, which can be expressed as a variation of the electron mobility.

In our study we have calculated thicknesses of depletion layers and their function of the gap field. We have calculated the Volt-Ampere Characteristics (VAC) of a 2D MESFET, saturation current as a function of gap voltage, and the cannel conductivity. In the case of high voltages, the correction to electron mobility decreases the current of VAC, as well as the saturation current, significantly.

The results of our calculations correlate with the experimental data reported in [3]. A small difference between the theory and the experiment is a result of the fact that the metal gap in experiment is three-dimensional. The theoretical model of MESFET transistors provides with the opportunity to take such parameters of MESFET (material of the channel, sizes, and alloying level) that in turn provide the desirable parameters for 2D MESFET more precisely.

As an approximation, we assume that the alloying level do not vary in direction from the stock to drain.

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CeB_6 hexaboride thin films deposition and investigation a promising material for a sensor of ultrafast single-photon detector

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The thermoelectric effect has numerous applications in science and technology. The problem of obtaining new materials with good thermoelectric properties is urgent and may be a base for either creation of more efficient thermoelectric devices or development of new types of devices, particularly, ultrafast thermoelectric single-photon detectors.

Effectiveness of employment in thermoelectric devices depends on the figure of merit of the material, Z, which is defined by the expression $Z=S^2/\rho k$, where S is the Seebeck coefficient, ρ is the electrical resistivity, and k is the coefficient of thermal conductivity of the material. The highest ZT for CeB_6 compounds is achieved around 5-9 K, i.e. above the liquid-helium boiling temperature which means higher feasibility in practical applications. The ZT parameter of CeB_6 reported in the literature can be as high as 1.5. It is important to note that the range of 0.039-1.5 for ZT implies an energetic resolution of 2–10 eV for a single photon; and if we are to remember that ultraviolet photons have an energy of 3–124 eV, this means that a QVD detector can feel an individual UV photon.

In this work we present data on CeB6 thin film synthesis conditions by e-beam evaporation method, measurement of the thickness, elemental composition, microstructure, temperature dependences of resistivity and Seebeck coefficient. The deposition was carried out from ceramic targets of CeB6, composition onto Si, Al_2O_3, AlN, W and Mo substrates at different deposition conditions. Proceeding from the data on elemental composition of deposited films, we interpret their thermoelectric properties. According to EDX microanalysis results, the films contain oxygen impurity, which probably is the reason of higher resistivity and low Seebeck coefficient values, compared to monocrystalline samples.

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Tunable and polarization dependent absorption in graphene-based hyperbolic metamaterials

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Hyperbolic metamaterials (HMMs) are a kind of anisotropic metamaterials in which dielectric permittivities in orthogonal directions have different signs. In the recent years, a new kind of HMMs was proposed using graphene-dielectric multilayers. In this paper, the absorption properties of a graphene-based HMM are investigated. These structures are strongly anisotropic in the range of long wavelengths. So, their optical properties such as absorption of the electromagnetic waves depend on the polarization and incidence angle. The results show that the perfect absorption is possible in some wavelength ranges for the TM modes while it is impossible for TE polarization. Besides, the value and wavelength range of the absorption depend on the incidence angle and geometrical parameters of the structure. It is shown that the orientation of the optical axis of the anisotropic HMM has also noticeable effect on the wavelength of absorption. These structures may have potential applications in the design of tunable filters, polarizers, photovoltaic devices and so on.

Influence of image charge effect on impurity-related optical absorption coefficient in a spherical quantum dot

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We have investigated the influence of an external electric field on the binding energies of the ground and some first few excited states of a hydrogenic impurity in a spherical quantum dot by taking into account the image charge effect. The oscillator strengths of transitions from the *1s*-like state to excited states of *2s*, $2p_x$ and $2p_z$ symmetries are calculated as functions of the applied electric field and strength of the confinement potential. We have shown that with and without image charge effect the increase of the strength of the parabolic confinement potential leads to the increase of the oscillator strengths of $1s$ - $2p_x$ and $1s$-$2p_z$ transitions. This indicates that the energy differences between *1s*- and $2p_x$- as well as *1s*- and $2p_z$-like states have a dominant role determining the oscillator strength. Although there is almost no difference in the oscillator strengths for transitions $1s$-$2p_x$ and $1s$-$2p_z$ when the image charge effect is not taken into account, it becomes significant with the image charge effect. We have also investigated the dependence of the linear optical absorption coefficient as a function of incident photon energy for several values of the confinement potential energy and the strength of electric field.

Homogenous Solution Analysis of Discrete Cavity Solitons with Carriers

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The homogenous solutions solution and dynamical behavior of Discrete Cavity Solitons (DCSs) in array of coupled optical cavities with nonlinear media have been studied without carrier population influence.

In this work, first of all, we modelized DCSs by including carried population equation in the previous model. Our results shows bistability behavior for homogenous solution for both electrical field amplitude (ES) and carrier density (Ds) versus injecting electrical field power. Linear stability analysis manifests some part of upper bistability branch is modulationaly unstable. Also, we studied turning points of bistability dependence on linewidth enhancement factor as well as the detuning of cavity ad pump frequencies.

Electron diffraction studies of solid mixtures CH4 – N2

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Structure investigations of binary mixtures of the simple molecular crystals are of considerable interest. Solidified methane and nitrogen are the fundamental solids for solving problems of the solid state [1]. Moreover methane is known to occur in the planetary environments [2]. Solid N2 are the formed by the linear and CH4 - tetrahedral molecules. In the lattice CH4 molecules demonstrate a tendency to approximate to spheres. Both the crystal have cubic (fcc) lattice at the equilibrium vapor pressure, symmetry of α – N2 corresponds to the Pa3 space group [3] and methane is described Fm3c [4] below 20,4 K. The nitrogen – methane solid phase diagram has been determined using X-ray diffraction method in studies [5, 6]. There are large discrepancies between results of these structural works. According to [5] a phase separation in CH4 – N2 system was not observed and solutions are cubic at all temperatures below α- β transitions of α – N2 at all concentrations. While authors [6] appointed that the mutual solubility of the components is practically absent in low temperature range despite the small difference in the lattice parameter of the components and their similarity of crystallographic structure. More experiments are required to resolve this controversy. Structure analyses of such solid solutions make it possible to obtain important information for a creation new theoretical approaches and a check of the existing models.

Structure of solid CH4 – N2 mixtures was studied with the transmission electron diffraction techniques equipped with a helium cryostat. The samples were grown “in situ” by condensation gaseous mixtures on Al or C substrate at T = 20 and T = 5 K. The deposition regime was chosen in order to obtain random distributions of impurity. The error in the lattice parameter measurements was usually 0.1 %.

Based on analysis of the obtained diffraction patterns and the concentration dependences of the lattice parameter and diffraction intensity the region of existence of solid solutions was determined. The limiting solubility of CH4 in the nitrogen matrix approaches 10 % mol. The phase separation of the solutions is studied. The effect of dilution CH4 in N2 molecular crystal matrix on the orientation order has been investigated. At low enough impurity fractions obtained data were analyzed with using cluster model.

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FR-IRK mathematical model for solving numerical solution of ordinary differential equations

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Improved Runge-Kutta (IRK) which is named FR-IRK is a mathematical model for solving numerical solution of first order ordinary differential equations (ODEs) which arise in many fields of science such as physics, mechanics and etc. FR-IRK is type of mathematical software that is programmed using the Maple.

FR-IRK software by using a new technique has less computational cost and high error accuracy could be one of useful software for scientists for solving first order ODEs. Also, FR-IRK software could form as a part of mathematical library routines as in Maple, Matlab, Mathematica and other mathematical software.

The numerical results of many tested problems using FR-IRK shows that the new model has less computational cost with higher accuracy compared to the existing classical methods. This proves the efficiency of FR-IRK method.

Peculiarities of the cavity with parallel plate at excitation through subwavelength slit

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The excitation of standing wave shaped by TM mode in the parallel plate resonator by the subwavelength slit milled in one of the metallic plates is presented. Here the excitation coefficient strongly depends on the incident wavelength, which promotes to the further growth of Q factor. The Q factor of the system, calculated using finite element method (FEM), reaches up to values of 104. Resonant wavelength, Q factor, peak to peak distances are controlled using the properties of the slit. The dependence of the resonant curves from the resonator width, incident wavelength, slit displacement and dielectric medium permittivity are presented. The application range of the presented resonator varies from the optical bistability to the single photon radiation sources.

Exciton states and optical absorption in core/shell/shell spherical quantum dot

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The problem of the exciton states in core/shell/shell spherical quantum dot with three dimensional Winteritz-Smorodinkiy confinement potential are considered. The problem is discussed in the framework of adiabatic approximation when the heavy hole is situated in the effective potential well caused by the electron [1, 2]. The interband and intraband optical transitions caused by incident light polarized in z direction have been considered in such system. The selection rules for quantum transitions have been obtained. The ensemble of quantum dots and their size dispersion have been taken into account in the calculations. The Lifshitz-Slezov distribution have been chosen to describe the size dispersion of the core/shell/shell quantum dots thicknesses. The dependence of the absorption coefficient and photoluminescence spectra on the energy of incident light for both cases of interband and intraband transitions have been received.

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Detection of adulteration in edible oils using a low cost imaging spectrometer

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A low-cost imaging spectrometer was designed and built using an in-house grating and a webcam and demonstrated its applications ranging from understanding light spectra from various sources to detecting adulteration in edible oils. The performance of the spectrometer is benchmarked to commercial spectrometers and showed excellent correlation for wavelengths between 450 nm to 650 nm. The spectral range can be improved by removing infra-red filters integrated in webcams.

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«ОПТИКА И ЕЕ ПРИЛОЖЕНИЯ»

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