

IONS Yerevan 2018

August 31 - September 2



IONS YEREVAN 2018



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IONS Yerevan 2018

Օգոստոսի 31 - Սեպտեմբերի 2
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Տեղեկություն գիտաժողովի վերաբերյալ և
գեկուցումների թեզիսները

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International Conference

IONS Yerevan 2018

August 31 - September 2
Yerevan, Armenia, 2018

**Information about the conference and
the abstracts of presentation**

Foreword

IONS™, the International OSA Network of Students conferences, are organized worldwide by OSA student chapters targeting on a huge variety of topics from optics and photonics, which connects you with people from around the globe. While ordinary scientific conferences focus strongly on just one particular topic in optics and are rather impersonal, IONS™ conferences focusses on you. Present your latest results to fellow young scientists from across optics during the scientific sessions, discuss it, and get informed about other young scientist's cutting-edge research projects. IONS conferences gave an opportunity to every student to be a part of a great network between young researchers and talented scientists on an international scale.

IONS Yerevan 2018 is organized by the OSA and SPIE (The International Society for Optics and Photonics) Student Chapters of Armenia in cooperation with Yerevan State University's Student Scientific Society and co-hosted by the OSA student chapter of Taras Shevchenko National University of Kiev. It was hosted in Yerevan State University (Yerevan, Armenia) between August 30 to September 2, 2018, mainly targeting MS, Ph.D students and postdoctoral fellows worldwide whose speciality is optics and photonics. Our aim is to create a warm environment where knowledge sharing and collaboration between young and senior scientists is of huge priority. Both technical and professional development talks and poster presentations are scheduled along with plenary talks and lectures of invited speakers.

**With kind regards,
Organizing committee**

Local Scientific Committee

Levon ASLANYAN: Vice-dean of the Faculty of Physics at YSU

Levon MOURADIAN: Scientific director of the Ultrafast Optics and Photonics Laboratory

Roman ALAVERDYAN: Head of the Chair of Optics at Faculty of Physics, YSU

Rafik HAKOBYAN: Head of Laboratory of Liquid Crystals at Faculty of Physics, YSU

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Natalya GAYDUK

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Invited Speakers



Dr. Carlos Lopez Mariscal
Underwater Photonics, Mexico



Dr. Gregory Quarles
Chief Scientist at The Optical Society



Prof. Juan Campos
Universidad Autónoma de Barcelona



Dr. Yaseera Ismail
University of KwaZulu-Natal



Dr. Viktor O Lisyuk
Institute of Semiconductor Physics (Ukraine)

Conference Venue

Yerevan State University

Organizing Centers

- ✓ *YSU and NAS OSA Armenian Student Chapter*
- ✓ *YSU and NAS SPIE Armenian Student Chapter*
- ✓ *Taras Shevchenko National University of Kiev*
- ✓ *Young Scientists Union of YSU*

Program Highlights

- ✓ *Invited speakers from OSA*
- ✓ *Invited local speakers*
- ✓ *Student talks and poster presentations*
- ✓ *Chapter session*
- ✓ *Lab tour*
- ✓ *Social day*

Topics

- ✓ *Laser and Ultrafast Phenomena*
- ✓ *Fiber Modeling and Fabrication*
- ✓ *Optical Fabrication & Testing*
- ✓ *Optics, Photonics and Optoelectronics*
- ✓ *Micro- and Nanotechnologies*
- ✓ *Advanced Materials and Thin Films*
- ✓ *Lasers in Life Sciences*
- ✓ *Applied Spectroscopy*
- ✓ *Quantum Computing and Information*
- ✓ *Laser Cooling and Atom Trapping*
- ✓ *Plasma Physics and Applications*

Yerevan State University

Physics Faculty

The process of training specialists in the field of physics and materials began in 1922 in Yerevan State University. The establishment of an independent faculty of Physics and Mathematics comprised of separate Chairs of Physics and Mathematics comprised of separate Chairs of Physics and Mathematics comprised of separate Chairs of Physics and Mathematics in 1993 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 on the faculty is comprised of highly qualified specialists. Currently NAS RA three Academics and NAS RA five Associate members, 36 Doctors of Sciences, and more than 80 Candidates of Sciences are involved in the tutoring process of this faculty.

Beginning with 2006-2007 Academic year the specialization (distance learning) of Pedagogue Specialist of Physics is available, too.

The scientific-research activities, which are conducted in the laboratories of the faculty, correspond to the present demands of the field both scientifically and technically. 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 state budget, witness about the active scientific life at this faculty.

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Contents

<i>Foreword</i>	3
<i>Local Scientific Committee</i>	4
<i>Local Organizing Committee</i>	4
<i>Co-hosting Chapter Committee</i>	4
<i>Invited Speakers</i>	5
<i>Conference Venue</i>	6
<i>Organizing Centers</i>	6
<i>Program Highlights</i>	6
<i>Topics</i>	6
<i>Yerevan State University</i>	7
<i>Physics Faculty</i>	7
Oral presentations	10
Yaseera Ismail	
Quantum Technology for the 4th Industrial Revolution	11
Victor Lysiuk	
SPR sensor on plastic substrate: increasing sensitivity vs disc format.....	12
Victor Lysiuk	
Optical and electronic structure properties of $(\text{SiO}_2)_x(\text{Co}_4\text{Fe}_3\text{B}_2\text{O}_{20})_{100-x}$ nanocomposites	13
Hrayr Azizbekyan	
Optical Vector Magnetometry Based on Nonlinear Hanle Effect in Rubidium Vapor	14
Claudio Castellan	
What is the role of trapped charges on the second harmonic generation in strained silicon waveguides?	15
Tatevik Chalyan	
Development of an optical biosensor based on silicon photonics	16
Davit Martiryan	
Study of momentum spectrum of backward scattered protons in electron-nucleus interaction using CLAS (JLAB) data.....	17
Davit Khachatryan	
Selective reflection from the dilute Fabry-Perot interferometer.....	18
Narek Margaryan	
Optoelectrical Properties of Turbostratic Few Layer Graphene.....	19
Vardan Martikyan	
Optimal Control of Linear Systems-Application in Ion Cyclotron Resonance	20
Anastasiia Mykytiuk	
Local trapping and recombination of charge carriers in heterostructures with Ge nanoclusters.....	21

Armen Sargsyan	
Studies of energy levels of alkali atoms in external magnetic fields by selective reflection method and a nanocell.....	22
Hamid Toloue	
Effect of multilayer graphene-coated surface plasmon resonance biosensor on reflection curve.....	23
Badrinath Vadakkapattu	
Improving immersion of head mounted displays through optical design optimizations.....	24
Poster presentations	25
Soumyabrata Banik	
Characterization of Vegetable Oils by Optical Spectroscopy	26
Vitali Ghogoberidze	
Density of quantum states in periodical structures	27
Naira Grigoryan	
Fourier modal method analysis of light interactions with binary dielectric gratings	28
Nataliia Haiduk	
Fluorescence-based monitoring for the spatial and temporal temperature distribution in liquid medium	29
Astghik Kuzanyan	
Thermoelectric Single-Photon Detector Base on FeSb ₂ or CeB ₆ Sensor.....	30
Karen Petrosyan	
Control optical properties of hybrid aligned nematic liquid crystal caused by direct volume expansion.....	31
Lusine Tsarukyan	
Pattern formation in a laser beam propagating through a LiNbO ₃ :Fe crystal.....	32
Harutyun Dashtoyan	
Fabrication And Investigation Of (Pr,Ba)CoO ₃ Thin Films For Oxygen Evolution Reaction.....	33

Oral presentations

Quantum Technology for the 4th Industrial Revolution

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Keywords: Quantum Technology, Quantum Communication, 4th Industrial Revolution

The development of technology is progressing towards the merger between digital technologies and physical systems which is essential for progression towards the Fourth Industrial Revolution. The combination of cyber-physical systems and the Internet of Things will influence most disciplines, economies, and industries. Furthermore machine learning with the combination of quantum assisted optimisation techniques will improve the management of imperative systems. This includes the shift towards quantum information science and the development of quantum technology. The aim of the field is to provide the next generation of information and communication tools. Quantum communication and quantum computing are the two main areas of focus within the field of quantum information science. Upcoming techniques such as machine learning is also revolutionising the way we portray the advancement of technology. Here, we focus on emerging quantum technology and its importance towards the 4th Industrial Revolution.

SPR sensor on plastic substrate: increasing sensitivity vs disc format

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Keywords: plasmonics, surface plasmon resonance, biosensors, refractometers.

Tendencies to miniaturization, cost-effective and high-sensitive marker-free optical sensors for direct detection of molecular interaction in real time, and application of these sensors in the fields such as environment and industrial waste monitoring, production quality estimation, discovery of the new medicaments and clinical diagnosis have been observed and requested on the market. In these sensors one of the interacting molecules is immobilized on the sensor surface, forming a sensitive element, and the binding of a complementary molecule is monitored by measuring the changes in optical density at the sensor surface. The surface plasmon resonance (SPR) method is one of the most advanced and well-developed optical sensing techniques and is widely applied for detection of chemical and biological substances. However, up to this date the SPR-based instruments suffer from insufficient performance, sensitivity, and high production cost [1].

Surface plasmons are the normal modes of charge density existing at the interface between dielectric and metal. Conditions for the resonant coupling of SP and electromagnetic field of the excitation light are extremely sensitive to the changes in optical properties of dielectric medium near the metal surface. These conditions are characterized by the SPR phenomenon and can be registered with the help of various configurations for surface electromagnetic wave excitation (prism or grid) and various methods for measurement of the metal/dielectric interface reflectance (scanning of the incidence angle at the fixed wavelength, wavelength scanning for the fixed angle of incidence, or combination thereof).

To make SPR sensors cost-effective and check availability of development SPR based sensor device in disc format, for which using of plastic substrate is necessary condition, resonant curves (SPR spectroscopy with prism excitation on Kretschmann configuration of scanning incident angle) and microrelief peculiarities of the surface of golden films (AFM – Nanoscope IIIa, Digital Instrument, Santa-Barbara), deposited by thermal evaporation method in vacuum on plastic substrates (optical polycarbonate) have been investigated. Analysis of molecular adsorption kinetics of bovine serum albumin (BSA) in phosphate buffer (PB) has been made to compare plastic and glass substrates both coated by thin gold films. We demonstrated that using of plastic substrates reduces chip cost, leads to easier production technology due to washless preparation method for deposition of gold film and preceded by deposition of adhesive chromium layer, improves gold film surface topography and has a positive effect on surface processes of interaction with chemical or biological analyte. On the other hand resonant SPR curves measured on plastic and glass substrates in gas and liquid medium have almost the same shape, but device response on adsorption of BSA molecules in case of plastic is more sensitive and stable.

The new design of multielement SPR sensor in disk format [2] based on polymer integrated chip, including two reflected metallized surface relief grating (for optical input-output) and sensor space between them coated by gold layer. Traditional glass prisms is changed by diffraction gratings (with linear variable period) which will focus incident light on sensor's space, and reflected light transfer to the line of photodetectors.

Main advantages of the presented sensor configuration are: (1) absence of expensive glass components, (2) procedure of adjustment of immersion liquid refractive index is not required, (3) minimal requirements for adjustment optics, (4) integrated and mechanically rigid construction, (5) sensor chip can be made multielement, single-use by commercially mass production for specific application [3].

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Optical and electronic structure properties of $(\text{SiO}_2)_x(\text{Co}_{41}\text{Fe}_{39}\text{B}_{20})_{100-x}$ nanocomposites

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Keywords: ellipsometry, effective medium theory, metallic nanocomposites, transition-metal-doped materials.

Investigation of complex metallic nano-compounds towards application in systems of magnetic information recording, appropriate sensors, and catalysts in chemical industry, is one of the most priority areas of solid state theory where fundamental and applied interests to studying such kind of materials are expected in due course.

The idea was to find the relations between the optical properties of alloys and its crystal grating structure. Such explorations are extremely interesting even from a pure practical point of view due to possible applications. The approach consisted from the both theoretical and experimental parts. The latter included high spatial resolution scanning tunneling microscopy and spectral ellipsometry. Also we conducted intensive numerical quantum mechanical simulations of superlattice with structures close to the crystal properties of our experimental samples.

The electronic structure calculations we conducted by finding numerically the solutions of steady state Schrodinger equation. Hamiltonian in such approach describes all possible system interactions and wave functions of the electrons which results in finding all energy states. ABINIT software has been used for calculations of the superlattice which contained five atoms $\text{Co}_2\text{Fe}_2\text{B}$ and which chemically close to experimentally studied $(\text{SiO}_2)_x(\text{Co}_{41}\text{Fe}_{39}\text{B}_{20})_{100-x}$.

The numerical calculations of the optical conductivity dispersion curves appeared to be in good correspondence with experimental spectral ellipsometry data if we used well-known Spicer ratio [1] with some modifications. At that point we proposed to take into account only those optical transitions which occurred between energy levels with different orbital quantum numbers (in our case between p- and d- shells). Nanostructured grains of amorphous ferromagnetic alloy $\text{Co}_{41}\text{Fe}_{39}\text{B}_{20}$ included in amorphous dielectric matrix SiO_2 have been produced for investigation of its optical properties by ellipsometry methods in wavelength range from 0,24 to 1,0 μm and surface structure by AFM method. It has been shown formation of Fe clusters with Co and B inclusions producing intense and additional bands that are related with electron transitions from the base states located near Fe to impurity states formed by Co. The comparison of measured data for $\text{Co}_{41}\text{Fe}_{39}\text{B}_{20}$ with theoretically calculated for $\text{Co}_2\text{Fe}_2\text{B}$ demonstrated that intensive absorption bands in Fe-Co-B compounds are formed in result of transition also from s-, p- states of B to electronic states near Fe and Co. Sufficient widening of energy zones, located above Fermi level is happening due to strong scattering of electrons, participated in light absorption, as well as finite lifetime of excited electrons, what has led to sufficient widening of appropriate bands in absorption spectrum $\sigma(h\nu)$.

Scanning tunneling microscopy techniques was used to study the crystal structure of $(\text{SiO}_2)_x(\text{Co}_{41}\text{Fe}_{39}\text{B}_{20})_{100-x}$ nanocomposites. INTEGRA NT-MDT microscope allowed us to conduct measurements for precise scanning of our sample surfaces. Spatial resolution of the measurements reached down to 0.2 nm.

Our results confirmed earlier proposed models where absence of long-range order for crystal with Co atoms in Fe crystal grating resulted in appearance of an additional energy band. Scanning tunneling microscopy measurements also confirmed existence of the crystal lattice far-range ordering. Structure of Fe-Co-B alloys contains clusters of Fe with Co and B impurities and basically its structure consists of different Fe, Co and B clusters. Fe-Co-B nanocomposites absorption curves contain additional strong absorption bands which are mostly the results of these Fe and Fe-Co clusters. There are transitions from energy states in the vicinity of Fe atoms to the states related to Co atoms.

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Optical Vector Magnetometry Based on Nonlinear Hanle Effect in Rubidium Vapor

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Keywords: Optical Magnetometry, Nonlinear Hanle Effect, Rubidium Vapor

A concept of optical two-axis magnetometer based on compensation of measured B -field to the zero value, monitored by a nonlinear Hanle effect in an unshielded Rb atomic vapour cell was recently proposed in [1]. We report on further elaboration of this technique, enhancement and optimization of its performance characteristics. The following issues were addressed in particular: i) upgrading the optical scheme of vector magnetometer to three-axis operation; ii) significant reduction of measurement time by implementing appropriate scanning algorithms; iii) developing automated computer-controlled operation of the device, with friendly readout of the measured B -field.

This was achieved by exciting Rb vapour with two mutually perpendicular resonant radiation beams, branched from the same laser source, and recording fluorescence in an orthogonal direction. Furthermore, alternative B -field scanning algorithms were employed, allowing much faster steering towards compensation value. Proof-of-the-concept measurements have been performed using experimental configuration appropriate for elaboration of a non-expensive prototype device. Although the preliminarily obtained characteristics (≈ 1 mT B -field resolution for ≈ 1 s measurement time) are far from those attained for the state-of-the-art optical magnetometers, there are specific application areas where the proposed scheme can be appropriate. These areas include, but not limited to, geophysical monitoring of ambient magnetic field, laboratory B -field cancellation (alternative to mu-metal shielding), positioning systems.

Among the advantages of developed magnetometry approach are: i) wide measurement range (up to ± 4 mT region where fluorescence signal monotonously increases towards $B = 0$); ii) sign-symmetric shape of the fluorescence dependence on B -field, helpful for precise determination of resonance position; iii) wide $B = 0$ magnetic resonance allowing implementation of feedback-based maximum steering algorithms; iv) uniformity of sensitivity across the whole measurement range. Moreover, the technique is immune against background biasing illumination and slow variations of laser radiation intensity. Further elaboration of the proposed scheme leading to a 10-fold gain in sensitivity and prospective of developing a compact magnetometer device will be discussed.

This work was supported by the RA MES State Committee of Science, in the frame of the research project No 15T-1C277.

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What is the role of trapped charges on the second harmonic generation in strained silicon waveguides?

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Keywords: strained silicon, second harmonic generation in silicon, nonlinear optics, field induced second harmonic generation

The study of optical nonlinearities is receiving rising attention in last years. Among material nonlinearities, second-order processes are preferred because they require less pump power to be activated. However, centrosymmetric materials - like silicon - do not possess second order nonlinearities. In recent years, a great effort has been spent to overcome this limit. One of the most interesting ideas is based on breaking the silicon crystalline structure using a straining layer [1]. In this way, a strong second order susceptibility $\chi^{(2)}$ has been measured via Second Harmonic Generation (SHG) [2]. However, the origin of this result has been debated, due both to the use of highly multimodal waveguides and to the presence of trapped charges at the waveguide-cladding interface [3].

In this work, we perform SHG adopting a multimodal phase-matching mechanism using the experimental setup described in [4]. We study waveguides engineered to convert a pump signal propagating on the fundamental TE mode to a second harmonic signal propagating the TM mode. We measure a $\chi^{(2)}$ of about 0.5 pmV^{-1} . Then, we investigate in detail the origin of this $\chi^{(2)}$. To this purpose, we study SHG under external load using a screw equipped sample holder analogous to the one described in [5]. We demonstrate that SHG efficiency does not depend on the applied stress. To conclude, we expose the waveguide to UV light. In this way, we passivate the trapped charged that have been deposited at the waveguide border during silicon nitride deposition [6]. The complete suppression of the SHG signal is shown in Figure 1(b). This demonstrates that charges play a crucial role, introducing an electric-field-induced SHG. The strength of the strain-induced SHG is below our experimental error, and we estimate it under the level of 0.05 pmV^{-1} .

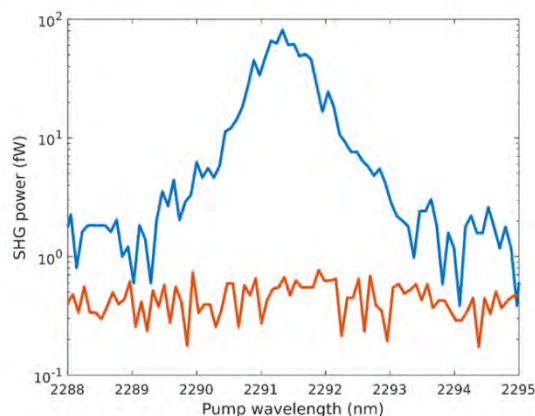


Fig. 1 SHG power as a function of the pump wavelength before (blue) and after (red) the UV treatment.

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Development of an optical biosensor based on silicon photonics

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Keywords: Optical biosensors, silicon photonics, Aflatoxin M1, food safety, asymmetric Mach-Zehnder interferometers.

Optical biosensors and in particular label-free optical biosensors have become one of the most active and attractive fields within the biosensing devices. The portability and the possibility to set free from the laboratory settings gave a new hint for integrated photonic biosensors development and use in numerous applications. Integrated photonic sensors have shown very promising results, and in particular, devices like Whispering Gallery Mode (WGM) resonators and interferometers are showing high sensitivities and miniaturization abilities, which allow the realization of an integrated complete lab-on-chip device.

Within a European Project named SYMPHONY, we develop an integrated silicon-phonic biosensor based on the optical microring resonators (MRR) and the asymmetric Mach-Zehnder Interferometers (aMZI) for mycotoxins detection in real milk samples. The sensing is performed by measuring the resonance wavelength shift in the MRR transmission or the phase shift of aMZI caused by the binding of the analyte to the ligand immobilized on the sensor surface.

Study of momentum spectrum of backward scattered protons in electron-nucleus interaction using CLAS (JLAB) data.

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Keywords: backward going protons, CLAS eg2, coincidence electron-proton events.

The main goal of this analysis is to study momentum (or kinetic energy) distribution of the backward going protons using data from CLAS EG2 experiment at Jefferson Lab. In this experiment scattering of a 5.014 GeV electron beam off various nucleus targets, ranging from deuterium to lead, have been recorded. The analysis includes selection of events in the reaction $A(e, e' p_{\text{back}})X$, where p_{back} is a proton scattered above 90° either in the lab coordinate frame or with respect to the direction of the interacting virtual photon, then performing required corrections and studying the protons momentum distribution as a function of energy transfer. The spectrum of backward scattered protons has been studied since 1970s' with various probes hadron beams at ITEP, FNAL, JINR [1, 2], with photons at YerPhi [3] and with electrons [4, 5]. In this paper identification of electron-proton events is presented.

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Selective reflection from the dilute Fabry-Perot interferometer

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Keywords: spectroscopy, interference, dispersion, Fabry-Perot, line shapes and shifts, selective reflection, theoretical physics

Reflection of radiation from the boundary between a dielectric and atomic vapor, when laser field is detuned in the vicinity of atomic transition frequencies is termed as selective reflection (SR) [1]. Selective reflection spectroscopy has wide application including retrieval of group refractive index [2] locking a diode laser frequency to atomic resonance lines [3], marking atomic transitions [4], determination of the homogeneous width and the shift of resonance lines and atom-wall interactions [5].

Selective reflection has sub-Doppler spectral width that comes from the atom-wall interactions. Atoms after collision to the dielectric boundary lose their polarization (here we assume only diffusive collisions [6]) and after reflection from the wall they will need time (or distance) for regaining their polarization back. Therefore, due to this effect, transient spatial region is formed, where in the different spots we have different polarizations. Also, because this effects atoms that are fling to the wall and atoms that are departing from the wall have different contributions in selective reflection spectrum. This kind of behavior leads to narrower than the Doppler width spectral response for reflection spectrum.

In this work we consider one dimensional problem with cell that has plane-parallel boundaries. We developed self-consistent theory for dilute Fabry-Perot interferometer filled with alkaline vapor. We obtained formulas for single and multiple (see Fig.1) reflections spectra. Also, we obtained spectrum of effective refractive index for single selective reflection. All results are compared with well-known experiments.

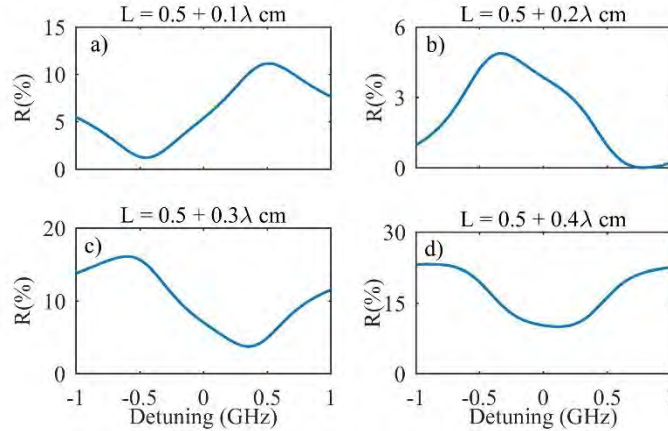


Fig. 1 Selective reflection spectra from Fabry-Perot interferometer for different cell lengths L for atomic density $N = 10^{11} \text{cm}^{-3}$ and $\lambda = 780 \text{nm}$.

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Optoelectrical Properties of Turbostratic Few Layer Graphene

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Keywords: Graphene, Raman spectroscopy, optical absorption, AFM.

Carbon nanostructures and especially graphene are under general attention of international science society due to their unique physical properties and huge application potential [1]. Production of such nanostructures by the most optimal methods is the goal of many studies. The methods based on exfoliation deserve special attention, among other methods [2]. In our research large scale fractal graphene layers are obtained by complex method of liquid phase exfoliation and self- organization. Atomic force microscopy (AFM) is used to study the surface properties of formed layers and to assess their thickness. Surface potential of graphene and potential transition between the graphene and substrate is measured by Kelvin probe method. Raman scattering spectra were used for structural analysis and assessment of the level of defects (Fig. 1). The influence of twisting deformation between layers on Raman spectra is discussed [3].

The optical absorption spectra for these layers indicate the presence of an exciton transition along the M-point of symmetry of the Brillouin zone. These spectra of are affected by dielectric confinement [4] effect (Fig. 2).

In addition, current-voltage characteristics of graphene ribbons were measured and discussed for different number of layers.

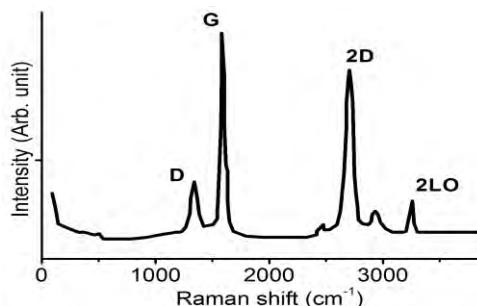


Figure 2: Figure illustrating the Raman spectra of few-

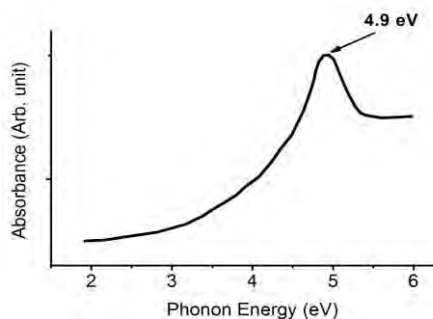


Figure 2: Optical absorption spectra of obtained graphene affected by dielectric confinement.

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Optimal Control of Linear Systems-Application in Ion Cyclotron Resonance

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Keywords: optimal control theory, Fourier Transform Ion Cyclotron Resonance Mass Spectrometry

The motivation comes from a well-known experimental technique for measuring ion masses called Fourier Transform Ion Cyclotron Resonance Mass Spectrometry. Standard fields used in the excitation phase of the experimental process are rectangular, monochromatic and adiabatic pulses. The problem is to find the optimal pulse to excite the ions with minimum energy and higher efficiency. Another issue is also to estimate the advantages of optimal pulses with respect to standard solutions. In order to solve this optimal problem, analytical and numerical calculations were made from the Pontryagin's optimal control theory. Experimental values have been used and some realistic results have been obtained for the optimal fields and trajectories of the ions.

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Local trapping and recombination of charge carriers in heterostructures with Ge nanoclusters

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Keywords: Ge nanoclusters, Si-Ge heterostructures, recombination of charge carriers, Kelvin probe force microscopy

Low-dimensional Si-Ge heterostructures have been extensively studied focusing on many different aspects ranging from growth and characterization of nanoclusters (NCs) to the prospects of their application in novel electronic and optoelectronic devices [1-3]. The transport properties of a lattice mismatched system are to a large degree governed by the presence of quantum states, strain fields, and interface defects created during epitaxial growth. These features can cause nanometer scale variations in the electrostatic potential, which have a significant impact on the recombination processes in the generation and transport of charge carriers. An efficient tool capable of resolving nanometer-scale potential variations is the atomic-force microscopy (AFM) based Kelvin probe force microscopy (KPFM) technique [4].

The Ge NC structures resulted from Stranski-Krastanov growth [5] during Ge MBE on boron doped ($N_a \sim 10^{15} \text{ cm}^{-3}$) Si(001) substrates with resistivity of $7.5 \Omega \cdot \text{cm}$. Ge was deposited at a deposition rate of $\sim 0.05 \text{ \AA/s}$ and a substrate temperature of 600°C resulting in a strain driven formation of faceted Ge NCs with lateral extensions between 60 and 450 nm, and heights between 60 and 450 nm. For electrical characterization an AuSi eutectic contact was fabricated at the back of the Si wafer pieces by melting at 370°C . In order to quantify the Ge content and strain values, micro-Raman spectra were measured at room temperature. Excitation was performed using the 488 nm line of a Ar-Kr ion laser having a power of 3 mW and a spot diameter of 0.50 mm.

Topographic and surface potential measurements of Ge-Si heterostructure were performed simultaneously under normal ambient conditions. Silicon probe-tips with conductive diamond coating doped with nitrogen were used to measure the contact potential difference (CPD) between the tip and the surface. These probes have a typical tip radius of 35 nm. The cantilever's force constant and the resonance frequency were in the range of 5.5-22.5 N/m and 190-325 kHz, respectively. The area under investigation was $1 \times 1 \mu\text{m}^2$, which was scanned at 1 Hz scan rate and 1 V peak-to-peak AC voltage applied to the tip.

The observation of a surface potential distribution with maxima at the Ge NC location and lowest values at the NC's surrounding is indicative for trapping of positive charges within the NCs. A clear linear decrease of the potential from the top of the Ge NCs to their bases is observed. This manifests that the number of holes stored in the individual Ge NCs is higher as compared to holes captured by other traps of the substrate surface.

Electrons or holes were injected into the isolated Ge NC on top of the Si layer using a conductive AFM tip. After charging of a single nanocluster, significant changes in the surface potential and charge redistribution were observed. After electron injection, the CPD map exhibits higher contrasts due to electron-hole recombination and a decrease of positive charges trapped by Ge NCs and surface states. On the other hand, holes injected into a single Ge nanocluster can spread out into the surrounding region when biasing of the n-tip/i-Ge NC/p-Si junction in the reverse direction. As a consequence, the CPD map exhibits the highest value and becomes practically equipotential between NC and surrounding.

The role of Ge NCs and surface (WL) states in recombination of excess of charge carriers on the nanometer scale could be evaluated by analyzing the time evolution of the CPD after hole injection. The surface or WL states were found to be more efficient Shockley-Read-Hall recombination centers as compared to the Ge NCs. The observed temporal evolution of the CPD map confirms the ability of NCs to retain the holes during a long time after injection.

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Studies of energy levels of alkali atoms in external magnetic fields by selective reflection method and a nanocell

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Keywords: alkali atoms, selective reflection, nanocell, magnetic field

A number of magneto-optical processes running at interaction of a narrow-band laser radiation with atomic vapours are adapted in laser technology, metrology, problems of quantum communications, etc [1,2]. That's why the detailed studies of atomic energy levels in external magnetic fields is in extreme importance. As it is known, the energy levels of atoms undergo frequency shifts and changes in their transition probabilities in an external magnetic field B [1,2].

Recently we have shown that the selective reflection of a laser radiation from an interface of dielectric window and atomic vapour confined in a nanocell with a thickness of a $\sim 300\text{nm}$ is a proper tool for atomic spectroscopy [1-4]. The real-time derivative of SR signal (dSR), where each frequency position of the recorded peaks coincides with the atomic transition one, is used and provides a 30 - 80 MHz spectral resolution with respect to the transition probabilities [3-5].

Below by selective reflection method and a nanocell use the high resolution study of energy levels of alkali atoms as Rubidium, Cesium and Potassium will be presented. The comparison of dSR with other sub-Doppler methods as saturated absorption will be discussed. Possible applications will also be shown.

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Effect of multilayer graphene-coated surface plasmon resonance biosensor on reflection curve

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Keywords: SPR, biosensor, graphene, sensitivity, COMSOL.

In this research, the effect of multilayer graphene on reflection curve of surface plasmon resonance (SPR) biosensor is numerically simulated to develop the highly sensitive detection. In a conventional SPR sensor, a thin metal layer is sandwiched between two dielectrics. Noble metals such as gold (Au) or silver (Ag) are used as the metallic films since they lead to SPR at visible light frequencies [1]. Unfortunately, biomolecules are absorbed poorly on the metal surface, and the sensitivity is ultimately limited. Another drawback of the conventional SPR sensor is oxidation of metal surface, causing dramatically degradation in sensitivity. An attractive alternative is to functionalize the metal surface with biomolecular recognition elements (BRE). Graphene is applied as BRE by coating the top of metal film. The reflection curve becomes wider and broader by increasing the number of graphene layers which may affect measurement [2]. In comparison to conventional SPR sensors, graphene-coated biosensors give a larger local change in the refractive index of sensing medium near the sensor surface [3]. Surface plasmons interacts with an optical wave in the Kretschmann configuration. This interaction can be appropriately analyzed by using transfer matrix method based on Fresnel multilayer reflection [4]. The light reflection coupled into a SPR mode propagating along a gold-graphene layer is calculated and compared to a conventional SPR sensor with varied gold thicknesses. The electromagnetic field in SPR condition analyzed using COMSOL Multiphysics. The change in the minimum reflection in regard to the number of extra graphene layers on varied Au films is demonstrated. It is confirmed from the simulation that the sensitivity of multilayer graphene-coated SPR biosensor is expected to achieve improvement of (about 190%) in comparison with conventional sensors. The figure of merit for wavelength modulation is enhanced about 23% compared with the case of angular modulation even in the exactly same structure.

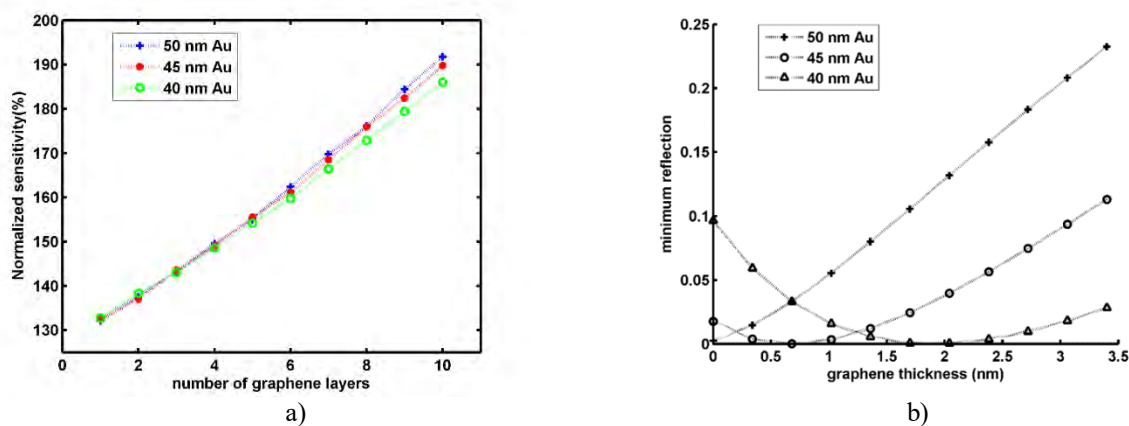


Fig. 1 a) The normalized sensitivity to refractive index change versus number of graphene layers; b) Minimum reflection versus graphene thickness for three different thicknesses of gold.

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Improving immersion of head mounted displays through optical design optimizations

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Keywords: Vergence-Accommodation Conflict (VAC), Field of View (FOV), Optical Design Optimizations

The emergence of new Virtual Reality (VR) and Augmented Reality (AR) technologies has changed the gaming and entertainment industry but also have shown great potential in engineering and medical applications. This has increased the importance to improve the immersive experience in the most natural way possible. Some of the hurdles like Vergence-Accommodation Conflict (VAC) and limited Field of View (FOV) need to be addressed. The aim of our work is to adapt the optics of a head mounted display (HMD) to achieve an improved perceptual experience. Furthermore, we want to simulate and present the 3D environment in the most comprehensible way.

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Poster presentations

Characterization of Vegetable Oils by Optical Spectroscopy

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Keywords: Fluorescence, Raman spectroscopy, Vegetable oils, Adulteration.

Abstract: Vegetable oils are edible oils as well as has many applications in cosmetics and industries which usually prone to adulteration due to the similar physical appearance of the oils. The adulterants added to the vegetable oils can have two impacts either it can affect the genuineness or authenticity of the oil or it can have kind of health-related side effects to consumers. Argemone oil is an adulterant mainly in mustard oil, which can cause the clinical condition known as epidemic dropsy and several other health-related issues. The quantification of the quality of oils is the big concern of the techniques used; chemical analytical methods and chromatography techniques are usually expensive, time-consuming and require sample preparation for the analysis. In order to overcome these, fluorescence and Raman spectroscopy are used for investigating the adulteration in vegetable oils which are not time-consuming, expensive, less quantity of sample and do not require sample preparations. Fluorescence spectroscopy can quantify different fluorophores present in the various types of vegetable oils (olive oil, sunflower oil, coconut oil, mustard oil and palm oil) such as chlorophyll which respond in the region of 650 nm - 730nm, similarly, vitamin E can be detected in the region of 500nm-600nm. In Raman spectroscopy, the unique Raman spectra of the vegetable oil signifies the chemical nature for each oil. Each peak in the spectra corresponds to particular chemical bond; the wavenumber 3015 cm^{-1} represents the =CH bond, $2970\text{-}2860\text{ cm}^{-1}$ represents the C-H bond, 1750 cm^{-1} represents the C=O bond and 1100800 cm^{-1} represents the C-C bond. This paper proposes a method to analyze the adulteration in vegetable oils through fluorescence signals and chemical signature using series of excitation wavelengths in fluorescence spectroscopy and Raman spectroscopy.

Acknowledgement: We would like to thank Dr. K. Satyamoorthy, Director, School of Life Sciences and Manipal Academy of Higher Education (MAHE), Manipal, India for providing the fund and infrastructure needed to perform the project. We would like to thank Mr. Subhash C, Department of Biophysics, School of Life Sciences, MAHE, Manipal, India for discussion and technical support.

Density of quantum states in periodical structures

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Keywords: Material Sciences

New quantum effects have been studied in thin nanograting layers. Nanograting on the surface imposes additional boundary conditions on the electron wave function and reduces the density of states. When the dimensions of the nanograting are close to the De Broglie wavelength the density of states reduction is considerable and leads to change in the layer properties. Calculations of the density of states are challenging to perform and are related to the quantum billiard problem. Performing such calculations requires to find solutions for the time-independent Schrodinger equation with Dirichlet boundary conditions [1].

It was one of the goals of this work to solve this problem using numerical methods. There is a full mathematical analogy between quantum billiards and electromagnetic resonators. Therefore, it is reasonable to use the Method of Auxiliary Sources (MAS) for quantum billiard calculation, as it is most efficient numerical approach for solving eigen value problems. It was one of the goals of the project to solve this problem using digital methods. MAS has been proposed by Georgian mathematician V. Kupradze [2]. Method was adopted by Georgian scientists for solving eigen value problems related to wave guides with arbitrary cross-section [3, 4]. 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 which solutions are coefficients of the decomposition. Coefficients should be obtained by solving of the mentioned linear system where one of the coefficients is fixed. It means that the field inside area of interest becomes non-trivial only when the main parameter of the problem is near to eigenvalues and we can easily observe the forming of eigenfunctions. Intensity of the field reaches maximum on eigenvalues. The calculations are performed in Fortran.

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Fourier modal method analysis of light interactions with binary dielectric gratings

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Keywords: Binary dielectric grating, FMM, TE and TM polarization

Scattering of monochromatic light at a two-dimensional binary dielectric grating is analysed by use of Fourier modal method (FMM). The light is linearly polarized and is obliquely incident at an arbitrary angle upon the grating bounded by two semi-infinite different media. The FMM is a straightforward rigorous technique especially suited to obtaining numerically exact solutions of Maxwell's equations for the problems of light diffraction at periodic and aperiodic planar structures. This method shows good convergence with no instabilities and overflows. It can be applied equally well to thin, thick and surface relief gratings. The transmitted and reflected diffraction efficiencies of TE and TM polarized waves have been numerically evaluated and mutually compared. These efficiencies have been plotted for different grating periods and for different fractions of the grating period occupied by the ridge.

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Fluorescence-based monitoring for the spatial and temporal temperature distribution in liquid medium

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In many technological processes and in biomedical applications, it is important to know the spatial and temporal distribution of temperature in a heated medium. Usually there is a need to control the local temperature by a non-contact method. Traditionally, the temperature is controlled by pyrometric measurements. However, for a wide range of technological processes and biomedical applications, the pyrometric method is not sensitive enough.

It is well known that the fluorescence spectra of some organic dyes solutions are very sensitive to temperature. In the present work, the aqueous and glycerin solutions of the organic dye of rhodamine 6G (R6G) were used as a non-contact temperature sensor. Two parameters of the fluorescence spectrum showed a unambiguous temperature dependence over a wide range of temperatures: the wavelength at the maximum of the spectrum and the asymmetry of the spectral band. At not very high temperatures these dependences are almost linear. This behavior completely corresponds to the existing concepts, since the temperature dependence of fluorescence spectra of solutions is essentially due to the relaxation kinetics of the solvent.

The fluorescence spectrum of the sample was excited with a semiconductor laser (405 nm, 50 mW) and detected by a low-dispersion spectrometer. In output plane of spectrometer the CCD camera has been planted and connected with computer. Capture video and preprocessing of spectrum was carried out with help of open source software *ImageJ*.

The saturated aqueous solution of R6G was heated up to $t = 100^{\circ}\text{C}$, and glycerin solution – up to $t = 300^{\circ}\text{C}$ in a microwave oven. Temporal changes in the parameters of the fluorescence spectrum corresponded to the calculated heating dynamics and showed good correlation with the operating mode of the microwave oven.

An aqueous solution of R6G was used to monitoring the spatial and temporal temperature distribution in a rectangular (18 x 3 mm) glass cuvette. The wide side had heat-conducting contact with a surface heated to 70 °C. The dynamics and the spatial profile of the temperature distribution corresponded to the calculated data.

Thermoelectric Single-Photon Detector Base on FeSb₂ or CeB₆ Sensor

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Keywords: Thermoelectric, Single photon, Detector

Sources and detectors of single photons have attracted significant research attention in the recent years due to their wide use in different areas of science and technology. Single photon detectors capable to determine the photon energy and to provide high count rates are demanded in quantum electronics, astrophysics, high energy physics, quantum informatics, telecommunication systems, quantum metrology, measuring systems for applications in medicine, homeland security and other fields [1]. Among the developments of last 17 years, superconducting nanowire single-photon detectors (SNSPD) are considered as the most promising. According to their characteristics they are much favorable in comparison to all earlier known detectors. They possess gigahertz count rate and are able to register photons in a wide range of the electromagnetic spectrum [2]. The thermoelectric single-photon detectors (TSPD) have similar characteristics. The physical concept of TSPD was suggested in 2000 [3] being the only new approach in single photon detection methods introduced during quite long time period. Next investigations have shown that TSPD may compete with superconducting detectors, since in some properties and characteristics they are better. Computer simulation of heat distribution processes in a detection pixel of TSPD has shown that the multilayer architecture of detection pixel has some advantages over a single layer [4, 5]. In this work are presented the results of computer simulation of heat propagation processes in the three-layer detection pixel of TSPD with FeSb₂ and CeB₆ sensors, W absorber and heat sink.

It is obvious that low operating temperatures of single-photon detectors are necessary to suppress the thermal noise. This requirement leads to the necessity of using the compounds having high Seebeck coefficient at low temperatures in TSPD. FeSb₂ and CeB₆ have high Seebeck coefficient at 9 K.

Computer modeling is carried out on the basis of the equation of heat propagation from the limited volume by the use of three-dimensional matrix method for differential equations. It is shown that a single-photon thermoelectric detector with a three-layer detection pixel will have gigahertz count rate, high energy resolution, and detection efficiency exceeding. Considering the advantages of three-layer detection pixel compared to the single-layer, we can hope that further use of three-layer detection pixel of thermoelectric detector will solve a number of single-photon detection tasks.

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Control optical properties of hybrid aligned nematic liquid crystal caused by direct volume expansion

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Keywords: Nematic Liquid Crystals, hybrid alignment, hydrodynamics, light-induced reorientation

The optical properties of Nematic Liquid Crystal (NLC) layer depend on the alignment of NLC molecules [1]. Because of its large optical anisotropy NLC is sensitive to such external influences such as electromagnetic fields and hydrodynamic flow. Under the influence of the hydrodynamic flow alignment of the NLC molecules varies and the optical properties of the NLC layers become different. One of the methods of inducing a hydrodynamic flow in NLC layer is based on the mechanism of direct volume expansion.

The hybrid alignment of nematic (HAN) molecules is obtained when one of the substrates of the NLC cell is imposing homeotropic orientation and the other planar orientation. Across the layer thickness the molecules of the NLC are tilting with respect to the cell normal from perpendicular to parallel. It was shown that reorientation of the NLC molecules in HAN is a phenomenon which has no threshold which will enable creation of low threshold optical components. That's why it is interesting problem to create methods of controlling the orientation of HAN molecules.

Light induced hydrodynamical reorientation of NLC director was predicted long ago and is widely investigated. In [2] was studied the influence of the hydrodynamic flow induced by low power laser irradiation on the optical properties of NLC layer with homeotropic alignment. In this work we investigate the influence of the hydrodynamic flow on the optical properties of hybrid aligned NLC layer. We measure the transmission coefficient dependence on the flow velocity and structural changes occurring in the NLC layer.

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Pattern formation in a laser beam propagating through a LiNbO₃:Fe crystal

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Keywords: Pattern formation, Beam propagation, Gaussian beam, Lithium niobate crystal

Lithium niobate (LN) crystals are very promising materials for holographic data storage and readout, light driven manipulation phenomena and optical communication systems due to their excellent photorefractive and pyroelectric properties. Dark and bright solitons and vortex beam formation were observed in LN crystals.

We report for the first time the regular optical pattern formation in a laser beam passed through a photorefractive Fe doped lithium niobate crystal (LN:Fe).

The experiments were performed with the use of single mode He-Ne laser Thorlabs HP-100 generating at 632.8 nm wavelength laser beam with maximum power of 10 mW. The LN:Fe samples with reduced 0.03 wt% concentration of Fe and the lengths of 4, 6, 10 mm along beam propagation Y and transverse sizes of 4.2 mm (X) and 4.4 mm (Z) were used in the experiments. The series of experiments were performed for 0.02, 0.08, 0.5, 1, 2 and 5 mW powers of laser beam and keeping the crystal at room temperature of 22 °C. The C-axis of the crystal was oriented in vertical Z direction. Laser beam has ordinary polarization. The laser beam was focused by short focal length objective (3.8×) to the size of 72 μm at the input face of the LN:Fe crystal. The forward travelling laser beam at the output face of the crystal was projected by lens to the entrance of CCD camera, connected to computer, which provides the registration and measurements of beam transverse profile time evolution.

The results of experiments on the time evolution of the laser beam profile during propagation through the LN crystal detected at the output face of the crystal are shown in Fig.1.

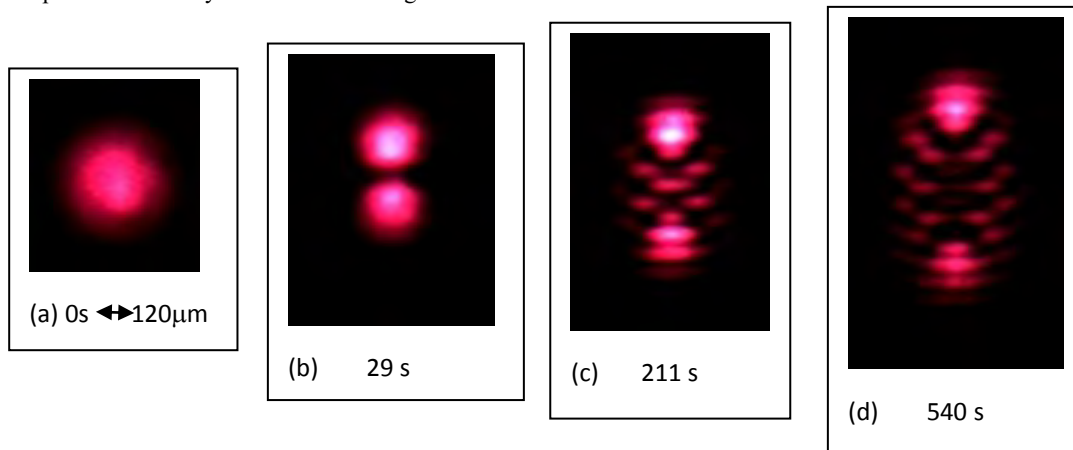


Fig.1. Time evolution of the laser beam profile at the output face of the LN crystal

Time evolution of the laser beam during propagation through the crystal shows the splitting of a Gaussian beam (Fig.1a) into two beams (Fig.1b) and then formation of very regular pattern of focal spots. In particular, for 0.5 mW laser beam power and 10 mm crystal length a regular light pattern is formed after 211 s (Fig.1c). This pattern remains unchanged and stable until 328 s. Further evolution shows formation of more complicated but regular pattern at 540 s (Fig.1d). The observed patterns are reproducible for fixed power of input laser beam.

Observed phenomenon of optical pattern formation can be connected with the light induced complex refractive index variation with a central minimum (negative lens) and side maxima (positive lenses) [1]. Light induced complex lens structure produces beam defocusing from the beam centre and focusing on the periphery. Mutual interference of the beams with different phases leads to the regular light pattern formation.

The formed filaments inside the LN crystal are narrow micrometric scale light channels promising for optical information transfer through these channels. The obtained overall refractive index distribution inside the LN crystal is a quasi-crystalline photonic structure because has no translation symmetry but a 2-fold rotation symmetry.

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Fabrication And Investigation Of (Pr,Ba)CoO₃ Thin Films For Oxygen Evolution Reaction

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Keywords: oxygen evolution reaction, pulsed laser deposition, (Pr,Ba) CoO₃ epitaxial thin films.

The epitaxial (Pr,Ba)CoO₃ thin films with different strain on different substrates have been fabricated by PLD for oxygen evolution reaction (OER). We have investigated the relation between the crystal structure as a function of strain and the resulting effect on the electrocatalytic performance for OER. The RHEED-controlled PLD growth, AFM, XRD, RMS investigation of the thin films, and the analysis of electrochemical properties in electrochemical cells is carried out.

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