CONTENTS

Foreword

During 2016 the Institute organized the following events: on 26th of February an Info Day, on 22nd of June a Round Table "Research and Innovation for Smart and Sustainable Economy", on 16th of September an Open Day, and an exhibition in the lobby of the administrative building of BAS.

During the third year of the project INERA time span the eight recently purchased experimental equipment, namely: Atomic Layer Deposition System (Beneq TFS 200); Automatic Spectroscopic Ellipsometer (M2000D, Woollam) Microfluidic Platform (CellASIC® ONIX, Millipore Merck); Automated Handheld Cytometer (Scepter 2.0); Compact Electrochemical Workstation (SP-200, Bio-Logic); Membrane Filtration System (MaxiMem, Prozesstechnik GmbH); Experimental Setup for Chemical Vapour Deposition (Oxford Nanofab Plasmalab 100); Femtosecond Laser System (Mai Tai SP) were put into exploitation and the first scientific results were obtained and published in internationally recognized journals. Several training seminars were organized, aiming at improving the expertise of the institute's scientific personnel and giving detailed information on the specifications and capabilities of the equipment.

Two scientific events were organized in the frames of the project INERA: The Conference "Vapour Phase Technologies for Metal Oxide and Carbon Nanostructures" was held from 5th to 9th of July, 2016 in Velingrad, Bulgaria and the workshop MELINA 2016 "Membrane and Liquid Crystal Nanostuctures" was held from September 3rd to September 6th, 2016 in Varna, Bulgaria.

The traditional 19th International School on Condensed Matter Physics devoted to "Advances in Nanostructured Condensed Matter: Research and Innovations" was held from August 29th to September 2nd, 2016 in Varna, Bulgaria.

The total number of publications of ISSP during 2016 is 192, 173 among them printed and 19 at press. 119 papers have been published in high impact journals indexed in ISI web of knowledge and SCOPUS. The total number of citations in 2016 exceeds 1236. ISSP currently holds 8 BG patents and 4 applications for patents are in procedure, 5 of which are filed in 2016.

Acad. Nicola Sabotinov received an award of Optics Communications – Certificate of Reviewing and became an honorary member of the Scientific Council of the Institute of Polymers – BAS. Honorary membership of ISSP during 2016 was awarded to Prof. Nikolay Tonchev and postmortem to Prof. Vesselin Kovachev. Assoc. Prof. Mihail Bushev was awarded with the Georgi Nadjakov prize.

The scientific teams, led by Assoc. Prof. Victoria Vitkova and Assoc. Prof. George Hadjihristov were awarded the prize for major scientific achievements for the year 2016 in ISSP.

Hassan Chamati

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Bulgarian Academy of Sciences

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Mission of the Institute: achievement of fundamental knowledge in the condensed matter physics, optics, spectroscopy and laser physics; application of this knowledge for the creation of new materials, devices and analytical methods for micro- and nano-technologies, as well as for new approaches in the interdisciplinary fields of the physics with biology, medicine, archaeology; transfer of the achieved results to the economy of Bulgaria.

Every second year since 1980, ISSP organizes at the Black Sea coast an International School-Simposium on contemporary problems in condensed matter physics (ISCMP).

EQUIPMENT, METHODS AND TECHNOLOGIES

ISSP has at his disposal rich variety of equipment, precise methods and technologies:

- Equipment and methods for electron microscopy and electron diffraction investigations, atomic, electric and magnetic force microscopy, X-ray diffraction with topographic, diffractometric and spectrometric facilities, ellipsometric measurements, spectroscopy from VUV to IR spectral regions, time-resolved spectroscopy, EPR spectroscopy;
- Equipment and know-how for single crystal growth from oxide materials for laser techniques and photorefractive effect applications, techniques and technology for thin layer deposition for microelectronic, optoelectronic and acoustoelectronic sensors and laser technology, cleanroom, complex equipment for molecular beam epitaxy, equipment for synthesis and investigation of high temperature superconducting materials;
- Equipment for polarization measurements in mesophases and polymer liquid crystals for display techniques, equipment for stroboscopic videomicroscopy and micromanipulation of lipid membranes;
- Various laser systems: gas discharge metal vapour and solid state (ns and fs) lasers, oscillating in UV, visible and IR spectral range, for plasma physics applications, laser analysis and material processing, for application in nanotechnology, medicine, archaeology, ecology, etc.;
- High-tech experimental setup for laser cooling of atoms (~ 0.0001K);
- Equipment (Physical Properties Measurement System produced by Quantum Design, USA) for studies of electrical, magnetic and thermal properties of materials, surfaces and structures;
- Scanning probe microscope (VEECO, Multimode, USA) for precise surface characterization at the nanoscale.

HISTORICAL REFERENCE: *ISSP at BAS is created by a Decree No 362 / October16, 1972, of the Ministry Council of Bulgaria. This Decree splits the existing Institute of Physics with Atomic Scientific Experimental Center (IP with ASEC) at BAS, founded by Academician G. Nadjakov in 1946, into ISSP and INRNE (Institute of Nuclear Research and Nuclear Energy), starting January 1, 1973. Since February 16, 1982 the Institute of Solid State Physics is named after Academician Georgi Nadjakov. The first Director (1973-1991) of the Institute of Solid State Physics was Academician Milko Borissov. The second Director (1991-1999) was Professor Nikolay Kirov. The third Director (1999-2015) of the Institute of Solid State Physics was Academician Alexander G. Petrov.*

ORGANIZATION OF THE INSTITUTE OF SOLID STATE PHISICS

DIRECTORATE

Director:	Prof. H. Chamati, D.Sc.
Deputy Directors:	Prof. K. Blagoev, D.Sc. Prof. A. Paskaleva, D.Sc.
Scientific Secretary:	Assoc. Prof. J. Genova, Ph.D.

DEPARTMENTS

Theory	Head: Prof. H. Chamati, D.Sc.
Functional Materials and Nanostructures	Head: Prof. A. Paskaleva, D.Sc.
Nanophysics	Head: Prof. D. Nesheva, D.Sc.
Physical Optics and Optical Methods	Head: Assoc. Prof. T. Tenev.
Soft Matter Physics	Head: Prof. I. Bivas, D. Sc.
Laser, Atomic, Molecular and Plasma Physics	Head: Prof. K. Blagoev, D.Sc.
Innovation Department:	Head: Assoc. Prof. D. Spassov, Ph.D.
Education Department:	Head: Prof. A. Paskaleva, D.Sc.
Center for Investigation of the Physical Properties of Materials, Surfaces and Structures:	

SCIENTIFIC COUNCIL

Chairman: Prof. D. Nesheva, D.Sc.
Deputy Chairman: Prof. I. Bivas, D.Sc.
Secretary: Assoc. Prof. E. Dimova, Ph.D.

1. Acad. A. G. Petrov, D.Sc.
2. Prof. K. Blagoev, D.Sc.
3. Prof. H. Chamati, D.Sc.
4. Assoc. Prof. A. Paskaleva, D.Sc.
5. Assoc. Prof. V. Vitkova, Ph.D.
6. Assoc. Prof. J. Genova, Ph.D.
7. Assoc. Prof. M. Grozeva, Ph.D.
8. Assoc. Prof. P. Zahariev, Ph.D.
9. Assoc. Prof. O. Ivanov, Ph.D.
10. Assoc. Prof. V. Mihailov, Ph.D.
11. Assoc. Prof. E. Nazarova, Ph.D.
12. Assoc. Prof. G. Popkirov, Ph.D.
13. Assoc. Prof. M. Primatarowa, Ph.D.
14. Assoc. Prof. P. Rafailov, Ph.D.
15. Assoc. Prof. T. Tenev, Ph.D.
16. Stefan Karatodorov (young scientists representative)

RESEARCHG GROUP

ELECTROMAGNETIC SENSORS

HEAD: Assoc. Prof. Ognyan Ivanov, Ph.D.
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TOTAL STAFF: **6**
RESEARCH SCIENTISTS: **2**

Assist. Prof. L. Mihailov, Ph.D.; P. Todorov, Ph.D. student – Mechanical engineer; Y. Ralev, Ph.D. student – Mechatronic engineer; S. Markova, B.Sc. student – Laboratory technical assistant; V. Altunova, B.Sc. student – Laboratory technical assistant;

RESEARCH ACTIVITIES:

During the year we have been working on the project COUNTERFOG – European project under the program *Security*. During 2016 studies of the interaction of solid surface with two-phase fluid were conducted. For this purpose Surface photo charge effect (SPCE) was used. Based on the obtained results, sensors for biphasic fluids have been developed.

Carbon dc sputtered films have been studied. The substrate used was soda lime glass. It is known that this α-carbon/silicate glass system is characterized by processes of self-organization. During arc deposition of carbon on glass surface typical spirals are formed. The aim of the study was to find the origin of spirals appearance – whether or not mechanical stress in the system gives as a result spirals formation. It turns out that its shape, dimensions and concentration depend on film thickness. It has been found that this dependence is in a good agreement to mechanical stress dependence on film thickness. This correlation shows that spirals are formed for 10 to 100 nm film thickness.

The ground-state electron energies, the mass correction and mass polarization of low and multiply charged helium-like ions are analytically and numerically calculated. Approximately 3500 different kinds of ions with charge Z from 2 to 118 are considered. The two-electron Schrodinger equation was solved using a discrete variational-perturbation approach developed by the authors. The results are presented with and without the inclusion of the mass polarization in the minimization procedure. The role of the inclusion of the mass polarization in the minimization procedure as an instrument to present and take into account the effects induced by the nuclear properties, structure and characteristics has been shown. As a result of Landau quantization of electron motion, the equation of state for magnetars (neutron stars endowed with surface magnetic fields) is considered including dependencies on the magnetic field strength.

PUBLICATIONS:

1. A. F. Fantina, N. Chamel, Y. D. Mutafchieva, Zh. K. Stoyanov, **L. M. Mihailov**, J. M.

Pearson, R. L. Pavlov. Role of the symmetry energy on the neutron-drip transition in accreting and nonaccreting neutron stars, *Phys. Rev. C,* **93**(1), 015801 (2016)

2. N. Chamel, Y. D. Mutafchieva, Zh. K. Stoyanov, **L. M. Mihailov**, R. L. Pavlov, Landau quantization and neutron emissions by nuclei in the crust of a magnetar. *J. Phys. CS,* **724**, 012034 (2016)
3. Zh. K. Stoyanov, R. L. Pavlov, **L. M. Mihailov**, Ch. J. Velchev, Y. D. Mutafchieva, D. Tonev, N. Chamel. Nuclear induced effects and mass correlations in low and multiply charged helium-like ions, *J. Phys. CS,* **724**, 012048 (2016)

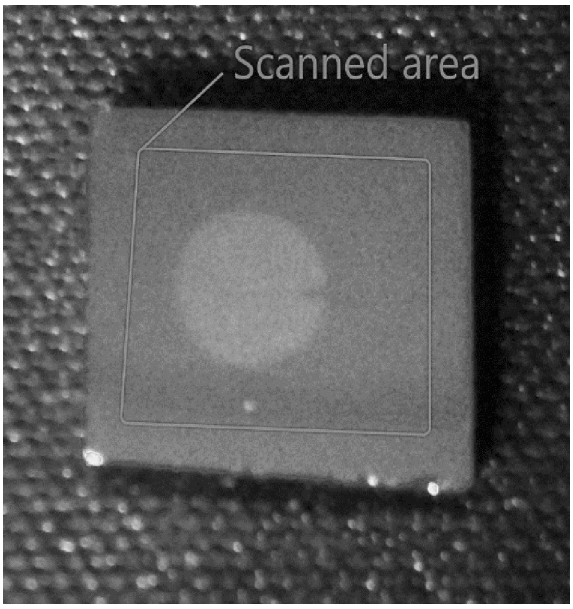
ONGOING RESEARCH PROJECTS:

European project: *Device For Large Scale Fog Decontamination* (COUNTERFOG) – FP7, Programme *Security,* Project Number - 312804

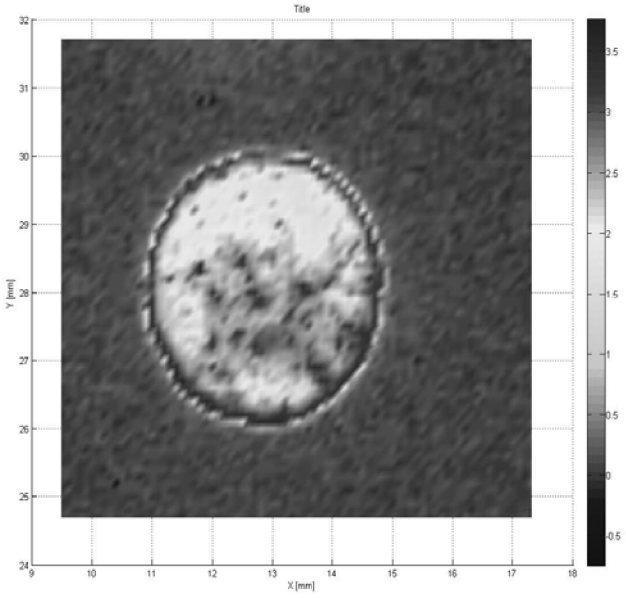
INTERNATIONAL COLLABORATION:

We are working together with 9 European research centers which are members of the consortium running the project COUNTERFOG.

We initiated the creation of a system for automated scanning of wafer specimens. It finds SPCE-sensitive spots on various solid surfaces.



The specimen being scanned



Proof of concept scan over a known ion implanted area of a specimen

DEPARTMENT THEORY

LABORATORY

THEORY GROUP

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TOTAL STAFF: **12**
RESEARCH SCIENTISTS: **11**
ASSOC. MEMBERS: **1**

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Assoc. Prof. DSc Elka Koroucheva, Assoc. Prof. Dr Zlatinka Dimitrova,
Assoc. Prof. Dr Radostina Kamburova, Asst. Prof. Dr Alexander Donkov,
Asst. Prof. Dr Javor Boradjiev, Asst. Prof. Dr Stanislav Varbev,
Asst. Prof. Hristo Tonchev, Physicit Kostadin Gaminchev,
PhD Student Miroslav Georgiev

Associated members: Assoc. Prof. Marina Primatarowa

RESEARCH ACTIVITIES:

Following the established tradition the scientists at the Theoretical Department applied the physical methods to create models and to do analyzes in the modern areas of the science with important implications for improving the quality of life, as biophysics, biomedicine and medical physics, new materials, nano and information technologies physiological and social systems.

The functionality of lipid vesicles is tightly related to their overall stability in biological environments. We have addressed the thermodynamic behavior and the structural stability of pure lipid vesicles of either dipalmitoylphosphatidylcholine (DPPC) or distearoylphosphatidylcholine (DSPC) in water via molecular dynamics simulations. We have employed the GROMACS 4.x molecular dynamics package in conjunction with the MARTINI coarse grain force field to perform our simulations. To achieve our goal, we designed a script to construct in advance general initial configurations with different shapes. We have shown that the preformed DPPC and DSPC vesicles remain thermodynamically stable throughout the simulation time, although the time step needed to solve the equation of motion for DSPC vesicles is several orders of magnitudes smaller than that of DPPC. The success of the proposed approach enables us to “build” an initial simulation set of vesicles and to shorten the simulation time significantly.

Statistical and multivariate analysis are applied to medical study to evaluate the spread of disease and identification of significant clinical indicators of its development and the corresponding risks. After analysis of CT images and numerical calculations of the blood flow in the abdominal aorta and aneurysm sac we search for additional factors to determining the risk of rupture and death for sick people.

Spin system in Heisenberg approximation is considered, which consists of two magnetic sublattices with different type of atoms, respectively of different intra-exchange interaction. The interaction between sublattices is weak compared to intra sublattice ones. The calculations are done for body centered cubic and body centered tetragonal crystal structure. When the interaction between different magnetic sublattices is ferromagnetic the system may serve to

describe volume ferrimagnets with compensation point as $DyFe_5Al_7$, for example, whose phase diagram experimentally shows the presence of spin reorientation phase transition which nature is not sufficiently clarified. For antiferromagnetic interaction between the different magnetic sublattices , residual magnetic moment is observed as well as emergence of non-collinear antiferromagnetic structure, as well as possibility for occurrence of reentrant transition with the temperature decrease for certain magnitudes of exchange interactions. The description of reentrant phase transition especially concerns the Heusler alloys and their use in spintronics. For the application of the theoretical results to real experimental systems will be necessary to include the spin-orbit interaction in order to describe precisely the magnetic moment directions in both subsystems.

A field theory is developed and grounded for layered anisotropic antiferromagnets with frustrated (not compensated) exchange interactions. The theory describes a wide class of such systems by using the usual mean-field approximation, perturbation schemes and the renormalization group methods. Research is completed on fluctuation phenomena close to the spinodal points in the first order phase transition vicinity (general theory).

We continue the studies concerning phases and low-lying excited states in strongly frustrated magnetic systems. Now the focus was on the role of three-site exchange interactions in low-dimensional (D=1,2) Heisenberg systems. In particular, using the DMRG method, as well as some analytical calculations, the full quantum phase diagram of the basic 1D model with additional three-site interactions and two types of alternating site spins (S=3/2, and s=1/2) has been obtained.

We have investigated a theoretical model describing the dynamical propagation of solitons in system of two coupled magnetic chains with different types of linear and nonlinear interactions between them. The exchange interaction between two adjacent spins in the same chain is ferromagnetic, while the interaction between the spins of the two chains can be either ferromagnetic or antiferromagnetic. In the model is also included the one-ion anisotropy in the chains. It is found a condition for forming bright and dark solitons in the system. It is examined the evolution of a soliton which is excited in one of the chains and is found the condition for perfect transfer of the soliton from one chain to the other and vice versa. The soliton dynamics, in the case of ferromagnetic interaction between the spins of the chains, is more stable.

The Jaynes-Cummings model from the quantum optics has been used to study the interaction between one mode of the quantized electromagnetic field with a spin molecule, which consists of spin-1/2 spins, the interaction is via one of the spins in the spin molecule. The spin-spin interactions of the Ising, the XY, or the Heisenberg type have been used. Analytical expressions for the energy levels in the case of 4 spins in the molecule have been obtained, and numerically configuration of up to 10 spins have been analyzed. The energy levels have been classified using the invariant, that is an analog of the total magnetic moment, present in the model. This allowed to make a comparison the even and odd spin number cases, the ring and opened type configurations of the spin molecules, and to analyze the differences in the energy spectra between the different models. In addition, for the case of the XY model of the spin-spin interactions, the energy spectra of the model with multiple photons (modes of the em-field) have been numerically obtained in the case of photons coupled to one of the spins in the spin molecule. The difference in the spectra as compared to the one mode case have been observed.

The registers to be used in quantum computers are qubits, or more generally, qudits, which is a quantum system with two, respectively, d levels. The Grover algorithm is a quantum search algorithm in an unordered database of N elements. While in a classical search algorithm the number of required steps may grow linearly with the number of the elements N, in the Grover algorithm this scales as sqrt (N), which gives a quadratic speed-up. One of the precursors to use this algorithm is to find the number of elements, that satisfy the search conditions. This number is determined by the so called quantum count algorithm. Such an algorithm is a

particular case of a more general quantum phase determination algorithm. So far, the quantum counting algorithm have been aimed at qubit registers. A new quantum phase determination as well as a new quantum counting algorithms have been proposed for qudit registers. Their fidelity, as applied to qubit and qudit registers, have been obtained numerically. Along with the exponential grow of the size of the registers, the simulations show a much higher probability to obtain the number of solutions when a qudit based algorithm is used as compared to a qubit based one.

We consider the amplitude for the decay of Higgs boson into two Z-bosons through the *W*-loop, and through the *ZZH*-loop. Applying the *Cutkosky's* rules we found analytical formulas for the imaginary parts of the Feynman amplitudes. The next step is to recover the Feynman amplitudes from their imaginary parts by means of dispersion relation.

It is present a one-parameter families of mKdV-type equations related to $D_4^{(1)}$ and $D_4^{(2)}$ algebras. They are a set of partial differential equations, integrable via the inverse scattering method. This method is reduced to Riemann-Hilbert problem. The system of equations admit a Hamiltonian formulation and the corresponding Hamiltonians are also given.

The synchronization process have been studied in the context of a network topology of the Small World type. The networks are formed by chaotic elements with delay interactions between them. Introducing dynamic links, it is shown that rapidly changing topology of binding contributes better for the synchronization of the system. Networks topology of the Small World type were researched also in the context of opinion formation in social systems in the case where the elements take 3 values. The influence of various parameters on the behavior of the system have been studied by numerical simulations and show a good agreement with results from real social systems.

From the point of view of the theory of thermodynamic systems and the theory of nonlinear dynamical systems we present the importance of the scientific organization for economic and social development of society. For this purpose scientific organization is presented from the perspective of the theory of thermodynamic systems. In the aspect of physical science, scientific organization is open, dissipative and to develop, i.e. to have a continuous development of knowledge, it must be far from equilibrium state. Therefore, continuous flows of energy, matter and information which are needed for its self-organization have to direct to it. Scientific organization as dissipative structures can exist only in close interaction with the larger social systems and structures. When this connection is interrupted (stop the financing and stop coming young people in scientific organizations), then under the laws of thermodynamics, scientific organization will go into a state of thermodynamic equilibrium (maximum entropy and minimal organization). Research shows that "destruction" of scientific organizations leads to lower GDP growth of the country, since 90% of GDP of developed countries today is generated based on the activity of scientific organization.

PUBLICATIONS:

1. Bian, C, Lin, R, Zhang, X, Ma, Q D Y, **Ivanov, P Ch**. Scaling laws and model of words organization in spoken and written language. EPL (Europhysics Letters), 113, 1, IOP, 2016, ISSN:0295-5075, DOI:10.1209/0295-5075/113/18002, 18002-1-18002-6. ISI IF:1.963
2. Caprena, P, Coronado, A. V., Carretero-Campos, C, Bernaola-Galván, P, **Ivanov, P. Ch**. First-Passage Time Properties of Correlated Time Series with Scale-Invariant Behavior and with Crossovers in the Scaling. Time Series Analysis and Forecasting, Part of the series Contributions to Statistics, Springer, 2016, ISBN:978-3-319-28723-2, DOI:10.1007/978-3-319-28725-6_7, 89-102

3. **Chamati, H.**, Romano, S.. Nematic order in a simple-cubic lattice-spin model with full-ranged dipolar interactions. Physical Review E, 93, American Physical Society, 2016, DOI:10.1103/PhysRevE.93.052147, 052147-052147. ISI IF:2.252
4. **Chamati, H.**, Trobec, R., Pavlič,.J.I.. Peculiarities in the study of DSPC lipid vesicles by coarse-grain molecular dynamics. Advances in Biomembranes and Lipid Self-Assembly, 23, Elsevier, 2016, ISBN:978-0-12-804715-6, DOI:10.1016/bs.abl.2015.12.002, 20, 169-185. SJR:0.204
5. Drumev K.P., **Georgieva A.I.**. Interrelations between the Pairing and Quadrupole Interactions in the Microscopic Shell Model. EPJ Web of Conferences, 107, EDP Sciences, 2016, ISBN:2100-014X, DOI:10.1051, 6
6. Drumev, K P, **Georgieva, A I**. The use of the pairing-quadrupole connections in PQM for application in nuclear systems. AIP Conference Proceedings, 1722, American Institute of Physics, 2016, ISSN:0094-243X, DOI:10.1063/1.4944126, 030003-030003. SJR:0.2
7. Fernandez, M A, **Korutcheva, E**, de la Rubia, F J. A 3-states magnetic model of binary decisions in sociophysics. Physica A, 462, Elsevier, 2016, ISSN:0378-4371, DOI:10.1016/j.physa.2016.06.017, 603-618. ISI IF:1.785
8. **Georgieva A. I.**, Drumev K.P.. Phases and Phase Transitions in the Algebraic Microscopic Shell Model. EPJ Web of Conferences, 107, EDP Sciences, 2016, ISSN:ISSN (Electronic Edition): 2100-014X, DOI:10.1051, 03019-1-03010-6
9. **Georgieva, A I**, Drumev, K P. Connections between the dynamical symmetries in the microscopic shell model. AIP Conference Proceedings, 1722, American Institute of Physics, 2016, ISSN:0094-243X, DOI:10.1063/1.4944127, 030004-030004. SJR:0.2
10. Gerdjikov, V. S., Mladenov, D. M., Stefanov, A. A., **Varbev, S. K.**. MKdV equations related to the D(2)4 algebra. Romanian Journal of Physics, 61, 1-2, Publishing House of the Romanian Academy, 2016, ISSN:1221-146X, 100-123. ISI IF:1.398
11. Gómez-Extremera, M, Carpena, P, **Ivanov, P Ch**, Bernaola-Galván, P A. Magnitude and sign of long-range correlated time series: Decomposition and surrogate signal generation. Physical Review E, 93, American Physical Society, 2016, ISSN:2470-0053, DOI:doi.org/10.1103/PhysRevE.93.042201, 042201. ISI IF:2.252
12. **Ivanov, N.B.**, Petrova, S.I., Schnack, J.. Alternating-spin S=3/2 and s=1/2 Heisenberg chain with three-body exchange interactions. The European Physical Journal B, 89, Springer, 2016, ISSN:1434-6036, DOI:10.1140/epjb/e2016-70057-y, 121-6 pages. ISI IF:1.345
13. **Ivanov, P. Ch.**, Liu, K K, Bartsch, R P. Focus on the emerging new fields of network physiology and network medicine. New Journal of Physics, 18, Institute of Physics, 2016, ISSN:1367-2630, DOI:10.1088/1367-2630/18/10/100201, 100201. ISI IF:3.57
14. Li, S, Lin, R, Bian, C, Ma, Q, **Ivanov, P Ch**. Model of the Dynamic Construction Process of Texts and Scaling Laws of Words Organization in Language Systems. PLoS ONE, 11, 2016, DOI:10.1371/journal.pone.0168971, e0168971. ISI IF:3.234
15. Lin, A, Liu, K K, Bartsch, R P, **Ivanov, P. Ch.**. Delay-correlation landscape reveals characteristic time delays of brain rhythms and heart interactions. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 374, 2067, Royal Society, 2016, ISSN:1364–503X, DOI:10.1098/rsta.2015.0182, 20150182. ISI IF:2.441

16. Martin, M J, D'Huys, O, Lauerbach, L, **Korutcheva, E**, Kinzel, W. Chaos synchronization by resonance of multiple delay times. Physical Review E, 93, American Physical Society, 2016, ISSN:2470-0045, DOI:10.1103/PhysRevE.93.022206, 022206-022206. ISI IF:2.252
17. Nikolova, E., Goranova, E., **Dimitrova, Z. I.**. Assessment of Rupture Risk Factors of Abdominal Aortic Aneurysms in Bulgarian Patients Using a Finite Element Based System. Comptes rendus de l'Acade'mie bulgare des Sciences, 69, 9, Издателство на БАН, 2016, ISSN:1310-1331, 1213-1222. ISI IF:0.233
18. **Tonchev, H**, **Donkov, A. A.**, **Chamati, H**. Energy spectra of a spin-½ XY spin molecule interacting with a single mode field cavity: Numerical study. Journal of Physics: Conference Series, 764, Institute of Physics, 2016, ISSN:1742-6596, DOI:10.1088/1742-6596/764/1/012017, 012017. SJR:0.21
19. **Tonchev, H. S.**, Vitanov, N. V.. Quantum phase estimation and quantum counting with qudits. Physical Review A, 94, American Physical Society, 2016, DOI:10.1103/PhysRevA.94.042307, 042307-042307. ISI IF:2.765
20. **Tonchev, H.**, **Donkov, A. A.**, **Chamati, H.**. Interaction of a single mode field cavity with the 1D XY model: Energy spectrum. Journal of Physics Conference Series, 682, Institute of Physics, 2016, DOI:10.1088/1742-6596/682/1/012032, 012032-1-012032-6. SJR:0.22
21. Vitanov, N. K., **Dimitrova, Z. I.**, Kantz, H.. ON MODELS OF SCIENCE DYNAMICS AND ASSESSMENT OF RESEARCH PRODUCTIVITY. BULGARIAN-GERMAN SCIENTIFIC COOPERATION: PAST, PRESENT, AND FUTURE PROCEEDINGS OF THE HUMBOLDT-KOLLEG Sofia, November 26 – 28, 2015, Faber Publishing House, 2016, ISBN:978-619-00-0517-9, 194-208

ONGOING RESEARCH PROJECTS:

- Field theoretical approach and numerical studies of macromolecular chains in confined geometries, Bilateral Agreement between Bulgarian Academy of Sciences and The Polish Academy of Sciences.
- Low dimensional Heisenberg spin systems with three-body exchange interactions, Bilateral Agreement between Bulgarian Science Fund and DAAD Germany
- Synthesis and theoretical studies of graphene nanostructures, Bilateral Agreement between Bulgaria and JINR Dubna, Russia
- *New Frontiers of Peer Review – COST Action TD1306*
- *European Cooperation for Statistics of Network Data Science – COST Action CA15109*
- Phases and excited states of highly frustrated magnetic systems, Bulgarian Science Fund

INTERNATIONAL COLLABORATION:

University of Bielefeld, Germany

University of Pavia, Italy,

Technical University of Cracow, Poland

Universidad Autónoma de Madrid

TEACHING ACTIVITIES:

Courses at the Education Center, Bulgarian Academy of Sciences

Prof. Hassan Chamati, DSc

COMPUTER MODELING OF COMPLEX SYSTEMS

Latex Basics

DEPARTMENT FUNCTIONAL MATERIALS AND NANOSTRUCTURES

LABORATORY

PHYSICS OF MATERIALS AND LOW TEMPERATURES

HEAD: Assoc. Prof. Peter Rafailov, Ph.D.
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TOTAL STAFF: **16**
RESEARCH SCIENTISTS: **10**
HONORARY MEMBERS: **1**
ASSOC. MEMBERS: **1**

Prof. M. Gospodinov, DSc; Prof. N. Tonchev, DSc; Assoc. Prof. P. Rafailov, PhD; Assoc. Prof. E. Nazarova,, DSc; Assoc. Prof. P. Sveshtarov, PhD; Assoc. Prof. D. Dimitrov, PhD; Assoc. Prof. E. Vlakhov, Ph.D.; Assist. Prof. K. Buchkov; Assist. Prof. A. Zahariev Assist. Prof. L. K. Yankova; V. Tomov, MSc; S. Petrov, MSc; O. Mihailov, technician; M. Valkovski, technician; S. Simeonov, technician; P. Zashev, technician;

Associated members: Prof. Marin Gospodinov, DSc
Honorary members: Prof. Nikolay Tonchev, DSc

RESEARCH ACTIVITIES:

During the reporting period in-depth research on the magnetocaloric effect in complex metal oxide crystals was conducted. We established a strong rotating magnetocaloric effect in single crystal of TbMn2O5. The results reveal prospects for the development of compact embedded magnetocaloric devices for use at low temperatures and under extreme conditions.

Surface states, structural and transport properties in the topological insulators Sb2Te2Se and Bi3Se2Te were investigated. Thin layers of Bi3Se2Te were synthesized by pulsed laser deposition of material from Bi2Se2Te single crystal. They have a linear magnetoresistance at high magnetic fields (B $\geq$ 4 T) and two-dimensional weak antilocalization effect at low fields B ($\pm$ 1 T), which is due to topological surface state. The investigated Sb2Te2S single crystals represent semiconductors with isolated Dirac cone and high stability of the topological surface state. It was found that the maximum of their valence band in the volume is lowered below the Fermi level and that they exhibit Seebeck effect of the same sign for the surface and volume charge carriers, which makes the system Sb2Te2Se promising material for spintronic and thermoelectric devices.

Single- and multilayer graphene was obtained by chemical deposition on copper foil. Vertically grown carbon nanotubes were obtained in the plasma enhancement mode. The synthesized samples were characterized by Raman spectroscopy and scanning electron microscopy.

An analytical approach is developed to the problem of computation of monotone Riemannian metrics (e.g. , Bogoliubov-Kubo-Mori, Bures, Chernoff, etc.) on the set of quantum states. The obtained expressions originate from the Morozova, Cencov and Petz correspondence of monotone metrics to operator monotone functions. The used mathematical technique provides analytical expansions in terms of the thermodynamic mean values of iterated (nested) commutators of a model Hamiltonian T with the operator S involved through the control parameter h. Due to the sum rules for the frequency moments of the dynamic structure factor, new presentations for the monotone Riemannian metrics are obtained.

Particularly, relations between any monotone Riemannian metrics and the usual thermodynamic susceptibility or the variance of the operator S are discussed. If the symmetry properties of the Hamiltonian are given in terms of generators of some Lie algebra, the obtained expansions may be evaluated in a closed form. These issues are tested on a class of model systems studied in condensed matter physics.

Electro-transport studies of Ag–doped $FeSe_{0.94}$ polycrystalline superconductors are performed. The effect of different AC current amplitudes on the superconducting transition and pinning properties are investigated. Inverse power low dependence of the pinning energy from the applied current is detected, corresponding to a domination of collective pinning / creep of large size vortex bundles. Using a V-I dynamical (hysteresis type) characteristics, the weak links effects on the vortex dynamics were studied and particularly the temperature dependence of the critical current at close vicinity region near T_c. The strong implication for the proximity coupling of grains was found due to the Ag segregation at grain periphery.

The effects of high pressure during annealing on the structural and superconducting properties of Ag –doped $FeSe_{0.94}$ superconductors were evaluated. The obtained results indicate that the annealing at high pressure increases the critical temperature, upper critical field and irreversibility field due to the improved uniformity and grain connectivity.

Surface enhanced Raman scattering (SERS) was observed from arrays of gold nano-particles, produced on glass substrates by 2-photons photo-reduction of the metallic precursor ($HAuCl_4$) hosted in a Poly-Vinyl Alcohol matrix. Samples with different nano-particles size and density were obtained by varying the writing laser power and scanning speed. The Raman spectra were recorded from samples immersed in a solution of rhodamine-6G (R6G), as well as, after exposure of the samples in xylene. SERS enhancement factor of up to ~10^4 were obtained for both analytes. The measurements show that the SERS enhancement is maximized on golden strips produced at higher writing laser power and lower scanning speed, were closer nano-particles packing is obtained.

AWARDS: Prof. DSc Nikolay Tonchev was awarded the honorary member status by the Colleguium of the ISSP – BAN.

Team headed by Assoc. Prof. E. Nazarova, PhD and collaborators Assoc. Prof. N. Balchev, PhD, Assist. Prof. K. Buchkov, PhD and Assist. Prof. A. Zahariev, PhD won first place in the competition for excellent scientific achievement with initiator and donor Academician A. Petrov.

PUBLICATIONS:

1. Wang, Z.S., Qureshi, N., Yasin, S., Mukhin, A., Ressouche, E., Zherlitsyn, S., Skourski, Y., Geshev, J., Ivanov, V., Gospodinov, M., Skumryev, V.. Magnetoelectric effect and phase transitions in CuO in external magnetic fields. NATURE COMMUNICATIONS, 7, 2016, 10295. ISI IF:11.329.
2. Tomov, V., Rafailov, P.M., Chih-Wei Luo. Growth, composition, ferroelectric and magnetic properties of new multiferroic Pb3.3Mn4.8Ni1.1Ti0.56O15.3 single crystals, Crystal Research & Technology, vol 51, issue 7, 2016, DOI:10.1002, 446-452. ISI IF:0.88.
3. Rohrbeck, A., de la Flor, G., Aroyo, M. I., Gospodinov, M., Bismayer, U., Mihailova, B.. The effect of chemical variations on the structural polarity of relaxor ferroelectrics studied by resonance Raman spectroscopy. JOURNAL OF PHYSICS-CONDENSED MATTER, 28, 2016, 475902. ISI IF:2.209.

4. Petrov, M., Katranchev, B., Rafailov, P.. Induction of chiral phases in originally achiral hydrogen-bonded dimer liquid crystals. Molecular Crystals and Liquid Crystals, 641, 1, 2016, ISSN:ISSN:1542-1406, 95-105. ISI IF:0.532.
5. Lee, C. K., Cheng, C. M., Weng, S. C., Chen, W. C., Tsuei, K. D., Yu, S. H., Chou, M. M. C., Chang, C. W., Tu, L. W., Yang, H. D., Luo, C. W., Gospodinov, M. M.. Robustness of a Topologically Protected Surface State in a Sb2Te2Se Single Crystal. SCIENTIFIC REPORTS, 6, 2016, 36538. ISI IF:5.228.
6. Le, P. H., Chiu, S. P., Jian, S. R., Luo, C. W., Lin, J. Y., Lin, J. J., Wu, K. H., Gospodinov, M.. Nanomechanical, structural, and transport properties of Bi3Se2Te thin films. JOURNAL OF ALLOYS AND COMPOUNDS, 679, 2016, 350-357. ISI IF:3.014.
7. Lai, Y.-C., Rafailov, P. M., Vlaikova, E., Marinova, V., Lin, S. H., Yu, P., Yu, S.-C., Chi, G. -C., Dimitrov, D., Sveshtarov, P., Mehandjiev, V., Gospodinov, M. M.. Chemical vapour deposition growth and Raman characterization of graphene layers and carbon nanotubes. Journal of Physics Conference Series 682, 2016, 012009.
8. B S Blagoev, E Vlakhov, V Videkov, B Tzaneva, G Łuka, B S Witkowski, P Terziyska, J Leclercq, T A Krajewski, E Guziewicz, D Z Dimitrov, V B Mehandzhiev and P Sveshtarov "Atomic layer deposition of ZnO:Al on PAA substrates" Journal of Physics: Conference Series 764, 012004 (2016).
9. S. Mansouri, S. Jandl, M. Balli, J. Laverdière, P. Fournier, and D. Z. Dimitrov "Raman and crystal field studies of Tb-O bonds in TbMn2O5" Phys. Rev. B, 94, 115109 (2016)
10. M. Balli, S. Mansouri, S. Jandl, P. Fournier, and D. Z. Dimitrov "Large rotating magnetocaloric effect in the orthorhombic DyMnO3 single crystal" Solid State Communications, Volume 239, pp. 9–13 (2016).
11. M. Balli, S. Jandl, P. Fournier, and D. Z. Dimitrov "Giant rotating magnetocaloric effect at low magnetic fields in multiferroic TbMn2O5 single crystals" Applied Physics Letters, 108, 102401 (2016).
12. S Mansouri, S Jandl, B Roberge, M Balli, D Z Dimitrov, M Orlita, C Faugeras "Micro-Raman and infrared studies of multiferroic TbMn2O5" Journal of Physics: Condensed Matter, 28, 055901 (6pp) (2016).
13. B S Blagoev, D Z Dimitrov, V B Mehandzhiev, D Kovacheva, P Terziyska, J Pavlic, K Lovchinov, E Mateev, J Leclercq and P Sveshtarov "Electron transport in Al-doped ZnO nanolayers obtained by atomic layer deposition" Journal of Physics: Conference Series 700, 012040 (2016).
14. N. Bozhinov, B. Blagoev, V. Marinova, T. Babeva, E. Goovaerts, D. Dimitrov "Properties of ALD Aluminum-doped ZnO as transparent conductive oxide" Bulgarian Chemical Communications, Volume 48, Special Issue G, pp. 193-197 (2016).
15. N. Tonchev, "Monotone Riemannian metrics and dynamic structure factor in condensed matter physics", J. Math. Phys. 57 (2016) 071903.
16. K. Buchkov, E. Nazarova, N. Balchev, D. Gajda, K. Nenkov, A. Zahariev, "Electro-transport studies of silver doped FeSe0.94 superconducting system" AIP Conf. Proceed. 1722 (2016) 080002; doi: 10.1063/1.4944167.
17. G. Gajda, A. Morawski, K. Rogacki, T Cetner, A. J. Zaleski, K. Buchkov, E. Nazarova, N. Balchev, M. S. A. Hossain, R. Diduszko, K. Gruszka, P Przyslupski, Ł. Fajfrowski, D. Gajda, "Ag-doped FeSe0.94 polycrystalline samples obtained through hot isostatic pressing with improved grain connectivity", Supercond. Sci. Technol. 29 (2016) 095002.
18. V. G. Ivanov, N. D. Todorov, L.S. Petrov, T. Ritacco, M. Giocondo, E. S. Vlakhov, "Strong surface enhanced Raman scattering from gold nanoarrays obtained by direct laser writing", J. Phys. Conf. Ser. 764 (2016) 012023.

PATENTS:

ONGOING RESEARCH PROJECTS:

I. Financed by the Bulgarian National Scientific Research Foundation at the Bulgarian Ministry of Education and Science:
1.“Novel hybrid structures based on photorefractive crystal-liquid crystal and graphene” – started December 2014.
2. Atomic layer deposition of nanolayers of dielectrics on two-dimensional materials as active components for multifunction devices” – started December 2016.

II. Financed by the COST Programme:
“Functional oxide nanolayers and nanolaminates deposited by the ALD method”.

III. Financed by BAS (Junior scientist projects)
“Investigation of the ac magnetic flux in Fe-based superconductors and multiferroic materials”

IV. Project with JINR Dubna - Russia
“Synthesis and theoretical studies of graphene nanostructures”

V. Projects funded under the Academy’s bilateral agreements
“Investigation of transport and mixed-state properties of the iron-chalcogenides FeSe system modified by Ag-addition”.

INTERNATIONAL COLLABORATION:

Funded under Academy’s bilateral agreement – joint project with the Institute of Optical Materials and Technologies – BAS and the National Chiao Tung University – Taiwan.

DEPARTMENT FUNCTIONAL MATERIALS AND NANOSTRUCTURES

LABORATORY

PHYSICAL PROBLEMS OF MICROELECTRONICS

HEAD: **Assoc. Prof. Dencho Spasov, Ph.D.**
tel: 979 5731; e-mail:d.spassov@issp.bas.bg

TOTAL STAFF: **8**
RESEARCH SCIENTISTS: **4**
HONORARY MEMBERS: **0**
ASSOC. MEMBERS: **0**

Prof. A. Paskaleva, D.Sc.; Assoc. Prof. D. Spasov, PhD;. Assoc. Prof. E. Manolov, Ph.D.;Senior Res. Assist. Ts. Ivanov, Ph.D.; E.Gajdarzhieva, physicist; S. Tsvetanov, technologist; M. Stoicheva, technologist, Ch. Petkanov, technologist

RESEARCH ACTIVITIES:

The research activities of the Laboratory are focused on nanoelectronics and cover the following topics:

- investigation of thin and ultra-thin dielectrics (incl. high-k dielectrics for advanced dynamic and non-volatile memories), semiconductor and metal layers of interest for future nanoelectronic devices.
- development of solid state sensors based on the silicon and the thin-film microelectronics (gas- sensitive layers for sensor devices; mono- and polycrystalline silicon, anisotropic and hard ferromagnetic layers).
- development and optimization of the technology for deposition of the layers investigated.
- development of new microelectronic structures and devices (incl. memory and sensor structures).

The investigations of the electrical characteristics of metal-insulator-silicon (MIS) structures with multilayered HfO_2-Al_2O_3 dielectrics deposited by Atomic Layer Deposition (ALD) demonstrated the feasibility of application of these complex high-k films in the non-volatile memory devices functioning on the principle of charge trapping. Conduction mechanisms, density of the charge traps and the dielectric constant of the multilayered films were studied as a function of the thickness of Al_2O_3 sublayers. The effect of the post-deposition annealing (PDA) in oxygen was considered and it was established that this type of treatment affects the traps ‘density, sign of the initial charges present in the films as well as films resistivity. The obtained results imply that PDA in oxygen is effective approach for improving the charge trapping characteristics of the multilayered HfO_2-Al_2O_3 films and enhancing the size of their memory window.

The impact of the metal electrode type on the effect of resistive switching in metal-insulator-metal structures with reactively sputtered tantalum pentoxide (Ta_2O_5) was investigated. It was found that titanium nitride is most suitable material for electroactive electrode to reactively sputtered Ta_2O_5 guaranteeing stable resistive switching with a ratio between the low-resistive and high-resistive states above 100. The results suggest that the

resistive switching effect is also influenced by the chosen method of deposition of electroactive electrode.

Dielectric and optical characteristics of thin gallium oxide (Ga_2O_3) layers obtained by Metal Organic Chemical Vapor Deposition were examined to access the feasibility for integration of Ga_2O_3 in silicon microelectronics technology. The dielectric constant, the oxide charge and the band gap of Ga_2O_3 were determined by electrical investigations of metal-Ga_2O_3-silicon structures and by spectral ellipsometry. It was established that relatively thick interfacial silicon oxide layer is formed during the Ga_2O_3 deposition on silicon substrates.

Homogeneous SiO_x films (x=1.3) and annealed at 700 ^oC composite films, containing amorphous Si nanoparticles (a-Si NPs/SiO_x), have been irradiated by 20 MeV electrons with two different fluences (7.2×10^{14} and 1.44×10^{15} el.cm^{-2}). Control (non-irradiated) and irradiated films have been investigated by Atomic force microscopy (AFM), Raman spectroscopy and electrically by capacitance (conductance) - voltage ($C(G)$-V) measurements. The AFM study and the Raman scattering data show that the electron irradiation decreases the film surface roughness of the homogeneous layers, due to effect of annealing and formation of amorphous silicon phase. The results from C(G)-V measurements on irradiated MOS structures with composite films speak about formation of electrically active defects in the oxide matrix.

The deposition process of thin titanium oxide (TiO_2) films on silicon and glass substrates by electron beam evaporation under various technological conditions (substrate temperature, ion assistance with different type of gases) was mastered. The optical dispersion characteristics of the films were obtained by spectrophotometry and spectral ellipsometry and the results of the both measurement methods were compared. The technological conditions for deposition of thin TiO_2 films suitable for multilayered optical filters were refined. Preliminary electrical characterization of the evaporated TiO_2 films was conducted.

PUBLICATIONS:

1. Spassov, D, Skeparovski, A, Paskaleva, A, Novkovski, N., „A comparative study of charge trapping in HfO_2/Al_2O_3 and ZrO_2/Al_2O_3 based multilayered metal/high-k/oxide/Si structures“, Thin Solid Films, 614, (2016) 7-15.
2. Novkovski,N, Paskaleva, A., Skeparovski,A, Spassov, D., **„**Model based precise analysis of the injection currents in $Al/ZrO_2/Al_2O_3/ZrO_2/SiO_2/Si$ structures for use in charge trapping non-volatile memory devices“. Materials Science in Semiconductor Processing, 44 (2016) 30-37.
3. Spassov, D.**,** Paskaleva, A.**,** Guziewicz, E., Luka, G., Krajewski, T.A., Kopalko, K, Wierzbicka, A., Blagoev, B., „Electrical characteristics of multilayered $HfO_2 – Al_2O_3$ charge trapping stacks deposited by ALD“, Journal of Physics: Conference Series, 764 (2016) 012016.
4. Duta, M., Simeonov, S.**,** Teodorescu, V, Predoana, L., Preda, S., Nicolescu, M., Marin, A., Gartner, M., Spasov, D.**,** Gartner, M., Zaharescu, M., Szekeres, A., „Structural and electrical properties of Nb doped TiO_2 films prepared by the sol-gel layer-by-layer Technique“, Materials Research Bulletin, 74, Elsevier Limited, (2016) 15-20.
5. D. Nesheva, V. Dzhurkov, M. Šćepanović, I. Bineva, E. Manolov, S. Kaschieva, N. Nedev, S. N. Dmitriev, Z. V. Popović, High energy electron-beam irradiation effects in Si-SiO_x structures, Journal of Physics: Conference Series, 682, (2016), 012012

PATENTS:

1. Metal-insulator-silicon structures containing silicon nanoparticles for detectors of ionizing radiation and methods for their fabrication

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Ministry of Education and Science:

1. Atomic layer deposition of dielectric nanolayers on two-dimensional materials as active components for multifunctional devices.

Financed by the Bulgarian Academy of Sciences:

1. Reliability aspects and radiation hardness of HfO_2-based multilayer stacks for non-volatile flash memories.
2. Optimization of structures demonstrating resistive switching effect for memory applications
3. Charge trapping storage in metal-high-k-SiO_2-silicon (MOHOS) structures for applications in non-volatile memories
4. Investigation of surface morphology of thin nanostructured films using scanning probe microscopy, Agreement between Bulgarian Academy of Sciences and Macedonian Academy of Sciences and Arts

Financed by the contracts and programs of other international organizations:

1. Optical and electrical characterization of three-dimensional assemblies of silicon nanoparticles within thin layers of silicon oxide for applications in electronic devices; National Council of Science and Technology (CONACYT), Mexico

INTERNATIONAL COLLABORATION:

1. Fraunhofer Inst. of Integrated Systems and Device Technology, Erlangen, Germany
2. Institute of Electronic Engineering, Slovak Academy of Sci., Bratislava, Slovakia
3. Insitute of Physics, St.St. Cyril and Methodius Universty, Skopie, Macedonia
4. University of Nish, Serbia
5. Universidad Autonoma de Baja California, Mexicale, Mexico
6. Institute of Physics, Polish Academy of Sci., Warsaw, Poland

DEPARTMENT FUNCTIONAL MATERIALS AND NANOSTRUCTURES

LABORATORY

ACOUSTOELECTRONICS

HEAD: **Assoc. Prof. Velichka Georgieva, Ph.D.**
tel.: 979 5681, e-mail: lazarova@issp.bas.bg

TOTAL STAFF: **8**
RESEARCH SCIENTISTS: **5**
HONORARY MEMBERS: **1**
ASSOC. MEMBERS: **0**

Prof. I. Avramov, Ph.D., D.Sc.; Assoc.Prof. E. Radeva, Ph.D.; J. Lazarov Ph.D., engineer; chemist; L. Vergov, engineer;Assist. Prof. K. Esmerian, Ph.D.; S. Staikov

Honorary member: Prof. Lozan Spassov, Ph.D., D.Sc., Corresponding member of BAS

RESEARCH ACTIVITIES:

In 2016 the scientific and applied research of Acoustoelectronics laboratory were focused on new materials, technologies and elements following the Academy's basic strategic goal - creation of a society based on knowledge that is an active partner in the European scientific area.

The research efforts in the laboratory were carried out in the following directions:

• Application of bulk acoustic waves (BAW) in resonant structures for preparation and investigation of sensor devices for detection of harmful gases in the environment.

• Synthesis and investigation of thin plasma polymer films and composites for applications in sensors and biocomposites.

• Resonant structures using surface transverse waves (STW), Rayleigh surface acoustic waves (RSAW) and BAW and their applications in communications and sensor technologies.

Thin films of ZnO obtained by ALD method were studied as sensitive coatings for registration of NO_2 in the atmosphere using a quartz crystal microbalance (QCM). It has been found that the process of NO_2 sorption is reversible. Layers of 16nm ZnO have registered of NO_2 concentrations below 100 ppm. ALD layers insignificant burden QCM and parameters of resonators remained almost unchanged, i.e. there is full technological compatibility. The study demonstrates the possibility of practical use in gas sensors.

Were studied substrates of graphite, tungsten, silicon and amorphous titanium dioxide for use in the laser induced electron transfer during desorption / ionization of the metal complexes (LETDI). It was found that at the same temperature for the ion yield from the various substrates varies of three orders of magnitude. It is shown that LETDI of titanium dioxide and amorphous silicon offers the best opportunities for the preparation of ions of molecules of the metal complexes.

By plasma polymerization from hexamethyldisiloxane (HMDS) and diamond nanoparticles various composite layers that are transparent and very smooth were obtained. The change in the Raman and FTIR spectra of composites has demonstrated the penetration of diamond nanoparticles in the polymer matrix, which allows the synthesis of layers with desired composition and properties.

An alternative approach for preparation of polymer layers on a polymer by plasma polymerization is proposed. The characterization of these materials obtained from HMDS,

pentane and toluene showed that the layers of the siloxane type are thick and dependent on the type of substrate, and the films obtained from the aliphatic and aromatic hydrocarbons are more porous and have a similar structure because of the method of synthesis in plasma.

A novel method for measuring the concentration of hard particles in liquids has been developed. It is based on a resonator using BAW, RSAW or STW used a highly sensitive sensor resonator detecting the mass of the hard particles on its surface. The method is being further investigated and is in the process of patenting. It is expected to find applications in systems for testing and monitoring the quality of the drinking water, spa and swimming pools, industrial fish breed, growth of vegetables using the hydroponics method, in the chemical industry, health care, etc.

The gas sorption properties of aggregates consisting of zink oxide nanowires have been studied by means of a RSAW resonator using a corrosion proof gold electrode structure on AT-cut quartz. This method demonstrates high sensitivity towards toxic gases of pyridine and hexamethyleneimine and a distinguished selectivity towards ammonia and acetic acid vapors. It has been shown that, by pretreating the sorption aggregate layer with acetic acid, it is possible to achieve much higher sensitivities towards toxic gases compared to the traditional BAW quartz crystal microbalance. The physical and chemical features of the adsorption processes have been explained with focus on the inverse effect of gas adsorption on the nanowires sensing efficiency.

It was developed a new method for rapid synthesis of inherently robust and durable superhydrophobic carbon soot coatings. Their mechanical durability was improved by using a specially-designed conical chimney that reduces the amount of oxygen involved in the combustion of a paper wick immersed in rapeseed oil. The quantity of oxygen functional groups on the surface of carbon nanostructures was controlled *in-situ* by manipulating the size of the inlet-air opening, thus, allowing the deposition of carbon coatings with different chemical reactivity and wettability. In one of the regimes, we observed catalyst-free graphite-to-diamond transformation at low flame temperatures of approximately 270 °C. The critical phase transition temperature is much lower than that of an oxyacetylene flames (3000 °C), recently used for flame synthesis of nanodiamonds. Therefore, the scientific results are unique and suggest a new kinetically driven mechanism for diamond formation in flames rather than the conventional thermodynamically induced phase transition. Furthermore, the superhydrophobic carbon soot coatings were further functionalized with aqueous ethanol and fluorocarbon solutions, as a result of which their mechanical robustness under simulation of harsh environmental/operational conditions (e.g. gusty winds, heavy rains, multiple icing/de-icing cycles, high rotational velocities of the sample) was significantly enhanced. It was found that the functionalized soot exhibits icephobic properties and prevents the atmospheric icing at substrate temperatures down to -35 °C, hence determining its potential applications in aircraft manufacturing, climatic systems, energy efficiency (wind turbines), etc.

PUBLICATIONS:

1. Boyadjiev, S, Georgieva, V, Baji, Z, Yordanov, R, Raicheva, Z, Szilagyi, I. Preparation and characterization of ALD deposited ZnO thin films studied for gas sensors. Applied surface science, 387, Elsevier, 2016, ISSN:0169-4332, 1230-1235. ISI IF:3.15

2. Esmeryan K. D., Bressler A. H., Castano C. E., Fergusson C. P., Mohammadi R.. Rational strategy for the atmospheric icing prevention based on chemically functionalized carbon soot coatings. Applied Surface Science, 390, Elsevier, 2016, DOI:10.1016/j.apsusc.2016.08.101, 452-460. SJR:0.93, ISI IF:3.15

3. Esmeryan K. D., Castano C. E., Bressler A. H., Abolghasemibizaki M., Mohammadi R.. Rapid synthesis of inherently robust and stable superhydrophobic carbon soot coatings. Applied Surface Science, 369, Elsevier, 2016, DOI:10.1016/j.apsusc.2016.02.089, 341-347. SJR:0.93, ISI IF:3.15

4. Esmeryan K. D., Castano C. E., Bressler A. H., Fergusson C. P., Mohammadi R.. Single-step flame synthesis of carbon nanoparticles with tunable structure and chemical reactivity. RSC Advances, 6, 66, Royal Society of Chemistry, 2016, DOI:10.1039/C6RA06436A, 61620-61629. ISI IF:3.289

5. Esmeryan K. D., Radeva E. I., Avramov I. D.. Durable superhydrophobic carbon soot coatings for sensor applications. Journal of Physics D: Applied Physics, 49, 2, IOP, 2016, DOI:http://dx.doi.org/10.1088/0022-3727/49/2/025309, ISI IF:2.772

6. Grechnikov, A, Georgieva, V, Donkov, N, Borodkov, A, Pento, A, Raicheva, Z, Yordanov, Tc. Comparison of different substrates for laser- induced electron transfer desorption/ionization of metal complexes. Journal of physics: Conference series, 700, 1, 2016, art.012025

7. Mitev, D, E Radeva, D Peshev, M Cook, L Peeva. PECVD polymerised coatings on thermo-sensitive plastic support. Journal of Physics: Conference Series (JPCS), IOP, 2016, SJR:0.217

8. Radeva E., Hikov T., Mitev D., Stroescu H., Nicolescu M., Gartner M., Presker R, Pramatarova L.. Optical Characterization of Composite Layers Prepared by Plasma Polymerization. Journal of Physics: Conference Series, IOP, 2016, SJR:0.217

9. Zykova, A, Safonov, V, Goltsev, A, Dubrava, T, Rossokha, I, Donkov, N, Yakovin, S, Kolesnikov, D, Goncharov, I, Georgieva, V. Surface modification of the tantalum pentoxide coatings deposited by magnetron sputtering method and further correlation with cell adhesion and proliferation in vitro tests. Journal of physics: Conference series, 700, 2016, DOI:10.1088/1742-6596/700/1/012027
10. V. L. Strashilov, G. E. Alexieva, G. G. Tsutsumanova, I. N. Kolev, I. D. Avramov, "Gas adsorption on ZnO nanowires as studied by surface acoustic wave resonators", 2016, Bulgarian Chemical Communications, Volume 48, Number 1, pp. 134 – 140

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PATENTS:

Y. Satoh, O. Ikata, T. Matsuda, Y. Takahashi, I. D. Avramov, "Phase-shift oscillator having ladder-type saw filter feedback circuit", US Patent No.: US 5874866 A, https://www.google.com/patents/US5874866

ONGOING RESEARCH PROJECTS:

"Investigation of devices based on different acoustic wave modes bulk (BAW) Lemb (LAW), Rayleigh (RSAW) and surface transverse waves (STW) for sensor application" 2013-2016.
"Development of a leaky surface acoustic wave (LSAW) sensor on lithium tantalate for liquid analysis" - Research Center Karlsruhe, Germany.

DEPARTMENT FUNCTIONAL MATERIALS AND NANOSTRUCTURES

RESEARCH GROUP

BIOCOMPATIBLE MATERIALS

HEAD: Assoc. Prof. Dr. Emilia Pecheva
tel: 979 5699; e-mail: emily@issp.bas.bg

TOTAL STAFF: **3**
RESEARCH SCIENTISTS: **3**

physicist Todor Hikov; Ivailo Tsvetanov, BSc

RESEARCH ACTIVITIES:

The research activities of the group of Biocompatible materials (BCM) are related to the development of methods for obtaining and characterization of materials with biomedical and dental applications. Our themes are directly related to some of the main scientific directions of the EC as well as of the strategic tendencies and priorities accepted in the BAS, Bulgarian National Science Fund and the Bulgarian National Innovation Fund. These include "Fighting with socially important diseases", "Improving the human potential and quality of life", "Improvement of strategies, oriented to the increase the human life duration". Other theme priorities are related to "Obtaining new materials by innovative technologies", "Modeling and designing multifunctional materials", "Intelligent biomaterials for modifying or restoring of human bone".

Keywords: biocompatible materials, composite layers, organosyloxane polymer-nanodiamond, laser interaction with biocompatible and biological materials.

AWARDS:

PUBLICATIONS:

1. E. Pecheva, R.L. Sammons, A.D. Walmsley, The performance characteristics of a piezoelectric ultrasonic dental scaler, Medical Engineering and Physics38(2016) 199-203
2. N. Vyas, E. Pecheva, H. Dehghani, R.L. Sammons, Q.X. Wang, D.M. Leppinen, A.D.Walmsley, High Speed Imaging of Cavitation around Dental Ultrasonic Scaler Tips, PLoS ONE 11(3) (2016) :e0149804
3. E. Radeva, T. Hikov, D. Mitev, H. Stroescu, P. Petrik, R. Presker, L. Pramatarova, Optical Characterization of Composite Layers Prepared by Plasma Polymerization, Journal of Physics: Conference Series, 2016

PATENTS:

ONGOING RESEARCH PROJECTS:

1. "Laser interaction with biological tissues and titanium implants", 2016/18, budjet subsidy from the Bulgarian Academy of Sciences (BAS)

2. "Precise ablation of dental hard tissues and titanium implants with a femtosecond pulsed laser", DFNP-159/2016, 2016/17, funded through a Programmee for supporting young scientists at the BAS

3. "Precise ablation of dental hard tissues with ultra-short pulsed laser. Preliminary investigation on adequate laser parameters", bilateral agreement with the Romanian Academy of Sciences (RAS), Romania, 2016/18

INTERNATIONAL COLLABORATION:

IPP group, University of Strasbourg, France

National Institute for Plasma and Radiation Physics, RAS, Bucarest, Romania

School of Dentistry, University of Birmingham, UK

DEPARTMENT NANOPHYSICS

LABORATORIES

PHOTOELECTRICAL AND OPTICAL PHENOMENA IN WIDE BAND GAP SEMICONDUCTORS
and
SEMICONDUCTOR HETEROSTRUCTURES

HEAD: **Prof. Diana Nesheva, D.Sc.**
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TOTAL STAFF: **11**
RESEARCH SCIENTISTS: **10**
HONORARY MEMBERS: **2**
ASSOC. MEMBERS: **5**

Assoc.Prof. D. Arsova, Ph.D.; Assoc.Prof. Z. Ivanova, Ph.D.; Assoc. Prof. Z. Levi, Ph.D.; Assoc. Prof. I. Bineva, Ph.D.; Assist. Prof. T. Vasileva, Ph.D.; Assist. Prof. P. Terziyska, Ph.D.; Physicist S. Bakalova, Ph.D.; Assist. V. Dzhurkov, Assist. R. Dzhurkova, Technologist E. Zaharincheva;

Associated members: Prof. S. Kaschieva, D.Sc; Prof. S. Alexandrova, D.Sc; Assoc.Prof. S. Balabanov, Ph.D.; *Assoc.Prof. S. Simeonov, Ph.D.*; *Assoc.Prof. A. Szekeres, Ph.D.*;
Honorary members: Prof. E. Vateva, D.Sc; Assoc. Prof. K. Kolentsov;

RESEARCH ACTIVITIES:

The investigation of the possibility for thin films topography change by applying the new method of frequency assisted thermal evaporation in vacuum continues. Films of glassy As_2Se_3 with thicknesses of 60, 250 and 500 nm were prepared by applying mechanical vibrations with frequencies of 0, 50 and 4000 Hz on the substrates during the deposition process. The analysis of the results and their comparison with the ones, acquired for amorphous Se and crystalline Te, has shown strong influence of the crystallographic structure of the deposited materials on the topography of the deposited films. The surface change effect decreases with the increase of the structural disorder of the materials - for the Se and Te films an equal curving period is observed on the surface with significant divergences in the height profile with priority to the crystalline films, while for the As_2Se_3 films with the same thicknesses no surface curvature is observed. These investigations have been financed by the Program for career development of young scientists of the Bulgarian Academy of Sciences (contract DFNP-160/13.05.16).

Thin films of cubic $CuInS_2$, syntesized in Macedonia in 2015, were analyzed by AFM, TEM and XRD. TEM results have showen changes in both the structure and the composition of the films in comparison with the XRD data obtained immediately after the film synthesis. These changes are probably due to coalescence of the quantum dots, proven by AFM, and to crystal lattice relaxation with the time. XRD studies conducted within international cooperation with Romania have also proven the existence of stable chalcopyrite phase which is characteristic of $CuInS_2$. Impurities of $CuSO_4.5H_2O$ have also been registered. Formation of such a phase was previously reported for thin films annealed above 250 ^oC.

Nanocrystalline Cu-In-S thin films were prepared together with colleagues from the LAMPPD department. Pulsed laser ablation in vacuum of previously synthesized in Macedonia $CuInS_2$ quantum dots was carried out with Nd:YAG laser and a wavelength of 1064

nm In collaboration with colleagues from Romania the structure and morphology of the deposited layers was studied. It has been shown that they are nanocrystalline, with a dominant $Cu_{1.7}In_{0.05}S$ phase. The effect of the laser pulse energy and the ablation time on the structure and morphology of the produced films was investigated. A small increase in the average nanocrystalline diameter of 8 nm to 13 nm has been observed, as the dependence on the deposition time is more pronounced. The effect of the laser pulse energy on the topography of the layers is much stronger - an increase from 7.4 to 44.3 nm of the root mean square roughness of the surface has been determined. The process of laser ablation with this wavelength is used for the first time for the transfer of already synthesized nanoparticles from Cu-In-S, and it has been shown that it is suitable for the preparation of stable Cu-In-S films with controlled surface roughness.

Spectroscopic ellipsometry measurements and analysis of thin films and multilayer structures were performed using the Woollam M2000D spectroscopic ellipsometer, acquired by the Institute of Solid State Physics in the frame of the INERA Project. The following thin films deposited on Si, glass, Al_2O_3 or ITO/glass substrates were analyzed: AlN, Al_2O_3, ZnO, RF sputtered HfO_2, TiO, CoO, Fe_2O_3, NiO, GaN, ZnMgO, Ga2O3, $W_{0.92}Mo_{0.08}O_3$, WO_3, thermal SiO_2, DLC, C. Thicknesses and optical constants of the layers were determined. Superlattices of ALD HfO_2/Al_2O_3 were also investigated and the thickness of each layer as well as the optical constants were estimated.

Room temperature photoluminescence of 200 thick layers of SiO_x (x = 1.5, 1.7) deposited on crystalline silicon substrates by thermal evaporation of SiO in a vacuum is investigated. The films studied are homogeneous or composite (the latter contain amorphous or crystalline silicon nanoparticles). The layers are irradiated in Dubna, Russia with electrons having energy of 20 MeV at a fluence of $2.4.10^{14}$ el/cm^2. It is been found that the irradiation caused some increase of the photoluminescence from homogeneous samples, which is related to initial phase separation and appearance of a small amount of a-Si nanoparticles. The irradiation with electrons of the composite layers with initial x = 1.7, containing any type of Si nanoparticles as well as of x = 1.5 layers with nanocrystals leads to a decrease of the integrated intensity of photoluminescence. The intensity decrease is associated with electronic-induced increase of the nanoparticle size, leading to a weakening of the quantum size effect.

Thin layers of ZnO are deposited by sol-gel method using two different modifiers. Microwave treatment was applied during the film preparation. Two different polymers were used to affect the structure and morphology of the layers. Studies by scanning electron microscopy and atomic force microscopy showed that the use of polymers has a strong influence on the microstructure and surface roughness of the layers as well as that the effect is dependent on the combination of the modifier used and the type of the added polymer. The changes in the layers conductivity caused by layer exposure to ethanol vaporse were examined at room temperature. It was found that at the same concentration of ethanol these changes are larger in the layers produced with the addition of polymer which indicates that the polymer modification is promising to improve reported in the literature very low sensitivity of ZnO films to ethanol at room temperature.

The study on multilayered TiO_2, deposited by chemical methods was continued. MIS structures with embedded TiO_2 layers doped with Nb or V were prepared and capacitance-voltage and current-voltage characteristics were measured at different temperatures and frequencies. It has been found that the concentration of the donor Nb/V atoms is around or higher than 10^{16} cm^{-3}. Despite the high level of doping, the specific resistance of the layers is high ($\rho \sim 10^4$ -10^5 Ω.cm) which has been explained by the compensating effect of deep acceptor generated by the deposition process. The decrease of the specific resistivity when increasing the electrical field has evidenced the bulk character of electrical conduction in the doped TiO_2 layers, as the current through the layers is limited by the space charge of electrons captured in deep levels. It has been concluded that in the temperature range 77 K - 300 K, the predominant

charge transport mechanism in TiO_2 is tunneling of electrons from occupied deep levels to unoccupied nearest ones.

The influence of temperature on the luminescence efficiency of chalcohalide GeSIn-CsX (X=Cl, Br and I) glasses has been studied. The observed emission bands have been attributed to the corresponding radiative transitions in the energy level diagram of Er^{3+} ions. The comparison with the GeSGa-CsBr system shows strongly pronounced narrowing of the emission band at ~ 1500 nm and splitting towards the related electronic terms.

The effect of direct holographic recording of the surface relief by photo-induced mass transport on amorphous thin films of Ge-S and Ge-Se systems has been investigated. The gratings were created by orthogonally ±45° linearly polarized light beams of various wavelengths (λ = 473 - 650 nm). The obtained results show significantly enhanced optical media recording when increasing Se content into the Ge-Se samples. The surface structure of the relief gratings was investigated by atomic force microscopy.

The structure and optical properties of ternary $Ge_xSb_{40-x}Se_{60}$ (x = 15, 20, 25, 27, 32 and 35) chalcogenide glasses and thin films, deposited on quartz substrates by evaporation of glass with the corresponding composition were studied at atomic level. The optical constants (n and k), optic band gap energy (E_{og}) and oscillator energetic parameters of the bulk materials and thin films, and for the layers also their thickness, have been determined. A threshold in the compositional dependence of E_{og} at an average coordination number Z = 2.67 has been observed. It has been explained by topological phase transition in the vicinity of Z = 2.67, where mostly two-dimensional (2D) glassy structure transforms into a three-dimensional (3D) network. The 3D structure is less dense and more transparent causing lower values of n and k at compositions with x = 27, 32 and 35. By RMC simulation of the neutron and X-ray diffraction data, amorphous phase has been found in the studied samples and the atomic parameters have been determined. It is shown that the $Ge_xSb_{40-x}Se_{60}$ network is built from interconnected tetrahedral $GeSe_4$ and pyramidal $SbSe_3$ units. With increasing the Sb atomic concentration, along the basic Ge-tetrahedral structural units well defined Sb-pyramidal units appear in the glassy structure.

PUBLICATIONS:

1. Andreeva T.D., Danailova K.A., Terziyska P., Krumova S.B., Taneva S.G., Krastev R., Hofmeister anions effect on the thickness and morphology of polyelectrolyte multilayers for biofunctionalization of cardiovascular stents, Bulgarian Chemical Communications, 48, 23-28, 2016.

2. Antonova K., Szekeres A., Duta L., Stan G.E., Mihailescu N., Mihailescu I.N., Orientation of the nanocrystallites in AlN thin film determined by FTIR spectroscopy, Journal of Physics: Conference Series, 682, 012024, 2016.

3. Balchev I., Tzvetkova Kr., Kolev S., Terziyska P., Szekeres A., Miloushev I., Tenev T., Antonova K., Peyeva R., Ivanova T., Avramova I., Tzvetkov M., Avdreev G., Valcheva E., Milenov T., Tinchev S., Synthesis and characterization of thin amorphous carbon films doped with nitrogen on (001) Si substrates, Journal of Physics: Conference Series, 764, 012013, 2016.

4. Blagoev B.S., Dimitrov D.Z., Mehandzhiev V.B., Kovacheva D., Terziyska P., Pavlic J., Lovchinov K., Mateev E., Leclercq J., Sveshtarov P., Electron transport in Al-doped ZnO nanolayers obtained by atomic layer deposition, Journal of Physics: Conference Series, 700, 012040, 2016.

5. Blagoev B.S., Vlakhov E., Videkov V., Tzaneva B., Łuka G., Witkowski B.S., Terziyska P., Leclercq J., Krajewski T.A., Guziewicz E., Dimitrov D.Z., Mehandzhiev V.B., Sveshtarov P., Atomic Layer Deposition of ZnO:Al on PAA substrates, Journal of Physics: Conference Series, 764, 012004, 2016.

6. Duta L., Stan G.E., Stroescu H., Gartner M., Anastasescu M., Fogarassy Zs., Mihailescu N., Szekeres A., Bakalova S., Mihailescu I.N., Multi-stage pulsed laser deposition of Aluminum Nitride at different temperatures, Applied Surface Science, 374, 143-150, 2016.

7. Duta M., Simeonov S., Teodorescu V, Predoana L., Preda S., Nicolescu M., Marin A., Gartner M., Spasov D., Gartner M., Zaharescu M., Szekeres A., Structural and electrical properties of Nb doped TiO_2 films prepared by the sol-gel layer-by-layer Technique, Materials Research Bulletin, 74, 15-20, 2016.

8. Gesheva K., Arvizu M.A., Bodurov G., Ivanova T., Niklasson G.A., Iliev M., Vlakhov T., Terzijska P., Popkirov G., Abrashev M., Boyadjiev S., Jágerszki G., Szilágyi I.M., Marinov Y., Optical, structural and electrochromic properties of sputter- deposited W-Mo oxide thin films, Journal of Physics: Conference Series, 764, 012010, 2016.

9. Halova E., Kojuharova N., Aleksandrova S., Szekeres A., Interface characterization of nanoscale SiO_x layers grown on RF plasma hydrogenated silicon, Journal Physics Conference Series, 700, 012029, 2016.

10. Hristova-Vasileva T., Bineva I., Dinescu A., Arsova D., Nesheva D., "Cymatics" of selenium and tellurium films deposited in vacuum on vibrating substrates, Surface and Coatings Technology, 307, 542-546, 2016.

11. Hristova-Vasileva T., Bineva I., Dinescu A., Nesheva D., Arsova D., Pejova B., Thickness influence on the morphology and the sensing ability of thermally deposited tellurium films, Journal of Physics: Conference Series, 700, 012037, 2016.

12. Kaschieva S., Angelov Ch., Dmitriev S.N., MeV electron irradiation of Si-SiO_2 structures with magnetron sputtered oxide, Journal of Physics: Conference Series, 700, 012036 2016.

13. Levi Z., Nesheva D., Bineva I., Hristova-Vassileva T., Stambolova I., Blaskov V., Electrical and Photoelectrical Properties of Nanocrystalline ZnO Films Prepared by Microwave Assisted Sol-Gel Method, Nanoscience & Nanotechnology, 16, 16-19, 2016.

14. Nesheva D., Comanescu F., Bineva I., Purica M., Levi Z., Aneva Z., Muller R., Raman Study of Compositional Variations in $Zn_xCd_{1-x}Se$ Films Prepared by Thermal Vacuum Evaporation, Journal of Nanoscience and Nanotechnology, 16, 8513-8518, 2016.

15. Nesheva D., Scepanovic M., Grujic-Brojcin M., Dzhurkov V., Kaschieva S., Bineva I., Dmitriev S., Popovic Z., Photoluminescence from 20 MeV electron beam irradiated homogeneous SiO_x and composite Si-SiO_x films, Journal of Physics: Conference Series, 764, 012018, 2016.

16. Nesheva D., Dzhurkov V., Scepanovic M., Bineva I., Manolov E., Kaschieva S., Nedev N., Dmitriev S., Popovic Z., High Energy Electron-Beam Irradiation Effects in Si-SiO_x Structures, Journal of Physics: Conference Series, 682, 012012, 2016.

17. Pejova B., Bineva I., Sonochemically assisted colloidal route to CdSe quantum dot assemblies: an alternative way to further fine-tune the size-dependent properties, Journal of Materials Science: Materials in Electronics, 27, 10600-10615, 2016.

18. Reinfelde M., Loghina L., Ivanova Z.G., Teteris J., Vlcek M., Slang S., Photoinduced surface relief grating formation in $As_{40}S_{60-x}Se_x$ thin films, Journal of Optoelectronics and Advanced Materials, 18, 1-4, 2016.

19. Terziyska P.T., Butcher, K.S.A., Self-Catalytic Growth of InN Nanowires, Bulgarian Journal of Physics, 43, 54-63, 2016.

20. Vassilev V., Aljihmani L., Milanova V., Hristova-Vasileva T., Phase equilibria in the Sb_2Te_3-InSb system, Journal of Phase Equilibria and Diffusion, 37, 524-531, 2016.

21. Ivanova Z.G., Djouama T., Poulain M., Teteris J., Microstructural Characterization and Local Ordering of Fluorophosphate Ternary MnF_2-$NaPO_3$-ZnF_2 Glasses, International Journal of Innovative Science and Modern Engineering, 8, 14-18, 2016.

22. Fefelov S.A., Kazakova L.P., Arsova D., Koziuhin S.A., Cendin K.D., Prihodko O.Yu., Voltage oscillations during switching effect in current mode regime of thin films from the Ge-Sb-Te chalcogenide system, Sov. Phys. Tech. Semiconductors, 50, 958-962, 2016. (in Russian)

PATENTS:

Bulgarian Patent Office, Patent Application: 111032/15.09.2011, Pretender: ISSP-BAS
Inventors: Nedev N., Manolov E., Nesheva D., Krezhov K., Curiel M., Nedev R., Valdez B.
Invention: Metal-Insulator-Semiconductor structures for detectors of ionizing radiation, containing silicon nanocrystals, and method for their production

Bulgarian Patent Office, Patent Application: 109759/01.12.2006, Patent No: 65971/09.09.2010
Pretender: ISSP-BAS
Inventors: Nesheva D., Nedev N, Manolov E., Brüggemann R., Meier S., Levi Z., Bineva I.
Invention: Metal-Insulator-Silicon structures, containing silicon nanoparticles, and method for their production

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:

1. Preparation and properties of nanostructured and amorphous chalcogenide, oxide and nitride semiconductors and structures for applications in optoelectronics and sensors.
2. Frequency assisted thermal evaporation in vacuum – a perspective method for thin films topography change - DFNP 160/13.05.2016, BAS.

Financed by the Bulgarian Ministry of Education and Science:

1. Characterization of new chalcogenide materials by atomic force microscopy, Contract DMU 03-91/12.2011.

Financed by the contracts and programs of other international organizations:

1. Interaction of MeV electrons with amorphous and crystalline nanoparticles in semiconductor structures, financed by the National Agency for Nuclear Energy

INTERNATIONAL COLLABORATION:

1. Investigation of surface morphology of thin nanostructured films using scanning probe microscopy, Agreement between Bulgarian Academy of Sciences and Macedonian Academy of Sciences and Arts.
2. Investigation of the interaction of high energy electrons with SiO_x and nc(a)-Si-SiO_x thin films, Center for Solid State Physics and New Materials, Belgrade, Serbia.
3. Investigations of optical and structural properties of special glasses for photonic applications, Institute of Photonics and Electronics, Prague, Czech Republic.
4. Light-induced phenomena in chalcogenide glasses for optoelectronic applications, Riga, Latvia.
5. Studies of different transparent conductive oxide (TCO) thin films for solar energy and optoelectronics applications, Institute of Physical Chemistry, Bucharest, Romania.
6. Structural and optical properties of new semiconductor materials and structures for advanced opto- and nanoelectronics applications, Centre for energy research, Hungarian Academy of Sciences.
7. Morphological and structural investigations of nanostructured and amorphous semiconductor films for application in microelectronics and sensorics, National Institute for Research and Development in Microtechnology, IMT Bucharest, Romania.

DEPARTMENT SOFT MATTER PHYSICS

LABORATORY

LIQUID CRYSTALS

HEAD: **Assoc. Prof. Victoria Vitkova, Ph.D.**
tel: 979 5825; e-mail: victoria@issp.bas.bg

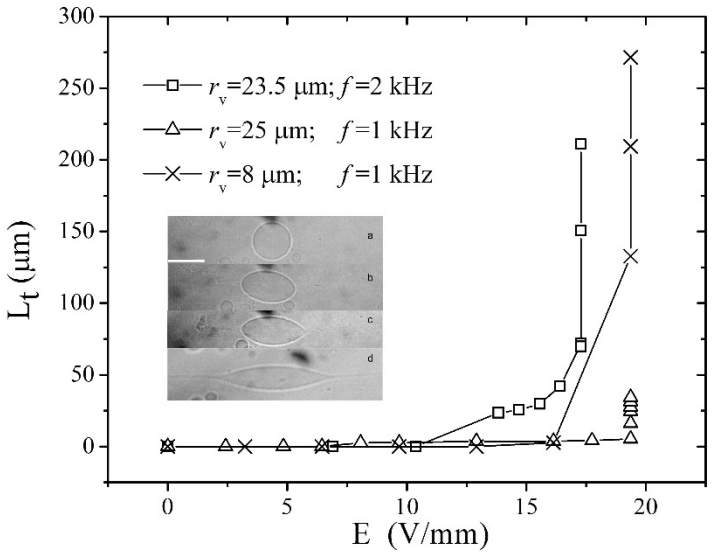
TOTAL STAFF: **4**
RESEARCH SCIENTISTS: **3**
ASSOC. MEMBERS: **2**

Prof. Isak Bivas, Ph.D., D.Sc. Assoc. Prof. J. Genova, Ph.D.; Eng. D. Mitkova, PhD student

Associated members: Assoc. Prof. H. Hinov, D.Sc.; Assoc. Prof. A. Zheliaskova, Ph. D.

RESEARCH ACTIVITIES:

The bending elasticity modulus of lipid membranes is obtained by applying for the first time, to the best of our knowledge, a novel experimental technique based on digital holographic microscopy. The fluctuations of the radius with time were extracted by tracking and measuring the optical thickness at the vesicle poles. The temporal autocorrelation function of the vesicle diameter computed for each of the studied vesicles was then fitted with the theoretical expression to deduce the membrane's tension and bending constant. For the bending elasticity modulus of SOPC bilayers, the value of (0.93±0.03) perg was obtained. This result is in accordance with values previously obtained by means of other conventional methods for the same type of lipid membrane in the presence of sugar molecules in aqueous medium. The obtained results encourage the future development of the digital holographic microscopy as a technique suitable for the measurement of the bending elasticity of lipid membranes.



We studied the formation of tubular membrane protrusions from giant unilamellar vesicles in alternating electric fields. The construction of the experimental chamber permitted the application of external AC fields with strength of dozens of V/mm and kHz frequency during relatively long time periods (several minutes). Besides the vesicle electrodeformation from quasispherical to prolate ellipsoidal shape, the formation of long tubular membrane protrusions with length of up to several vesicle diameters, arising from the vesicular surface in the field direction, was registered and analyzed. The threshold electric field at which the electro-induced protrusions appeared was lower than the field strengths inducing membrane electroporation.

In 2016 Assoc. Prof. V. Vitkova performed a research stay with one-month duration in the School of Engineering at the Brown University, Providence (Rhode Island, USA). Assoc. Prof. V. Vitkova was invited to share her expertise in the thermal shape fluctuation analysis of quasispherical lipid vesicles as an advanced method measurements in membranology for the measurement of the bending elasticity in order to implement it in the host institution. During her visit in the Brown University she gave a lecture before the Division of Applied Mathematics and School of Engineering entitled „Rheology of lipid vesicles and red blood cell suspensions".

PUBLICATIONS:

- C. Minetti, V. Vitkova, F. Dubois, I. Bivas, Digital holographic microscopy as a tool to study the thermal shape fluctuations of lipid vesicles, Optics Letters 41(8): 1833- 1836 (2016)

- D. Mitkova and V. Vitkova, The aqueous surroundings alters the bending rigidity of lipid membranes, Russian Journal of Electrochemistry, 2016, Vol. 52, No. 12, pp. 1172–1178

- R. Georgieva, K. Mircheva, V.Vitkova, K. Balashev, Tz. Ivanova, C. Tessier, K. Koumanov, P. Nuss, A. Momchilova, G. Staneva, Phospholipase A2 induced remodeling processes on liquid-ordered / liquid-disordered membranes containing docosahexaenoic or oleic acid: a comparison study, Langmuir 32, 1756−1770 (2016)

- K. Antonova, V. Vitkova, C. Meyer, Membrane tubulation from giant lipid vesicles in alternating electric fields, Physical Review E 93, 012413 (2016)

- C. Minetti, V. Vitkova, F. Dubois and I. Bivas, New optical method for measuring the bending elasticity of lipid bilayers, Journal of Physics: Conference Series 682 (2016) 012031

- J. Genova, M. Dencheva-Zarkova, J. I. Pavlič, Morphological study of lipid vesicles in presence of amphotericin B via modification of the microfluidic CellASIC platform and LED illumination microscopy, Journal of Physics: Conference Series 682 (2016) 012029

ONGOING RESEARCH PROJECTS:

Research Project "The deformability as a key feature of biomembranes and the influence of biologically relevant substances on it – experimental studies on model systems" (National Science Fund, Bulgaria – Grant DMU03-80/2011), coordinator Assoc. Prof. Dr. V. Vitkova

Research Project "Mechanical and electrical properties of model lipid membranes in the presence of biologically active substances" (National Science Fund, Bulgaria – Grant DN08-7/13.12.2016), coordinator Assoc. Prof. Dr. V. Vitkova

Bilateral Research Project /ISSP – BAS and Wallonie Bruxelles International – Belgium/: "Etude des propriétés mécaniques par holographie digitale", coordinator Assoc. Prof. Dr. V. Vitkova

INTERNATIONAL COLLABORATION:

BELGIUM: Dr Christophe MINETTI, Université libre de Bruxelles

FRANCE: Dr Thomas PODGORSKI, Laboratoire Interdisciplinaire de Physique, UMR 5588 (CNRS – Université Grenoble-Alpes)

GERMANY: Dr. habil. PD Rumiana DIMOVA, Max Planck Institute of Colloids and Interfaces, Science Park Golm

RUSSIA: Prof. Yury Ermakov, Dr Oleg Batishchev, Frumkin Institute of Physical Chemistry and Electrochemistry, Russian Academy of Sciences

TEACHING ACTIVITIES:

Ph.D. student Denitsa Mitkova Brankova, supervisor Assoc. Prof. V. Vitkova

DEPARTMENT SOFT MATTER PHYSICS

LABORATORY

BIOMOLECULAR LAYERS

HEAD: **Assoc. Prof. Yordan G. Marinov, Ph.D.**
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TOTAL STAFF: **11**
RESEARSCH SCIENTISTS: **3**

Assoc. Prof. Dr. Angelina K.Stoyanova-Ivanova; Assist. Prof. L. Todorova; Assist. Peter A. Lilov; Chem. Eng. M. Dencheva-Zarkova; Chem. Todor E. Vlahov; Physicist, Dr. Stanimira D. Terzieva; Chem. Eng. PhD Ivana Ilievska; Techn. Fellow Alexander Y. Vasev; Techn. Fellow P. Marin Marinov; Techn. Fellow Violeta P. Petrova

Honorary member: Acad. A. G. Petrov D.Sc.

RESEARCH ACTIVITIES:

In 2016, science activity of BML laboratory involved investigations on nanocomposites of nematic liquid crystals, superconductive ceramics, polymer electrolites and biomaterials by the methods of impedance spectroscopy, flexo-dielectro-optical spectroscopy, dielectric spectroscopy etc.

Composite material prepared from polyethylene oxide (PEO) and polyvinylpyrrolidone (PVP) doped with Sodium (meta)periodate ($NaIO_4$) salt was studied by complex impedance spectroscopy at room temperature. The polymers PEO and PVP were mixed in a weight ratio 70:30 %, and the concentration of the embedded $NaIO_4$ compound was 7.5 wt.%. The effect from $NaIO_4$ filler on the dielectric permittivity of the three-component mixed system was analyzed in the frequency range 0.1 Hz – 1 MHz. As compared with the two-component polymer host PEO/PVP, a distinctly enhanced electrical and dielectrical response and an increase of the value of dielectric constant of the polymeric (PEO/PVP):$NaIO_4$ composite were present. This suggests the potential of this composite as a material for soft electronics and applications such as solid electrolytes.

In 2016, we continued research on the electro-optical properties of the nanocomposite material consisting of soft gel nematic liquid crystal 4-heptyl-4'-cyanobiphenyl (7CB) containing nanospheres of SiO_2 (Aerosil 300) with dimensions of 7 nm, in various concentrations (see Figure 1). The three-year lasting experimental work was summarized and analyzed. As a result a patent application is prepared. Patent is a method for electro-optical characterization of nanostructured nematic liquid crystals. This method can be applied in a wide field: liquid crystal optoelectronics, integrated electrooptics, light modulation, as well as in research.

We studied nanocomposite soft gel produced from nano-filled nematic by doping with 3 wt.% photoactive azobenzene liquid crystal 4-(4'-ethoxyphenylazo)phenyl hexanoate (EPH). It is of research interest to be analyzed the dielectric behavior of this photo-responsive nanostructured nematic system as exposed to UV light at the wavelength of 375 nm. If the UV light intensity is high enough, the dipole moment of the azobenzene group can be reversibly switched between approximately from 0 (for *trans*) to 3 D (for *cis* conformers). We applied the electrochemical impedance spectroscopy (to determine the UV-light-produced effect upon continuous *trans*-to-*cis* photoisomerization of EPH molecules by varying the UV light intensity.

By the method of double dipping micropipette technique for membrane fragments fixation (Patch-clamp technique) we studied non-specific ion channels in the bilayer model membranes formed by the antibiotic elayofilin. It has been found that the antibiotic induce conductivity in the phospholipid bilayer by formation of stable cation selective ion channels.
The research group within the Laboratory "Biomolecular layers" conducted research on multifunctional materials and materials for medicine. Superconducting ceramics are prepared in order to be use as an additive in the active mass of the electrode for Ni-Zn rechargeable batteries. The electrode material of Ni-Zn battery was characterized by electrochemical impedance apparatus SP-200. The results obtained extend our knowledge on the potential of superconducting ceramics for improving the performance of negative zinc electrode used in alkaline battery.
We studied as well the materials used for medical treatment by dentists. During treatment the brackets, providing the movement of the teeth are characterized by: XRD; SEM, EDS, DSC, PPMS and LIPS.

PUBLICATIONS

1. Y.G. Marinov, G.B. Hadjichristov, A.G. Petrov, S. Krishna Prasad, 'Photo-controllable electro-optics of aerosil/7CB nanocomposite nematic doped with azo-bonded molecules', Journal of Physics: Conference series, 682, 012030, 2016.
2. Y.G. Marinov, G.B. Hadjichristov, A.G. Petrov, S. Krishna Prasad, Electro-optic modulation by silica-nanostructured nematic system (aerosil/7CB nanocomposite), Composites Part B: Engineering, Volume 90, 1 April 2016, Pages 471–477
3. G B Hadjichristov, Y G Marinov, A G Petrov, L Marino and N Scaramuzza, Dielectric and electrical characterization of 5CB nematic liquid crystal doped with silver nanoparticles, Journal of Physics: Conference Series 682 (2016) 012015
4. Georgi B. Hadjichristov and Yordan G. Marinov, Optical diffraction by using electrically-controlled spatially patterned nematic pentylcyanobiphenyl films under static electric field, MCLC, 632, 9-20, 2016
5. Lidia T. Popova, Flexo-dielectro-optical spectroscopy of PDLC films modified by nano-rubbed PTFE layers, Journal of Physics: Conference Series, 682 (2016) 012027.
DOI: 10.1088/1742-6596/682/1/012027
6. K Gesheva, M A Arvizu, G Bodurov, T Ivanova, G A Niklasson, M Iliev, T Vlakhov, P Terzijska, G Popkirov, M Abrashev, S Boyadjiev, G Jágerszki, I M Szilágyi and Y Marinov, Optical, structural and electrochromic properties of sputter-deposited W-Mo oxide thin films, Journal of Physics: Conference Series 764 (2016) 012010
7. H K Koduru, M T Iliev, K K Kondamareddy, D Karashanova, T Vlakhov, X-Z Zhao, N Scaramuzza, Investigations on Poly (ethylene oxide) (PEO) – blend based solid polymer electrolytes for sodium ion batteries, Journal of Physics: Conference Series 764 (2016) 012006
8. I. Ilievska, D. Karashanova, V. Petrunov, A. Zaleski, M. Drozd, V.Mikli, A. Stoyanova-Ivanova. Characterization of titanium–niobium orthodontic archwires used in orthodontic treatment. Bulgarian Chemical Communications, 48, Special Issue G, 2016, 183-187.
9. Ayriyan, A. A., Ayrjan, E. A., Egorov, A. A., Hadjichristov, G. B., Marinov, Y. G., Maslyanitsyn, I. A., Petrov, A. G., Pribis, J., Popova, L., Shigorin, V. D., Strigazzi, A., Torgova, S. I.. Some Features of Second Harmonic Generation in the Nematic Liquid Crystal 5CB in the Pulsed-Periodic Electric Field. Physics of Wave Phenomena, 24, 4, Allerton Press, Inc., 2016, ISSN: 1541-308X, DOI:0.3103/S1541308X16040026, 259-267.
10. S. Georgieva, T. Nedeltcheva, A. Stoyanova- Ivanova. Development of the Titrimetric and Spectrophotometric Methods for Determination ofthe Oxygen Content in Superconducting Cuprates. American Chemical Science Journal, 1, 13, 2016, ISSN:2249-0205, 1-15

11. Stela Georgieva, Angelina Stoyanova-Ivanova, Miroslav Abrashev. Estimation of the oxygen content of RBa2Cu3Oy (R = Er, Y, Eu, Dy) superconducting samples by spectrophotometry and raman spectroscopy: a comparison between chemical and physical methods for oxygen determination. Mediterranean Journal of Physics, 1, 1, 2016, 16-21

PATENTS (Bulgarian Patent Applications)

1. Reg No BG 112 325 / 23.06.2016 г

"Method for characterization of nanostructured nematic liquid crystals". Inventors: L. Todorova, Y. Marinov and A. G. Petrov

2. Reg. No BG 112 345 filed 26.07.2016

"Method and device for determination of kinematic viscosity and mass density of aerosols". Inventors: K. Damov, A. Antonov, M. Iliev, Y. Marinov

3. Reg. No BG 112 311 / 20.05.2016 г., "Composite material and method for its preparation". Inventors: Angelina Stoyanova Koleva-Ivanova Dimitrova Stanimira Terzieva, Blagoy Blagoev Spasov, Daniela Georgieva Kovacheva, Stela Ivanova D.-Kiskinova

CITATIONS FOR 2016

34

ONGOING RESEARCH PROJECTS

1. Project financed by the Ministry of Education and Science, National Science Fund of Bulgaria DFNI-TO2/18: "Nanostructured liquid crystals for tunable photonic devices" (2015-2016)

2. Projects, additionally financed by contracts with Ministry of Education and Science:
Indo-Bulgarian intergovernmental programme, contract DNTS/ India 1/04, NSF, "Investigations of Photostimulation Effects in Nano-Structured Liquid Crystals".

3. Bilateral Scientific Exchange, Estonia 2015-2017: ISSP and Tallin University of Technology - Estonia, Prof. Valdek Mikli: „Synthesis and structural investigations of nanomaterials"

TEACHING ACTIVITIES

Assoc. Prof. Dr. Angelina Koleva Stoyanova-Ivanova is a PhD supervisor of Ivana Ilievska, appointed on 01/09/2015г. in ISSP.

Assoc. Prof. Dr. Angelina Koleva Stoyanova-Ivanova – The Erasmus Programme lecture courses: 15 hours.

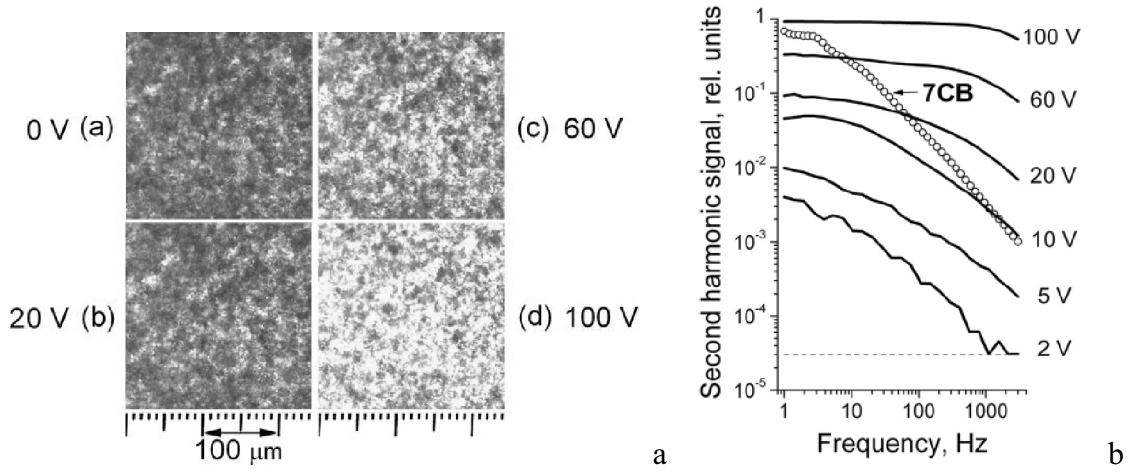

Fig. 1. Electro-optic (EO) response of thin 25 μm films of a nanocomposite gel 7CB nematic liquid crystal and 3 wt.% hydrophilic aerosil nanoparticles (ca. 7 nm): a) under AC electric field the nanostructured films exhibit a gradual increase of light transmittance with the increasing voltage, b)reversible EO responce of transmitted light EO second harmonic modulation of the driving electric field. The slope of the EO modulation can be controlled by the field.

DEPARTMENT PHYSICAL OPTICS AND OPTICAL METHODS

LABORATORY

OPTICS AND SPECTROSCOPY

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TOTAL STAFF: **19**
RESEARCH SCIENTISTS: **14**
ASSOC. MEMBERS: **4**

Prof. K. Panayotov D.Sc.; Assoc. Prof. L. Tsonev, Ph.D.; Assoc. Prof. A. Andreev, Ph.D.; Assoc. Prof. S. Tonchev, Ph.D.; Assoc. Prof. A. Angelov, Ph.D.; Assoc. Prof. G. Hadjihristov, Ph.D.; Assoc Prof. K. Antonova, Ph.D.; Assoc. Prof. B. Zafirova, Ph.D.; Assoc. Prof. M. Kuneva, Ph.D; Assoct. Prof. B. Katranchev, Ph.D.; Assoc. Prof. E. Karakoleva, Ph.D.; Assist. Prof. H. Naradikian Ph.D.; Assist. Prof. I. Milushev, Ph.D.; Physicist M. Sandulov; Physicist E. Stoyanova; Physicist M. Molerova; Technologist Y.Velkova; Technician Y. Sarafov.

Associated members: Prof. M. Petrov, D.Sc.; Prof. S. Rashev, D.Sc.; Assoc. Prof. T. Tsvetkova, Ph.D.; Assoc. Prof. R. Peeva, Ph.D.;

RESEARCH ACTIVITIES:

The dimerization of aromatic carboxylic acids is the base of the structure formation of hydrogen bonded in dimers liquid crystals (HBDLCs), that exhibit non-conventional mesomorphism. The structural units of these LCs are amphiphilic-type molecules, which after suitable functionalization, induce supramolecular complexes, nanocomposites based on HBDLCs. The liquid crystalline character of the nanocomposites strongly dependent on intermolecular hydrogen bonds between symmetric, where the H-donors and H acceptors are contained in similar and non-symmetric HBDLCs, where the H-donors and H acceptors are contained in unlike molecules. A set of new chiral ferroelectric phases, including C_G phase, were found in the nanocomposites, otherwise not appearing in the pristine achiral HBDLCs materials. We have indicated that the ferroelectric C_G phase induced in non symmetric supramolecular complexes is developable one and thermodynamically non stable, while the recently found by us C_G phase in the symmetric nano-composite mixtures with single wall carbon nanotubes reaches a stable thermodynamical state and forms microtexture with large and convenient for electrooptical investigations single local mono crystals. For evaluation of the ferroelectric polarization in the symmetric and fully developed C_G phase we apply the known pyroelectric method, and for nonsymmetric developable one we proposed a new method, consisting of a Neel wall microtexture polarization analysis in the presence of *dc* or low frequency *ac* electric fields. Molecular and macromolecular models are created for the induced C_G state in the symmetric and non symmetric states. A diffraction grating induced plasmonic resonance by chiral dimeric liquid crystals is obtained. Raman, IR, and X-ray structural investigations of the nanocomposites are in progress, aiming a deeper insight into the induced chiral and/or ferroelectric states.

The nonlinear optical effect of optical second harmonic generation (SHG) was investigated as induced by pulsed Nd^{3+}:YAG laser beam (with a wavelength of 1064 nm, pulses with duration of 30 ns and pulse energy of 0.2 mJ) passed through a thin layer of nematic liquid crystal (NLC) pentylcyanobiphenyl (5CB) upon an external pulsed-periodic electric

field (periodic pulses with a duration of about 10 μs of high-voltage static electric field, synchronized with the laser pulses). The experimental results for the electric-field-induced SHG from the incident fundamental wave as obtained at various thicknesses of the 5CB layers (25, 75 and 100 μm) at room temperature and by variation of incidence angle were processed with corresponding theoretical methods. For the observed macroscopic nonlinear effect, the deformation of the NLC under the applied pulsed-periodic electric field was analyzed and explained, and the possibility for accumulation of this deformation is established. The observed SHG features are due to spatial domains with quite different director orientations emerging in the bulk of the considered NLC. These findings were confirmed by observations with optical polarizing microscopy.

By electrical measurements (applying external electric field) is characterized a nanocomposite material produced from the room-temperature nematic liquid crystal pentylcyano-biphenyl (5CB) doped with 0.5 wt. % silver (Ag) nanospheres with a mean diameter ca.10 nm. Thin films (25 μm) of this nanostructured nematic were studied by means of dielectric spectroscopy in the frequency range from 1 mHz to 100 kHz. The effect from the Ag nano-dopants on the frequency spectra of the dielectric function and dielectric loss of Ag/5CB nematic nanocomposites were thoroughly investigated. Because the dielectric permittivity and dielectric loss are the key parameters that determine the performance of electric and electro-optic devices, the results obtained are useful for evaluating the feasibility of the considered nanocomposites for practical applications. Further, they can also be useful for the development of multi-segmented thin-layered electronic devices for nematic-based soft electronics.

A stable photoactive nanocomposite material is proposed that is based on a nano-filled nematic, doped with 3 wt.% photoactive azobenzene liquid crystal 4-(4'-ethoxyphenylazo) phenyl hexanoate (EPH). The basic nanomaterial (the nano-filled nematic) was a gel formed from the nematic 4-*n*-heptyl cyanobiphenyl (7CB) and 3 wt.% silica nanospheres (Aerosil 300) of size ca. 7 nm, that is photoinsensitive itself. The addition of the photoactive agent EPH enables an efficient control of the electro-optical (EO) characteristics of the produced photoresponsive three-component nematic system. This can be done by illumination with ultraviolet (UV) light or with a light in the blue spectral region, that leads to *trans-cis* conformation of EPH molecules, or reverse process, respectively. Under alternating-current (AC) electric field such films of nanostructured LC exhibit a gradual increase of light transmittance with increasing voltage, a reversible EO behavior of transmitted light, as well as a specific effect of slightly varying amplitude-frequency EO modulation at the doubled frequency of the driving electric field. The slope of the EO modulation characteristics of ANPs/7CB can be controlled by the field. These features make the studied nematic nanocomposites attractive for EO modulation applications.

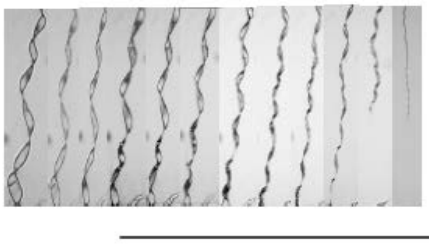
Upon UV-light illumination, the EO response of photosensitized EPH/Aerosil/7CB can be photo-stimulated, and the threshold voltage at which is activated the AC voltage-dependent optical transmittance of these nanocomposites can be largely reduced (useful for the practice). This photo-induced effect results from the *trans-cis* photoisomerization of azobenzene molecules that decorate the network formed within the aerosil/7CB nanostructured gel. By the back *cis*-to-*trans* photo- isomerization of the EPH azo-molecules, the initial electro-optical response (before the UV illumination) of the considered photoactive nanostructured nematic system can be easily restored. Thus, an efficient control by light can be achieved, useful for photo-controllable electro-optical applications (e.g., efficient optical switches, EO attenuators and high-contrast EO modulators and other devices for active control of light, as well as for sensors whose function is based on electro-optics).

A new nanomaterial was proposed that was composed from the polymer poly(sodium acrylate) doped with gold nanospheres. Such a soft nanocomposite was prepared by using gold nanospheres with diameter of 11 nm that were caped with a polymeric nanolayer with a

thickness of ca. 10 nm. This nanomaterial, that is of interest for electrical energy storage applications, was characterized by optical spectroscopy (transmittance) in the near UV-visible-near IR range. This technique was combined with the application of direct-current or alternating-current electric fields, to examine the nanocomposite stability. The material was studied at room temperature by electrical measurements (cyclic *voltammetry and* chronoamperometric) in order to be inspected for the presence of electric charging. For this purpose, special cells made of glass were constructed. The initial research shows that the produced material should have better electric characteristics if it is a concentrated soft gel without hydroxyl groups, and the gold nanospheres are not mixed, but incorporated and linked within the polymer network.

A new soft plastic composite material prepared from polyethylene oxide (PEO) and polyvinylpyrrolidone (PVP) doped with $NaIO_4$ was studied by electrical measurements and complex electro-impedance spectroscopy at various temperatures. This new polymeric complex in a form of thin films with a thickness of 100 μm was prepared by Dr. H.K. Koduru, (INERA visiting researcher from the University of Calabria, Cosenza-Rende, Italy). Samples of PEO-PVP-$NaIO_4$ were characterized by diffuse reflectance optical spectroscopy and FT-NIR spectroscopy. The effect from $NaIO_4$ filler on the dielectric permittivity of the three-component mixed system was analyzed in the frequency range 0.1 Hz – 1 MHz and over a temperature range 20–60 ˚C. As compared with the two-component polymer host PEO-PVP, a distinctly enhanced electrical and dielectrical response and an increase of the value of the dielectric constant of the polymeric PEO-PVP-$NaIO_4$ complex were present. This suggests the potential of the studied composite as a material for soft electronics and electric applications such as solid electrolytes. A further advantage of PEO-PVP-$NaIO_4$ films is the lack of electric charge trapping effect on the surface that is closely related to the electrolyte applicability. The lack of *trapped charge* carriers (ions) was correlated with the surface morphology of the examined thin films. The results will be useful for the optimization (both compositional and structural) of this flexible polymeric composite, as well as for its future practical application.

The behavior of double helices (DH*) formed in the temperature interval N*-SmA* in compounds of a non chiral liquid crystal doped with chiral molecules was investigated. Two different systems presenting left-handed or right-handed chirality were studied. A statistics of the handedness of the DH* revealed a correlation with the molecular chirality. A decrease of the DH*'s pitch upon cooling was registered. Under an applied AC electric field was observed a decrease of the pitch of the DH*s, due to shrinking the diameter of the cylinder containing them. This effect was similar to that produced by the decrease of the temperature in the absence of a field.



Spectroscopic measurements were carried out to optimize the capabilities of the FTIR Vertex 70, Bruker and its accessories for qualitative and quantitative spectroscopy of powders, gels and liquids. Spectrophotometric studies of about 100 samples were made in different spectral regions and special geometries for the purpose of the ISSP' InERA project, for colleagues from BAS' institutes and other external users.

A technology for deposition of multilayer optical structures in the visible range by electron beam evaporation and ion assisting in newly purchased under the Operational Programme "Competitiveness of Bulgarian Economy" 2007-2013 vacuum system Symphony 9 was tested. A serie of more than 50 samples (test deposits) to obtain single optical layers of

substances with a high (TiO_2), medium (Al_2O_3) and low (SiO_2) refractive index at different technological conditions on microscope slides, Si wafers and colorless optical test glasses (BK7, SF56, SF11, H-ZF13 with refractive indices between 1.5 and 1.85) was conducted.

The layers were prepared at different processing conditions: i) at temperature between 50^o to 350^o C without ion assistance; and ii) at room temperature by using ion assistance with oxygen ions, argon ions, or a mixture of argon and oxygen ions at various parameters of the ion source. Optimal technological conditions were searched for the process to obtain layers with the required characteristics (refractive index, density, strength, adhesion, etc.). The spectral characteristics (transmission and/or reflection) of the resulting samples were tested in a wide spectral range (320-1800/2500 nm) with a spectrophotometric system Lambda 1050 (Perkin-Elmer) and the optical dispersion of the layers were determined. The results were compared with those obtained using the spectral elipsometer Alfa-SE (Woolam) and dispersions taken from literature sources. Simultaneously, geometric factor (the impact of the mutual disposition of the electron evaporation sources, details and quartz sensors of vacuum technological system) and different uniformity masks to improve the uniformity of layers depending on the position of samples in the holder were tested.

Selected deposition conditions of thin layers with the necessary characteristics have been used in experimental design and accomplishment of over 30 different multilayer structures: antireflection coatings, edge cutting filters, single and double cavity narrowband filters. In the realization of antireflection coatings the optical thickness control for layers deposition has been tested, that gave good results in the implementation of complex coatings with requirements in two spectral ranges simultaneously.

In collaboration with the Free University of Brussels and the University of Glasgow, Scotland, were discovered and then experimentally and theoretically confirmed vector spatial solitons in Vertical Cavity Surface Emitting Lasers (VCSELs) with a wide aperture. So-called "rare events" with great amplitude, also known as "killer waves" in oceanography, were also examined.

The synchronization of chaotic dynamics of two mutually coupled VCSELs, caused by the polarization degree of freedom or optical feedback, was examined. The studies were conducted in collaboration with the University of Cantabria, Santander, Spain.

Resonant laser mirror causing YAG disc laser to generate only basic transverse mode is experimentally demonstrated. The mirror is composed of a multilayer coating and a two-dimensional hexagonal diffraction grating which through a destructive interference provides suppression of the transverse mods of higher order.

It is found that for deep two-dimensional diffraction gratings, the electromagnetic field is extremely high around the vertices of the grid. This effect can be used for construction of precise chemical sensors and also for detection of single biomolecules.

Realization and study of optical gas sensors based on nanosized thin layers of zeolite as a gas sensitive material are in process, in collaboration with the Laboratory "Composite and nanostructured optical materials" of the Institute of optical materials and technologies, BAS. The zeolite layers are coated on the surface of the planar waveguides (Ta_2O_5) which are optically connected with D-shape optical fibers. The influence of the gas stream’s parameters on the time of reaction and the sensitivity of the sensor system are investigated. The experimental results permit the invention of a new chamber for gas-sensing measuremenrs. This new scheme will give a possibility for better control of gas stream’s parameters and more precise work of the device.

By the approach of adding and subtracting of media in the development of the Galerkin method for modeling of photonic crystal fibers (PCFs), theoretical expressions are obtained which give possibility for the spurious modes to be removed from the real ones propagating along the PCFs.The expressions are incorporated in the code for modeling of PCFs with the development of the Galerkin method application.

A bibliographical reference book on the articles published by the Sofia University lecturers in mathematics and science during the first 50 years after the University has been founded (1889-1939) is issued. In this period the number of lecturers in mathematics, physics and chemistry is not large, but they have published 588 articles in 101 scientific journals. These are presented in the book bibliographically including author's name, scientific area and faculty, the name, volume and year of the journal where the article has been published. The distribution of papers in journals, as well as by authors enables the contribution of the University of Sofia to the natural sciences in the considered period to be evaluated and made known to the scientific community. The e-version of the book is available on the Faculty of Chemistry and Pharmacy library site.

Two review papers were published aiming to analyze and summarize the most significant technological modifications of the method of proton exchange for obtaining optical waveguides in lithium niobate and lithium tantalate, its advantages and disadvantages. Discussed are the methods of characterization of waveguide layers and the most important waveguide structures of $LiM_{1-x}H_xO_3$ (M = Nb, Ta) for different modulators used in modern optoelectronic devices (navigation equipment, communication systems, biosensors, etc.). The articles are based on our own results and a bibliographical study as well.

The potential field of the thiophosgene ground electronic state was studied theoretically. The structure and the dynamics of the very highly excited vibrational states in the region of dissociation were computed.

The noises in interferometric systems such as the interferometer of Mach-Zehnder are theoretically estimated. By a Wigner distribution, an equation for the wave function of the phase space state of the quantum system is obtained.

In the frame of the project 7FP CareRAMM ("Carbon resistive random access memory materials"), in which ISSP is a partner, investigations on the application of the diamond-like carbon for the electrical and optical recording of information in the nano-scale range are accomplished by surface characterisation of Ga+ ions implanted into thin layers of ta-C. The structural modification of the ta-C during the incorporation of Ga+ and N+ ions is studied.

Some archaeological sites lying outside the attention of professional archaeologists and not yet exhaustively explored, were analyzed from a physical point of view (luminescent dating and archaeoastronomy).

A new approach in the study of megaliths in Bulgaria was systematically introduced, namely: the continuity in development from prehistoric megaliths to pagan shrines from Antiquity and to early Christian monuments.

AWARDS:

In the competition for the best scientific achievement (Applied Science Research) of the Institute of Solid State Physics, BAS – 2016 :

Nanocomposites of nematic liquid crystal 7CB and SiO_2 nanospheres for photo-controllable electro-optics

Research Team: *from ISSP-BAS – G. B. Hadjichristov, Y.G. Marinov, A.G. Petrov*
from India – S. K. Prasad, Centre for Nano and Soft Matter Sciences, Jalahalli, Bangalore

A stable photoactive nanocomposite material is proposed that is based on a nano-filled nematic doped with 3 wt.% photoactive azobenzene liquid crystal 4-(4'-ethoxyphenylazo)phenyl hexanoate (EPH). The base nanomaterial (the nano-filled nematic) was a gel composed from the nematic 4-*n*-heptyl cyanobiphenyl (7CB) and 3 wt.% silica nanospheres (Aerosil 300) of size ca. 7 nm (Fig. 1a) that is photoinsensitive itself. The addition of the photoactive agent EPH enables an efficient control of the electro-optical (EO)

characteristics of the produced photoresponsive tree-component nematic system. This can be done by illumination with ultraviolet (UV) light or with a light in the blue spectral region, that leads to *trans-cis* conformation of EPH molecules, or the back process, respectively.

In view of practical applications, the optical and EO characteristics of thin (25 μm) films of photoactive EPH/Aerosil/7CB nanocomposites were investigated as depending on the intensity and polarization of the illuminating light, as well as on the frequency and intensity of the applied alternating electric field. Upon UV-light, the EO response of the considered nanostructured EPH/Aerosil/7CB films can be photo-stimulated, and the threshold voltage at which is activated the AC voltage-dependent optical transmittance of the studied nanocomposites can be largely reduced (Fig. 1b) (useful for the practice). The obtained results are of principal importance for the electro-optics of nano-filled nematic liquid crystal systems. Further, they imply that the composed nanomaterial and the specific effects we have reported are of interest for photo-controllable EO applications (e.g., efficient optical switches, EO attenuators and high-contrast EO modulators and other devices for active control of light, as well as for sensors whose function is based on electro-optics).

PUBLICATIONS:

1. **Angelow, A.**, **Stoyanova, E**. Fiber-Optic Laser Gyroscope with Current Modulation of the Optical Power. Bulgarian Journal of Physics, 43, 2, 2016 Heron Press Ltd., 2016, ISSN:1310-0157, 100-109
2. **Antonova K.**, **Szekeres A.**, Duta L., Stan G.E., Mihailescu N., Mihailescu I.N.. Orientation of the nanocrystallites in AlN thin film determined by FTIR spectroscopy. Journal of Physics: Conference Series, 682, IOP Science, 2016, ISSN:17426588, DOI:10.1088/1742-6596/682/1/012024, 012024. SJR:0.211
3. **Antonova, K. T.**, **Vitkova, V.**, Mayer, C.. Membrane tubulation from giant lipid vesicles in alternating electric fields. Physical Review E, 93, APS, 2016, DOI:http://dx.doi.org/10.1103/PhysRevE.93.012413, 012413. ISI IF:2.288
4. Averlant E., Tlidi M., Thienpont H., Ackemann T., **Panajotov K.**. Vector cavity solitons in broad area Vertical-Cavity Surface-Emitting Lasers. Scientific Reports, 6, Springer Nature, 2016, ISSN:ISSN 2045-2322 (online), DOI:10.1038/srep20428, 20428-1-20428-7. ISI IF:5.578
5. Averlant, E., Tlidi, M., Ackemann, T., Thienpont, H., **Panajotov, K**. Polarization properties of localized structures in VCSELs. Proceedings of SPIE - The International Society for Optical Engineering, 9892, SPIE, 2016, ISSN:0277786X, DOI:10.1117/12.2225161
6. Ayriyan, A. A., Ayrjan, E. A., Egorov, A. A., **Hadjichristov, G. B.**, **Marinov, Y. G.**, Maslyanitsyn, I. A., **Petrov, A. G.**, Pribis, J., **Popova, L.**, Shigorin, V. D., Strigazzi, A., Torgova, S. I.. Some Features of Second Harmonic Generation in the Nematic Liquid Crystal 5CB in the Pulsed-Periodic Electric Field. Physics of Wave Phenomena, 24, 4, Allerton Press, Inc., 2016, ISSN:1541-308X, DOI:0.3103/S1541308X16040026, 259-267. ISI IF:0.55
7. Balchev, I., Tzvetkova, Kr., Kolev, S., **Terziyska, P.**, **Szekeres, A.**, **Miloushev, I.**, **Tenev, T.**, **Antonova, K.**, **Peyeva, R.**, Ivanova, T., Avramova, I., Tzvetkov, M., Avdreev, G., Valcheva, E., Milenov, T., Tinchev, S.. Synthesis and characterization of thin amorphous carbon films doped with nitrogen on (001) Si substrates. Journal of Physics: Conference Series, 764, 1, IOP Publishing Ltd, 2016, ISSN:17426588, DOI:doi:10.1088/1742-6596/764/1/012013, SJR:0.211

8. **Berova M.**, **Sandulov M.**, **Tsvetkova T.**, Avramova I., Boettger R., Bischoff L.. X-Ray Photoelectron Study of Ion Implanted Tetrahedral Carbon. Przeglad Elektrotechniczny, 92, 8, 2016, ISBN:0033-2097, DOI:doi:10.15199/48.2016.08.16, 59-61. SJR:0.244
9. **Berova M.**, **Sandulov M.**, **Tsvetkova T.**, Bischoff L., Boettger R., Abrashev M.. Vibrational spectroscopy of Ga+ ion implanted ta-C films. Journal of Physics: Conference Series, 682, 2016, 012020. SJR:0.217
10. **Berova M.**, **Sandulov M.**, **Tsvetkova T.**, Karashanova D., Boettger R., Bischoff L.. Structural modification of Ga+ and N+ ion implanted ta-C films. Journal of Physics: Conference Series, 700, 2016, ISSN:17426588, DOI:doi:10.1088/1742-6596/700/1/012035, SJR:0.211
11. Blaha, S., Averlant, E., **Panajotov, K.**, Tlidi, M.. Self-organized light bullets in type-I intracavity second-harmonic generation. Proceedings of SPIE - The International Society for Optical Engineering, 9892, SPIE, 2016, ISSN:0277786X, DOI:10.1117/12.2230311
12. Dyankov, G, Zhelyazkova, K, **Petrov, M**, **Katranchev, B**. A pitch of helicoid of chiral liquid crystals and surface plasmon excitation: A theoretical study. Molecular Crystals and Liquid Crystals, 632, 1, 2016, ISSN:1542-1406, 2-8. ISI IF:0.532
13. Frasunkiewicz, L., Czyszanowski, T., Choquette, K., **Panajotov, K.**. Mixed transverse modes in coupled-cavity VCSELs. Proceedings of SPIE - The International Society for Optical Engineering, 9892, SPIE, 2016, ISSN:0277786X, DOI:10.1117/12.2227845
14. Frasunkiewicz, L., Czyszanowski, T., Thienpont, H., **Panajotov, K**. Polarization- and Modal-Control in a Vertical-Cavity Surface-Emitting Laser with an External-Cavity Formed by a Liquid Crystal Overlay. Journal of Lightwave Technology, 34, 23, Institute of Electrical and Electronics Engineers Inc., 2016, ISSN:07338724, DOI:10.1109/JLT.2016.2619178, 5437-5443. SJR:2.006
15. **Hadjichristov G B**, **Marinov Y G**, **Petrov A G**, Marino L, Scaramuzza N. Dielectric and electrical characterization of 5CB nematic liquid crystal doped with silver nanoparticles. Journal of Physics: Conference Series, 682, 1, IOP Publishing Ltd., 2016, ISSN:1742-6596 1742-6588, DOI:10.1088/1742-6596/682/1/012015, 012015. SJR:0.211
16. **Hadjichristov G B**, **Marinov Y.G**. Optical diffraction by using electrically-controlled spatially patterned nematic pentylcyanobiphenyl films under static electric field. Molecular Crystals and Liquid Crystals, 632, 1, 2016, ISSN:1542-1406 1563-5287, DOI:10.1080/15421406.2016.1185566, 9-20. ISI IF:0.532
17. **Hadjichristov, G. B.**, **Marinov, Y. G.**, **Petrov, A. G.**. Electrically and spatially controllable PDLC phase gratings for diffraction and modulation of laser beams. AIP CP, 1722, 1, American Institute of Physics (AIP) Publishing, 2016, 290007(1)-290007(4). SJR:0.2
18. Hong Y., Quirce A., Wang B., **Panajotov K.**, Spencer P. S.. Complexity of Chaos in Three Cascaded Vertical-Cavity Surface-Emitting Lasers. Proceedings of SPIE, 9892, SPIE, 2016, DOI:10.1117/12.2225526, 98920M-1-98920M-8
19. Hong, Y., Quirce, A., Wang, B., Ji, S., **Panajotov, K.**, Spencer, P.S.. Concealment of Chaos Time-Delay Signature in Three-Cascaded Vertical-Cavity Surface-Emitting Lasers. IEEE Journal of Quantum Electronics, 52, 8, Institute of Electrical and Electronics Engineers Inc., 2016, ISSN:00189197, DOI:10.1109/JQE.2016.2587099, 1-8. SJR:1.128
20. **Katranchev, B**, **Petrov, M**, **Rafailov, P M**, Todorov, N. Chiralization and ferroelectric state induction in nanostructured liquid crystals. Journal of Physics: Conference Series, 682, 2016, DOI:10.1088/1742-6596/682/1/012001, SJR:0.22

21. **Katranchev, B**, **Petrov, M**, **Rafailov, P**, Todorov, N, **Keskinova, E**, **Naradikian, H**, Spassov, T. Ferroelectric state induced in mixture of dimer liquid crystal and perfluorooctanoic acid. Molecular Crystals and Liquid Crystals, 632, 1, 2016, ISSN:1542-1406, 21-28. ISI IF:0.532
22. **Katranchev, B**, **Petrov, M**. Phase transitions in nanocomposites of hydrogen-bonded dimeric liquid crystals with mesogenic and non-mesogenic components. Phase Transitions, 89, 2, Taylor & Francis, 2016, DOI:10.1080/01411594.2015.1075242, 115-132. ISI IF:0.954
23. **Kuneva, M. K.**. Proton exchange technology for optical waveguides in lithium niobate and lithium tantalate –an overview. Bulgarian Chemical Communications, 48, Special Issue G, 2016, ISSN:0324-1130, 21-24. ISI IF:0.349
24. **Kuneva, M.**. Optical Waveguides Obtained Via Proton Exchange Technology in LiNbO3 and LiTaO3 – a Short Review. IJSRST, 2, 6, 2016, ISSN:2395-6011, 40-50
25. **Marinov Y.G**, **Hadjichristov G B**, **Petrov A.G**, S. Krishna Prasad. Electro-optic modulation by silica-nanostructured nematic system (aerosil/7CB nanocomposite). Composites Part B: Engineering, 90, 1 April, 2016, 471-477. ISI IF:3.85
26. **Marinov Y.G**, **Hadjichristov G B**, **Petrov A.G**, S. Krishna Prasad. 'Photo-controllable electro-optics of aerosil/7CB nanocomposite nematic doped with azo-bonded molecules'. Journal of Physics: Conference Series, 682, 1, IOP Publishing Ltd., 2016, ISSN:1742-6596 1742-6588, DOI:10.1088/1742-6596/682/1/012030, 012030. SJR:0.211
27. **Marinov, Y. G.**, **Hadjichristov, G. B.**, **Petrov, A. G.**, Prasad, S. K.. Thin films of silica nanoparticle doped nematic liquid crystal 7CB for electro-optic modulation. Photonics Letters of Poland, 7, 4, Photonics Society of Poland, 2016, 94-96. SJR:0.288
28. Meyer, C, Rabette, C, Gisse, P, **Antonova, K**, Dozov, I. DH* in chiral smectics under electric field. Eur. Phys. J. E, 39, 7, Eur. Phys. J. E, 2016, DOI:10.1140/epje/i2016-16076-7, 76-80. ISI IF:1.757
29. **Panajotov K.**, Puzyrev D., Vladimirov A.G., Gurevich S. V., Tlidi M.. Impact of time-delayed feedback on spatiotemporal dynamics in the Lugiato-Lefever model. PHYSICAL REVIEW A, 93, American Physical Society, 2016, DOI:10.1103/PhysRevA.93.043835, 043835-1-043835-7. ISI IF:3.042
30. **Petrov, M.**, **Katranchev, B.**, **Rafailov, P.**. Induction of chiral phases in originally achiral hydrogen-bonded dimer liquid crystals. Molecular Crystals and Liquid Crystals, 641, 1, 2016, ISSN:ISSN:1542-1406, 95-105. ISI IF:0.532
31. Quirce A., Pérez, P., Popp A., Valle A., Pesquera L., Hong Y., Thienpont H., **Panajotov K.**. Theoretical and experimental study of polarization switching in longwavelength VCSELs subject to parallel optical injection. Proceedings of SPIE, 9892, SPIE, 2016, DOI:10.1117/12.2227786, 98920Q-1-98920Q-9
32. Quirce A., Valle A., Thienpont H., **Panajotov K.**. Chaos synchronization in mutually coupled 1550-nm vertical-cavity surface-emitting lasers with parallel polarizations and long delay time. J. Opt. Soc. Am. B., 33, 1, The Optical Society of America, 2016, ISSN:0740-3224, DOI:10.1364/JOSAB.33.000090, 90-98. ISI IF:1.806
33. Quirce, A., Pérez, P., Popp, A., Valle, A., Pesquera, L., Hong, Y., Thienpont, H., **Panajotov, K**. Polarization switching and injection locking in vertical-cavity surface-emitting lasers subject to parallel optical injection. Optics Letters, 41, 11, OSA - The Optical Society, 2016, ISSN:01469592, DOI:10.1364/OL.41.002664, 2664-2667. SJR:2.397

34. Quirce, A., Valle, A., Thienpont, H., **Panajotov, K**. Chaos synchronization in mutually coupled long-wavelength vertical-cavity surface-emitting lasers with long delay time. Proceedings of SPIE - The International Society for Optical Engineering, 9892, SPIE, 2016, ISSN:0277786X, DOI:10.1117/12.2227532
35. Quirce, A., Valle, A., Thienpont, H., **Panajotov, K**. Enhancement of chaos bandwidth in VCSELs induced by simultaneous orthogonal optical injection and optical feedback. IEEE Journal of Quantum Electronics, PP, 99, IEEE, 2016, ISSN:00189197, DOI:10.1109/JQE.2016.2605400, SJR:1.128
36. **Rashev S.**, Moule D. C.. Large scale vibrational calculations on IVR in S0 thiophosgene. J. Theoret. and Comput. Chem., 15, 1, World Scientific Publishing Company, 2016, DOI:DOI: 10.1142/S021963361650005X, 1-16. ISI IF:0.638
37. **Rashev S.**, Moule. D. C.. Theoretical study on the vibrational structure of S0 thiophosgene from the origin to dissociation. Vibrational Spectroscopy, 84, Elsevier, 2016, 118-126. ISI IF:2.003
38. **Stefanova M. S.**, **Pramatarov P. M.**, Kudryavtsev A. A., **Peyeva R. A.**, Patrikov T. B.. Collisional electron spectroscopy method for gas analysis. J. Phys: Conf Series, 719, 012010, IOP Publishing, 2016, ISSN:1742-6596, DOI:http://dx.doi.org/10.1088/1742-6596/715/1/012010, 1-5. SJR:0.45
39. **Stoyanova.E.**. Fiber-Optic Laser Gyroscope with Current Modulation of the Optical Power. Bulgarian Journal of Physics, 43, 2, Heron Press Ltd., Sofia., 2016, ISSN:1310-0157, 100-109
40. Tlidi M., Gandica Y., Sonnino G., Averlant E., **Panajotov K.**. Self-Replicating Spots in the Brusselator Model and Extreme Events in the One-Dimensional Case with Delay. Entropy, 18, 2016, DOI:10.3390/e18030064, 64-1-64-10. ISI IF:1.502
41. **Tsvetkova T.**, **Berova M.**, **Sandulov M.**, Kitova S., Avramov L., Boettger R., Bischoff L.. Focused ion beam optical patterning of ta-C films. Surface and Coatings Technology, 306, 2016, ISSN:0257-8972, DOI:10.1016/j.surfcoat.2016.07.088, 341-345. SJR:0.96, ISI IF:2.223
42. Virte M., Pawlus R., Elsasser W., **Panajotov K.**, Sciamanna M., Breuer S.. Range-dependent effects of optical feedback on multimode two-color Quantum Dot Lasers. Proceedings of SPIE, 9892, SPIE, 2016, DOI:10.1117/12.2227086, 98920W-1-98920W-7
43. Virte, M., Breuer, S., Sciamanna, M., **Panajotov, K**. Recurrent state-switching of a two-state quantum dot laser by optical feedback. Proceedings of SPIE - The International Society for Optical Engineering, 9892, SPIE, 2016, ISSN:0277786X, DOI:10.1117/12.2227085
44. Virte, M., Pawlus, R., Sciamanna, M., **Panajotov, K.**, Breuer, S.. Energy exchange between modes in a multimode two-color quantum dot laser with optical feedback. Optics Letters, 41, 14, OSA - The Optical Society, 2016, ISSN:01469592, DOI:10.1364/OL.41.003205, 3205-3208. SJR:2.397
45. Virte, M., Sciamanna M., Thienpont H., **Panajotov K.**. Nonlinear Dynamics of Vertical-Cavity Surface-Emitting Lasers: Deterministic Chaos and Random Number Generation. M. Tlidi and M.G. Clerc (eds.), Nonlinear Dynamics: Materials, Theory and Experiments, 173, Springer Proceedings in Physics, 2016, ISBN:978-3-319-24869-1, DOI:10.1007/978-3-319-24871-4_4, 10, 59-69

46. Virte, M., Sciamanna, M., **Panajotov, K**. Synchronization of polarization chaos from a free-running VCSEL. Optics Letters, 41, 19, OSA - The Optical Society, 2016, ISSN:01469592, DOI:10.1364/OL.41.004492, 4492-4495. SJR:2.397
47. Virte, M., Sciamanna, M., Thienpont, H., **Panajotov, K**. One way synchronization of polarization chaos from a solitary Vertical-Cavity Surface-Emitting Laser. Proceedings of SPIE - The International Society for Optical Engineering, 9892, SPIE, 2016, ISSN:0277786X, DOI:10.1117/12.2227084
48. Virte, M., Sciamanna, M., Thienpont, H., **Panajotov, K.**. Chaos in solitary VCSELs: Asymmetry and noise. Proceedings of SPIE - The International Society for Optical Engineering, 9, SPIE, 2016, ISSN:0277786X, DOI:10.1117/12.2227083
49. **Кънева, М. К.**, Христов, Д.. МАТЕМАТИКАТА, ФИЗИКАТА И ХИМИЯТА В СУ „КЛ. ОХРИДСКИ" 1889-1939, ОТРАЗЕНИ В СТРАНИЦИТЕ НА ГОЛЕМИТЕ ЗАПАДНИ СПИСАНИЯ. I, Фараго, 2016, ISBN:ISBN 978-619-206-044, 63
50. **Цонев, Л., Борисов, И.**. Резултати от антропологическата експедиция по билото на Калините и Поличите, Западна Рила, 2015. Вяра и култ - Годишник на асоциация Онгъл, XV, Род, 2016, ISSN:1311-493X, 42-57
51. **Цонев, Л.**. Луминесцентно датиране в археологията. Паметници, реставрация, музеи, 2016, февруари-април, Арх-Арт, 2016, ISSN:1312-3327, 61-68

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:
1. Photonics, optics and spectroscopy of nonlinear and anisotropic media.

Financed by the Bulgarian Ministry of Education and Science:
1. Participation in three-year (2014-2016) project on a thematic Competition 2014 NSF entitled "Nano-structured liquid crystals for tunable photonic devices" (DFNI-TO2 / 18) head: Assoc. prof. J. Marinov, ISSP-BAS

2. Participation in three-year (2016-2018) project "Liquid crystal approach for model lipid membrane functions optimization by nanoparticles insertion" (FNI-DH08-2) head: Assoc. prof. J. Genova, ISSP-BAS

INTERNATIONAL COLLABORATION:

Final report of the 4-years COST Action: "European network for development of electroporation-based technologies and treatments Acronym – EP4Bio2Med" (2012 – 2016) is prepared for the activities of the members from ISSP: assoc. prof., PhD V. Vitkova and assoc. prof., PhD K. Antonova.

TEACHING ACTIVITIES:

M. Kuneva: 120 teaching hours in the University of Architecture, Civil Engineering and Geodesy, Sofia (General Physics in English for preparatory year students).

DEPARTMENT LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

ATOMIC SPECTROSCOPY

HEAD: **Assoc. Prof. Valentin Mihailov, Ph.D.**
tel: 979 5740; e-mail: valentin@issp.bas.bg

TOTAL STAFF: **9**
RESEARCH SCIENTISTS: **8**
ASSOC. MEMBERS: **3**

Prof. Kiril Blagoev, DSc.; Assoc. Prof. Emilia Dimova, Ph.D.; Assoc. Prof. Galina Malcheva, Ph.D.; Assoc. Prof. Margarita Stefanova, Ph.D.; Assoc. Prof. Boian Torosov, Ph.D.; Assist. Prof. Vasilka Steflekova, Ph.D.; Assist. Hristina Hristova; Ph.D student Vani Tankova

Associated members: Prof. Dimo Zhechev,; Prof. Renna Djulgerova, DSc.; Assoc. Prof.Petko Pramatarov

RESEARCH ACTIVITIES:

The electron temperature T_e and electron density n_e are measured in the negative glow plasma of a dc mictrodischarge in pure *He* and *He-Ar* mixture at intermediate and high pressures. It is shown that the electron temperature of the slow group of electrons is low - about 0.2 - 0.3 eV and does not change significantly by the variations in the *He* pressure from 14 Torr to 400 Torr, as well as by the changes in the discharge current. The experimental results obtained for T_e disagree with the results from the commonly used fluid approximation at high pressures, which encounters fundamental difficulties associated with the need to take into account the nonlocal ionization by fast electrons in the negative glow plasma. The electron density n_e increases by the *He* pressure an discharge current increase, as follows: 1) n_e= $1.7\text{x}10^{12}\div 8.9\text{x}10^{12}\text{cm}^{-3}$ at 14 Torr *He* and $i = 2 \div 4$ mA; 2) n_e=$6\text{x}10^{13}\div 3.4\text{x}10^{14}$ cm^{-3} at 200 Torr *He* and $i = 6\div 13.5$ mA.

The time-resolved emission characteristics of spectroscopic source combining laser ablation and DC hollow cathode glow discharge are studied. The experimental results show that the intensity of the analytical lines increases in order of magnitude in comparison to stand-alone hollow cathode discharge and laser ablation. The spectral lines are detectable a few tenths of μs longer for the coupled sources compared to the stand-alone laser ablation. Thus is established the time interval in which the process of material sampling and excitation can be separated. The obtained results for the system combining laser ablation with hollow cathode glow discharge are promising for obtaining spectrochemical analysis with enhanced precision and sensitivity and lower detection limits than standard LIBS. The work on this topic was carried out jointly with colleagues from MVL laboratory.

During implementation of the project - "Thracian - genesis and development of ethnic, cultural identities, interactions and civilizational heritage of antiquity" qualitative elemental analysis of various ancient thracian bronze objects was performed. The analisis were performed by the method of laser-induced plasma spectroscopy (LIBS). The data are processed and prepared for publication.

We continue the work on the theory of a new method for decomposition of spin chains with nearest-neighbor interaction. In order to achieve this, we use a modification of the Morris-

Shore transformation, which allows the system to be reduced to independent pairs of interacting spins. In the case of odd number of total spins, the systems possesses a "dark spin".

In collaboration with prof. N. V. Vitanov (Sofia University), assoc. prof. A. A. Rangelov (Sofia University) and prof. G. Montemezzani (LMOPS, Metz) the adiabatic evolution of light in nonlinear crystal was theoretically investigated. A technique for broadband frequency conversion was proposed on the analogy of adiabatic population transfer between two quantum energy states mediated by phase jump in the coupling. The proposed technique can be implement experimentally by joining two nonlinear crystals oriented in opposite directions or by poling half of the nonlinear crystal in one direction and the other half in the opposite direction.

On the basis of theoretical model, using the theory of the composite pulses an experiment for second harmonic generation SHG λ = 532nm by illumination of the crystal with λ =1064nm laser pulse, has been realized.

PUBLICATIONS:

1. H. Lundberg, H. Hartman, L. Engström, H. Nilsson, A. Persson, P. Palmeri, P. Quinet, V.Fivet, G. Malcheva and K. Blagoev“ Oscillator strengths for high-excitation Ti II from laboratory measurements and calculations”;, *MNRAS, 922, (2016)*
2. V. Tankova, K. Blagoev, M. Grozeva, G. Malcheva and P. Penkova “Qualitative and quantitative laser-induced breakdown spectroscopy of bronze objects” *J. Phys.: Conf. Ser. 700 012003, (2016).*
3. H. S. Hristova, A. A. Rangelov, G. Montemezzani and N. V. Vitanov Adiabatic frequency conversion with a sign flip in the coupling *Phys. Rev. A 94, 033849 (2016)*
4. Emiliya Dimova, Wei Huang, George Popkirov, Andon Rangelov, Elica Kyoseva, Broadband and ultra-broadband modular half-wave plates, *invited paper, Optics Communications 366 (2016) 382–385*
5. M. S. Stefanova, P. M. Pramatarov, A. A. Kudryavtsev, R. A. Peyeva and T.B. Patrikov “Collisional electron spectroscopy method for gas analysis” *J Phys: Conf Series, 715 (2016) 012010*
6. A. Kudryavtsev,M. S. Stefanova and P. M. Pramatarov Response to “Comment on ‘Use of dc Ar microdischarge with nonlocal plasma for identification of metal samples” *J. Appl. Phys. 119(13) IF 2.101*
7. D Zhechev, V Steflekova, Nonselective and polarization effects in time-resolved optogalvanic spectroscopy, *Journal of Physics: Conf. Series 682 (1), 2016, 012036*
8. V Tankova, K Blagoev, M Grozeva, G Malcheva, V Steflekova, S Alexandrov, T Hristova, GIvanov, G Nekhrizov, Qualitative and quantitative laser-induced breakdown spectroscopyanalysis of archaeological metal artefacts, *SPIE 2016 (in press)*
9. G. Dobrev, V. Gerginov, and S. Weyers, Loading a fountain clock with an enhanced low-velocity intense source of atoms *PHYSICAL REVIEW A **93**, 043423 (2016)*
10. Bineva I., Pejova B., Mihailov V., Dinescu A., Danila M., Karatodorov S.. Structural and morphological characterization of ternary nanocrystalline Cu-In-S thin films prepared by laser ablation. *Journal of Physics: Conference Series, IOP Science, accepted: 2016, SJR:0.211*
11. Ivana Ilievska, Valeri Petrov, Valentin Mihailov, Stefan Karatodorov, Laura Andreeva, Angelina Stoyanova-Ivanova” Study of elemental composition of heat activated orthodontic archwires in in-vivo environment *Ортодонтски преглед/Orthodontic review 18, 1, 3-9, (2016)* ISSN: 1311-3313

12. S Karatodorov, V Steflekova, V Mihailov, D Mihailova, J van Dijk, J van der Mullen, M Grozeva, A novel device for spectrochemical analysis based on a combination of LIBS and a hollow cathode discharge, *Journal of Physics: Conference Series 715 (1), 2016, 012009*
13. S. Karatodorov, V. Mihailov, T. Křenek and M. Grozeva Optical emission spectroscopy of plasma produced by laser ablation of iron sulfide *Journal of Physics: Conference Series 700 (2016) 012001*

ONGOING RESEARCH PROJECTS:

- Thracians - genesis and development of ethnic, cultural identities and heritage of antiquity, (private donation to BAS, 2016),
- Composite pulses in quantum engineering, Marie Curie reintegration grant (Horizon 2020 and COST),
- Atomic, Molecular and Plasma Physics (funded by the budget subsidy of BAS),
- Non-Hermitian Hamiltonian approach to quantum control (Program of BAS to support young scientists,
- "Research and Innovation Capacity Strengthening of ISSP-BAS in Multifunctional Nanostructures" (INERA/FP7) - Financial and Administrative Management; WP 3 – Exchange of knowledge and mobility,
- Coherent effects in atomic gases (under the Academy's bilateral agreements with Jagiellonian University, Krakow, Poland),
- Experimental and theoretical study of physical processes in glow discharge (under the Academy's bilateral agreements with University of Belgrade, Serbia)

INTERNATIONAL COLLABORATION:

The ATOMIC SPECTROSCOPY LABORATORY has international collaborations with:

- ✓ Faculty of Physics, Jagiellonian University, Krakow, Poland,
- ✓ Faculty of Physics, University of Belgrade, Serbia,
- ✓ ITMO University, Saint Petersburg, Russia
- ✓ French National Centre for Scientific Research CNRS, Institut de physique.

TEACHING ACTIVITIES:

In 2016 one PhD student (Vani Tankova) were working in the Laboratory under the supervision of prof. K. Blagoev**.**

DEPARTMENT LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

METAL VAPOUR LASERS

HEAD: **Assoc. Prof. Todor Petrov, Ph.D.**
tel: 979 5748; e-mail: petrovts@gmail.com

TOTAL STAFF: **18**
RESEARCH SCIENTISTS: **14**
HONORARY MEMBERS: **1**
ASSOC. MEMBERS: **2**

Assoc. Prof. Dimo Astadjov, Ph.D.; Assoc. Prof. Margarita Grozeva, Ph.D.; Assoc. Prof. Krassimir Temelkov, Ph.D.; Assoc. Prof. Peter Zahariev, Ph.D.; Assist. Prof. Krassimir Dimitrov; Assist. Prof. Lubomir Stoychev, Ph.D.; Assist. Prof. Ognian Sabotinov, Ph.D.; Assist. Prof. Stefka Slaveeva, Ph.D.; Physicist Stefan Karatodorov, Ph.D. student; Physicist Viktoria Atanasova, Ph.D. student; Physicist Danka Iordanova; Physicist Yu. I. Fedchenko, Ph.D. student; Physicist Blagovela Blagoeva; Physicist Kaloyan Zlatanov

Honorary members: Prof. Nikola Sabotinov, D.Sc., member of BAS, Prof. E. Vateva, D.Sc.

RESEARCH ACTIVITIES:

The femtosecond laser system has been adapted and expanded for conducting experimental work aimed to investigate the matter interaction laser radiation. For this purpose has been developed a microscope system. With this system can be achieved fine adjustment of the laser focus and monitoring at real-time of the processing material by laser radiation. Furthermore, a precise scanning XY translation stage has been adjusted for fully automated control of the processing. This in turn allows with great precision to control the position and the speed of the investigated material. By number of test measurements the femtosecond laser system and the additional peripheral equipment have been calibrated. The optimal modes of operation of each component of the experimental setup have been found. The experiments have been carried out on a bio material polydimethyl siloxane (PDMS), nickel and aluminum. The optimal work conditions have been achieved for each of the samples. Thus by controlling the main parameters such as pulse energy, wavelength and repetition rate of the laser pulse. Main part of the experimental work has been focused on modification of the polymer PDMS, which is widely used in medicine and medical devices. Surface modification by laser irradiation causes a change of the optical properties and morphology of the surface. The aim of the investigation has been to find the optimal conditions for formation of micro channels in the material that subsequently is metallized. This process is a complex function of the wavelength, fluence, number of pulses and the material properties as well. Further analysis of the PDMS samples have been carried out in the laboratories of the National Institute of Laser Plasma and Radiation Physics in Bucharest. The material properties within the laser irradiated area have been investigated by confocal microscopy to monitor the profiles of the irradiated

areas. Three modified samples have been examined at different wavelengths and the same energy density. Metallized sample of PDMS polymer has been analyzed by LIBS method. Traces of Pt have been found in the sample. A SEM and micro-Raman spectroscopy analysis have been done as well. Part of the obtained results and conclusions of the analysis have been presented at an international conference in Brasov, Romania. A preliminary study of the surface modification of a 3D model of polycaprolactone by irradiation of ultrashort laser pulses has been done.

The linear and nonlinear optical properties of newsynthesized glassy matrice TeO_2–Bi_2O_3–GeO_2–Li_2O, have been measured.

Experiments for determination of ablation threshold of ZnO samples are performed with the aim of optimization of the processes of pulsed laser deposition of thin films of this material by irradiation with pulsed nanosecond Nd:YAG laser.The dimensions of the craters, that are formed due to irradiation with varied pulse energy, are measured. It is shown that the diameters and depths of the craters correlate with the pulse energy. The obtained dependence of the crater depth as a function of the pulse energy is used to extrapolate the threshold energy at which the processes of ablation begin. The knowledge of the threshold energy of ablation allows for optimization of the thin films deposition procedures according to the desired outcome: depositing a thin film with precise thickness, decreasing the time duration of deposition procedure, etc.

A fluid model, simulating DC hollow cathode discharge in neon interacting with neutral copper atoms injected by laser ablation, is developed as part of the plasma simulation platform Plasimo. The conditions, which are simulated, are similar to those at which experimental observations of the emission of the hybrid spectral source – laser ablation in hollow cathode discharge, are done. The fluid model results show the changes in the distribution of the discharge species at injection of copper atoms and the processes that take place – ionization of the copper atoms, increase of ion cathode sputtering, etc. These results enable the interpretation of the experimental data in terms of the elemental processes in the plasma.

A numerical model for determination of the important pathways in a complex system of chemical reactions in gas discharge is developed. The algorithm will be implemented in the framework of the platform for plasma simulation Plasimo. The model is tested for various complex systems with different numbers of reaction and particles. The developed module and the results obtained were presented at 19th ICSQE in September 2016 in Sozopol.

The proposed new method for determination of thermal conductivity of multicomponent gas mixture is used for determination of thermal conductivity of Ne-H-H_2-Br-Br_2-Cu and several Ne-He-Br-Br_2-Sr gas mixtures under gas-discharge conditions, which are optimal for laser oscillation at Cu^+ и Sr spectral lines in nanosecond pulsed longitudinal discharge.

On the basis of the obtained thermal conductivities for 6- and 5-component gas mixtures radial gas temperature distribution is obtained in DUV Cu^+ Ne-H_2-CuBr and MIR He-(Ne)-$SrBr_2$ lasers for the corresponding laser tube constructions at uniform and radially nonuniform electrical power input into the discharge.

Radial and time distribution of electron temperature $T_e(r, t)$ is determined in DUV Cu^+ Ne-H_2-CuBr laser with the development of a new method, which combines experimental and theoretical investigations.

The monograph "High-end state-of-art copper bromide vapor lasers: optical, electric and thermal properties" has been submitted for printing by Assoc. Prof. Dimo Astadjov.

The experiments on laser cleaning of different surfaces were continued. A comparison between the cleaning efficiency of two laser sources on the surface of different stone samples – marble, limestone and granite, was done. A Q-switched Nd:YAG laser generating pulses with duration 8 ns, wavelength 1064 nm and 532 nm and repetition frequency 1 Hz and 10 Hz and Copper Bromide vapour laser (CuBrVL) generating light with wavelength 510.6 nm, pulse duration 30 ns and repetition frequency 20 kHz were applied. The results were evaluated via optical microscopy. Some of the stone samples were contaminated with various colors of graffiti sprays – black, white, red, blue and green. Part of the marble samples was contaminated with black soot and a combination of black soot and oil. It was found that the laser cleaning with high-frequency laser (CuBrVL) provides the advantage of uniform and gradual (layer by layer) decontamination. However, depending on the chemical and physical properties of the stone, different laser parameters, such as wavelength, pulse repetition frequency and pulse energy, are suitable for the different stones. A comparison with chemical method of cleaning applying chemical solution was done as well. The results of the research were reported at the 19th ICSQE in September 2016 in Sozopol and 5th Balkan Symposium on Archaeometry. Two papers are submitted for print.

AWARDS:

In 2016, two members of the laboratory were awarded, as follow:

- Physicist Stephen Karatodorov received the award for the best poster presentation of the 13th European Workshop on Laser Ablation;
- Physicist Viktoria Atanasova received the award for excellent report of the first period of her project.

PUBLICATIONS:

1. Anatoly Soldatov, Bogdan Doroshenko, Ivan Kostadinov, Yury Polunin, Nikola Sabotinov, Alexey Shumeiko. Computer Control of the Spectral Composition of the Powerful Laser System Irradiation with a Wide Range of Laser Transitions on Metal Vapors. MATEC Web Conf. Volume 79, 2016 VII Scientific Conference with International Participation "Information-Measuring Equipment and Technologies" (IME&T 2016), 79, EDP Sciences, 2016, 01003
2. Chernogorova, T. P., Temelkov, K. A., Koleva, N. K., Vuchkov, N. K.. 2D numerical modeling of gas temperature in a nanosecond pulsed longitudinal He-SrBr2 discharge excited in a high temperature gas-discharge tube for the high-power strontium laser. Journal of Physics: Conference Series, 715, 2016, ISSN: 1746-6596, SJR: 0.19
3. Daskalova, A, E Iordanova, I Bliznakova, G Yankov, M Grozeva, B Ostrowska. Preliminary study of surface modification of 3D Poly (ε - caprolactone) scaffolds by

ultrashort laser irradiation. Journal of Physics: Conference Series (JPCS), IOP Publishing, 2016, SJR: 0.27

4. Dimowa, L., Piroeva, I., Atanasova-Vladimirova, S., Petrova, N., Ganev, V., Titorenkova, R., Petrov, T., Shivacheva, B.. Synthesis, structural, thermal and optical properties of TeO_2–Bi_2O_3– GeO_2–Li_2O glasses. Optical Materials, 60, Elsevier, 2016, DOI: http://dx.doi.org/10.1016/j.optmat.2016.09.008, 577-583. ISI IF: 2.183
5. Garasz K., Tanski M., Kocik M., Iordanova E., Yankov G., Karatodorov S., Grozeva M.. TheEffect of Process Parameters in Femtosecond Laser Micromachining. Bulg. J. Phys 43 92016), 110-120, 43, 2, 2016, ISSN: Print: 1310-0157 Online: 1314-2666, 110-120.
6. Karatodorov S., Mihailov V., Křenek T., Grozeva M.. Optical emission spectroscopy of plasma produced by laser ablation of iron sulfide. J. Phys.: Conf. Ser., 700, IOP Publishing, 2016, DOI: doi: 10.1088/1742-6596/700/1/012001, 012001. SJR: 0.27
7. Karatodorov, S, Steflekova, V, Mihailov, V, Mihailova, D, van Dijk, J, van der Mullen, J, Grozeva, M. A novel device for spectrochemical anlysis based on a combination of LIBS and a hollow cathode discharge. Journal of Physics: Conference Series (JPCS), IOP Publishing, 2016, SJR: 0.2
8. Soldatov, A., Vasilieva, A., Kostadinov, I., Loeva, Y., Polunin, Y., Sabotinov, N., Schumeiko, A.. Programmable Control of the Pulse Repetition Rate in the Multiwave Strontium Vapor Laser System. MATEC Web of Conferences (Vol. 79, p. 01017), 79, EDP Sciences, 2016, 01017
9. Temelkov, K. A., Iliev, I. P., Gocheva-Ilieva, S. G., Slaveeva, S. I., Vuchkov, N. K.. Determination of spatially-resolved electron temperature in nanosecond pulsed longitudinal discharges. Journal of Physics: Conference Series, 768, 2016, ISSN: 1746-6596, SJR: 0.19
10. Temelkov, K. A., Slaveeva, S. I., Chernogorova, T. P.. Determination of space-time resolved electron temperature in nanosecond pulsed longitudinal discharge in various noble gases and discharge tube constructions. Journal of Physics: Conference Series, 700, 2016, ISSN: 1746-6596, SJR: 0.19
11. Temelkov, K. A., Slaveeva, S. I., Fedchenko, Yu. I.. Theoretical and Experimental Study on Some Plasma Parameters and Thermophysical Properties of Gas Discharges Used for Excitation of Powerful Metal and Metal Halide Vapour Lasers. Bulgarian Journal of Physics, 43, 2016, ISSN: 1310–0157, 224-232. SJR: 0.19
12. Temelkov, K. A., Slaveeva, S. I., Fedchenko, Yu. I.. Theoretical study of thermal conductivities of various gas mixtures through generalized Lennard-Jones interaction potential for application in gas-discharge lasers. Journal of Physics: Conference Series, 700, 2016, ISSN: 1746-6596, SJR: 0.19
13. Temelkov, K. A., Vuchkov, N. K. A simple method for experimental determination of electron temperature and electron density in a nanosecond pulsed longitudinal discharge used for excitation of high-power atomic and ionic metal and metal halide vapour lasers. Journal of Physics: Conference Series, 715, 2016, ISSN: 1746-6596, SJR: 0.19

PATENTS:

Maintained patents:

1.	Laser tube for strontium infrared laser with strontium halide vapours	N.K.Vuchkov, K.A.Temelkov, N.V.Sabotinov
2.	Тръба за кухокатоден лазер с разпрашване на катода	M. Grozeva, D. Mihailova, N.V.Sabotinov
3.	Газов лазер с пари на халогениди на медта	N.V.Sabotinov, K. Dimitrov
4.	Газов меден лазер	N.V.Sabotinov
5.	Laser tube for ultraviolet copper laser	N.K.Vuchkov, K.A.Temelkov, P. Zahariev, N.V.Sabotinov
6.	Ultraviolet copper laser	N.K.Vuchkov, K.A.Temelkov, N.V.Sabotinov
7.	Three-component glassy matrices prossessing variable nonlinear optical properties	T. Petrov, B. Shivachev, Hitoki Yoneda
8.	Ultraviolet ion gold laser	N.V. Sabotinov, T. Petrov

Patents in procedure:

1.	"Method of atmospheric electricity extraction" (No. 112379 13.09.2016)	D. Astadjov, I. Angelov, M. Gospodinov
2.	Method and system for deposition of micro- and nanoparticles on transparent substrate	K. Dimitrov

ONGOING RESEARCH PROJECTS:

- Laser induced formation of three-dimensional structures of nanoparticles and study of their optical properties, (funded by NFS №.H08/25 01.09.2016).
- Thracians - genesis and development of ethnic, cultural identities, civilizational interactions, and heritage of antiquity, (private donation to BAS, 2016).
- Lasers and Laser Assisted Annealing of nanostructures (WG 5) – part of "Research and Innovation Capacity Strengthening of ISSP-BAS in Multifunctional Nanostructures" (INERA/FP7-REGPOT-2012-2013-1).
- Lasers, laser technologies and applications (funded by the budget subsidy of BAS).
- Femtosecond laser applications (under the Academy's bilateral agreements with

IFFM, Gdansk, PAS, Poland).

- Ultrafast laser applications in material processing and characterization (under the Academy's bilateral agreements with National Institute for Lasers Plasma and Radiation Physics, RAS, Romania).
- Laser induced fluorescence analysis for cultural heritage investigation and preservation (funded by NFS MDU 03/79 2012).

INTERNATIONAL COLLABORATION:

The **METAL VAPOUR LASERS,** has international collaborations with:

- ✓ Institute of Fluid-flow Machinery - Polish Academy of Sciences, Gdansk, Poland;
- ✓ Institute for Laser Science – UEC, Chofu-shi, Tokyo, Japan;
- ✓ TU/e, Eindhoven, The Netherlands
- ✓ National Research Tomsk Polytechnic University, Tomsk, Russian Federation
- ✓ National Institute for Lasers Plasma and Radiation Physics, RAS, Romania

TEACHING ACTIVITIES:

Assist. Prof. Ognian Sabotinov is organizing series of introductory courses for medical doctors for work with laser systems.

In 2016 three PhD students were working in the Laboratory under thr supervision of assoc.prof. M.Grozeva and one PhD student was supervised by assoc.prof. K. Temelkov**.**

The young scientists of the Laboratory participated in the traditional XIX Winter Seminar of PhD Students and Young Scientist, as well as in a number of training workshops organised in the frame of INERA project.

Assoc. Prof. Todor Petrov reads lectures on a topic "Ultrafast laser processing" in Technical University – Sofia.

Assoc. Prof. Dr. K. Temelkov gave an invited lecture at 19th Winter Seminar of PhD Students and Young Scientists, December, Koprivshtitsa, Bulgaria, 2016.

MUSEUM

HISTORY OF PHYSICS IN BULGARIA

CURATOR: **Assoc. Prof. Dr. Ganka Kamisheva**
Tel. +359 2 979 58 31, E-mail: gkamish@issp.bas.bg

TOTAL STAFF **1**

RESEARCH SCIENTIST **1**

2016

RESEARCH ACTIVITIES:

Several events marked the jubilee of Georgi Nadjakov during the year 2016. Building of technology in Dupnitsa hosted a technical conference "Inventiveness and innovative entrepreneurship" in the 28 June 2016. Politicians, scientists, writers, inventors, and entrepreneurs joined in it. The conference launched an initiative Georgi Nadjakov's monument to be placed in Dupnitsa. The subject "120 anniversary of Georgi Nadjakov (26.12.1896 – 24.02.1981)" was reported. A new aspect of his scientific interest was published [1]

History of Physics Group at the Union of Physicists in Bulgaria organized scientific session during the 3 National Congress on Physics (29.09.2016-02.10.2016) marking off 120 years jubilee of Georgi Nadjakov. Three plenary lectures, nine scientific reports and ten posters were presented. The proceedings edited by Assoc. Prof. Dr. G. Kamisheva and Assoc. Prof. Dr. M. Zamfirov is ready in electronic form [2]. A new research subject was reported in it [3].

Two publications [4-5], one report [6], and two posters [7-8] are devoted to the 180 years anniversary of Nestor Marcoff (1836 – 1916).

In 2016, the Museum gave 1 patent 10 inquires about Stefan Kanev, Georgi Nadjakov, Emil Nadjakov and Stoycho Panchev. Eight of them came from external visitors and two were placed by administrative order. Some literature sources are used too. Vera Dacheva, Plamen Manolov, and the Union of inventors secretary Ivan Iliev visited the exhibition of Georgi Nadjakov. There are seven new donations. They came from Alexander Karastoyanov, Stefan Balabanov, Krum Kolentsov, the low temperature laboratory, and the laboratory of Stoyko Neov (INRNE).

PUBLICATIONS:

1. Г. Камишева, Научните интереси на акад. Георги Наджаков По случай 120 години от рождението му. – Списание на БАН, кн. 5, с. 56-62 (2016).
2. Proceedings of the 3rd Bulgarian National Congress on Physical Sciences, Sofia, Bulgaria, Sep. 29 - Oct. 02, 2016, [DVD: ISBN 978-954-580-364-2] Heron Press: Sofia.
3. Г. Камишева, А. Камишев, Исторически методи за измерване на разстояния. – of the 3rd Bulgarian National Congress on Physical Sciences, Heron Press: Sofia, p. .
4. Г. Камишева, "Приносът на Нестор Марков за обучението по физика през 19 век", в: Нестор Марков (1836-1916) биобиблиография (М. Младенова, автор), Регионален исторически музей, Плевен (2016) с. 33-42.
5. Г. Камишева, Приносът на Нестор Марков за обучението по физика и математика (1836 – 1916), Светът на физиката, кн. 3, с. 281-293 (2015).
6. Г. Камишева, Ролята на Нестор Марков за създаването на българска физическа терминология, Юбилейна научна сесия "Нестор Марков и неговият принос в лексикографията и образованието", 24.11.2016, Институт за български език, БАН (2016) с. 63-76.
7. G. Kamisheva, Nestor Marcoff contribution to Bulgarian physical and mathematical education, Biomath International Conference on Mathematical Methods and Models in Bioscience, 19-25 June 2016, Blagoevgrad (poster).

8. G. Kamisheva, Bulgarian textbooks on Physics up to 1878, 2nd International Conference on the History of Physics, Echophysics, Pollaw, Austria 5-7 September 2016 (poster).
9. Г. Камишева, Заявка за патент № 112181 “Метод за създаване на подвижно електронно копие на печатен или ръкописен материал” от 17 декември 2015 година.