CONTENTS

Dear Colleagues,

2011 marked an emerging from the crisis situation of the previous years. We all hope it would be a sustainable tendency in the functioning of ISSP. All the efforts of the staff and administration aiming at a finance stabilization of the Institute have to be admired.

The 2011 productivity of ISSP in total is 232 publications, printed and in press. 113 of them have been published in high impact factor or impact rank journals. The total number of citations in 2011 is 878. Two books by foreign publishers were edited by O. Ivanov and by L. Pramatarova. One book on the history of physics was published in Bulgaria, with the co-authorship of M. Kuneva.

In 2011 the Internal Project Competition of the Institute has been resumed. Five scientific projects, three of them lead by young researchers, were supported by modest levels of funding, which nevertheless permits a more extended scientific activity and attracts much attention among the scientists.

Notably, four scientific projects of young team leaders were well funded by the National Science Fund. Successful leaders provide a very good perspective for their teams in the next few years.

The European Optical Society Prize 2011 was awarded to a paper published by Assoc. Prof. S. Tonchev et al. Prof N.Vuchkov was included in the Golden Book of Bulgarian Inventors as an Inventor of the year 2011. S. Terzieva received the Ivan Geshov prize of BAS for young researcher.

Academician N. Sabotinov and Assoc. Professor K. Kolentsov were elected Honorary Members of the Institute. Assoc. Professors M. Mitov, M. Grozeva, L. Pramatarova and D. Dimitrov were awarded the Georgi Nadjakov Sign of Honour 1st degree. Assoc. Professor P.Simeonova was awarded the Georgi Nadjakov Sign of Honour 2nd degree. Awards for the best scientific achievements of the year 2011 in ISSP were presented to the teams lead by Assoc. Professor E. Vlahov and Assist. Professor J. Genova. Medals and diplomas brought pride and satisfaction not only to their winners, but to the Institute as a whole.

The 17th edition of our broadly recognized International School of Condensed Matter Physics will take place in September 2012. The School will be devoted to 40th anniversary of ISSP. This and other jubilee activities will be the main focus of the starting year.

Alexander G. Petrov

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The Georgi Nadjakov Institute of Solid State Physics (ISSP) is specialized in fundamental and applied research in the field of condensed matter physics, microelectronics, optics, spectroscopy, and laser physics.

The main scientific and applied achievements of the Institute are in the field of condensed matter theory, critical phenomena and phase transitions, superconductivity and superconducting materials, low temperature physics, liquid crystal physics, soft and living matter physics, structure and properties of crystals and amorphous materials, nanophysics, atom and plasma physics, integrated optics, optical fibres, acoustoelectric and microelectronic sensors, metal vapour lasers.

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, 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 videomicroscopy and micromanipulation of lipid membranes;
- Lasers of various systems - metal vapour, hollow cathode, picosecond lasers for plasma physics and laser analysis of materials with possible application in ecology;
- High-tech experimental sets for laser cooling of atoms (~ 0.0001K) and application of lasers to archaeology;
- Equipment (Physical Properties Measurement System produced by Quantum Design, USA) for studies of electrical, magnetic and thermal properties of materials, surfaces and structures.

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.*

ORGANIZATION OF THE INSTITUTE OF SOLID STATE PHISICS

DIRECTORATE

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Secretaries:	Mrs. L. Dedinska, Dipl. Eng. Assist. Prof. E. Vlaikova (FP7 of EU)

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Administration's office:	Head: Mrs. I. Velkova, Dipl. Eng.
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DIVISIONS

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Center for Investigation of the Physical Properties of Materials, Surfaces and Structures:	Head: Assoc. Prof. V. Lovchinov, Ph.D.

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13. Assoc. Prof. D. Dimitrov, Ph.D.
14. Assoc. Prof. S. Tonchev, Ph.D.
15. Assoc. Prof. T. Milenov, Ph.D.

DIVISION THEORY

THEORETICAL DEPARTMENT

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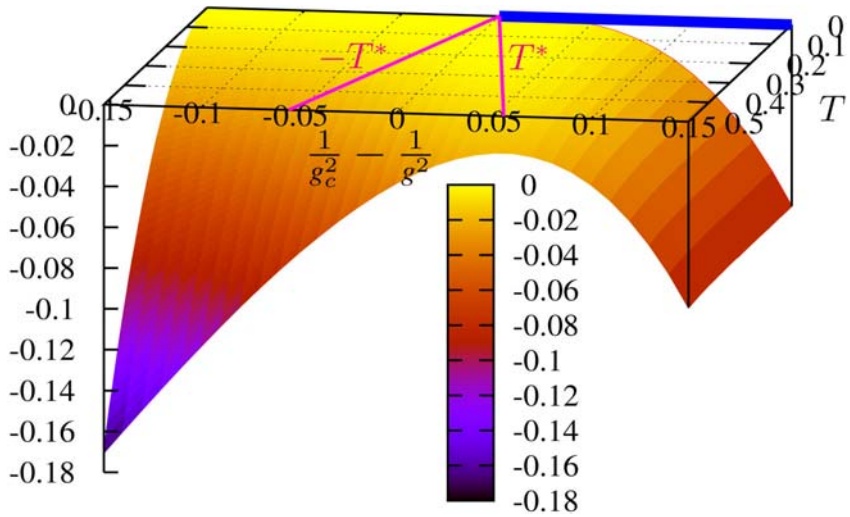
RESEARCH SCIENTISTS: **6**

Prof. N.B. Ivanov, D.Sc.; Prof. P.C. Ivanov, D.Sc.; Assoc. Prof. E.R. Korutcheva, D.Sc.; Assoc.Prof. M.T. Primatarowa, Ph.D.; Assist. Prof. R. S. Kamburova; K.G. Gaminchev, PhD student; I. Ilievska, technical assistant

RESEARCH ACTIVITIES:

The quantum critical behavior of the 2+1 dimensional Gross-Neveu model in the vicinity of its zero temperature critical point is considered. This model is widely used in condensed matter theory and high energy physics. We have used the concept of finite-size scaling to extract information about the leading temperature behavior of the free energy and the mass term, defined by the fermionic condensate and determined the crossover lines in the coupling (g) - temperature (T) plane. These are given by $T \sim |g - g_c|$, where g_c denotes the critical coupling at zero temperature. According to our analysis no spontaneous symmetry breaking survives at finite temperature in contrast to previous studies. The scaling function of the singular part of the free energy is found to exhibit a maximum corresponding to the crossover line $T \sim g - g_c$. Its universal value at the quantum critical point was found to be negative. Interpreted in terms of the thermodynamic Casimir effect, this result implies an attractive Casimir "force".



We present an interatomic potential for nickel within the second moment approximation of tight-binding theory. The potential is an improved version of a previously developed potential for nickel and its stable alloys with aluminum. The present model is fitted to experimental values of the lattice parameter and the cohesive energy of Ni. The potential is

found to reproduce fairly well a variety of the physical properties of the element under study. Most of the properties computed with the aid of the new potential were not used in the fitting procedure, which demonstrates its ability to predict other properties. Advantages and weaknesses of the new potential are discussed in detail.

The molecular wheel Fe_18(pdH)_12(O_2CEt)_6(NO_3)_6 (shortly, Fe_18) is the largest molecular wheel synthesized so far. We have made a comprehensive study of the magnetic properties of this system bases on inelastic neutron scattering (INS) and SQUID magnetometer experiments supplemented by semiclassical, DMRG, and Quantum Monte Carlo calculations. As a result, we show that the adequate magnetic model describing the system is the S=5/2 quantum Heisenberg chain composed of alternating J1=J2=2.88 meV, J3=1.02meV exchange bonds supplemented by very weak single-ion magnetic anisotropy term.

We analyze the quantum phase diagram of the mixed-spin Heisenberg chain containing general isotropic three-spin exchange interaction term. The study is based on the numerical DMRG method as well as on a number of exact analytical results concerning the phase boundaries. The analysis demonstrates, in particular, that the considered quantum spin system possesses a number of quantum dimerized phases characterized by multiferroic properties.

We study the ferromagnetic spin chain with both first- and second-neighbor interactions. We obtained the condition for the appearance and stability of bright and dark solitons for arbitrary wave number inside the Brillouin zone. The influence of the second-neighbor interaction and the anisotropy on the soliton properties is considered. The scattering of dark solitons from point defects in the discrete spin chain is investigated numerically.

We employ a concept popular in physics the Zipf rank approach in order to estimate the number of years that EU members would need in order to achieve "convergence" of their *per capita* incomes. Assuming that trends in the past twenty years continue to hold in the future, we find that after $t \approx 30$ years both developing and developed EU countries indexed by i will have comparable values of their *per capita* gross domestic product $g_{i,t}$. Besides the traditional Zipf rank approach we also propose a weighted Zipf rank method. In contrast to the EU block, on the world level the Zipf rank approach shows that, between 1960 and 2009, cross-country income differences increased over time. For a brief period during the 2007–2008 global economic crisis, at world level the $g_{i,t}$ of richer countries declined more rapidly than the $g_{i,t}$ of poorer countries, in contrast to EU where the $g_{i,t}$ of developing EU countries declined faster than the $g_{i,t}$ of developed EU countries, indicating that the recession interrupted the convergence between EU members. We propose a simple model of GDP evolution that accounts for the scaling we observe in the data.

PUBLICATIONS:

1. H. Chamati and N. S. Tonchev, Quantum critical scaling and the Gross-Neveu model in 2+1 dimensions, EPL (Europhysics Letters) **95** (2011) 40005, 6 pages. **ISSN** 0295-5075
2. H. Chamati, Molecular dynamics study of the thermal properties of nickel, J. Mater. Sci. Tech. **19** (2011) pp. 42-51. **ISSN** 0861-9786
3. J. Shao, P. Ch. Ivanov, B. Urosevic; H.E. Stanley, B. Podobnik, Zipf rank approach and cross-country convergence of incomes, EPL (Europhysics Letters), **94** (2011), 48001. **ISSN** 1286-4854
4. M. T. Primatarowa, R. S. Kamburova, Dark solitons in ferromagnetic chains with first- and second-neighbor interactions, arXiv:1111.5477v1 [nlin.PS] (2011), 7 pages
5. J. Ummelthum, J. Nehrkorn, S. Mukherjee, N.B. Ivanov, S. Stuiber, Th. Straessle, P.L.W. Tregenna-Pigott, H. Mutka, G. Christou, O. Waldmann, and J. Schnack,

Trimerized quantum Heisenberg model for the magnetic molecular wheel system Fe_18(pdH)_12(O_2CEt)_6(NO_3)_6 (sumbitted to Phys. Rev. B).

6. J. Ummelthum, N.B. Ivanov, and J. Schnack, Quantum phase diagram of the mixed-spin Heisenberg chain (S,s)=(1,1/2) with three-spin exchange interaction (in preparation for publication)
7. Fernandez del Rio, E. Korutcheva and F.J. de la Rubia, Interdependent binary choices under social influence: phase diagram for homogeneous unbiased populations, Complexity, in press 2011
8. Baschan, R.P. Bartsch, J.W. Kantelhardt, S. Havlin, P.Ch. Ivanov, Physiological Networks: towards systems physiology, Nature Communications - accepted for publication on 8 Dec 2011, to appear in February 2012
9. I. Ilievska, 100 years from the superconductivity discovery, Journal of the Bulg. Acad. Sci. **5** (2011) pp. 30-32 (in Bulgarian).

ONGOING RESEARCH PROJECTS:

Quantum effects in spin systems with strong competing interactions (National Science Fund, Project DO02-264)

DIVISION THEORY

RESEARCH GROUP

COLLECTIVE PHENOMENA
in Condensed Matter

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TOTAL STAFF: **2**
RESEARCH SCIENTISTS: **2**

Assoc. Prof. D.V. Shopova, Ph.D.

RESEARCH

Some important features of the *P-T* (pressure-temperature) phase diagram of unconventional ferromagnetic superconductors with spin-triplet Cooper pairing of electrons have been investigated by the means of the modern theory of phase transitions. The results have been compared with the experimental data for the intermetallic compound UGe_2. In our previous publications (2005-2009), the basic features of this phase diagram have been explained in a remarkable agreement with the experimental results but some problems related to the meta-magnetic phase transition and to the order of the paramagnetic-to-ferromagnetic phase transition at relatively high pressure have not been elucidated. In order to resolve these problems we extend our theory by an additional term of sixth order in the magnetisation. In this way, under certain circumstances, the theory may describe the first order paramagnetic-ferromagnetic phase transition at relatively high pressures (up to the quantum phase transition at $T = 0$ and $P = P_C$ – critical pressure ; for UGe_2, $P_C = 1.6$ kbar) and the change of the order of the same phase transition (at a tri-critical point P_t) to a second order phase transition at relatively lower pressures (for UGe_2, $P_t \sim 1$ kbar and the second order phase transition extends up to the ambient pressure). This picture, in a total agreement with the experiments for UGe_2, is described by the theory, provided the coefficient of the fourth order term in the expansion of the free energy in powers of the magnetisation linearly depends on the pressure and changes sigh at the tri-critical pressure P_t.

For the same class ferromagnetic superconductors, the diamagnetic susceptibility above the superconducting phase has been investigated. The most interesting cases of three dimensional (3D), quasi-2D (thin films) and 2D (single atomic layer) ferromagnetic superconductors have been described in details. A part of the results are submitted for a publication; other results are still in course of preparation for a publication.

DIVISION MATERIAL PHYSICS

LABORATORY

ELECTRON-PHONON INTERACTIONS

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RESEARCH SCIENTISTS: **4**

Assoc. Prof. O. Ivanov, Ph.D.; L. Mihailov, Ph.D.; I. Boradjiev – physicist; Y. Mutafchieva – physicist; Z. Stoyanov - technical assistant

RESEARCH ACTIVITIES:

A model for studying the properties of electron gas in crystal structures was created. The relation of the electron gas equilibrium density to pressure and external magnetic field has been studied. A system of non-linear equations was composed to describe the dependence of the equilibrium density, pressure, external magnetic field and chemical potential of crystal lattice, consisting of isotopes with certain nuclear charge and mass number. A numerical procedure was developed to allow solving systems of equations with extreme accuracy. The minimum of the Gibbs energy has been investigated.

Coherent excitation of quantum systems with ultrashort laser pulses is essential for a variety of fields such as spectroscopy, quantum information and control of molecular dynamics. Recently, the proposed method of piecewise adiabatic passage (PAP) appears to be a promising technique for executing complete and robust population transfer between quantum states using a series of femtosecond laser pulses with constant (but varying from pulse to pulse) phases. Exploiting the periodicity of the femtosecond pulses combined with the pulse to pulse slowly varying peak amplitudes and phases, we analyze this piecewise problem with the adiabatic Floquet theory. Then, with the use of Kolmogorov-Arnold-Moser type perturbation theory we obtain an effective smooth (nonpiecewise) Hamiltonian, and analyze the conditions for adiabatic transfer. Due to its effectively adiabatic nature the method of PAP is robust to a variation of intensities, durations and shapes of the pulses.

Multiphase proton-exchanged waveguide layers in X, Y and Z-cut $LiNbO_3$ have been studied. The phase composition of proton-exchanged waveguides was studied by mode spectroscopy, IR absorption spectroscopy and mechanical stress measurements. An attempt to indicate stress correlation to the relative quota of the different phases in the proton exchanged layer adds to the physical knowledge on this matter. It is found that: i) a correlation exists between mechanical stress and the phase composition; ii) highly protonated phases and deep waveguides with very low mechanical stress could be obtained in Y-cut $LiNbO_3$ at specific technological conditions; iii) an optimal thickness of the three-layer structure at which the stress of the layer as a whole is minimal exists; iv) the substitution-interstitial proton ratio could be estimated from the sign and the magnitude of the stress; v) stress measurements confirm the paraelectric state of highly protonated phases since such layers had lost their anisotropy.

A book dedicated to quality control entitled “Applications and Experiences of Quality Control”, ed. by Ognyan Ivanov, was issued by the publisher INTECH. Various aspects of quality control have been presented in it. In the creation of the book were involved 98

scientists. The publication will be of assistance to professionals working in different fields but having an interest in quality control. One of the chapters is dedicated to original research conducted in ISSP. It deals with two cases of electromagnetic field-matter interactions: when the field is excited by acoustic waves propagating along the surface of a piezoelectric material and when there is an unspecified field source. Specific developments with practical applications have also been presented.

PUBLICATIONS:

Monographs:

1. O. Ivanov, M. Kuneva,
Quality control methods based on electromagnetic field-matter interactions. In *Application and Experience of Quality Control*, **Ed. O. Ivanov**, INTECH, Vienna, 509-536 (2011)

Papers:

2. M. Kuneva, K. Christova, S. Tonchev
LiNbO3 proton-exchanged waveguide layers: phase composition and stress
EPL 95, 2011, 67005.
3. N. Chamel, R.L. Pavlov, L. M. Mihailov, Ch. J. Velchev, Zh. K. Stoyanov, Y. D. Mutafchieva, M.D. Ivanovich,
Effects of strong magnetic fields on the equation of state of cold non-accreting neutron-star crusts, Nuclear Theory 30, 2011, 240-246, Eds. A. Georgieva, N. Minkov, Heron Press, Sofia
4. I. Boradjiev and S. Guerin.
„Piece wise passage revealed by Floquet thoery",
Young European physicists, 18.06.2011-22.06.2011, Toulouse (France) – oral presentation
5. I. Boradjiev and S. Guerin
"Piece wise passage revealed by Floquet thoery", Control of Quantum Dynamics of Atoms, Molecules and Ensembles by Light,
Nessebar (Bulgaia), 03.07.2011- 09.07.2011 – oral presentation
6. N. Chamel, R. L. Pavlov, L. M. Mihailov, Ch. J. Velchev, Zh. K. Stoyanov, Y. D. Mutafchieva, M. D. Ivanovic.
Effects of strong magnetic fields on the equation of state of cold non-accreting neutron-star crusts, XXX Anniversary International Workshop on Nuclear Theory, 26 June - 2 July 2011, Rila Mountains, Bulgaria.
7. O. Ivanov, Zh. Stoyanov, B. Stoyanov, M. Nadoliisky, A. Vaseashta,
Fast contactless control of the chemical composition of raw materials,
In Innovations in Detection and Sensing of Chem.-Bio-Radiological Nuclear Threats and Ecological Terrorism, Springer, (2012) (in press)

ONGOING RESEARCH PROJECTS:

- Electronic properties of solid state systems (BAS)
- Coherent control of quantum systems (NSF)
- Quantum computers and quantum information (NSF)
- COST Proposal Oct. 2011-2-10974 Revised proposal reference number Oct. 2010-1-7388 /30 Sept. 2011/ "Correlation, relaxation, and relativistic effects in quantum systems interacting with electromagnetic fields"

DIVISION MATERIAL PHYSICS

LABORATORY

CRYSTAL GROWTH AND STRUCTURAL METHODS

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RESEARSCH SCIENTISTS: **8**

Assoc. Prof. T.I. Milenov, Ph.D.; Ph.D.; Assoc. Prof. P.M. Rafailov, Ph.D.;
Assoc. Prof. Z. I. Dimitrova, Ph.D.; Assist. Prof. L.K. Yankova; Assist. Prof. V.T. Tomov;
O.B. Mihailov, Technician

RESEARCH ACTIVITIES:

In the framework of the research activity of the Laboratory following crystals were synthesized: La_2CoMnO_6 (LCMO) in pure state and doped with Pb and (Pb+Pt); La_2NiMnO_6 (LNMO); $LaMnO_3$ (LPMO) in pure state and doped with Pb; $RMnO_3$ (R=Ho, Er, Yb, Tm, Lu); Bi_2NiMnO_6 (BNMO); $Bi_2Fe_4O_9$; $Bi_2Mn_4O_{10}$; $Pb_3Ni_{1.4}Mn_{5.6}O_{15}$ (PNMO); $YMnO_3$; $YCrO_3$; $NiFe_2O_4$; $NiZnFe_2O_4$; $MnWO_4$; $LiFe_5O_8$ (LFO); $(PbZn_{1/3}Nb_{2/3}O_3)_{0.9}$ –$(PbTiO_3)_{0.1}$; $PbSc_{0.5}Ta_{0.5}O_3$ and $Pb_{0.78}Ba_{0.22}Sc_{0.5}Ta_{0.5}O_3$ as well as thin films of LCMO, LNMO, BNMO and structures consisting of thin films permalloy on an antiferromagnetic substrate ($LuMnO_3$). The obtained crystals were structurally characterized with single-crystal X-ray diffractometry, and in some cases (e. g. $Bi_2Fe_4O_9$) with neutron scattering measurements, as well as with measurements of their magnetic properties. The magnetic and electric behavior of the obtained crystals and thin films was investigated. A series of Raman and Infrared spectroscopic investigations were carried out to clarify the interplay of lattice deformations, phonon mixing, spin-phonon coupling and the type of magnetic ordering in the obtained multiferroic and magnetoelctric crystals. Their normal vibrations of various symmetries were theoretically analyzed and the pertinent frequencies were experimentally determined.

Crystals of $Bi_{12}SiO_{20}$ doped with Se were grown and it was established that doping with Se was accompanied with preferential absorption of Fe from the melt by means of the substitution of $3Si^{4+}$ by (Se^{6+}+ 2 Fe^{3+}) ions. The measured absorption spectrum in UV-VIS region, polarized Raman spectra and an IR transmission spectrum indicated local lowering of the symmetry of the Fe-occupied tetrahedral positions. The compound $Bi_{36}MgP_2O_{60-\delta}$ was synthesized and its structure was refined as cubic (sillenite type) - *I*23 with lattice parameter of a_o = 10.15704(12) Å. Its fundamental vibrations were characterized by Raman and IR transmission spectroscopy.

It is established that small quantities of single-walled carbon nanotubes (SWNTs) enhance the flexoelectric response in some liquid crystals (LC). The asymmetric anchoring of the LC molecules induces a dipole moment in the SWNT which leads for the LC E7 to a three-times increase of its flexoelectric coefficients.

With a recently developed method a large class of exact solutions of the running-wave type are obtained for the b-equation and the generalized equation of de-Gasperis processes which facilitates the assessment of the behavior of various systems.

PUBLICATIONS:

1. Mihailova, B., Angel, R.J., Maier, B.J., Welsch, A.M., Zhao, J., Gospodinov, M., Bismayer, U., *The Structural State of Lead-Based Relaxor Ferroelectrics Under Pressure,* IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL Volume: 58 Issue: 9 (2011) Pages: 1905-1913.
2. Waeselmann, N., Mihailova, B., Maier, B. J., Paulmann, C., Gospodinov, M., Marinova, V., Bismayer, U., *Local structural phenomena in pure and Ru-doped 0.9PbZn(1/3)Nb(2/3)O(3)-0.1PbTiO(3) near the morphotropic phase boundary as revealed by Raman spectroscopy,* PHYSICAL REVIEW B Volume: 83 Issue: 21 (2011) Article Number: 214104.
3. Dul'kin, E., Mihailova, B., Gospodinov, M., Roth, M., *Electric field dependence of characteristic temperatures in PbSc(0.5)Ta(0.5)O(3) and Pb(0.78)Ba(0.22)Sc(0.5)Ta(0.5)O(3) relaxors studied via acoustic emission***,** EPL Volume: 94 Issue: 5 (2011) Article Number: 57002.
4. Milenov, T. I., Rafailov, P. M., Tomov, V., Nikolova, Nikolova, R. P., Skumryev, V., Igartua, J. M., Madariaga, G., Lopez, Lopez, G. A., Iturbe-Zabalo, E., Gospodinov, M. M., *Growth and characterization of Pb(3)Ni(1.5)Mn(5.5)O(15) single crystal,* JOURNAL OF PHYSICS-CONDENSED MATTER Volume: 23 Issue: 15 (2011) Article Number: 156001.
5. Maier, B. J., Welsch, A. -M., Mihailova, B., Angel, R. J., Zhao, J., Paulmann, C., Engel, J. M., Marshall, W. G., Gospodinov, M., Petrova, D., Bismayer, U., *Effect of La doping on the ferroic order in Pb-based perovskite-type relaxor ferroelectrics,* PHYSICAL REVIEW B Volume: 83 Issue: 13 (2011) Article Number: 134106.
6. Wu, K. H., Chen, H-J, Chen, Y. T., Hsieh, C. C., Luo, C. W., Uen, T. M., Juang, J. Y., Lin, J-Y, Kobayashi, T., Gospodinov, M., *Marked enhancement of Neel temperature in strained YMnO(3) thin films probed by femtosecond spectroscopy,* EPL, vol.94, iss.2 (2011) 270-276.
7. V. Skumryev, V. Laukhin, I. Fina, X. Martı´, F. Sa´nchez, M. Gospodinov, and J. Fontcuberta, *Magnetization Reversal by Electric-Field Decoupling of Magnetic and Ferroelectric Domain Walls in Multiferroic-Based Heterostructures*, PHYSICAL REVIEW LETTERS Volume: 106 Issue: 5 (2011) Article Number: 057206.
8. Maier, B. J., Angel, R. J., Mihailova, B., Marshall, W. G., Gospodinov, M., Bismayer, U., *High-pressure powder neutron diffraction study on lead scandium niobate,* JOURNAL OF PHYSICS-CONDENSED MATTER Volume: 23 Issue: 3 (2011) Article Number: 035902.
9. Welsch, A.M., Maier, B.J., Mihailova, B., Angel, R.J., Zhao, J., Paulmann, C., Engel, J.M., Gospodinov, M., Marinova, V., Bismayer, U., *Transformation processes in relaxor ferroelectric PbSc(0.5)Ta(0.5)O(3) heavily doped with Nb and Sn***,** ZEITSCHRIFT FUR KRISTALLOGRAPHIE Volume: 226 Issue: 2 (2011) Pages: 126-137.
10. B.J.Maier, N.Waeselmann, B.Mihailova, R.J.Angel, C.Ederer, C.Paulmann, M.Gospodinov, A.Friedrich,and U.Bismayer, *Structural state of relaxor ferroelectric PbSc0.5Ta0.5O3 and PbSc0.5Nb0.5O3 at high pressuresup to30Gpa,* Phys. Rev. (B) 84 (2011) 174104.
11. S. Jandl, S. Mansouri, A.A. Mukhin, V. Yu. Ivanov, A. Balbashov, M. M. Gospodinov, V. Nekvasil and M. Orlita, *Study of crystal-field excitations and Raman active phonons in o-$DyMnO_3$,* Journal of Magnetism and Magnetic Materials **323** (2011) 1104–1108.
12. M. N. Iliev, V. G. Ivanov, N. D. Todorov, V. Marinova, M. V. Abrashev, R. Petrova, Y.-Q. Wang, and A. P. Litvinchuk, *Lattice dynamics of the α and β phases of LiFe5O8***,** PHYSICAL REVIEW B **83** (2011) 174111.

13. L. Kovacs, K. Lengyel, M. Gospodinov, *Antiferromagnetic ordering in $RMnO_3$ rare-earth manganites observed by optical spectroscopy*, Mat. Res. Bull. 46 (2011) 2567 – 2569.
14. T. Milenov, G. Avdeev, P. Rafailov, V. Tomov, S. Dobreva, L. Yankova, M. Veleva, D. Toncheva, *Growth, Characterization and Dielectric Properties of $Bi_2Mn_4O_{10}$ Single Crystals, C*omptes Rendus l'Acad. Bulg. Sci. **64, 7** (2011) 931.
15. T.I. Milenov, P.M. Rafailov, C. Thomsen, A. Egorysheva, R. Titorenkova, B. Kostova, V. Skorikov**,** *Raman and optical spectroscopy characteristics of Se-doped Bi12SiO20 crystals*, Optical Materials 33 (2011) 1573- 1577.
16. G. V. Avdeev, T. I. Milenov, A. V. Egorysheva, K. P. Petrov, V. M. Skorikov, R. Kh. Titorenkova and P. M. Rafailov, *Crystal Structure of $Bi_{36}MgP_2O_{60-\delta}$,* Russ. J. of Inorg. Chem.:Vol. 56, No. 6, (2011) pp. 913–918.
17. N. K. Vitanov, Z. I. Dimitrova, K. N. Vitanov*, On the class of nonlinear PDEs that can be treated by the modified method of simplest equation. Application to generalized Degasperis- Processi equation and b-equation*, *Communications in Nonlinear Science and Numerical Simulation*} 16 (2011) 3033 – 3044.
18. A. G. Petrov, Y. G. Marinov, H. P. Hinov, L. Todorova, M. Dencheva-Zarkova, S. Sridevi, P. M. Rafailov and U. Dettlaff-Weglikowska, *Observation of Flexoelectricity in a Mixture of Carbon Single Walled Nanotubes with a Nematic Liquid Crystal,* Molecular Crystals and Liquid Crystals **545** (2011) pp. 58[1282]–66[1290].
19. Н. Измирова, П. Узунов, И. Томова, М. Баева, *Оксидативен и ендоплазматичен ретикулярен стрес – холестерол и хомоцистеин,* Фармацевтичен монитор год. XII, брой 4 (2011) стр. 18-22.
20. Baeva M., N. Izmirova, A.I. Beskovnyi, *Characterization of zeolites from "Beli Plast" – East Rodopes by X-ray structural analysis*, Scripta Scientifica Medica, vol. 43, 3 (2011) p. 200.
21. N. K. Vitanov, K. Sakai, Z. I. Dimitrova, *On the low-dimensional dynamics and long-range correlations connected to photopletysmographic signals*, Series on Biomechanics **25**, No. 3-4 (2010) 33 – 44.

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian National Scientific Research Foundation at the Bulgarian Ministry of Education and Science:
1) TKX-1712/2007: "Growth, characterization and investigation of the physical properties of new crystals in the systems Bi-Co(Ni)- Mn(Ru)-O and La-Co(Ni)-Mn(Ru)-O with magneto-electric/ multiferroic behaviour" – April 2012.

COLLABORATION:

1. Synthesis and study of multifunctional materials based on the complex oxides of bismuth and allotropic forms of carbon- Institute of Common and Inorganic Chemistry, Russian Academy of Sciences, Moscow, Russia
2. Growth and characterization of oxide crystals for optical applications - Research Institute of Solid State Physics and Optics, Budapest, Hungary

DIVISION MATERIAL PHYSICS

LABORATORY

BIOCOMPATIBLE MATERIALS

HEAD: **Assoc.Prof. Liliana Pramatarova, Ph.D.**
tel.: 979 5699; e-mail: lpramat@issp.bas.bg

TOTAL STAFF: **4**
RESEARCH SCIENTISTS: **3**

Assoc. Prof. E. Pecheva, Ph.D.
Assistant Todor Hikov, MSc
Physicist Dimitrinka Fingarova, PhD student

RESEARCH ACTIVITIES:

The research activities of the Laboratory for Biocompatible Materials (BCM) in 2011 were:

1. Theme: "Biocompatible materials: Modification and functionalisation the surface of materials"
   - 1.1 Hydroxyapatite/nanodiamond (HA/DND) coatings are obtained and studied using the method of soaking in simulated body fluid (SBF);
   - 1.2 Hydroxyapatite/nanodiamond (HA/DND) coatings are obtained and studied using the method of laser-liquid-solid interaction (LLSI) and are obtained materials with organized micro- and nanometer scaled surface;
   - 1.3 The behaviour of different cell cultures on these materials is studied;
   - 1.4 Different DND powders and suspensions are obtained and studied;
   - 1.5 The obtained samples are studied with: SEM/EDX, XRD, AFM, FTIR and Raman spectroscopy, Nanoscaning, Coherent microscopy, Contact angle (wettability).
   - 1.6 A project on this theme was started with the Bulgarian Ministry of Education and Science, TK-X1708/07, which is successfully finished on 05.04.2011.

2. Theme: "Improving the method – white light interferometry for studying thick and rough coating of HA and HA/DND composite layers"
   - 2.2 New Z-scan techniques have been developed for analysis of thick transparent layers and making localised measurements of layer thickness and refractive index. Our software for the control, the measurement and the analysis by Z-scan has been improved greatly through this project.
   - 2.3 Several series of different samples were prepared at the ISSP for studying HA during the project, using DND nano-particles, bioceramics (CaP), polymers and fibronectine.
   - 2.4 A project on this theme was started with French partner from InESS, CNRS, Strasbourg, France, PICS project 4848, which was successfully finished on 10.12.2011

3. Theme: "Biocompatible materials: Obtaining of composite layers on solid substrates"

3.1. A microdesign is prepared for projecting on solid substrates using laser system and scanning head.
3.2. The combination of laser system and the growing layer system allows the obtaining of nanostructural composite layers of HA/DND
3.3. The method includes using of DND, as collagen (the organic part of bone tissue). It is known that DND provides architectural plan for HA mineralization, inorganic part of bone tissue, suck as collagen, which is a new perspective in medicine.
3.4. DND changes the mechanic parameters of composite layers and can strengthen the bone tissue, which is the main requirement for obtaining better artificial bones.
3.5. A project on this theme was started with National Inovation Found, NIF 02-54/28.12.07, which was successfully finished in the beginning of 2011.

4. 3D calcium phosphate (CaP) matrices were prepared from natural resources found in big amounts in nature (powdered egg-shells micex with phosphoric acid). Such 3D matrices characterized by high degree of porosity are used as bone scaffolds and thus they play an important role in tissue engineering. In the current experimental direction, the matrices are additionally functionalized through the immersion in several functional fluids (through bilateral project with the Hungarian Academy of Sciences).
5. Aiming at surface modification of various biomaterial surfaces, deposition of the natural polymer cellulose acetate has been carried out by applying the method of electrospinning. Polymer fiber network suitable for the incorporation of HA or DND particles has been obtained (through bilateral project with the Hungarian Academy of Sciences).

PUBLICATIONS:

L. Pramatarova, E. Radeva, E. Pecheva, T. Hikov, N. Krasteva, R. Dimitrova, D. Mitev, P. Montgomery. R. Sammons, G. Altankov, The advantages of polymer composites with detonation nanodiamond particles for medical applications, in: On Biomimetics, Lilyana Pramatarova (Ed.), InTech Publications, August 2011, Ch. 14, pp. 297-320

K. Hristova, E. Pecheva, L. Pramatarova, G. Altankov Improved interaction of osteoblast-like cells with apatite-nanodiamond coatings depends on fibronectin, Journal of Materials Science: Materials in Medicine 22(8) (2011) 1891-1900, ИФ- 2.325

L. Pramatarova, T. Hikov, R. Dimitrova, N. Krasteva, E. Radeva, E. Pecheva, Ph. Kern, J. Werckmann, Development and analysis of silver containing plasma polymer nanocomposites: scaffolds for tissue engineering, Word Congress on Engineering and Technology (CET), 28 October - 02 November 2011, Shanghai, China 2011, Proceedings of International Conference on Material Sciences and Technology (MST2011), vol. 04, pp. 620-624

FUTURE RESEARCH PLANS OF THE LABORATORY INCLUDE:

1. Control of the process of plasma polymerization of hexamethyldisiloxane on the surfaces of stainless steel, titanium, titanium alloys and glass. Growth of HA and HA-DND composite layers on the modified by plasma polymerization surfaces.

2. Preparation of titanium alloys with biomedical applications and DND incorporation and study of their bioactivity through the deposition of HA.
3. Cell culture experiments with various cell lines for biocompatibility investigation of the prepared samples and layers. Investigation of the protein adsorption and reorganization on the modified surfaces for improving their biocompatibility with living cells.
4. Study of the process of laser-liquid-solid interaction for stimulated HA growth by using different wavelengths, laser power, pulse repetition, time duration, etc.
5. Measurements by classical and novel techniques for complementary characterization of the surfaces.
6. Preparation of CaP scaffolds with additional functionalization for cell culture experiments.
7. Characterization of cellulose acetate polymer fiber network.
8. Preparation of CaP scaffolds with incorporated DND nanoparticles for bone scaffolds with improved properties.

DIVISION NANOPHYSICS

LABORATORY

PHOTOELECTRICAL AND OPTICAL PHENOMENA IN WIDE BAND GAP SEMICONDUCTORS

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

Assoc.Prof. D. Arsova, Ph.D.; Assoc.Prof. Z. Ivanova, Ph.D.; Assoc.Prof. V. Pamukchieva, Ph.D.; Assoc.Prof. Z. Aneva, Ph.D.; Assist.Prof. Z.Levi, Ph.D.; *Assoc.Prof. K. Kolentsov*; *Assoc.Prof. S. Balabanov*; Assist.Prof. I. Bineva, Ph.D.; Assist.Prof. M. Mineva, Ph.D.; E. Zaharincheva, technologist

RESEARCH ACTIVITIES:

1. NANOSTRUCTURED THIN FILMS

Studies were carried out and an application for Bulgarian patent has been submitted concerning Al/c-Si/ SiO_2/Si-SiO_2/SiO_2/Al metal-insulator-silicon (MIS) structures with Si-SiO_2 layer containing crystalline Si nanoparticles. It has been shown that these structures could be applied in dosimetry as an alternative of the presently used radiation sensors based on MIS structures having a SiO_2 dielectric layer. Essential characteristic of these structures is the high sensitivity at low doses of registered radiation which is important for their application in medicine, in dosimetric control for the nuclear industry and in cosmic research.

Crystal structure and microstructure of single layers of $Zn_xCd_{1-x}Se$ ($0.39 \leq x \leq 1$), prepared by thermal vacuum evaporation, have been investigated by means of X-ray diffraction and Raman scattering. It has been shown that both binary and ternary films have cubic structure. Pure CdSe and ZnSe phases have not been observed in the ternary films. Combined photoelectrical and Raman measurements were carried out to get information about spectral photosensitivity of the films. On the basis of the obtained results existence of Cd-enriched nanosized regions was assumed. A linear increase of the optical band gap with increasing Zn content has been observed.

2. DISORDERED MATERIALS - CHALCOGENIDE GLASSES AND THIN FILMS

It has been experimentally confirmed that the new “light annealing effect” recently reported by us is due to the duel action of light. The illumination of preliminary annealed thin Ge-As-S films causes changes of the Tauc parameter, characterizing the structural disorder, that are in correlation with the changes of the optical band gap energy. It has been observed that both values decreased after photodarkening, but after a long-term illumination the values began to increase. Thus the photobleaching (PB) overcomes the photodarkening (PD) without any thermal treating. The photobleaching occurred earlier in thinner films and in nanosized films only PB is observed. Changes of the both parameters of disorder i.e. the

Tauc slope and the Urbach energy, have been observed but no correlation between them has been found. This result is a proof for the different origin of the disordered parameters. The idea of the duel action of light gives new possibilities for explaining the peculiarities of the photoinduced phenomena in amorphous chalcogenide semiconductors.

Low-temperature photoluminescence of heavily Er-doped Ga_2S_3-GeS_2 glasses with a ratio of $[GeS_2/Ga_2S_3]$ = 4, 3, 2 and 1.8 - 2.4 mol % Er_2S_3 has been studied. The typical 4f–4f emission bands of Er^{3+} ions at 830, 1000 and 1550 nm have been observed in the whole investigated temperature range 10-300 K, while new PL bands with higher intensity centred at 670, 870, 1120, 1260 and 1350 nm have been observed for $[GeS_2/Ga_2S_3]$ = 3. Thus a considerable influence of the host on the efficiency of 4f–4f transitions of embedded Er^{3+} ions is documented with the outcome that the $(GeS_2)_{75}(Ga_2S_3)_{25}$ composition appears near optimal for the emission of Er^{3+} ions. With decreasing temperature the PL efficiency is enhanced considerably with pronounced narrowing of all bands. In the case of the strongest PL band at ~1550 nm, the narrowing at low temperature is further accompanied by the resolution of well pronounced fine structure due to "crystal field" splitting of corresponding electronic terms. The influence of Er-doping and thermal annealing at 100 and 200 ^oC on basic optical parameters of thin amorphous films with the optimal composition has been specified.

New alkali-antimonite $(Sb_2O_3)_{70}(Na_2O)_{20}(ZnO)_{10}$ glasses doped with 0.25, 0.5 and 1.0 mol% Er_2O_3 have been investigated by using UV-V-NIR absorption, infrared emission and fluorescence decay techniques. The role of Er-doping level on the evolution of the observed absorption bands at 1533, 977, 800, 652, 546, 521 и 489 nm has been established. The Judd–Ofelt theory has been applied to calculate the basic radiative parameters. With a view to possible applications, details of the Er^{3+} emission at ~1530 nm and spectroscopic characteristics such as the stimulated emission cross-section (σ_e), the parameter of ($\sigma_e \times$ FWHM) and the quantum efficiency ($\eta=\tau_R/\tau_{meas}$) have been summarized. The obtained results indicate that the glasses studied could be used as a laser medium and for optical amplification in the 1.5 μm region.

The optical properties and surface morphology of $Ge_xSb(As)_{40-x}S_{50}Te_{10}$ (x=10, 20 and 27) thin films evaporated from powdered glassy materials were studied by spectroscopic ellipsometry performed in the UV-VIS-NIR range and by AFM imaging. For both kinds of quaternary systems, the optical constants (n and k) decreased with increasing Ge content with their values being smaller for the $Ge_xAs_{40-x}S_{50}Te_{10}$ compositions. AMF images has revealed cracks-free film surface which is fully covered with uniformly distributed grains whose size and distribution depend on the film composition. For all films, the average roughness did not exceed 5 nm, giving evidence for sufficiently high smoothness. The vibrational properties of impurities in the powdered glasses and corresponding films were studied by FTIR spectroscopy. Vibrational modes attributed to O-H hydroxyl groups, molecular H_2O and carbon impurity atoms have been detected in the IR spectra of the powdered glasses but they have not been observed in the IR spectra of the thin films. Vibration modes of oxygen atoms bonded to basic elements, such as Ge-O and Te-O bonds have been detected in the IR spectra of both kinds of samples.

The dependence of second harmonic generation on the thickness of $Ge_{35}Sb_5S6_0$ chalcogenide glass films has been experimentally and theoretically investigated. It has been shown that there are two components in the quadratic optical susceptibility, a component which is dependent on the film thickness and a second one independent of the thickness. The relation of these contributions allows one to estimate the role of the bulk electric dipole mechanism, which increases with decreasing film thickness.

Chalcogenide thin films from the system $GeSe_2$-GeTe-PbTe with 10 different compositions were studied. It has been shown that the film dark conductivity varies within 5-6 orders of magnitude. It has also been found that the dark current activation energy

increases with both decreasing Pb content and increasing Ge content. A good sensitivity to ammonia has been demonstrated by $Ge_{32}Se_{55}Te_{13}$ films which made this composition suitable for ammonia sensors operating in damp air. The $Ge_{31}Se_{66}Te_3$ and $Ge_{32}Se_{64}Te_4$ films have shown good sensitivity and fast response to water/alcohol and water/acetone vapour, respectively and could be used for sensors operating in dry air.

PUBLICATIONS:

1. V. Pamukchieva, A. Szekeres, D. Arsova, "Spectroscopic ellipsometry study of the effect of illumination and thermal annealing on the optical constants of thin Ge-As-S films", Phys. Scr. **83** (2011) 025405. ISSN: 0031-8949 (Print), ISSN: 1402-4896 (Online).
2. S. Alexandrova, I. A.Maslyanitsyn, V. Pamukchieva, V. B. Tsvetkov, V. D. Shigorin ,"Second Harmonic Generation in Thin $Ge_{35}Sb_5S_{60}$ Films", Phys.Wave Phenomena **19** (3) (2011) 1–4. ISSN: 1541-308X.
3. D. Arsova and E. Vateva, "Dual action of light in photodarkened Ge-As-S films", Phys. Status Solidi B 1-5 (2011). ISSN: 1521- 3951.
4. Z.G. Ivanova, J. Zavadil, K.S.R.K. Rao, "Compositional trends in low-temperature photoluminescence of heavily Er-dpoed GeS_2-Ga_2S_3 glasses, J. Non-Cryst. Solids **357** (2011) 2443-2447. ISSN: 0022-3093
5. R.Brüggemann, D. Nesheva, S. Meier, I. Bineva, "Temperature dependence of the photoluminescence from ensembles of amorphous silicon nanoparticles with various average sizes", J. Nanosci. Nanotechnol. **11**, (2011) 959-965. ISSN: 1533-4880 (Print); EISSN: 1533-4899 (Online)
6. B. Pejova, D. Nesheva, Z. Aneva, A. Petrova, "Photoconductivity and Relaxation Dynamics in Sonochemically Synthesized Assemblies of $AgBiS_2$ Quantum Dots", Journal of Physical Chemistry B **115**, Issue 1, (2011) 37-46. ISSN (printed): 1089-5647. ISSN (electronic): 1520-5207
7. D Nesheva, Z Aneva, M J Scepanovic, Z Levi, I. Iordanova and Z V Popovic, "Crystal structure and spectral photosensitivity of thermally evaporated $Zn_xCd_{1-x}Se$ thin films", J. Phys. D: Appl. Phys. **44,** (2011) 415305 (7pp). ISSN: 0022-2727 (Print), 1361-64-63 (Online)
8. B. Stefanova, D. Nesheva, K.Petkov, M. Radonova, G. Vassilev, V. Vassilev, "Electrical properties of $GeSe_2$-Sb_2Se_3-PbTe thin films", J. Optoel. Adv. Mater. **13** (2011)1 393-1396. ISSN: 1454-. 4164.
9. D. Nesheva, E. Balabanova, Preparation of homogeneously dispersed CdSe nanoparticles in SiO_x thin films and their size distribution", Nanoscience & Nanotechnology, vol.11, 51-53 (2011). ISSN 1313-8995.
10. L. Yourukova, K. Kolentsov, E. Radeva, P. Zabov, Electroluminescent indicator lelements with improved parameters, Russian Izvestiq visshih uchebnih zavedenii – Fizika **54**, 301-310 (2011). ISSN 0021-3411 (in Russian)

ONGOING RESEARCH PROJECTS:

Financed by the Bulgarian Academy of Sciences:

1. Semiconductor nanoparticles in amorphous thin film matrix: formation, structure and properties.

Financed by the Bulgarian Ministry of Education, Youth and Sciences:

1. Three-dimensional assembles of semiconductor quantum dots: structure, optical, electrical and photoelectrical properties, Contract BM-1.
2. New amorphous and glassy materials based on Ge suitable for sensor applications, Contract D002-123.

COLLABORATION:

1. Preparation and investigation of optical properties of semiconducting glasses for photonic applications, Institute of Photonics and Electronics, Prague, Czech Republic.
2. Optical and photoelectrical characterization of thin films and nanostructured layers based on ZnSe, Institute of Physics, Belgrade, Serbia.
3. Investigation of disordered materials based on Se-Te chalcogenide glasses by means of neutron diffraction and IR spectrophotometry, Research institute for Solid State Physics and optics, Hungary.
4. Investigation of optical and electrical properties of nanostructures chalcogenide semiconductors suitable for memory applications, Physico Thechnical Institute, Sankt Peterburg, Russia.

DIVISION NANOPHYSICS

LABORATORY

SEMICONDUCTOR HETEROSTRUCTURES

HEAD: **Assoc. Prof. Anna Szekeres, Ph.D.**
tel: 979 5788; e-mail: szekeres@issp.bas.bg

TOTAL STAFF: **7**
RESEARCH SCIENTISTS: **3**
ASSOC. MEMBERS: **4**
Assoc.Prof. A. Szekeres, Ph.D.; Assoc.Prof. N. Peev, Ph.D.; Assist. Prof. E. Vlaikova;
Assoc. Prof. S. Simeonov, Ph.D.; Assoc. Prof. P. Danesh, Ph.D.; Prof. S. Kaschieva, D.Sc.; Prof. S. Alexandrova, D.Sc.

RESEARCH ACTIVITIES:

In 2011 the research activities of the Laboratory were focused on the study of structure, optical and electrical properties of Si-based semiconductor heterostructures with nano-sized dielectric layers (such as SiO_xN_y and SiO_x) and with nanostructured semiconductor films (such as AlN, AlN:Cr and AlN:Si) prepared by applying contemporary technological methods (such as plasma immersion implantation of low-energy N^+ and H^+ ions and pulsed laser ablation), revealing potential possibility for preparation of multifunctional Si-based structures and their usage for nano- and optoelectronics purposes.

1. STUDY OF PULSED LASER DEPOSITED NANOSTRUCTURED AlN FILMS

The study of the structure and properties of thin AlN films synthesized by pulsed laser deposition (PLD) at different technological conditions continued in 2011. The analysis of the results from the XRD, HRTEM and AFM measurements has shown that AlN films deposited in nitrogen ambient and at high laser incident fluence (> 5 J/cm^2) are predominantly amorphous with smooth film surface morphology. SEM micrographs have visualized the columnar film structure. By increasing the nitrogen pressure from 0.1 to 10 Pa, in the amorphous films small crystallites are formed, the phase and size of which are dependent on the dynamic N_2 pressure.

It has been established that doping of AlN films with Cr atoms (AlN:Cr) does not change the AlN:Cr films structure, while doping of AlN films with Si atoms (AlN:Si) facilitate the growth of nanosized crystallites in metastable cubic phase. The analysis of the I-V characteristics of MIS structures with the AlN:Cr and AlN:Si films has revealed that the electrical current though these films is carried out by electrons via deep levels in the AlN energy bandgap and it is limited by the space charge of electrons trapped in deep levels.

2. PREPARATION AND STUDY OF NANOSIZED SiO_xN_y LAYERS IN SILICON

Formation of nanosized SiO_xN_y layer through high-temperature annealing (1050^{o}C) in oxidizing ambient of Si substrates modified by low-energy (4 keV) plasma immersion implantation of nitrogen with fluences of 10^{16} - 10^{18} cm^{-2} is studied. The implanted profiles of the atomic (N^+) and molecular nitrogen (N_2^+) are modeled for different annealing durations taking into account the diffusion process. From the analysis of the FTIR and

ellipsometric spectra presence of Si-O and Si-N bonds is established in the synthesized layers with low refractive index (varying from 1.47 to 1.59 at λ=633 nm). These results have shown that the applied technological processes offer a potential possibility to synthesize nanosized (~10-40 nm) SiO_xN_y layers with low concentration of nitrogen.

3. THEORETICAL STUDY OF PROCESSES AT PHASE BOUNDARIES

The processes at phase boundaries are theoretically studied for liquid-phase epitaxy, considering smooth inter-phase boundaries. In the frame of the given assumptions the distribution of the components near phase boundaries is determined. The width of phase bondary is estimated at concrete values of the growth rate (39 and 15 Å/sec), experimentally established for liquid-phase epitaxy of GaAs. On the basis of the experimental results, the linear dependence of the growth rate on the temperature drop rate is checked and confirmed.

4. FORMATION OF Si NANOCRYSTALLITES BY HIGH-ENERGY ELECTRON IRRADIATION OF ION-IMPLANTED Si-SiO_2 STRUCTURES

The influence of high-energy electron (20 MeV) irradiation on the surface morphology of Si-SiO_2 structures implanted with Si^+ (15 keV) or O^+ (10 keV) and on the formation of nano-sized Si particles in the oxides is studied by atomic-force microscopy (AFM). Bombarding the SiO_2 surface with 20 MeV electrons generates radiation defects, which facilitates the out-diffusion of oxygen from the SiO_2 network and, as a consequence, the formation of nc-Si particles. This effect is more pronounced in Si-SiO_2 structures implanted with O^+ ions.

MONOGRAPH:

S. Kaschieva, S.N. Dmitriev, "Radiation Defects in Ion Implanted and/or High-energy Irradiated MOS Structures", 2011, Nova Science Publishers Inc., New York

PUBLICATIONS:

1. Szekeres, A., Fogarassy, Zs., Petrik, P., Vlaikova, E., Cziraki, A., Socol, G., Ristoscu, C., Mihailescu, I.N., "Structural characterization of AlN films synthesized by pulsed laser deposition", *Applied Surface Science* 257 (2011) 5370-5374.
2. V Pamukchieva, A Szekeres and D Arsova, "Spectroscopic ellipsometry study of the effect of illumination and thermal annealing on the optical constants of thin Ge–As–S films", *Phys. Scr.* 83 (2011) 025405.
3. M Fábián, E Sváb, V Pamukchieva, A Szekeres, P Petrik, S Vogel, U Ruett, „ Study of As-Se-Te glasses by neutron-, X-ray diffraction and optical spectroscopic methods", *J. Non-Cryst. Solids,* in press
4. N Dulgheru (Nedelcu), M Anastasescu, M Nicolescu, M.Stoica, M Gartner, V Pamukchieva, A Szekeres, K Todorova, "Surface topography and optical properties of Ge-Sb(As)-S-Te thin films by atomic-force microscopy and variable angle spectroscopic ellipsometry", *J. Phys. Conf. Series***,** in press
5. V Pamukchieva, K Todorova, O C Mocioiu, M Zaharescu, A Szekeres, M Gartner, " IR studies of impurities in chalcogenide glasses and thin films from the Ge-Sb-S-Te system", *J. Phys. Conf. Series***,** in press
6. S. Alexandrova, E. Halova, A. Szekeres, E. Vlaikova, M. Gartner, M. Anastasescu, "Annealing of Si surface modified by plasma immersion implantation of nitrogen", *J. Phys. Conf. Series***,** in press

7. I P Minkov, S Simeonov, A Szekeres, A Cziraki, G Socol, C Ristoscu, I N Mihailescu, "Study of the charge transport mechanism in pulsed laser deposited AlN:Si films", *J. Phys. Conf. Series***,** in press
8. A. Szekeres, A. Cziraki, G. Huhn, K. Havancsak, E. Vlaikova, G. Socol, C. Ristoscu, I. N. Mihailescu, "Laser technology for synthesis of AlN films: Influence of incident laser fluence on the films microstructure", *J. Phys. Conf. Series***,** in press
9. S. Kaschieva, A. Gushterov, Ch. Angelov, S.N. Dmitriev, „Formation of Si nanocrystals in ion implanted Si-SiO_2 structures by MeV electron irradiation", *J. Phys. Conf. Series,* in press

ONGOING RESEARCH PROJECTS:

"Structure and properties of semiconductor heterostructures with nano-sized and nanostructured dielectric and semiconductor films" *Financed by the Bulgarian Academy of Sciences*

INTERNATIONAL COLLABORATION:

1. "Structure and properties of new materials and thin films for nano-technologies in optoelectronics", ***with the Eotvos L. University, Budapest, Hungary***
2. "Multifunctional structures based on silicon prepared by physical and chemical methods for application in electronics and optoelectronics", ***with the Institute of Physical Chemistry, RA, Bucharest, Romania***
3. "Silicon oxide films with embedded silicon nanoinclusions for advanced opto- and nanoelectronics applicatios", ***with the Institute of Semiconductor Physics, NASU, Kyiv, Ukraine***
4. "Characterization of diluted magnetic semiconductor nanostructured thin films" ***with the National Institute for Lasers, Plasma and Radiation Physics, Bucharest, Romania***
5. "Enhancement of radiation hardness of semiconductor heterostructures by cyclic annealing" ***with the Joint Institute for Nuclear Research, Dubna, Russia***

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

PHYSICAL PROBLEMS OF MICROELECTRONICS

HEAD: **Assoc.Prof. Albena Paskaleva, Ph.D.**
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TOTAL STAFF: **12**
RESEARCH SCIENTISTS: **9**

Prof. E. Atanassova, D.Sc.; Assoc.Prof. A. Paskaleva, Ph.D.; Assoc.Prof. S. Georgiev, Ph.D., Assoc.Prof. J. Koprinarova, Ph.D.; Assoc.Prof. N. Nedev, Ph.D.; Assoc. Prof. D. Spasov, Ph.D.; Res.Assist. M. Georgieva; Res.Assist. Ts.Ivanov; Res.Assist. E. Manolov; E. Gajdarzhieva, physicist; S. Tsvetanov, technologist; D. Popchev, technologist

RESEARCH ACTIVITIES:

The scope of the research activities of the Laboratory is addressed the nanoelectronics as follows:

- investigation of thin and ultra-thin dielectric, semiconductor and metal layers important for the production of large-scale integrated microelectronic structures (nanoscale) and for development of solid state sensors based on the silicon and the thin-film microelectronics (incl. high-*k* dielectrics for dynamic memories; gas-sensitive layers for sensor devices; mono- and polycrystal 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).

A strong dependence of the dominant conduction mechanism in high-*k* Ta_2O_5 layers (5-10 nm) on the presence and on the concentration of Hf and Al as dopants is established. Hf and Al passivate the deep traps in Ta_2O_5 due to oxygen vacancies and create new shallow traps. Tunneling processes through these shallow traps constitute both the mechanism of conductivity and the long-term reliability after electrical stress. Based on those results, *storage capacitors for dynamic memories in nanoelectronics*, with stable electrical parameters at high temperature working conditions (up to 100° C) are developed. Active dielectric is 6 nm Hf- or Al-doped Ta_2O_5. By this way is shown, that the introduction of small amount of Al and Hf into the matrix of Ta_2O_5 *can extent the potential of pure* Ta_2O_5 *as a high-k material*. The results are essential for fabrication of memory capacitors with pre-defined properties and electrical behavior, at various working temperatures (20-100° C).

Charge-trapping processes in MIS capacitors based on pure and Hf-doped Ta_2O_5 (~ 10 nm) as a function of type of the gate (Pt, Al, W, TiN, Ru, RuO_2) and of the chemical composition of the interface region at Si are investigated. The traps responsible for the charge trapping, and their effect on the long-term reliability of the stacks are identified.

Measurements giving information on the nanomechanical properties (elastic modulus and nanohardness) of pure and Hf- and Al-doped Ta_2O_5 films are realized. Both techniques Atomic Force Microscopy and Nano Indentation are used. The results for *the*

nanomechanical parameters of high-k Ta_2O_5-based films are priorited ones and they concern the implementation of ultrathin high-*k* dielectrics *in Micro Electro Mechanical Systems (MEMS) for the needs of nanoelectronics.*

The influence of oxidation time on the electrical properties of MIM structures with ZrO_2-based, (ZrAlO, ZrSiO) high-k dielectrics deposited by atomic layer deposition (ALD) is investigated. It is found that incorporation in ZrO_2 of Al and Si in small amounts *substantially decreases the leakage currents without compromising permittivity* and Al is more effective to do this. The oxidation time has to be carefully optimized in order to obtain favorable electrical behavior – the optimal oxidation time is found to be 5-10 s. Layers obtained by shorter oxidation times have high concentration of oxygen vacancies, hence higher leakage currents. Longer oxidation times result in less dense films. By using the optimized oxidation process, *ZrAlO and ZrSiO layers with equivalent oxide thickness less than 1 nm* and leakage currents satisfying the requirements for the *next generation MIM-based DRAMs, have been obtained*.

One-dimensional analytical model suitable for large scale cells under illumination has been developed. The model is based on two main assumptions. The first one is that in the case of wide gap semiconductors the concentration of the free dark carriers related to the non-equilibrium (generated) carriers can be neglected. This assumption simplifies the transport equations. In the second one, we accept electro-neutrality of the each d*x* region of the i-layer. This assumption is supported by the fact that the concentration of the non-equilibrium carriers is much smaller then the state density independently of their energy position in the forbidden gap. The model is successfully applied for a-Si:H, a-Si:Ge:H based cells. This model allows us to simulate the I-V characteristics using finite number of fundamental parameters (electron and hole diffusion lengths, light absorption coefficient and its intensity). By fitting of the simulated characteristics to the experimental ones the above parameters are determined.

SiO_x (x = 1.3) films with thicknesses of 50 and 100 nm deposited on c-Si by thermal evaporation of SiO in vacuum were subjected to N_2 or two-step N_2, $90\%N_2+10\%O_2$ annealing at 1000 ^oC for 60 min. The time of the second annealing step (oxidation) was varied in order to alter the depth to which the SiO_x films were intentionally oxidized. The I-V and XTEM results obtained confirm that the suggested *two-step annealing leads to a formation of two-layer SiO_2-Si nanocrystals/SiO_2 gate dielectric*, which contains Si nanocrystals. The nanocrystals are with a diameter of ~ 4-5 nm and are embedded in a stoichiometric SiO_2 matrix. The I-V measurement showed that the current through the two-layer gate dielectric is limited by the SiO_2 region, close to the top surface, formed during the second annealing step. MOS structures subjected to a two-step annealing show larger retention times when charged with electrons/holes in comparison with the control or annealed only in N_2 structures. This makes them suitable *for application in non-volatile memory devices* with high density, high switching speed and low energy consumption.

MOS structures containing *silicon nanocrystals* in the gate dielectric have been tested *as dosimeters for ionizing radiation*. Before irradiation the nanocrystals have been charged with electrons by applying a pulse to the gate electrode. γ-irradiation with doses in the range 0-100 Gy causes approximately linear variation of the flatband voltage, resulting in sensitivities of ~ 2.5 mV/Gy. At higher doses the sensitivity decreases because of decrease of the oxide electric field.

PUBLICATIONS:

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2. N. Novkovski, E. Atanassova, "Charge trapping during constant current stress in Hf-doped Ta_2O_5 films sputtered on nitrided Si", Thin Solid Films **519**, 2262-2267 (2011).
3. L. Stojanovska-Georgievska, N. Novkovski, E. Atanassova, "Charge trapping at Pt/high-k dielectric (Ta_2O_5) interface stacks", Phys. B **406**, 3348-3353 (2011).
4. A. Skeparovski, N. Novkovski, E. Atanassova, V. K. Lazarov, " Effect of Al gate on the dielectrical behaviour of Al-doped Ta_2O_5 stacks", J. Phys. D: Appl. Phys., **44,** 235103-235113 (2011).
5. I. Manič, E. Atanassova, N. Stojadinovič, D. Spassov, A. Paskaleva, "Hf-doped Ta_2O_5 stacks under constant voltage stress", Microel. Eng. **88**, 305-313 (2011).
6. A. Paskaleva, M. Tapajna, E. Dobrovčka, K. Hušekova, E. Atanassova, K. Fröhlich, "Structural and dielectric properites of Ru-based gate/Hf-doped Ta_2O_5 stacks", Appl. Surf. Sci. **257**, 7876-7880 (2011).
7. A. Paskaleva, M. Lemberger, E. Atanassova, A. J. Bauer, "Traps and trapping phenomena and their implications on electrical behavior of high-k capacitor stacks", J. Vac. Sci. Technol. B **29**(1), 076101-076111 (2011).
8. D. Spassov, E. Atanassova, A. Paskaleva "Lightly Al-doped Ta_2O_5: Electrical properties and mechanisms of conductivity", Microelectron. Reliab. **51**, 2102-2109 (2011).
9. A. Paskaleva, M. Lemberger, A.J. Bauer, L. Frey, **"**Implication of oxygen vacancies on current conduction mechanisms in $TiN/Zr_{1-x}Al_xO_2/TiN$ MIM structures", J. Appl. Phys.109, 076101 (2011).
10. N. Nedev, E. Manolov, D. Nesheva, K. Krezhov, R. Nedev, M. Curiel, B. Valdez, A. Mladenov, Z. Levi, Radiation dosimeter based on Metal-Oxide-Semiconductor structures containing silicon nanocrystals, Key Engineering Materials, 495,120-123 (2011).
11. E. Atanassova, A. Paskaleva, D. Spassov, "Doped Ta_2O_5 and mixed HfO_2-Ta_2O_5 films for dynamic memories apllications at the nanoscale", Microelectron. Reliab. (**invited paper**) (in press).
12. E. Atanassova, D. Spassov, N. Novkovski, A. Paskaleva, "Constant current-stress of lightly Al-doped Ta_2O_5", Mater. Sci. in Semicond. Processing (in press).
13. I. Karmakov, A. Paskaleva, E. Atanassova, „Inhomogeneous interface layers in Ta_2O_5/Si stacks by spectroscopic ellipsometry" Appl. Surf. Sci (in press).
14. E. Atanassova, D. Spassov, N. Novkovski, A. Paskaleva, "Constant current-stress of lightly Al-doped Ta_2O_5" Proc. of 28th Intern. Conf. on Microel. (MIEL), Nish, Serbia, 13-16 May, 2012 (in press).
15. L. S. Georgievska, N. Novkovski, E. Atanassova, "Charge trapping at low injection currents in (TiN, Mo, Pt)/Ta_2O_5:Hf/SiO_2/Si structures", Proc. of 28th Intern. Conf. on Microel. (MIEL), Nish, Serbia, 13-16 May, 2012 (in press).
16. A. Skeparovsky, N. Novkovski, A. Paskaleva, "Charge trapping in Ti-doped Ta_2O_5 on nitrided Si", Proc. of 28th Intern. Conf. on Microel. (MIEL), Nish, Serbia, 13-16 May, 2012 (in press).

ONGOING RESEARCH PROJECTS:

Physics and technology of thin and ultra thin films for application in micro- and nanoelectronics, (supported by Bulgarian Academy of Sciences).

Trapping phenomena and their implication on long-term reliability of nano-scale metal gate/high-k dielectric-based devices (supported by National Science Fund).

COLLABORATION:

1. Fraunhofer Inst. of Integrated Systems and Device Technology, Erlangen, Germany
2. Inst. of Electronic Engineering, Slovak Academy of Sci., Bratislava, Slovakia.
3. Institute of Semiconductor Physics, Kiev, Ukraine
4. Insitute of Physics ,Universty of Skopie, Macedonia
5. University of Nish, Serbia

DIVISION MICRO- AND ACOUSTOELECTRONICS

LABORATORY

ACOUSTOELECTRONICS

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RESEARCH ACTIVITIES:

In 2011 the scientific and applied research of Acoustoelectronics laboratory was focused on creation of new materials, technologies and elements in accordance with the Academy's basic strategic goal - delivery of the society based on knowledge and active partner in the European scientific area.

The scientific investigations in the laboratory are being carried out mainly in the following directions:

- Piezoelectric temperature microsensors – acoustic characteristics and metrological parameters.
- Mass sensitive quartz gas sensors on the base of BAW - preparation, investigation and application.
- Plasma polymers and composites – synthesis, structure, properties and application.
- Resonant structures using surface transverse waves (STW), Rayleigh surface acoustic waves (RSAW) and bulk acoustic waves (BAW) and their applications.

- PIEZOELECTRIC TEMPERATURE MICROSENSORS

The influence of the temperature on the motional resistance of quartz temperature sensors developed and realized in "Acoustoelectronics" laboratory is investigated. The results show that the resonators keep its working capacity with temperature up to +250^{o} C. This fact gave the reason for measuring of the acoustic characteristics and metrological parameters of quartz temperature sensors at temperatures between 150 to 250° C in order to widen their working temperature interval of 100 ^{o}C /4.2 to 520 K/.

A multi-channel generator (4 - 40 MHz) with acoustic resistance up to 120 Ohm was developed for the purpose of piezoelectric microsensors for cryogenic temperatures. The generator successfully passed the experimental test at the Acoustoelectronics laboratory. The result can be improved by development and implementation of software for management of functional modules.

- MASS – SENSITIVE QUARTZ RESONATORS

The sensitivity of silicon thin films obtained by E-beam evaporation to NO_2 was studied. The NO_2 sensitivity of the films was estimated by Quartz Crystal Microbalance (QCM)

method. The obtained results showed that the layers are amorphous and thin SiOx films exist on their surface. The layers possess high sensitivity in the interval 1000 ppm-2500 ppm NO_2. The process of sorption is physical and response times are short. The investigated Si-QCM structure could be used as sensor element for NO_2 detection.

Thin films from different oxides (Al_2O_3, ZrO_2 magnetron sputtered and Ta_2O_5 e-beam evaporated with different roughness parameters – 20, 200 and 400 nm were used in the research of stem cells (MSCs) adhesive potential, morphology, phenotypical characteristics in vitro tests and separation of different factors influenced on cell/biomaterial interaction such as nano topography, surface chemistry and surface free energy. The best results were obtained in the case of magnetron sputtered oxide coatings with minimum parameters of roughness, intermediate values of surface free energy and the greater part of SFE polar components and fractional polarity. The changes at molecular-genetic apparatus MSCs (IDO gene ex-pression degree) and MSCs marker number increasing on the oxide nanostructural surface were observed. The results show the effect of surface parameters modification on the regularities of nanomaterials interaction with mesenchymal stem cells and open the perspective for a direct control of such parameters as adhesion, proliferation, differentiation of MSCs during their culturing.

- SYNTHESES AND STUDY OF PLASMA POLYMERS AND COMPOSITES

Composite films from a mixture of hexamethyldisiloxane (HMDSO) and detonation nanodiamond particles (DNDs) are synthesized. The chemical structure of the composite consists of DNDs, distributed in the polymer matrix. The effect of DNDs on the humidity and ammonia sorptive properties of the polymers obtained is studied by measuring the mass changes as a result of gas sorption. For this purpose a QCM is used. The results show that with respect to obtain sensing element for measuring humidity, ammonia or other gases it is possible to maximize the sensor sensitivity to certain gas by using an appropriate concentration of DNDs in HMDSO. Thus a high degree of sensor sensitivity together with short response time and minimum hysteresis could be achieved. In this way composite of plasma polymerized HMDSO with DNDs could to be used as a gas sensitive layer for the development of quartz resonator sensors.

After optimization deposition parameters for obtaining plasma polymers from HMDSO on film plate acoustic resonators (FPAR) using Lamb waves, analysis of the results with respect to sensor's application was done.

- RESONANT STRUCTURES USING RAYLEIGH SURFACE ACOUSTIC WAVES (RSAW), SURFACE TRANSVERCE WAVES (STW) AND BULK ACOUSTIC WAVES (BAW) AND THEIR APPLICATIONS IN LOW-NOISE MICROWAVE OSCILATORS, COMMUNICATIONS AND SENSOR SYSTEMS

The mass loading sensitivity of the S0 mode of a Lamb wave propagating in a thin aluminum nitride (AlN) membrane on silicon (Si) has been studied theoretically and experimentally. The theoretical predictions have been confirmed experimentally with practical two-port 890 MHz film plate acoustic resonators (FPAR) operating on that mode. The resonators have been fabricated on the surface of a Si wafer coated with a thin AlN film using conventional photo lithography. The AlN membrane type waveguide has been obtained by etching the Si underneath the AlN layer in a dry plasma etching process. The mass sensitivity of the FPAR devices has been tested by a controlled deposition of hexamethyldissiloxane (HMDS) on top of the FPAR structure and subsequent measurement of the resonance frequency shift and device insertion loss as a function of the HMDS thickness. The results have been compared with surface transverse wave (STW) two-port resonators, coated with HMDSO films the thickness of which has been optimized for

maximum gas sensitivity as used in a variety of gas sensing applications. It has been shown that the Lamb wave mode features up to 5 times higher mass loading sensitivity of the resonant frequency compared to its well studied STW counterpart. In addition to that, the Lamb wave mode demonstrates an insignificant loss increase with mass loading which is very important from the application oriented point of view. These results imply the great potential of the S0 Lamb wave mode for gas sensing applications.

The investigations on low-noise microwave oscillators stabilized with Lamb wave FPAR devices have continued in 2011. Phase noise data from practical FPAR based feedback loop oscillators in the 900 MHz range have been evaluated and used to calculate the flicker noise constant of the FPAR device. Its value of $2{,}1\times10^{-36}$/Hz is lower or comparable with the best acoustic wave resonators built to date.

PUBLICATIONS:

1. Boyadzhiev, S., Georgieva, V., Rassovska, M., Yordanova, I., Yordanov, R., "Comparison between RF and DC Magnetron Reactive Sputtered Molybdenum Oxide Thin Films for Gas Sensors", Optoelectronics and Advanced Materials, Rapid Communications, vol.4, Issue10, Nov. 2010, pp.1485-1488.
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3. Ivan D. Avramov, Stephen R. Gilbert and Rich Ruby,1.5-GHz Voltage Controlled Oscillator With 3% Tuning Bandwidth Using a Two-Pole DSBAR Filter, IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 58, no. 5, May 2011, pp. 916-923
4. Lilia Arapan, Gergana Alexieva, Ivan D. Avramov, Ekaterina Radeva, Vesseline Strashilov, Ilia Katardjiev and Ventsislav Yantchev, Highly Mass-Sensitive Thin Film Plate Acoustic Resonators (FPAR) Sensors 2011, 11, 6942-6953; doi:10.3390/s110706942, ISSN 1424-8220, www.mdpi.com/1424-8220/11/7/6942/pdf,
5. L. Arapan, I.D. Avramov and V. Yantchev "Thin film plate acoustic resonators for integrated microwave power oscillator applications", ELECTRONICS LETTERS 2011 Vol. 47 No. 7
6. L. Pramatarova, E. Radeva, E. Pecheva, T. Hikov, N. Krasteva, R. Dimitrova, D. Mitev, P. Montgomery, R. Sammons and G. Altankov, The Advantages of Polymer Composites with Detonation Nanodiamond Particles for Medical Applications, InTech, Chapter On Biomimetics 14, 297-320 (2011)
7. Ivan D. Avramov, "Polymer Coated Rayleigh SAW and STW Resonators for Gas Sensor Applications", in Acoustic Waves – From Microdevices to Helioseismology, Edited by Marco G. Beghi, Chapter 23, pp. 521-546, ISBN 978-953-307-572-3, October 2011, printed in Croatia, www.intechopen.com/books/show/title/acoustic-waves-from-microdevices-to-helioseismology
8. Юрукова Л.С. Коленцов К.М. Радева Е.И., Электролуминесцентные индикаторные элементы с улучшенными параметрами, Журнал Известия высших учебных заведений. Физика, Издательство ООО "Издательство научно-технической литературы" ISSN 0021-3411, Том 54 Цит. в РИНЦ 0, Номер 2 Цит. в WOSR, Страницы 306-310 Цит. в ScopusR, 2011.
9. L. Arapan, I. Katardjiev, V. Yantchev, G. Alexieva, V. Strashilov, I. D. Avramov, E. Radeva "Polymer coated thin film plate acoustic resonators (FPAR) for gas sensing applications", Proc.2011 Joint Conference of the IEEE International Frequency Control

Symposium and the European Frequency and Time Forum, May 1-5, San Francisco, USA

ONGOING RESEARCH PROJECTS:

1. Project financed by Bulgarian Academy of Sciences

1.1 Mass-, gas- and thermosensitivity of sensor systems and devices using different acoustic wave modes Bulk, Lamb, Rayleigh and Transverce surface acoustic waves.

2. Projects financed by National Foundation of Scientific Research at the Ministry of Science and Education

2.1. New nanobiocomposite materials for bone implants.

3. Projects in frames of Inter-academic and Inter-institute collaboration

3.1 Development of new sensitive layers (coatings) based on nano-sized semi-conductive structures for analytical application using mass-sensitive piezoresonance sensors.

3.2 Investigation of impurities in helium gases on the base of quartz crystal microbalance.

3.3 Development of a leaky surface acoustic wave (LSAW) sensor on lithium tantalate for liquid analysis.

COLLABORATION:

1. "Development of mass sensitive quartz resonators for operation at cryogenic temperatures". - Join Institute for Nuclear Research, Dubna, Russia.
2. "Development of new sensitive layers (coatings) based on nano-sized semi-conductive structures for analytical application using mass-sensitive piezoresonance sensors"- Russian Academy of Science, Russia.
3. "Development of a leaky surface acoustic wave (LSAW) sensor on lithium tantalate for liquid analysis" - Research Center Karlsruhe, Germany.

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

LOW TEMPERATURE PHYSICS

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RESEARCH ACTIVITIES:

The Low temperature physics laboratory studies different problems in the field of condensed matter physics related to the phenomena of magnetism and superconductivity. The theoretical investigations of phase transitions (classical and quantum) and critical phenomena in various physical systems were carried out. The experimental work is connected with obtaining and investigation of new magnetic, superconducting and composite materials and improvement of their characteristics aiming the applications.

THEORETICAL STUDIES

Infinite sets of thermodynamic inequalities which generalize the well known inequalities of Brooks Harris, Bogoliubov (Jr.) and Jinibre are derived. They provide upper bounds on the difference between the quadratic fluctuations of intensive observables of a N-particle system and the corresponding Bogoliubov - Duhamel inner product The novel feature is that, under sufficiently mild conditions, the upper bounds have the same form and order of magnitude with respect to N for all the quantities derived by a finite number of commutations of an original intensive observable with the Hamiltonian. The results are illustrated on two types of exactly solvable model systems: one with bounded separable attraction used in the theory of magnetism and the other containing interaction of a boson field with matter.

MAGNETISM AND MAGNETIC MATERIALS

Magnetic and transport properties of $NdBaCo_2O_{5+\delta}$ system are studied in less investigated hole doped region ($0.52<\delta<0.72$) and in pulsed magnetic fields up to 47 T. The conductance in zero magnetic field and T < 130 K is described by a two-gap expression completed by the term of variable range hopping (VRH). The thermoelectric power $S(T)$ measurements confirm magnetic phase diagram found by magnetic and electric transport investigations. VRH mode gives good approximation at zero and high magnetic field 47 T. The isothermal magneto-conductance (G) of hole doped polycrystalline $NdBaCo_2O_{5.72}$ is well fitted by $G(H, T)/G(0) = G_0\exp(H/H_0)$ dependence at 55 K<T<138 K (the region where FM state appears) instead of simple linear dependence found for manganites $La_{0.7}Sr_{0.3}MnO_3$. The parameter H_0 is considered as the magnetic field of full spin sublattices' reorientation

and *MR* saturation. The magnetoconductance is possibly realized through the *a*-oriented grains due to the strong decrease of resistivity $\Delta\rho_c/\rho_c$ in magnetic field along *a*-axis.

SUPERCONDUCTIVITY AND SUPERCONDUCTING MATERIALS

Investigation of intra- and inter-granular effects in overdoped polycrystalline $R_{1-x}Ca_xBa_2Cu_3O_{7-\delta}$ (R=Y, Eu, Gd, Er and x=0, 0.025, 0.05, 0.10, 0.20, 0.30) samples was carried out by using different experimental techniques. It was established that low level overdoping leads to the improvement of intragranular critical current, flux pinning and irreversibility field of samples at 77 K making their values higher than for non substituted, fully oxygenated YBCO samples. Temperature dependence of intergranular critical current implies that it is governed by the S-I-S type joints between the grains. For highly overdoped samples the suppression of intragranular critical current and flux pinning has been observed. The intergranular critical current is characterized by S-N-S type. Indirect evidences suggest that this is a result of carriers' phase separation supporting the idea that the quality of superconducting condensate is strongly influenced by overdoping. The field dependence of activation energy for TAFF shows that 2D pancake vortices are typical for underdoped samples, while 3D vortex system exists in overdoped ones. Vortex dynamics and irreversibility line are also influenced by the doping effect. The existence of vortex glass-vortex liquid phase transition was established by transport and third harmonic AC susceptibility measurements. The scaling behavior of E-J data in Ca substituted samples is similar to the other polycrystalline YBCO samples. Previously established morphology dependence of dynamic exponent (**z**) was confirmed. However, **z** values are smaller than the usually reported for non-substituted YBCO. Static exponent (ν) shows a tendency for field dependence. These observations have been explained with the peculiarities of Ca substituted samples.

The pinning and transport properties of samples $MoSn_xSr_2YCu_2O_{8-\delta}$ (x=0 and 0.03) as a function of temperature and magnetic field have been investigated. It was established that Mo-1212 is a highly anisotropic superconductor with the formation of 2D vortices. The Sn doping increases the anisotropy and modifies the intergrain superconductivity of Mo-1212. The temperature dependences of resistivity of undoped and Sn-doped Mo-1212 were described by the relation $\rho(T) = (\rho 0/T) \exp(-U/k_BT)$. The fit to this relation indicates the temperature range of application of the flux-creep approximation. The penetration depth λ, the coherence length ξ and the attempt frequency ν_0 were determined for Mo-1212. The field dependences of the parameters ρ_0 and U denote the presence of a crossover field, H_{cross}. Some interpretations of the H_{cross}, as well as the nonlinear electric field vs. current density characteristics were discussed.

The multifilamentary modification of coated conductors in Roebel meander shaped strands was successfully performed by employing a picosecond-infrared laser system. The measured magnetization losses of the 125 mm wide striated single strand were five times lower than that of the non-striated one. In the case of the cable sample the loss were reduced by a factor of three at high field amplitudes. The additional ac loss reduction in the Roebel cable with filamentary modification of the coated conductor strands was confirmed in case of 12 mm wide cables. Self-field measurements under current flow were successfully employed to single striated Roebel strands by moveable Hall-sensor. It was found a different behavior for currents penetrating from the edges and currents penetrating from the top and bottom surfaces. In order to investigate the critical current of a stacked Roebel cable, the influence of flux creep on the cable's properties was analyzed. Using the material's properties derived from measurements on a single conductor as input for our calculations, we were able to predict the critical current of the cable in two limiting situations: good current sharing and complete electrical insulation among the strands. Our calculations are in agreement with the

measured critical current of three 4 mm wide Roebel cable samples. A non-homogeneous distribution of the magnetic field in the cable cross-section causes a variation of the critical current along the length of each strand. The critical current of the cable is the lowest when the strands are completely insulated and increases with reducing the resistance between the strands.

The oxygen non-stoichiometry content, *δ,* was determined in $GdBa_2Cu_3O_y$ and $ErBa_2Cu_3O_y$ (y=6.5+δ) by measuring the absorption of the blue colored I_3-starch compound. The unit cell lattice parameters were determined from XRD patterns. A correlation, between the unit cell parameter, *c,* and oxygen coefficient, y, was established. The derived new relation can be used for the rapid semi-quantitative analysis of the oxygen content in the mentioned compounds.

Bulk superconducting (SC) ceramics containing $Bi_{1.6}Pb_{0.4}Sr_2Ca_2Cu_3O_z$ and $La_{0.6}Pb_{0.4}MnO_3$ in weight ratio 90/10 have been produced from the initial components prepared by a low-temperature Pechini method. The obtained composites were analyzed by scanning electron microscopy (SEM) with energy-dispersive X-ray spectroscopy. They contain several phases. It was established that the SC 2212 phase predominates in the composite. The phase $La_{0.6}Pb_{0.4}MnO_3$ transforms in solid solution with preliminary composition $La_{0.5}(Sr+Ca)_{0.5}Mn_{1-z}Cu_zO_3$, which after full replacement of the La and Mn ions leads to the appearance of phases with nominal composition $Sr_{1-x}Ca_xCuO_y$. AC and DC magnetization measurements were used to study the SC and magnetic properties of the samples. Both samples are SC with critical temperatures 75 and 77 K, respectively. It was concluded that the SC and magnetic phases stably coexist in the composite.

PUBLICATIONS:

1. Brankov J. R., Tonchev N. S., *Generalized inequalities for the Bogoliubov-Duhamel inner product with applications in the approximating Hamiltonian method*, Condensed Matter Physics 14 (1), 2011, art. No. 13003
2. E. S. Vlakhov, N. Kozlova, L. S. Lobanovskii, R. Wawryk, and K. A. Nenkov, *High magnetic field study of magnetic and transport properties of hole doped cobaltite* $NdBaCo_2O_{5+\delta}$., Phys. Rev. B 84, 184440 (2011)
3. S Terzieva, M Vojenčiak, F Grilli, R Nast, J Šouc, W Goldacker, A Jung, A Kudymow and A Kling, *„Investigation of the effect of striated strands on the AC losses of 2G Roebel cables",* Supercond. Sci. Technol. **24** 045001 doi:10.1088/0953-2048/24/4/045001, pp. 045001 - (2011)
4. M Vojenciak, F Grilli, S Terzieva, W Goldacker, M Kovacova and A Kling *„Effect of self-field on the current distribution in Roebel-assembled coated conductor cables",* Supercond. Sci. Technol. **24** 095002 doi:10.1088/0953-2048/24/9/095002, pp. 095002 - (2011)
5. Emhofer, J., Hengstberger, F.; Eisterer, M.; Weber, H.W.; Terzieva, S.; Goldacker, W.; Badcock, R.A.; Long, N.J., *„Current and Field Distribution in Meandered Coated Conductors for Roebel Cables",* Journal of Applied Superconductivity, IEEE Transactions, Issue: **3**, doi: 10.1109/TASC.2010.2092394, pp. 3389 – 3392 (2011)
6. N.Balchev, V.Antonov and K.Nenkov, "*Pinning and transport properties of undoped and Sn-doped* $MoSr_2YCu_2O_{8-\delta}$", Supercond. Sci. Technol., 24, 095013 (2011)
7. A. Stoyanova-Ivanova**,** A. Staneva, B. Blagoev, A. Zaleski,V. Mikli,Y. Dimitriev**,** "*Microstructure and superconductivity of bulk BPSCCO/LPMO composite*", Philosophical Magazine Letters, Vol.91, № 3, 2011, 190-199

8. L. Dimova, O. Petrov, M. Kadiyski,, N. Lihareva, A. Stoyanova-Ivanova and V. Mikli, *Preparation and Rietveld refinement of Ag-exchanged clinoptilolite***,** Clay Minerals, V. 46, Issue2, 2011, pp. 205-212.
9. A**.** Stoyanova-Ivanova, St. Georgieva, T. Nedeltcheva, L. Dimova, B. Shivachev, "*Variation of the unit cell parameters of the* $REBa_2Cu_3O_y$ *(RE = Gd, Er) ceramics in function of the oxygen content* ", Bulgarian Chemical Communications, V.43, № 2, 2011, pp.320-324
10. E. Nazarova, K. Nenkov, K. Buchkov, A. Zahariev, *Scaling behaviour of current-voltage characteristics of* $Y_{1-x}Ca_xBa_2Cu_3O_{7-\delta}$ *polycrystalline samples,* The Open Superconductors Journal, V.3, 2011, pp.1-6; arXiv: 1012.5267v1
11. E. Nazarova, K. Nenkov, A. Zaleski, K. Buchkov, A. Zahariev, *Investigations of the overdoped state in polycrystalline* $R_{1-x}Ca_xBa_2Cu_3O_{7-\delta}$ *samples (R=Y, Gd, Er)*, Chapter of book "Superconductivity: Theory, Materials and Applications", ed. by V. Romanovskii, Nova Publishers, NY, USA

TEACHING ACTIVITIES:

Ph.D. Student K. Buchkov, supervisor Assoc. Prof. E. Nazarova

AWARDS:

- S. Terzieva wins The "I. Geshov" award of the Bulgarian Academy of Sciences for the prosperous young scientist in Physics;
- The scientific team leading by E. Vlakhov (E. S. Vlakhov, N. Kozlova, L. S. Lobanovskii, R. Wawryk, and K. A. Nenkov, High magnetic field study of magnetic and transport properties of hole doped cobaltite $NdBaCo_2O_{5+\delta}$., Phys. Rev. B 84, 184440 (2011)) wined the First place in the ISSP BAS competition for the Most important ISSP BAS scientific achievement in 2011.

ONGOING RESEARCH PROJECTS:

I. Projects financed by Bulgarian Academy of Sciences:
1. New materials and multifunctional magnetic materials.

II. Projects financed by contracts with EU, NATO and other international sources:
1. Overdoping of 1-2-3 HTS materials and its influence on the ac losses, critical current, flux pinning, activation energy-**EURATOM-FU07-CT-2007-00059**

INTERNATIONAL COLLABORATION:

1. Obtaining and investigation of thin film structures of magnetic oxides (manganites and cobaltites), Institute of Physics, Polish Academy of Sciences, Warshaw, Poland;
2. Synthesis and structure investigation of multifunctional materials, Center for Materials Research, Tallin Technical University, Tallin, Estonia;
3. International Laboratory for High Magnetic Fields and Low Temperatures – Wroclaw, Poland.

DIVISION LOW TEMPERATURE PHYSICS

LABORATORY

ENVIRONMENTAL PHYSICS

HEAD: **Assoc. Prof. Vasil Lovchinov, PhD**
Tel: 9746265; e-mail: lovcinov@issp.bas.bg

TOTAL STAF: **5**
RESEARCH SCIENTIST: **4**
Assoc. Prof. P. Simeonova, PhD; Assist. Prof. I. Radulov, PhD; Dimitar Petrov, PhD student; Petja Papazova, PhD student; Technician P. Zashev

RESEARCH ACTIVITIES:

In 2011 the Laboratory of Environmental Physics continued its activities in completing the tasks and goals of the project "Improvement of the life quality by the use of sustainable management of surface waters – application to the catchments of the rivers Struma and Mesta" (DO-02-352) granted by the National Science Fund. The results obtained could be summarized as follows:

- The multivariate statistical (environmetric) strategy was further improved and applied for assessment of the river water quality with introduction of original models of the risk assessment and pollution sources ranking along the flows of the rivers Struma and Mesta.
- New original integral indices for pollution and for climate impact were created. Special attention was paid for introduction of indices for assessment of risk events (floods, draughts) in the river catchments of Struma and Mesta.
- Analysis of monitoring data from River Tundja has started ;
- A dataset from monitoring results from Maritsa River was completed to perform environmetric analysis .

The research scientists of the Laboratory worked also on the project "Environmental Physics" sponsored by Bulgarian Academy of Sciences. The summarized results are as follows:

- Systematic investigation of the application of environmetric strategies for modeling and interpretation of air-borne particles monitoring data;
- Statistical method for calibration of analytes model solutions;
- Classification and modelling of clinical data for patients suffering from alcohol abuse.

The studies on the magnetic and surface properties of nano-structured lantanoide monoaluminates were completed and included in the PhD thesis of Dimiter Petrov.

In 2011 the postdoc specialization of Assist. Prof. Dr. Ilia Radulov (Marie-Curie program) in Creta, Greece was finished. His activity was concentrated on studies of magnetic, transport and thermodynamic properties of high temperature superconductors. As a results of these studies by AFM observation of the magnetic properties of powder samples of $CaFe_2As_2$ evidences have been found for the presence of partial superconductivity in the domain walls.

- Another aspect of the postdoc specialization of Assist. Prof. Dr. Ilia Radulov is the investigation of the spin – charge interaction in high temperature superconductors and more specifically in slightly doted monocrystals of La_2CuO_{4+x} ($x<0.1$). By the use of unique instrumentation and samples for the first time clear experimental evidence is obtained for launching of FE arrangement in monocrystal phase of La_2CuO_{4+x} at temperature of nearly 4.5 K. An attempt was made to offer a theoretical background

(using the phenomenological theory of Landau type) of the effect observed. A publication for Physical Review Letters is submitted for consideration.

- The Laboratory was presented during the International Symposium on «Dissipation and development of the physical and mathematical knowledge on the Balkans" in Sofia, October 17-18, 2011. A special session was dedicated to the 100 anniversary of the superconductivity where Doc. Dr. V. Lovchinov presented a plenary lecture entitled "Low temperatures and superconductivity". The world tendencies in the joint development of these two phenomena as well as their development in Bulgaria were discussed. The presentation will be published in a special issue.
- The successful activity of Doc. Dr. V. Lovchinov for the creation and functioning of the Centre for investigation of the physical properties of the materials, surfaces and structures (associated with the Institute of Solid State Physics) has to be mentioned. In 2011 with the active participation of the PhD student Krastyu Buchkov (Laboratory of low-temperature physics) and Assist. Prof. Irina Bineva (Laboratory of photoelectric and optic phenomena in broad zone semiconductors) a series of measurements for both local and external users were performed using the unique apparatus PPMS and AFM.
- In 2011 the researchers from the Laboratory of Environmental Physics took part in reviewing of 3 scientific manuscripts for international scientific journals. Additionally, Doc. Dr. P. Simeonova was reviewer of the dissertation of Ishtiak Ahmed Najar, Faculty of Ecology, Pondicharry University, Kashmere, India on invitation of the University Rector Office.
- Doc. Dr. V. Lovchinov was member of scientific juries appointed for obtaining the educational and scientific degree "Doctor" at Faculty of Chemistry, University of Sofia and Institute of Solid State Physics.

TEACHING ACTIVITIES:

Ph.D. Student D. Petrov, supervisor Doc. Dr. V. Lovchinov;
Ph.D. Student P. Papazova, supervisor Doc. Dr. P. Simeonova.

PUBLICATIONS:

1. Stefan Tsakovski, Pavlina Simeonova, Vasil Simeonov, Sediment Pollution Assessment by Chemometric Methods. *Ecological Chemistry and Engineering S*, Vol. 18, no. 2, (2011), 141-170.
2. Stefan Tsakovski, Pavlina Simeonova, Vasil Simeonov. Classification and Modeling of Different Fractions of Aerosol Monitoring Data, *Journal of Environmental Science and Health, Part A,* Vol. 46, (2011), 157-169.
3. D. Petrov, B. Angelov, V. Lovchinov Magnetic susceptibility and surface properties of $EuAlO_3$ nanocrystals, *Journal of Alloys and Compounds***,** vol. 509 (2011), pp. 5038-5041.
4. D.Petrov, B. Angelov, V. Lovchinov. Metamagnetic $DyAlO_3$ nanoparticles with very low magnetic moment*, J. of Sol-gel Science and Technology***,** vol. 58 no.3 (2011), pp. 636-641.
5. D. Petrov, Nanocrystalline $GdAlO_3$: XPS, EPR and magnetic susceptibility Studies, *Applied Physics A*, vol.104 (2011), 1237-1242.
6. Stefan Tsakovski, Pavlina Simeonova, Vasil Simeonov. Statistical Modeling of Air Pollution. *Journal of Environmental Science and Health, Part A,* Vol. 47, (2011).
7. D. Simeonov, L. Spasov, P. Simeonova. Statistical Calibration of Model Solutions of Analytes. *Ecol. Chem. Eng. S,* Vol. 19, No. 1, (2012), 67-75.
8. Bardarov, V., P. Simeonova, L. Neikova, K. Bardarov, V. Simeonov, S. Tsakovski, K. Kanev. Statistical Interpretation of Medical Data of Patients with Alcohol Abuse. *Centr. Europ. J. Med.,* (in press)

9. P. Simeonova, D. Simeonov, L. Spasov. Determination of Cadmium and Zinc in Mollusks from Black Sea. *Ecol. Chem. Eng. S*., (in press).
10. P. Papazova, P. Simeonova. Long-term Statistical Assessment of the Water Quality of Tundja River. *Ecol. Chem. Eng. S*., (in press).
11. T Xiao, A. P. Dioguardi, N. Roberts-Warren, A. C. Shockley, J. Crocker, Viskadourakis, Z X. Y Tee, I Radulov, C. C Almasan, N. J Curro, C Panagopoulos, "Evidence for domain wall superconductivity in antiferromagnetic $CaFe_2As_2$", *Physics* (in press).
12. Z. Viskadourakis, I. Radulov, A. D. Petrovic, S. Mukherjee, B. M. Andersen, G. Jelbert, N. S. Headings, S. M. Hayden, K. Kiefer, S. Landsgesell, D. N. Argyriou, C. Panagopoulos "*Ferroelectricity and magnetoelectric coupling in underdoped* La_2CuO_{4+x}", *Physics* (in press).
13. S. Mukherjee, B. M. Andersen, Z. Viskadourakis, I. Radulov, C. Panagopoulos "*Theory of the magnetoelectric effect in* La_2CuO_{4+x}*", Physical Review Letters* (in press).
14. V. Lovchinov, "The low temperature and superconductivity", Proceedings of "Dissipation and development of the physical and mathematical knowledge on the Balkans" Symposium (in press).

ONGOING RESEARCH PROJECTS:

1. "Improving of life quality by sustainable management of surface waters – application for the catchments of the rivers Struma and Mesta", funded by № DO - 02-352 (2010).
2. "Environmental Physics" funded by Bulgarian Academy of Sciences.

INTERNATIONAL COLABORATION:

1. Universite de Liege, Belgium - L'Universite de Liege, Depart. Physique, Group SUPRA.TECS.
2. International Laboratory for High Magnetic Fields and Low Temperatures – Wroclaw, Poland.

FUTURE RESEARCH PLANS OF THE LABORATORY INCLUDE:

1. The work on Project DO-02-352 (Environmetric assessment of the quality of surface waters along the streams of the Struma River and Mesta River) will be continued. Monitoring data will be interpreted by the use of multivariate statistical methods (cluster analysis, principal components analysis, neuron nets).
2. Development of environmetric long-term strategy for assessment of the quality of the Tundja River and Maritsa River using data from monitoring. The results will be used in the PhD thesis of the PhD student Petia Papazova.
3. Statistical interpretation of marine organisms monitoring data (heavy metal content) from the Black Sea to identify pollution sources.
4. Participation in a scientific team (along with scientists from the Military hospital) for establishing alcohol abuse effects using statistical interpretation of medical parameters.
5. Start of the project "Structural and physical investigations of nano-structured thin layer and bulk materials based on ordered porous dielectric matrices" with the Russian Academy of Sciences.
6. Continuation of the cooperation with Universite de Liege, Belgium - L'Universite de Liege, Depart. Physique, Group SUPRA.TECS with the new project entitled "Electrical and magnetic properties of perovskite magnetic materials".

DIVISION PHYSICAL OPTICS AND OPTICAL METHODS

LABORATORY

OPTICS AND SPECTROSCOPY

HEAD: **Prof. Svetoslav Rashev, D.Sc.**
tel: 8757095, 979 5795; e-mail: rashev@issp.bas.bg

TOTAL STAFF: **19**
RESEARCH SCIENTISTS: **18**

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. E. Keskinova, Ph.D.; Assoc. Prof. G. Hadjihristov, Ph.D.; Assoc. Prof. T. Tsvetkova, Ph.D.; Assoc. Prof. R. Peeva, Ph.D.; Assoc Prof. K. Antonova, Ph.D.; Assoc. Prof. B. Zafirova, Ph.D.; Assoc. Prof. M. Kaneva, Ph.D; Assist. Prof. T. Tenev, Ph.D.; Assist. Prof. B. Katranchev, Ph.D.; Assist. Prof. B. Panchev; Assist. Prof. H. Naradikian; Assist. Prof. E. Karakoleva; I. Milushev, Ph.D.; Y.Velkova

RESEARCH ACTIVITIES:

The studies on the electroconvectivity in nematic liquid crystals with short range smecic C order, and a dimer molecule as a structural unit were aimed at taking into account the effect of the angle of smectic tilt in the supramolecular complexes (clusters) on the relaxation processes initiated by low and high frequency electric fields. The first studies have been carried out on the growing of a smectic C liquid crystal with temperature independent tilt angle, in a liquid crystal cell, oriented by single walled carbon nanotubes (SWCNTs). It was demonstrated that the most effective alignment of the kayers is achieved on SiOx/ITO treated surfaces. Well aligned and sufficiently large for experimental studies local smectic C monocrystals have been fabricated.

Using laser polarization micro-Raman spectroscopy, organic material has been studied, that was obtained through implantation of polymethylmethacrylate (PMMA) with Si ions accelerated to 50 keV at 10^{14} to 10^{17} ions/cm^2. The depolarization ratio has been measured at different wavelengths of the exciting laser light, the size of the carbon clusters produced in the ion implanted polymer has been estimated experimentally and their special orientation has been determined. Using impedance measurements, the photoelectrical response of donor-acceptor molecular systems (two-component molecular complexes), including carbonyl groups has been studied. The photo-flexoelectrical properties have been investigated of thin homeotropic layers of liquid crystal mixtures of the type guest-host, where the host is a nematic liquid crystal.

We have developed a technology for reducing the VICCEL thickness down to 20 microns, and their packing into a flexible carrier of 75 microns thickness, capable of bending with a radius of 2 mm. The optical, electrical, mechanical and thermal properties of the lasers have been characterized. This new packing approach has been demonstrated for such applications as optical sensors and optical communications. The VICCELs in combination with liquid crystals have been studied theoretically, for three configurations of the liquid crystal cell. We have predicted the possibility for choosing the orientation of the linear polarization of the generated light by varying the cell length; by electro-optical switching and control; by electro

optical tuning of the light wavelength. The electrical properties of VICCELs with two resonators have been investigated. The theoretical studies on the effect of the parameters of the optical crystal structure on the operation mode of VICCELs with a photonic crystal have been carried on. The spatial distribution of the light polarization upon focusing with a metal-dielectric multilayer has been studied theoretically. It was shown, that linear and circular polarizations are not preserved and a matrix form for the optical resolution was derived. The influence of the optical feedback on the behavior of solitons in wide aperture VICCELs was studied theoretically and the presence of bifurcation of light waves, leading to spontaneous motion with constant velocity was demonstrated.

The nechanical strains in protonated waveguide layers have been measured, obtained at various technological regimes in lithium niobate crystals from all three orientations. The contractability coefficient was calculated for a multiphase protonated lithium niobate with various thicknesses of the phase sublayers.

A review has been made of the spectroscopic methods, used for investigation of proton-exchange waveguides. A review was written on the methods for dotation of Li Niobate with ions of rare earth elements. In a book chapter have been described the applications of the transverse acousto-electrical effect and the surface photocharge effect for quality control of a number of production parameters in a wide range of technological branches, as well as the original development of methods and sensors, based on these two effects. A reference bibliography has been composed with quantitative exploration of the publications of Bulgarian authors in the field of physics for the period 1889-1960.

A new approach was demonstrated for dynamical recording of long diffraction gratings, that can also be used as phase masks for preparation of large area diffraction gratings. The recording of a diffraction grating with a period of 500 nm and length above 300 nm was experimentally demonstrated. The conditions have been investigated for the formation of a "self-organized" relief on a metal surface upon exposure by ultrafast laser pulses by stimulated excitation of a surface4 plasmon-polariton (SPPs) by means of a diffraction grating. The connection of femtosecond laser pulses with a surface electromagnetic wave has been systematically studied by varying the period of the grating couple in broad limits (440 - 800 nm). A method for has been developed for fabrication of diffraction grating with an exact number of lines, on the wall of a cylinder, oriented along its axis. The method was demonstrated for a grating with 2^{15} lines. An external resonator polarization transformator was developed, that converts effectively the polarization of a laser beam from radial into axial. The element was prepared on the basis of a resonance structure of hydrogenated amorphous silicon.

A functional method has been developed for contactless characterization of resonance chemical- and bio- sensors. Besides for testing of bio-sensors, the method can be used for characterization and testing of all kinds of optical devices or modules, working on the basis of optical resonance. Studies have been performed on microstructured optical fibers with "hanged core", used as sensor elements for biochemical measurements. Experiments were carried out on the application of these fibers as refractometric biosensors – spectral response of the Bragg grating as function of the refraction index, as well as problems with the microcapillary filling and cleaning of the optical fibers.

Calculation have been carried out on the propagation of electrical and magnetic fields in photonic crystal fiber, consisting of a waveguide optical medium containing 6 air cylinders, placed at the edges of an uniform hexagon. The calculated results are analyzed in order to

obtain the value of the longitudinal constant for propagation of the waveguide mode of photonic crystal fiber with the highest accuracy.

The aging dynamics of interfacial processes in the anchoring of liquid crystals on polymer surfaces has been studied. A specific interface of the nematic liquid crystal 4-*n*-pentyl-4'-cyanobiphenyl (5CB) and a polymer surface of poly(vinyl-4 fluorocinnamate) (PVCN-F) was explored, obtaining a 10 fold reduction of the relaxation time of the easy axis. Electrooptical studies were performed on suspensions of lipid vesicleswith the aim of establishing whether the induced structural anisotropy of the vesicles under the effect of external electric field can lead to optical anisotropy of the entire suspension. In a suspension of giant vesicles with a radius of 10 μm (incident light is λ=0.5 μm) as in our case, the possible very weak anisotropy of the shape or phase as a whole, is being screened by the strong scattering.

In 2011 interdisciplinary research of megalithic and quasi-megalithic objects in Bulgaria was continued. In recent years, all studies are carried out in one of the general research directions in BAS, namely "Cultural heritage and national identity." This activity is also part of the mission of the ISSP, as far as proposing new approaches in interdisciplinary contact areas between physics and archeology, as well as transferring results to the cultural development of Bulgaria. A systematic search was conducted, strict localization and archaeo-astronomical interpretation of these monuments. Objectives include: a) cataloging and monitoring; b) analysis of the global picture of the Balkan megalithic region in comparison to Western European and Caucasian areas; c) monitoring of structural development from the viewpoint of building static; d) establishing a relationship with rock sanctuaries; e) selection of suitable sites for possible dating by photo-luminescence in future; f) establishing suitable sites for laser scanning for extracting and storing of complete and detailed three-dimensional information about them.

We have studied the effect of the rotational structure on the vibrational relaxation and electronic radiationless desactivation in molecules. Calculations have been performed on the characteristics of phosphorescence from the first excited triplet state of the thiophosgene molecule. Our variational method has been elaborated, designed for exploring the vibrational structure and IVR of a polyatomic molecule at very high levels of vibrational excitation, using the exact expression for the molecular kinetic energy. Theoretical investigations have been carried out on the vibrational structure and IVR characteristics of the formaldehyde molecule, up to very high vibrational excitation energies (~17000 cm^{-1}).

We have carried out studies aimed at clarifying the effect of hydrogen on the mechanical properties of hydrated amorphous silicon (a-Si:H). It is well known that hydrogen is an important factor for improving the electronic properties of a-Si:H. In a comparative study of the mechanical properties of hydrated and not hydrated amorphous silicon it has been established, that the presence of hydrogen in the silicon matrix does not change the elasticity module, but it enhances the material hardness. The nanohardness of a-Si:H was in the range 12.2–12.7 GPa, comparable to that of crystalline silicon. We have shown, that by treatment of amorphous silicon in hydrogen plasma, the material hardness in the surfacial area can be significantly enhanced. This result is of interest for purposes of applications, since it presents a technological method for restoring the mechanical hardness of silicon surfaces, if it has been reduced as a result of some kind of treatment (e.g. ion implantation).

Simulations have been carried out on the transmission of neutrons through materials like Be, Fe and W, that are eventual candidates for building material for the walls of the Thermo-nuclear reactor ITER, France.

Work has been done on the measurement of induced optical birefringence and scattering in a suspension, containing electrodeformable vesicles. Three layer structures ZnS/Ag/ZnS have been formed on diffraction gratings. A good polarization dependent transmission has been achieved through metal layer.

Various schemes of a high dispersion spectrograph of echelle type have been explored with the aim of building an echelle spectrograph designed for the 2-meter telescope in Rozhen observatory.

PUBLICATIONS

PUBLISHED PAPERS

1. A.G. Petrov, Y.G. Marinov, G.B. Hadjichristov, S. Sridevi, U.S. Hiremath, C.V. Yelamaggad, S.K. Prasad, "New photoactive guest-host nematics showing photoflexoelectricity", Mol. Cryst. Liq. Cryst, **544**(1) (2011) 3/[991]-13/[1001], [IF=0.537].

2. Y. Marinov, G. Hadjichristov, A. Petrov, S. Sridevi, U. Hiremath, C. Yelamaggad, S. K. Prasad, "Thermo-optical study of azo-dye doped nematic liquid crystals as flexoelectric guest-host systems", Compt. Rend. Acad. Bulg. Sci. **64**(5) (2011) 669-676 , [IF=3.526].

3. V.G. Ivanov, G.B. Hadjichristov, "Orientation of sp^2 carbon nanoclusters in ion-implanted polymethylmethacrylate as revealed by polarized Raman spectroscopy", J. Raman Spectrosc., **42**(6) (2011) 1340-1343, [IF=3.526].

4. G.B. Hadjichristov, Y.G. Marinov, A.G. Petrov, "Gradient polymer-disposed liquid crystal single layer of large nematic droplets for modulation of laser light", Appl. Opt. **50**(16) (2011) 2326-2333, [IF=1.763].

5. S. Sridevi, U.S. Hiremath, C.V. Yelamaggad, S.K. Prasad, Y.G. Marinov, G.B. Hadjichristov, A.G. Petrov, „Behaviour of photosensitive soft materials: Thermo-optical, dielectric and elastic constant studies on azo-dye doped nematic liquid crystals", Mater. Chem. Phys. **130**(3) (2011) 1329–1335, [IF=1.799].

6. Tz. Philipova, M. Hadjieva, K. Ivanova, I. Grabchev, N. Kirov, G.B. Hadjichristov, "Photo-sensitized donor-acceptor molecular systems with carbonyl-containing viologen", J. Optoelectron. Adv. Mater. **13**(6) (2011) 722-726, [IF=0.577].

7. B.Katranchev, H. Naradikian, E. Keskinova and M. Petrov, 'The role of the negative electroconductivity anisotropy at the electroconvection in nematic liquid crystals with short range smectic C order', J. Phys.: Conf. Ser., **253,** 012062, 2010, **ISSN**: 1742-6596**.**

8. M. Kuneva, K. Christova, S. Tonchev, "$LiNbO_3$ proton-exchanged waveguide layers: phase composition and stress"**,** EPL, **95**, 2011, 67005 [Doi: 10.1209/0295-5075/95/67005, IF=2.893].

9. M. Kuneva, S.Tonchev, "Spectroscopy of optical waveguiding layers", Bulgarian Chemical Communications, **43** (2), 2011, pp. 276-287 [IF=0.156].

10. N. Vermeulen, P. Wasylczyk, S. Tonchev, P. Muys, H. Ottevaere, O. Parriaux, H. Thienpont, "Low-loss wavelength tuning of a mid-infrared Cr^{2+}:ZnSe laser using a Littrow-mounted resonant diffraction grating", Laser Phys. Lett. **8**, No. 8, pp. 606-6012 (2011) [IF=6.010].

11. F. Garrelie, J. P. Colombier, F. Pigeon, S. Tonchev, N. Faure, M. Bounhalli, S. Reynaud, O. Parriaux, "Evidence of surface plasmon resonance in ultrafast laser-induced ripples**",** Optics Express, Vol. **19**, No. 10, pp. 9035-9043, 9 May 2011 [IF=3.749].

12. David Pietroy, Olivier Parriaux, Thibaut Epalle, Svetlen Tonchev, "Contactless functional testing of grating-coupled evanescent wave (bio)chemical sensors", Sensors and Actuators B: Chemical, ISSN: 0925-4005 Vol. 159, Iss.:1, Pages 27-32 (2011) [IF=3.368].

13. Kampfe, T.; Tonchev, S.; Gomard, G.; Seassal, C.; Parriaux, O., "Hydrogenated amorphous silicon microstructuring for 0th order polarization elements at 1.0μm - 1.1μm wavelength", IEEE, Photonics Journal, Volume: PP Issue:99, ISSN: 1943-0655 2011 [IF=2.344].

14. Y. Bourgin, I. Vartiainen, Y. Jourlin, M. Kuittinen, F. Celle, S. Tonchev, O. Parriaux, T. Niemi, "Three-grating monolithic phase-mask for the single-order writing of large-period gratings", Journal of the European Optical Society – Rapid Publications Vol. **6,** 11016s (2011), ISSN 1990-2573, [IF=1.044].

15. Philipp Mëuller, Yves Jourlin, Colette Veillas, Grerard Bernaud, Yannick Bourgin, Svetlen Tonchev, Olivier Dellea, **"**On-the-fly writing of a long grating phase mask, Optical Engineering, Vol. **50**, No. 3, pp. 038001-1÷038001-9, March 2011, [IF=0.815].

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17. S. Rashev, D.C. Moule and R.H. Judge, "The Role of Rotational Relaxation in the Intersystem Crossing Between a Triplet and a Singlet Electronic State", Int.J.Quant.Chem. **111** (2), 279-287 (2011), [IF=1.317].

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20. S. Tonchev, T. Kämpfe, O. Parriaux, "Rehabilitation of wet etching for the low-cost manufacturing of highly selective subwavelength gratings of high efficiency", Proceedings of the 2nd EOS Conference on Manufacturing of Optical Components (EOSMOC 2011), I) Theoretical and Practical Aspects of Manufacturing and Finishing Technologies, ISBN 978-3-00-033713-0, paper 4390.

21. S. Tonchev, N. Lyndin, Y. Jourlin, F. Celle, O. Parriaux, M. Kuittinen, J. Laukkanen, "Holistic fabrication of stitchingless subwavelength cylindrical gratings by phase-mask coordinatetransform", Proceedings of the 2nd EOS Conference on Manufacturing of Optical Components (EOSMOC 2011), I) Theoretical and Practical Aspects of Manufacturing and Finishing Technologies, ISBN 978-3-00-033713-0, paper 4392.

22. Y. Jourlin, C. Veillas, S. Tonchev, J. Sauvage-Vincent, U. Zeitner, O. Parriaux, "Grating phase-mask lithography for subwavelength radial polarizer fabrication", Proceedings of the 2nd EOS Conference on Manufacturing of Optical Components (EOSMOC 2011), III) Optical Manufacturing for Emerging Products and Processes, ISBN 978-3-00-033713-0, paper 4394.

23. Y. Bourgin, Y. Jourlin, S. Tonchev, I. Vartiainen, O. Parriaux, M. Kuittinen, A. Talneau, "Expanding the applicability domain of phase-mask lithography of gratings to the extreme", Proceedings of the 2nd EOS Conference on Manufacturing of Optical Components (EOSMOC 2011), I) Theoretical and Practical Aspects of Manufacturing and Finishing Technologies, ISBN 978-3-00-033713-0, paper 4391.

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40. Л.Цонев, Д.Колев, Я.Динчев, „Долмените в Сакар планина”, доклад в пълен текст (15 стр) в Материалите от Конференцията „Човекът и Вселената”, организирана от Съюза на учените в България, клон Смолян, 6-8.10.2011, Смолян.

41. Л.Цонев, Д.Колев, Я.Динчев „Долмените в Сакар”, сп.Обекти, брой 10 (2011).

MONOGRAPHS

1. O. Ivanov, M. Kuneva, **“**Quality control methods based on electromagnetic field-matter interactions”, In Application and Experience of Quality Control, (ed. O. Ivanov), published by INTECH, Vienna, 2011, ISBN 978-953-307-236-4, pp. 510-536.

2. Д. Христов, Е. Добрева, Ц. Бузова, М. Кънева, Х. Дарева, Р. Радков, Х. Вълчев, А. Ляпчева, М. Апостолова, В. Тенева, С. Златева, М. Козарова, Е. Бранкова, В. Тодоров, А. Цветанова, Д. Гулева, Г. Михайлова, В. Спасов, Н. Бъчварова, А. Николова, Ц. Чолова, Н. Кочев, Н. Бъчваров, Б. Пейчев, С. Аршинкова, А. Стойнев, Н. Сретенова, Р. Горгоров, С. Кирилова, А. Милтенова, „Физиката в България, т. II: Библиография 1889-1960. Наука. Образование. Просвета”, Изд. „Фараго”, София, 2011, 221 стр., 4 ил. [ISBN: 978-954-2961-04-8].

INTERNATIONAL COLLABORATION:

1. Free University of Brussels, Departmet of Photonics, Belgium
2. Forschungszentrum Rossendorf, Institut fuer Ionenstralphysik und Materialforschung, Germany
3. Pluridisciplinary Laboratory Joliot Curie at the Ecole Normale Supérieure, Lyon (CNRS UMR 5161) France, The Institute Albert Bonniot, UJF & INSERM U309, and CEA, Grenoble, France and funded by Ministry of Education and Science BG (K 1402/ 2004), and 6th FP ECC MCRTN “CLUSTOXDNA”
4. Ecole Normale Supérieure de Lyon, Laboratoire Pluridisciplinaire Joliot-Curie, (CNRS USR 3010) France; UJF, Institute Albert Bonniot, INSERM U309 and CEA-CENG, Grenoble, France
5. Research Institute of Solid State and Optics, Budapest, HAS, Hungary
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DIVISION SOFT MATTER PHYSICS

LABORATORY

LIQUID CRYSTALS

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TOTAL STAFF: **7**
RESEARCH SCIENTISTS: **6**

Assoc. Prof. H. Hinov, Ph.D., D.Sc.; Assoc. Prof. A. Zheliaskova, Ph.D.;
Assoc. Prof. V. Vitkova, Ph.D.; Assist. Prof. J. Genova, Ph.D.;
Assist. Prof. R. Marinov, Ph.D.; Ing. D. Mitkova

RESEARCH ACTIVITIES:

Studies of the optical absorption, thermo-optical and dielectric properties of photosensitive liquid crystal mixtures of the type quest –host were performed. In all three mixtures a strong response on UV light was detected due to isomerization of the photoactive additives. The temperature shift of clarification due to changes in the cis isomer population and in the length of azo-molecules under UV lightening was analyzed. A dependency of the dielectric constant on the nature of photoactive additive was shown. For the first time a reduction of the bending elastic constant at photoisomerization is observed. This result was explained via formation of reversed cis isomers.

The electro-optical properties of monolayer PDLC with gradient in liquid crystal droplets size were studied in order to use such a devise as a light modulator. Appling weak low frequency voltages a high contrast of the modulated light was achieved due to the significant phase shift in the passing coherent light. The spatial profile of the phase shift along the PDLC layer can be applicable in devises for modulation and active control of laser light.

The study of the influence of single-walled carbon nanotubes on nematic mixture E7, activated with DC voltage, which results in gradient flexoelectric and surface induced domains formation in cell with very thin (hundreds of nanometers) lipid layer was continued. The observed differences in the electro optic behavior were a result of the reduction of the nonhomogeneity of the electric field in presence of the carbon nanotubes as well as their concentration in the vicinity of the electrodes.

The bending elastic modulus of vesicles with long tubular protrusions, connected to their membranes was obtained via thermally induced shape fluctuation method as a weighted mean over 10 vesicles. The obtained value was compared to the bending elastic constant of quasishperical vesicle with the same lipid content without tubular protrusion, connected to their membrane. It was shown that the obtained values are identical.

The effect of the pH reduction of the water phase ($4 < pH < 5{,}5$) on the bending elasticity of pure phosphatidylcholine membranes was studied experimentally. It was shown that at higher acidity of the aqueous solution the value of the bending elastic modulus decreased. A significant influence of the bactericidal agent imidazole on the mechanical properties of lipid membranes was proven experimentally. The addition of millimolar concentration of imidazole in the aqueous solution led to considerable (of about 40%) increase of the bending elastic modulus of lipid membranes.

A computer program, performing the analysis of the time correlation of the shape of quasispherical lipid vesicle was developed. Preliminary data for the value of the friction coefficient between the monolayers, comprising the lipid bilayer was obtained using the new software.

A review on dynamics of lipid vesicles was prepared at the invitation of the prestigious serious Advances in Planar Lipid Bilayers and Liposomes, ELSEVIER. The opportunities that the dynamical study of membrane fluctuations offers as an experimental method for the study of material properties of lipid membrane were presented and discussed. An example was shown in details to illustrate how by means of analysis of thermally induced shape fluctuations of quasishperical lipid vesicle important material constants of the lipid bilayer (bending elastic modules of free and blocked exchange of molecules between the monolayers, comprising the lipid bilayer and friction coefficient between these monolayers) can be obtained. The second part of the review was focused on dynamics of free lipid vesicles in linear hydrodynamic flows. A special attention was given to the dependency of the rheological properties of vesicle suspension on the individual dynamics of vesicles in the flow.

PUBLICATIONS

1. J. I. Pavlič, J. Genova, G. Popkirov, V. Kralj-Iglič, A. Iglič, M. D. Mitov, "Mechanoformation of neutral (SOPC) giant phospholipid vesicles in high ionic strength solution (PBS)", Chem. Phys. Lipids 164 (2011) 727-731.
2. V. Vitkova, C. Misbah, Dynamics of lipid vesicles – from thermal fluctuations to rheology, Advances in Planar Lipid Bilayers and Liposomes vol.14 (Ed. Ales Iglic), Elsevier, Amsterdam (2011) 257-292, ISSN 1554-4516.

DIVISION SOFT MATTER PHYSICS

LABORATORY

BIOMOLECULAR LAYERS

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TOTAL STAFF: **4**
RESEARSCH SCIENTISTS: **3**

Acad. Alexander G. Petrov; Assist.Prof. L. Todorova; M. Dencheva-Zarkova, chem. engineer

RESEARCH ACTIVITIES:

Optical absorption, thermo-optical and dielectric studies have been performed on three guest–host nematic mixtures featuring photo-sensitized flexoelectric polarization. As host material the liquid crystal 4-butylcyclohexane carboxylic acid 4-pentyloxy-phenyl ester, a room temperature nematic with a negative dielectric anisotropy was taken. The different azo-dye compounds, also exhibiting liquid crystallinity were employed as the low-concentration guest component in the mixtures. In each case illumination of the sample with actinic (UV) light leads to strong photoisomerization driven effects. We have analyzed correlations among the shift of the isotropic–nematic phase transition temperature, population of the cis isomers, and the change in the length of the azo-dyes upon UV illumination. The UV induced changes demonstrate strong dependentcy in the dielectric constant values on the nature of the photoactive dopant. It was described the first observation of the lowering of the bend elastic constant upon photoisomerization, a feature ascribed to the formation of the bent-shaped cis isomers. The relationship between the photo-driven shift of the clearing temperature and the molecular conformation (cis and trans forms) may be helpful in the design of functional molecular systems and soft materials for molecular electronics and optoelectronics which make use of photosenstivity of azo-dye doped nematics.

A linear-gradient single-layered microscale PDLC film containing large nematic droplets is examined for tunable low-voltage modulation of a passed laser beam with a reduced light scattering. By such planar films with bipolar configuration of the droplets one can achieve a high-contrast amplitude modulation as well as an efficient electrically commanded phase modulation, both efficiently controllable through LC droplet-size gradient. These properties may be useful for tunable PDLC-based light filters and modulators, configurable phase masks, adaptive-optic and other practical devices and sensors, as well as systems of optical data processing, operating at video rates (30–80 Hz).

PUBLICATIONS:

1. New Photoactive Guest-Host Nematics Showing Photoflexoelectricity
Alexander G.Petrov, Y. G. Marinov, G.B.Hadjichristov, S. Sridevi, Uma S. Hiremath, C.V. Yelamaggad, and S. Krishna Prasad
Mol.Cryst.Liq.Cryst. **544**, no.1, pp 3/[991]-13/[1001] (June 2011), ISSN: 1542-1406

2. Observation of Flexoelectricity in a Mixture of Carbon Single Walled Nanotubes with a Nematic Liquid Crystal
A.G. Petrov, Y. G. Marinov, H. P. Hinov, L. Todorova, M. Dencheva-Zarkova, S. Sridevi, P. M. Rafailov, U. Dettlaff-Weglikowska
Mol.Cryst.Liq.Cryst. **545**, no.1, pp. 58/[1282]-66/[1290] (2011), ISSN: 1542-1406

3. Gradient polymer-disposed liquid crystal single layer of large nematic droplets for modulation of laser light
Georgi B. Hadjichristov, Yordan G. Marinov, and Alexander G. Petrov,
Appl. Opt. **50**, 2326-2333 (2011), ISSN: 1539-4522

4. Thermo-Optical Study of Azo-Dye Doped Nematic Liquid Crystals as Flexoelectric Guest-Host Systems, Yordan Marinov, Georgi Hadjichristov, Alexander Petrov, Sridevi Chakravarthy, Uma Hiremath, Channabasaveshwar Yelamaggad, Subbarao Krishna Prasad, Comptes Rendus Acad bulg Sci **64**, no 5, 669-676 (2011), ISSN: 1310-1331

5. Behaviour of photosensitive soft materials: Thermo-optical, dielectric and elastic constant studies on azo-dye doped nematic liquid crystals
S. Sridevi, Uma S. Hiremath, C.V. Yelamaggad, S. Krishna Prasad, Y.G. Marinov, G.B. Hadjichristov, A.G. Petrov
Materials Chemistry and Physics **130,** 1329– 1335 (2011), ISSN: 0254-0584

6. Study of the water systems quality by the energy spectra method
S. Todorov, L. Todorova
"Ecological approaches in harmless food fabrication", proceedings of IV Internat. symposium, Plovdiv, 269 – 274 (2011)

ONGOING RESEARCH PROJECTS:

Projects, additionally financed by contracts with Ministry of Education and Science:

1. "Flexoelectric properties of liquid crystals", Indo-Bulgarian intergovernmental program, contract Bin-5/07, NSF.

Projects funded under the Academy's bilateral agreements:

2. Nanostructured and bioactive liquid crystals, CNR Universita della Calabria, Italy

TEACHING ACTIVITIES:

Academician Alexander G. Petrov - lecture courses on Bioelectronics for Chemistry Dept. of St.Kliment Ohridski University of Sofia.

Assoc. Prof. Y. Marinov - one month student training: on research of lyotropic liquid crystaline nanostructures. One student from Biomedical engineering Department, Johns Hopkins University, Baltimor, USA.

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

ATOMIC SPECTROSCOPY

HEAD: **Prof. Kiril Blagoev, D.Sc.**
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TOTAL STAFF: **9**
RESEARCH SCIENTISTS**: 6**

Assoc. Prof. M. Stefanova, Ph.D.; Assoc. Prof. V. Mihailov, Ph.D.; Assoc. Prof. E. Dimova, Ph.D.; Assoc. Prof. G. Malcheva, Ph.D.; Assist. Prof. B. Torosov, Ph.D.; D. Yordanova - physicist; G. Dobrev - physicist; I. Temelkov - physicist; PhD student: V. Steflekova

RESEARCH ACTIVITIES:

Atomic structure and properties

The first experimental results have been obtained by new laboratory equipment, based on Laser Induced Break Down Spectroscopy method. The equipment consists of Q switched Nd:YAG laser, optical elements and their mountings and registration by multichannel spectrometer and corresponding electronic components. A number of bronze artifacts from "Baley" settlement were investigated. The artifacts were separated on several groups, depends on the different quantities of Pb and Sn, which are important elements for determination of technology (Fig. 1). "White" ceramic artifacts from Preslav were investigated. The artifacts were divided on two main groups, which have different quantities of Ca and Ti. The Li, K, Na, Rb elements from IA group were detected.

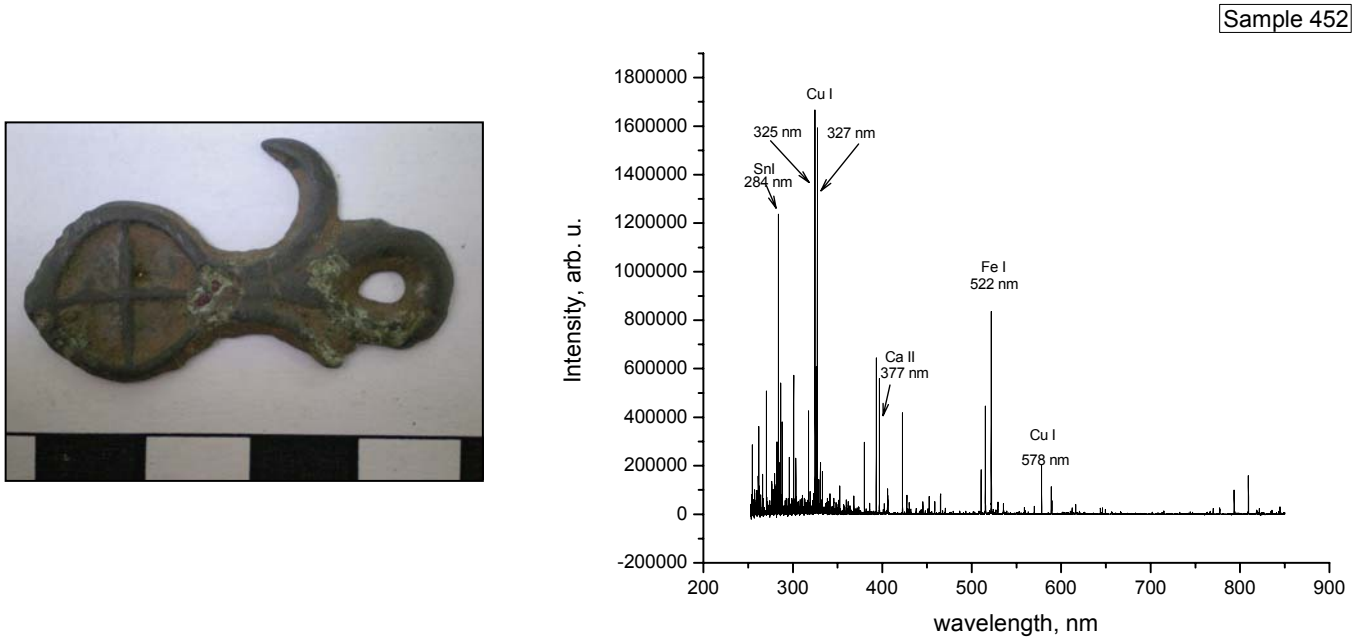

Figure 1. Bronze sample from late bronze age (2000BC) from "Balay" setelment-Bulgaria and its LIBS spectrum.

Quantum optics

The experiments on the new designed experimental set-up – magneto-optical trap were started. The base characteristics of the magneto-optical trap were determined. These are: number of the Rb atoms in the trap; relative size of the cooled atoms cloud; temperature of the atoms in the trap and time of trap filling. Saturation spectroscopy of "cooling" and "repump" lasers was done for stabilization on the isotope structure of ^{87}Rb. Systems for frequency stabilization of the lasers as well as for turn on/off were designed.

A technique for creation of arbitrary flat profile of excitation pulses was proposed. The method is based on composite pulses, which are formed by applying the sequences of pulses, having determined phases. In this way, the excitation profile can be influenced and the analog of π – pulses with flat profile could be created. If the composite phases are chosen in an appropriate way, the nonadiabatic losses can be canceled to the high degree.

The method for creation of high entangled states of atoms in an optical trap was proposed. The technique is similar to the method of laser cooling.

Plasma physics

Collision Electron Spectroscopy was proposed for determination of gas admixtures in main gas. The method is based on identification of atoms or molecules of impurities by selective registration of groups of fast electrons released in Penning ionization of the impurities by metastable helium atoms. The different groups of electrons do not relax in energy by collisions in the volume and behave independently of each other in collisional regime of movement. An original design of microplasma gas analyzer was proposed and registration of the energy spectra of penning electrons was carried out in the nonlocal steady-state plasma. Maxima in the electron energy spectra were recorded in helium with small admixtures of krypton, argon and air at pressures of 7 - 40 Torr (Fig. 2). It was demonstrated that the obtained maxima appear at the characteristic energies corresponding exactly to the expected maxima of penning electrons of the known gas impurities used. These investigations lead to the conclusion that the gas analyzer proposed could be used for monitoring of contaminations in different conditions.

The profile of the He I 492.2 spectral line was investigated in the space of the hollow cathode discharge. The observed deviation in the spectral line maximum and changing in the Lorenz spectral line halfwide depend on gas pressure and on the place in the hollow cathode discharge, from where the spectral line is emitted. This effect can be explained by penetration of the electric field in the negative glow of the discharge. Using the profile of the H_β spectral line, the distribution of intensity of electric field in Grim lamp was determined. The electric field distribution was obtained employing improved polarization – spectroscopy technique from the Stark widening of the Hydrogen spectral line. The obtained data allow creating theoretical model for spectral line profile forming in the spectral lamp conditions, as well as for determination of the dark cathode space parameters.

Deconvolution of experimental dynamic opto-galvanic signals in the glow plasma of hollow cathode discharge of Ar atomic transitions in the spectral range 451 nm – 462 nm was done. The obtained signals were fitted with theoretical determined function and the decay lifetimes of the states, taking part in the processes, which were responsible for the signal creation at different discharge currents.

The dynamic opto-galvanic signals of Fe positive ions were compared with nonresonances optogalvanic signals in Ar/Fe and Kr/Fe discharges in hollow cathode discharge. The differences of rising time and amplitude of these two types of signals were observed, which depends on discharge current and power of the illumination laser beam.

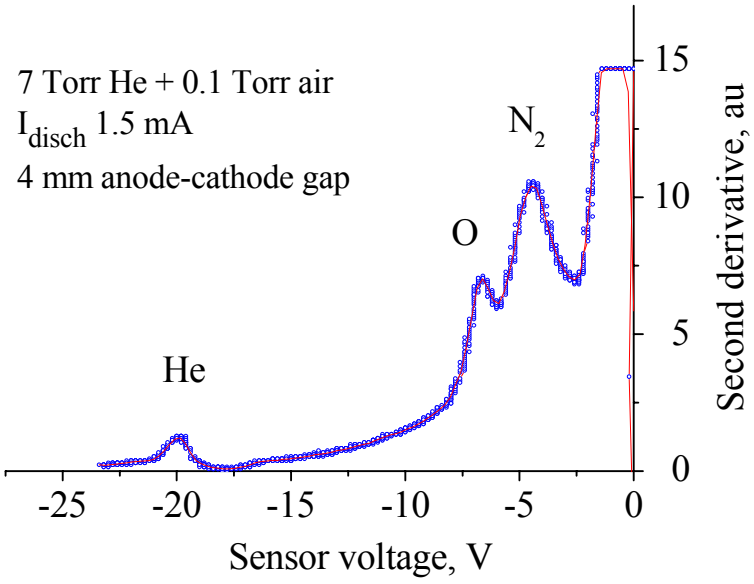

Figure 2. Colisional Electron Spectrum of mixture of He and air.

PUBLICATIONS

1. D. Zhechev and V. Steflekova, "Spatially resolved profile and shift of the spectral line in a hollow cathode discharge", Spectroscopy Letters **44** (1) (2011) pp. 47-51
2. G. T. Genov, B. T. Torosov, and N. V. Vitanov,
Optimized control of multistate quantum systems by composite pulse sequences,
Phys. Rev. A **84**, 063413 (2011)
3. G. T. Genov, B. T. Torosov, and N. V. Vitanov
Opitmized control of multistate quantum systems by composite pulse sequences
Phys. Rev. A **84**, 063413 (2011)
4. B. T. Torosov and N. V. Vitanov
Evolution of superpositions of quantum states through a level crossing,
Phys. Rev. A **84**, 063411 (2011) (БАН-ИФТТ)
5. D. Sofikitis, G. Stern, L. Kime, E. Dimova, A. Fioretti, D. Comparat, and P. Pillet, Loading a dipole trap from an atomic reservoir, Eur. Phys. J. D **61**, 437–442 (2011)
6. É. Biémont, K. Blagoev, L. Engström, H. Hartman, H. Lundberg,G. Malcheva, H. Nilsson, R. Blackwell Whitehead, P. Palmeri and P. Quinet, "Lifetime measurements and calculations in Y^{+} and Y^{2+} ions", Mon. Not. R. Astron. Soc.**414,** 3350-3359 (2011).
7. G. Malcheva, H. Nilsson, L. Engström, H. Lundberg, É. Biémont, P. Palmeri, P. Quinet and K. Blagoev, "Radiative parameters of Nb I excited states", Mon. Not. R. Astron. Soc.**412**, 1823-1827 (2011).
8. Dj. Spasojević, V. Steflekova, N. M. Šišović and N. Konjević, "A contribution to the study of electric field distribution in the cathode-fall region of anomalous glow discharge in hydrogen: theory and experiment", Submitted to: Plasma Sources Sci. Technol. (2011)
9. P. Pramatarov, M. Stefanova, N. Khrormrv and A. Kudryavtsev
"Application of dc microdischarge with additional anode as a gas-analysis sensor",
4th International Symposium on Advanced Plasma Science and its Applications for Nitrides and Nanomaterials, 4-8 March, Aichi, Japan

10. I. Temelkov, G. Dobrev, E. Dimova, D. Yordanova, P. Zachariev, A. Pashov, K. Blagoev, N.V. Vitanov "Rb Magneto-optical trap", III International School and Conference on Photonics, August 29 – September 2, 2011, Belgrade, Serbia
11. I. Temelkov, G. Dobrev, E. Dimova, A. Pashov, K. Blagoev, N.V. Vitanov , "Temperature of cold Rb cloud by shaking the MOT", July 4 - July 8, 2011, CAMEL VII, Nessebar, Bulgaria

INTERNATIONAL COLLABORATION

1. State Key Laboratory of Quantum Optics and Quantum Optics Devices, College of Physics and Electronics Engineering, Shanxi University contract № DO02-1/2008 with NSF
2. Institute of Physics Beograd, Serbia
3. Institute of Physics Yagelonia University Krakow Poland

EDUCATION

One student for bachelor degree (supervisor Dr. E. Dimova) and one for master degree (supervisor Dr. G. Malcheva) prepared their diploma work in the Laboratory.
One student for PhD was finished thesis – supervisor Prof. D. Zhechev.

ONGOING PROJECTS

1. Laser Diagnostics in archaeology DO 02-274/2008 with NSF
2. Physics of atoms, molecules and plasma – project in the framework of Bulgarian Academy of Sciences.
3. EURATOM – "Transport of W atoms and ions near the wall"
4. New techniques for quantum control and their application – NSF
5. Quantum computers and quantum information - NSF

FUTURE INVESTIGATIONS

1. Investigations of artefact from ceramic and metal, employing single and double pulse excitation. The LIBS method will be also applied to industry samples.
2. The manipulation of ensembles of cooled atoms will be carried out by external electromagnetic fields. Theoretical investigation will clarify the manipulation of quantum ensembles by composite pulses, having arbitrary pulse shape.
3. The Collision Electron Spectroscopy will be applied for investigation of plasma parameters and detection of admixture, including from solid samples. The computer compatible system for these analyses will be design.
4. Dynamic optogalvanic signals will be employed for plasma diagnostics.

DIVISION LASER, ATOMIC, MOLECULAR AND PLASMA PHYSICS

LABORATORY

METAL VAPOUR LASERS

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TOTAL STAFF: **16**
RESEARCH SCIENTISTS: **11**

Prof. Nikolay Vuchkov, D.Sc., Ph.D.; Assoc. Prof. Dimo Astadjov, Ph.D.; Assoc. Prof. Margarita Grozeva, Ph.D.; Assoc. Prof. Todor Petrov, Ph.D.; Assoc. Prof. Krassimir Temelkov, Ph.D.; Assist. Prof. Krassimir Dimitrov; Assist. Prof. Vesselina Gentcheva, Ph.D.; Assist. Prof. Peter Zahariev, Ph.D.; Assist. Prof. Lubomir Stoychev, Ph.D.; Assist. Prof. Ognian Sabotinov, Ph.D.; Physicist Stefan Karatodorov; Physicist Blagovela Blagoeva; Ph.D. student Stefka Slaveeva; Ph.D. student Nina Koleva; Ph.D. student Georgy Yankov

RESEARCH ACTIVITIES:

RESEARCH AND DEVELOPMENT of new laser sources; optimization of the excitation, laser efficiency and beam quality; processes in the gas discharge plasma:

- In order to increase the output laser parameters for application in laser surgery, a new laser tube design of He-Ne-$SrBr_2$ laser with considerably enhanced active volume is developed with in two versions: without (T1) and with (T2) incompact fill of ZrO_2 insulation in the discharge free zone.
- A 2D model (r, z) to determine numerically the gas temperature distribution in the T1 nanosecond pulsed longitudinal discharge at different binary He-Ne mixture is developed. The radial gas temperature distribution in T2 nanosecond pulsed longitudinal He discharge is analytically determined. By measurement of the relative time-resolved intensities of some He and Ne spectral lines the time-resolved electron temperature is determined in the discharge afterglow for different He, Ne и He-Ne mixtures.
- A kinetic Monte-Carlo model is developed describing the electron behaviour in a hollow cathode discharge (HCD) by following closely the electrons while they travell and collide in the discharge.in terms of kinetic quantities like electron energy distribution function, mean electron energy. Results of the electron energy distribution function, the mean electron energy and the distribution of the ionization events in the discharge volume under typical discharge conditions, are obtained. Analysis of the output data is done with special attention to the influence of the so-called pendulum electrons. The Monte-Carlo simulations of all the electrons in HCD show that there is a high concentration of highly energetic electrons in the whole discharge volume; the concentration is highest in the cathode fall region; showing that the inelastic processes - excitation and ionization are very probable.
- The results from the kinetic model demonstrate that due to the high concentration of energetic electrons in the whole discharge volume, theHCD is very appropriate medium for excitation and ionization of laser ablated material for elemental analysis. As the inelastic collisions have a maximum at the axis, the probability of ionization and excitation of the ablated atoms is higher at the axis, hence, the axis of the HCD is the most suitable place for the registration of the light signal, used for the spectroscopic determination of the elemental

composition. Based on the results of modeling, a discharge tube for combination of laser ablation and emission analysis in a hollow cathode discharge was designed.

LASER APPLICATTIONS:

- A master oscillator-power amplifier (MOPA) system, based on the atomic CuBr vapour laser with divergence close to the diffraction limit (100 μrad), is used for high-precision micromachining of nickel and tool steel samples in order to improve their mechanical characteristics for application in automobile industry. Laser micromachining consists in drilling of microholes in highly polished square plates with 10-mm size of the corresponding material. New software is developed to control the MOPA system and the XY table, on which the samples are placed, for drilling of the microholes by special patterning, i. e. in the apex of equilateral triangle and microhole depth is equal to the hole radius. The microhole diameter and the distance between their centres (the side of the equilateral triangles) are varied for each sample. A minimal diameter of the hole 4-6 μm and heat affected zone of 0.3 μm are achieved.

- The nonlinear properties ant the refraction coefficients of several synthesized multi-component glasses were measured. Quasi-oscillation of second harmonics is observed as a result of defects in the glass causing changes in the matrix symmetry.

- Laboratory set-ups for laser cleaning, based on nanosecond Nd:YAG and CuBr lasers, were built. Optical systems for guiding the laser beam and laser parameters control were designed. The cleaning parameters for different stone, marble, metal and leather samples were determined. Preliminary tests of laser cleaning of real marble and metal archaeological artifacts were done.

PUBLICATIONS:

Journal articles:

1. J.T. Mouchovski, K.A. Temelkov, N.K. Vuchkov, The growth of mixed alkaline-earth fluorides for laser host applications, **Progress in Crystal Growth and Characterization of Materials, vol. 57**, No. 1, 2011, pp. 1-41,. ISSN 0960-8974
2. Temelkov, Krassimir; Slaveeva, Stefka; Vuchkov Nikolay; Analytical calculation of gas temperature and experimental determination of electron temperature in gas discharge in Ne-He mixtures, **IEEE Transactions on Plasma Science, Volume: 39** Issue:3, March 2011, pages**:** 831 – 835, ISSN 0093-3813
3. I.P. Iliev, S.G. Gocheva-Ilieva, K.A. Temelkov, N.K. Vuchkov**,** N.V. Sabotinov, An improved radial temperature model of a high-powered He-SrBr2 laser**, Optics & Laser Technology, Volume 43,** Issue 3, April 2011, Pages 642-647, ISSN 0030-3992, DOI: 10.1016/j.optlastec.2010.09.005
4. K. A. Temelkov, S. I. Slaveeva, L. Lyutov and N. K. Vuchkov**,** Influence of some gaseous additives on gas-discharge parameters and laser performance of a volume-scaled MIR He-$SrBr_2$ laser, **Proc. of SPIE Vol. 7747**, 2011, 77471M.
5. K. A. Temelkov, S. I. Slaveeva, N. K. Vuchkov, L. Lyutov, N. V. Sabotinov, "Determination of Gas and Electron Temperatures for a Powerful MIR He-$SrBr_2$ Laser Excited in Nanosecond Pulsed Longitudinal Discharge", **Proc. of SPIE, vol. 7751**, art. 77510P, 2011, (8 pages).
6. D Mihailova, J van Dijk, M Grozeva, G Degrez and J J A M van der Mullen, , Towards a reduced chemistry module of a He–Ar–Cu hollow cathode discharge*,* **J. Phys. D: Appl. Phys, Vol.. 44,** 2011, 194001 doi:10.1088/0022-3727/44/19/194001, ISSN 0022-3727.

7. М. Замфиров, Н. Вучков, Нека бъде монохроматична, кохерентна и насочена светлина (50 години от създаването на лазера), **Светът на физиката 1**, 2011, стр. 32-40*,* ISSN 0861–4210.
8. М. Замфиров, Н. Вучков, Нека бъде монохроматична, кохерентна и насочена светлина (50 години от създаването на лазера) Втора част (продължение от кн. 1/2011 г.), **Светът на физиката 2**, 2011, стр. 160-178*, ,* ISSN 0861–4210*.*

Conference reports:

1. N. K. Vuchkov, K. A. Temelkov, Lasers Oscillating at deep Ultraviolet Cu^+ and middle infrared Sr lines, International Conference Atomic and Molecular Pulsed Lasers, Tomsk Russia, September 12-16, 2011.
2. K. A. Temelkov, N. K. Vuchkov, Determination of Characteristic Constants for Basic Plasma Processes and Major Plasma Parameters of High power Gas Discharje metal and Metal Halide Vapor Lasers, International Conference Atomic and Molecular Pulsed Lasers, Tomsk Russia, September 12-16, 2011.
3. F. A. Gubarev, N. K. Vuchkov, D. V. Shianov, V. A. Sukhanov, G. S. Evtushenko, S. N. Torgaev, M. V. Trigub, Modelling of Capacitive Discharge Pumping of CuBr laser active element, Atomic and Molecular Pulsed Lasers, International Conference Atomic and Molecular Pulsed Lasers, Tomsk Russia, September 12-16, 2011.
4. N. Soldatov, A. B. Sukhov, T. A. Gorbunova, N. K. Vuchkov, Optical pumping of Cesiu in the Periodic Pulse Discharge , International Conference Atomic and Molecular Pulsed Lasers, Tomsk Russia, September 12-16, 2011.
5. K. A Temelkov, S. I. Slaveeva, V. I. Kirilov, I. K. Kostadinov, N. K. Vuchkov, High-Power Metal Halide Vapour Lasers Oscillating in Deep Ultraviolet, Visible and Middle Infrared Spectral Ranges, Photonica 1011, International school conference on photonicics, August 29 – September 2, 2011, Belgrade, Serbia.
6. S. I. Slaveeva, K. A. Temelkov, N. K. Vuchkov, Analytical calculation of the gas temperature and measurement of the average and time-resolved electron temperatures for a gas discharge in binary He-Ne gas mixtures, 17 VEIT, 2011, Sunny Beach, Bulgaria.
7. T. P. Chernogorova, K. A. Temelkov, N. K. Koleva, N. K. Vuchkov, 2D and 3D gas-temperature models for the gas-discharge plasma of a high-power strontium laser, 17 VEIT, 2011, Sunny Beach, Bulgaria.
8. G.Malcheva, K.Blagoev, M.Grozeva, P.Zahariev, S.Karatodorov, P.Penkova, T.Hristova, D.Vasileva, S.Neikova, P. Leshtakov, 19th International Conference on Advanced Laser Technologies – ALT'11, 3-8 September 2011, Golden Sands, Bulgaria, P-1-LS, Application of Laser-Induced Breakdown Spectroscopy (LIBS) for investigation of ancient metal and ceramic objects.
9. S.Karatodorov, D.Mihailova, J van Dijk, J van der Mullen and M.Grozeva – 17^{th} VEIT, Abstracts, Sunny Beach, Bulgaria 2011, Monte Carlo simulation of a sputtering hollow cathode discharge for laser applications.
10. M.Grozeva, K.Blagoev, G.Malcheva, S.Karatodorov, P.Zahariev, D.Vasileva, P.Penkova and K.Boyadzhiev – LACONA IX, Abstracts, London 2011, LIBS analysis of ancient ceramics from V century B.C. and V millennium B.C.
11. G.Malcheva, K.Blagoev, M.Grozeva, P.Penkova, T.Hristova, G.Ivanov, S.Karatodorov, P.Zahariev - 6th EMSLIBS, Abstracts, Izmir 2011, Qualitative and Quantitative Laser-Induced Breakdown Spectroscopy (LIBS) Analysis for Separation of Technological Groups of Ancient Bronze Objects.

12. K. Blagoev, M. Grozeva, G. Malcheva and S. Neykova 6th EMSLIBS, Abstracts, Izmir 2011, Investigation by Laser-Induced Breakdown Spectroscopy (LIBS) of the Chemical Composition of White Clay Ceramic from Veliki Preslav
13. M.Grozeva, P.Zahariev, P.Penkova, S.Karatodorov, V.Atanasova, G.Malcheva, R.Radvan, M.Similianu, A.Moldovan, L.Ratoiu and L.Angheluta, CONScience 2011 "New techniques and solutions in heritage conservation and restoration", November 2011, Bucharest, Laser cleaning of archaeological artefacts by Nd:YAG and CuBr lasers: a comparison.
14. S. Karatodorov, D. Mihailova, J. van Dijk, J. van der Mullen and M. Grozeva, 23rd NNV-symposium Plasma Physics & Radiation Technology, Lunteren, March 2011, Monte Carlo simulation of a sputtering hollow cathode discharge for laser applications.
15. G. Yankov, H. Yoneda,I. Stefanov,, B. L. Shivachev, T. Petrov, ALT'11 Advanced laser technologies, 03-08 September 2011, Golden Sands, Bulgaria, Nonlinear refractive index measurement of new multicomponent glassy matrix possessing variable nonlinear susceptibility by using z-scan method.

PATENTS: 5

ONGOING RESEARCH PROJECTS:

- Metal vapour lasers: processes in the gas discharge plasma and interaction between laser emission and materials (funded by the budget subsidy of BAS).

- Novel multi-component glass-like telluride matrixes having variable nonlinear optical properties (funded by NSF DO 02-305/2008)

- Laser methods for diagnostics in archaeology (funded by NSF DO 02-274/2008)

- High-End-Performance Solid-State-Power-Supply Copper Lasers for Fine Material Processing ('Indo-Bulgarian Programme of cooperation in Science & Technology: supported by Ministry of Education and Science of Bulgaria by Grant BIn3/07).

- Standardization of laser techniques for investigation and restoration of cultural heritage (Bulgarian-Romanian bilateral agreement: funded by NSF HTC 02-21/2010)

- Plasma technologies and their applications (under the Academy's bilateral agreements – IFFM, Gdansk, PAN, Poland)

APPLIED RESEARCH UNIT

MOLECULAR BEAM EPITAXY

HEAD: **Assoc.Prof. Gencho M. Minchev, Ph.D.**
Tel.: 9795683; e-mail:mbe@issp.bas.bg

TOTAL STAFF: **3**
RESEARCH SCIENTISTS: **2**

Assist. Prof. T. Mincheva, Ph.D.

APPLIED RESEARCH RESULTS:

Patent pending method and instrument for measuring, with ultimate precision, the ratios of frequencies for a number of equal periodic processes have been developed. The method is applicable for a broad range of technical or fundamental measuring tasks exploiting periodic processes or frequency sensors – i.e. for medical diagnostics, field bio-control, precise instrumentation, (nano)technological control, etc. Its resolution is limited only by the unavoidable natural inherent phase noise of the used periodic processes or frequency sensors, so in this narrow sense no other solution could achieve better results. The advantages are clear: precision always closely to the natural limits; principal elimination of all internal souses of errors, imperfections and drifts; universal and "final" solution.

ONGOING RESEARCH PROJECTS:

Budget Project: "Identifying, registration and analysis of three-dimensional structure of biomacromolecules and cellular organelles based on bonding to sensors of a novel measuring equipment by conformal reaction".

MUSEUM

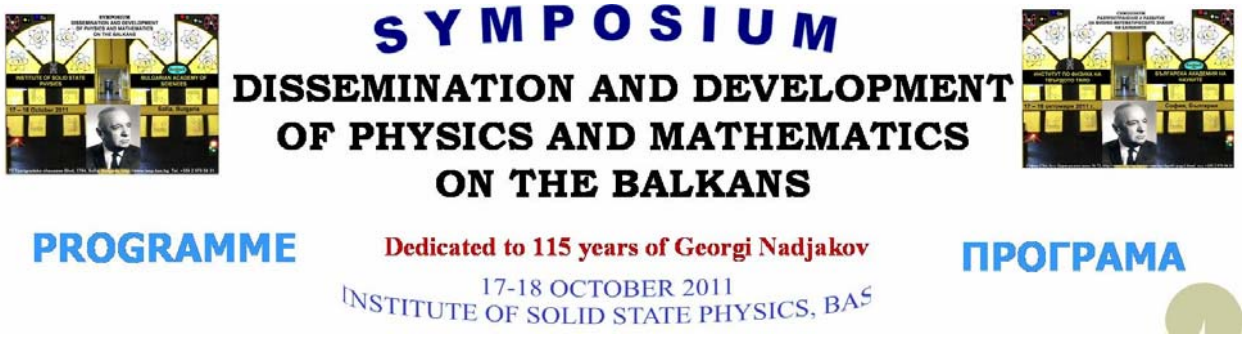
HISTORY OF THE PHYSICS IN BULGARIA

CURATOR: **Assist. Prof. Ganka Kamisheva**
tel. 979 5831, e-mail: gkamish@issp.bas.bg, skype: physmuseum

TOTAL STAFF **1**
RESEARCH SCIENTIST **1**

RESEARCH ACTIVITIES:

Documentary research in the museum fund of Prof. Eugenie Leyarovski presents history of the Laboratory on low temperature physics at the Bulgarian Academy of Sciences. We examine organization history, equipments, biography of some physicists and scientific results in the area of low temperature and superconductivity. Three stages in the history of superconductivity in Bulgaria are determined. The new scientific results are due to integration. Local integration between physicists, chemists and engineers has in the Laboratory. National level of integration between Sofia University and Bulgarian Academy of Sciences has built in the United Centre of Physics (1973 – 1988). The Laboratory for High Magnetic Field and Low Temperatures in Wroclaw gives international integration up to now [1].



The short reportage about third Symposium on history of physics and mathematics examines organization, thematic variations of reports and the participants in this international scientific event held in Bulgaria [2].

Memoirs of the Union of the physicists in Bulgaria carry on tradition since 1973 in electronic version. The names and the photographs of Presidents – physicists (1898 – 2011) are collected [3].

The reports of national seminar "From Rutherford to Collider" held in Yambol (24 - 25 March 2011) are shown in 11 short documentary films. Investigation for history of theoretical physics in Bulgaria illuminates many new areas created by the professors of the Sofia University during the first half of 20th century [4-5].

PUBLICATIONS:

1 G. Kamisheva, Historical remarks for the Superconductivity in Bulgaria, *Dissemination and Development of Physics and Mathematics on the Balkans*, 2011 (in print)

2 Г. Камишева, Разпространение и развитие на физико-математическите знания на Балканите, *Светът на физиката*, 2011 (in print)
3 Г. Камишева, Паметна книга на Съюза на физиците в България 2007 - 2011, *Отчетен доклад на Управителния съвет на Съюза на физиците в България*, VII Конгрес, София, 2011 (СФБ, София, 2011) 45-46
4 G. Kamisheva, Roots of the Theoretical Physics in Bulgaria, *Dissemination and Development of Physics and Mathematics on the Balkans*, 2011 (in print)
5 Г. Камишева, Корените на теоретичната физика в България, *От Ръдърфорд до колайдера*, Сборник с резюмета, Национален семинар, Ямбол, 2011, (НАОП, Ямбол, 2011) 13 – 14