CENTER OF NANOMATERIALS RESEARCH (CNR)

Publications 2016 and Program 2017

Laboratory of Novel Magnetic Materials (Team leader: Valeria Rodionova)

Papers 2016

1) Christina Gritsenko, Irina Dzhun, Georgy Babaytsev, Nikolai Chechenin, Valeria Rodionova, Exchange bias and coercivity fields as a function of the antiferromagnetic layer thickness in bi- and tri- layered thin-films based on IrMn and NiFe, Physics Procedia, 82 (2016) 51 – 55, doi: 10.1016/j.phpro.2016.05.010;

2) V. Bessalova, N. Perov, V. Rodionova, New approaches in the design of magnetic tweezers - current magnetic tweezers, Journal of Magnetism and Magnetic Materials, 415 (2016) 66–71, doi: 10.1016/j.jmmm.2016.03.038;

3) Vladimir V. Khovaylo, Valeria V. Rodionova, Sergey V. Taskaev, Anna Kosogor, Damping Properties of Magnetically Ordered Shape Memory Alloys, Materials Science Forum, 845 (2016) 77-82, doi: 10.4028/www.scientific.net/MSF.845.77;

4) V. Rodioniva, I. Baraban, K. Chichay, A. Litvinova, N. Perov, The stress components effect on the Fe-based microwires magnetostatic and magnetostrictive properties, Journal of Magnetism and Magnetic Materials, 422 (2017) 216–220, doi: 10.1016/j.jmmm.2016.08.082;

5) Manuel Vázquez, Rhimou ElKammouni, Galina V. Kurlyandskaya, Valeria Rodionova, and Ludek Kraus, Bimagnetic Microwires, Magnetic Properties, and High-Frequency Behavior" Chapter 7 in Novel Functional Magnetic Materials, Springer Series in Materials Science 231, A. Zhukov ed. (Springer, 2016) 279-310, DOI 10.1007/978-3-319-26106-5_7

Conferences 2016

1) The annealing effect of the amorphous ferromagnetic ribbons on the magnetoelectric effect in composite multiferroics; I.Baraban, F.Fedulov, L.Fetisov, K.Chichay, V.Rodionova, Università degli studi di Milano (Milan, Italy); 18.04.2016 - 22.04.2016

2) Magnetoplasmonic crystal as a magnetic field sensor, V. Belyaev, A.Grunin, A.Fedyanin, V.Rodionova, Università degli studi di Milano (Milan, Italy); 18.04.2016 - 22.04.2016

3) Experimental protocols for measuring magnetic properties of ferrofluids, Alexander Omelyanchik, Erzsébet Illés, Sara Laureti, Gaspare Varvaro, Valeria Rodionova, Davide Peddis, at al. Università degli studi di Milano (Milan, Italy); 18.04.2016 - 22.04.2016

4) New approaches in the design of magnetic tweezers–current
magnetic tweezers, Valentina Bessalova, Valeria Rodionova, Nikolai Perov; The Community Interest Company for Science (Varna, Bulgari); 08.05.2016 - 11.05.2016

5) Magnetoplasmonic crystals for sensor applications; V. Belyaev, A.Grunin, A.Fedyanin,

V.Rodionova; Tohoku University (Tohoku, Japan); 10.07.2016-15.07.2016

6) Magnetoelastic interaction influence on the micromagnetic structure and dynamics of head-to-head domain wall in microwires; Ksenia Chichay, Valeria Rodionova, Valentina Zhukova, Nikolay Perov, Arkady Zhukov; Swedish STINT (Jūrmala, Latvia); 09.08.2016-13.08.2016

7) Tunable Magnetostatic And Magnetodynamic Properties In Ferromagnetic Microwires; V. Rodionova, K. Chichay, S. Shevyrtalov, A. Omelyanchik, V. Belyaev, I. Baraban, K. Gritsenko; IKBFU (Kaliningrad, Russia); 12.10.2016-16.10.2016

8) Sequential Annealing Of The Ferromagnetic Layer And Its Effect On The Characteristics Of The Magnetoelectric Effect In Composite Structures Amorphous Ferromagnetic - Piezoelectric; I.Baraban, F.Fedulov, L.Fetisov, K.Chichay, V.Rodionova; Ikbfu (Kaliningrad, Russia); 12.10.2016-16.10.2016

9) Tailoring Of Micromagnetic Structure And Dynamics Of Head-Tohead Domain Wall In Microwires By Magnetoelastic Interaction; K. Chichay, V. Rodionova, V. Zhukova, N. Perov, A. Zhukov; Ikbfu (Kaliningrad, Russia); 12.10.2016-16.10.2016

10) The Exchange Bias Effect In Bi- And Tri- Layered Thin-Films Made From Nife And Irmn; Ch. Gritsenko, I. Dzhun, G. Babaytsev, N. Chechenin, V. Rodionova; Ikbfu (Kaliningrad, Russia); 12.10.2016-16.10.2016

11) Measuring Magnetic Properties Of Ferrofluids Using Henkel Plots Protocol; Alexander Omelyanchik, Erzsébet Illés, Sara Laureti, Gaspare Varvaro, Valeria Rodionova, Ana Mrakovic, Vladan Kusigerski, Vojislav Spasojevic, Sanja Vranjes-Djuric, Nikola Knezevic And Davide Peddis; Ikbfu (Kaliningrad, Russia); 12.10.2016-16.10.2016

12) Ni-Mn-Ga Shape-Memory Alloys For Sensor; Pplication; S. Shevyrtalov, V. Khovaylo, Eijiro Abe, Hiroyuki Miki, V. Rodionova; Ikbfu (Kaliningrad, Russia); 12.10.2016-16.10.2016

13) Magnetoplasmonic Crystals For Sensor Applications; V.K. Belyaev, A.A. Grunin, A.A. Fedyanin, V.V. Rodionova; Ikbfu (Kaliningrad, Russia); 12.10.2016-16.10.2016

14) Нелинейный магнитоэлектрический эффект в гибкой композитной структуре (in russia) // Nonlinear magnetocaloric effect in flexible composite structure; I. Baraban, V. Rodionova; RAS (Moscow, Russia); 21.11.2016-25.11.2016

15) Исследование магнитострикционных свойств быстрозакаленных лент состава FeGa и FeSiB (in russia) // Ivestigation of magnetostriction properties of fast tempering FeGa and FeSiB ribbons; I. Baraban, V. Rodionova; RAS (Moscow, Russia); 21.11.2016-25.11.2016

16) Исследование магнитных свойств суспензии наночастиц оксида железа (in russia) // Investigation of magnetic properties of suspension of iron oxide nanoparticles; A. Omelyanchik, V. Bagratashvily, A. Emelyanov, A. Inushkin, V. Rodionova, A. Tandenkov, L. Sajti, B.N.Chichkov; National Research Center «Kurchatov Institute» (Moscow, Russia); 8.11.2016 - 11.11.2016

Program 2017

Objectives

1) Development of 3D-construction of cellular tissue using new Current Magnetic Tweezers (CMT), for that: study of the magnetic properties of magnetite Fe3O4 nanoparticles for biological applications.
2) Development and design of new type of Ni-Mn-Ga Heusler alloys.
3) Investigation of exchange bias and spin valves structures, fundamental components of spintronic devices, and search the way how to enhance phenomena.
4) Development of new multiferroics structures based on polymer piezoelectric and high magnetostrictive wires and ribbons.
5) Experimental Investigation of domain wall dynamics in amorphous ferromagnetic microwires for application in novel magnetic memory and devices.
6) Development of a sensor of external AC and DC magnetic field based on magnetoplasmonic crystals

Description of the activity

1) A new technique will be developed to manipulate individual cells by magnetic tweezers that allow particle and cell manipulation in three dimensions by means of the magnetic field generated by the electric currents flowing through the non-magnetic wires. The research is carrying ou by the groups led by Dr. Valeria Rodionova (Institute of Physics, IKBFU), Prof. Larisa Litvinova (Laboratory of Immunology and Cell Biotechnologies, IKBFU) and Prof. Igor Khlusov from Siberian State Medical University (Tomsk, Russia). The main goals are: a) to optimize the manipulation and to understand the effect of the magnetic field which is created by an electric current in the wires of the tweezer on the biological cells; b) to control of the position of magnetite nanoparticles (e.g. Fe3O4; prepared by the Institute of Structure of Matter of the National Research Council, in Rome). The dynamics of cell motion in a magnetic field is unique for each type of cells due to the different zeta-potentials of cell membranes for example. No theoretical prediction or description exists so far. The main idea of this project is the construction of cellular and tissue structures for implantation of biological tissues in living organism. This can be done through the cultivation and building of cell structures in vitro with nanoparticles by CMT (Reference: New approaches in the design of magnetic tweezers–current magnetic tweezers, by V. Bessalova, N. Perov, V. Rodionova, J. Magn. Magn. Mat. 2016, 415, 66–71). The ultimate goal will ne to understand the influence of a magnetic field on cell dynamics, reproduction and functional activities for repairing malignous cell structures.
2) The activity will be devoted to the search of new materials for eco-friemdly magneto-refrigeration technology (magnetocalorics) and energy saving. In this context a project is devoted to the “Control of structural and magnetic properties by internal stresses in Ni-Mn-Ga based Heusler alloys in form of magnetic microwires and thin films in view of applications in energy saving. Magnetic Heusler alloys are multifunctional materials where the magnetic and structural order are closely connected. The co-occurring of structural and magnetic phase transitions leads to a variety of effects: magnetic field induced strain (MFIS), giant magnetocaloric effect (MCE) and giant magnetoresistance (GMR). Key factors for MFIS, i.e. promising for energy harvesting devices, are high magnetocrystalline anisotropy, high saturation magnetization and modulated crystal structure. To achieve the largest values of these parameters for materials with different forms and sizes (glass-coated microwires, thin films) the understanding of how structural and magnetic properties correlate with a change of form and size is required. When the first attempts of obtaining and studying of thin films and microwires were made, it became clear that optimal

chemical composition of the Heusler alloys for the bulk materials is not optimal for the Heusler alloys in the form of a thin film or microwire. One of the reasons of such discrepancy is the influence of internal stresses (because of glass coating in microwire, substrate in thin films) on the above objects. The dependence of structural and magnetic properties on applied stresses is well studied for Ni-Mn-Ga bulk Heusler alloys, but such behavior is more complex for thin films and microwires and still remains at rudimentary level. The objective of this work is to establish the relationship between structural and magnetic properties in Ni-Mn-Ga Heusler alloys with different forms (bulk materials, microwires, thin films), to find out how internal stresses affect these properties, to explain the mechanism of influence and to find a way how to control the properties through the changes of stresses.

3) The Exchange Bias (EB) phenomenon is still a hot topic of investigation, since it is the basis of spin-valves structures having a wide range of applications (spintronic, MRAM, magnetic field sensors, and memory devices). The main problem is to find ways of enhancing the exchange field value. We are working on thin films based on NiFe, IrMn and FeMn, prepared in cooperation with Dr. Nikolay Chechenin from Lomonosov Moscow State University. It is well established that exchange bias effect and the coercive field depend on the antiferromagnetic layer thickness, as found in in bilayered and trilayered thin films (Ni40Fe60/Ir72Mn25/Ni40Fe60), (Ni45Fe55/Ir72Mn25/Ni45Fe55), (Ni45Fe55/Ir72Mn25), (Ir72Mn25/Ni45Fe55), Ni81Fe19/Fe50Mn50. It was also investigated the influence of the layers deposition sequence and of the composition of ferromagnetic component on the exchange field value. In addition, it was determined the influence of temperature conditions on the exchange bias in above-mentioned structures.

4) There are multiferroic structures actively used in sensors and autonomous power sources. Amplification of the magnetoelectric effect in multiferroic structures is the main objectives for increasing the sensitivity and efficiency of the developed instruments. There is a lot of opportunities in changing settings of multiferroic structures (the using of different materials functional layers, a different arrangement relative to each other functional layers, their sizes, shapes, etc.), which change the interaction between the magnetostrictive and piezoelectric layers.

Presently, our focus is in using materials not only of different compositions but also different geometry as magnetostrictive layer: amorphous ferromagnetic glass covered microwires and rapidly quenched ribbons. On the Fe-based microwires the magnetostriction constants by small angle of rotation of the magnetization vector were measured. The magnetostriction values are in the range ~ 1-2 * 10-5 and this is enough to consider the microwires as a promising magnetostrictive material to create multifrroics based on them. These microwires will be placed in a piezoelectric polymer PVDF, which is the most promising at present. Also we will investigate the magnetostriction coefficient of the ribbons and will measure ME effect in these structures.

5) The investigation of magnetization dynamics in nano- and micro- objects is of a great interest due to its prospects in development of novel magnetic memory and logic devices Such devices can be implemented on the fast domain wall motion. The highest domain wall velocity, up to 8000 m/s, has been obtained in bistable glass coated amorphous ferromagnetic microwires. Besides the amorphous state, the distinguishing feature of these microwires is the presence of internal stresses, which together with magnetostriction result in a significant effect on the magnetoelastic energy and thereby define the micromagnetic structure and reversal magnetization process. Moreover there are many ways of manipulating the magnetic properties and the domain wall dynamics such as annealing, applying a mechanical stresses, changing of the ρ-ratio of the metallic nucleus diameter, d, to the diameter of the glass coated microwire, D and etc.

6) Our work is focused on investigation and comparison of magnetic, micromagnetic, optical and magneto-optical properties of Magnetoplasmonic crystals (MPlCs) based on diffraction gratings for designing a sensor of external AC and DC magnetic field. A prototype of MPlC-based sensor of AC and DC external magnetic field with sensitivity of 10-3 Oe was already developed. Theoretical calculations predict the possible increase of sensitivity up to 10-7 Oe. MPlC-based magnetic field

sensor can be used as a probe for monitoring weak magnetic fields with high spatial - smallest region is about 100 um2, and time resolution is limited only by time of magnetization processes in ferromagnetic layer and has an order of nanoseconds. Now we are searching the ways for achieving the theoretical sensitivity and development of theoretical model, which will connect magnetic and magneto-optical properties of MPlCs.

Expected results

According to the main objectives we are planning to develop novel type of materials with certain properties and develope new type of devices.

Running projects and applications to be submitted

Running (2017-2019): Trapping, pinning and injecting of domain wall in wire with cylindrical symmetry with diameters from submicron to few microns and mechanisms of formation of domain wall dynamics

Collaborations

Please, find here full list of collaborators:
http://lnmm.ru/collaborations/

Other activities (organization of Conferences….)

LNMM with FunMagMa support is organizer of conference in 2017:
http://lnmm.ru/ibcm_2017/

Three-year plan (planned developments and main goals to achieve):

In three year we are planning to achieve:
1) 3D-constructor of cellular tissue using new Current Magnetic Tweezers (CMT) with using of functionalized Fe3O4 nanoparticles.
2) Created new type of Ni-Mn-Ga Heusler alloys in the shape of wire with magnetic first order phase transition.
3) Sputtered exchange bias and spin valves structures, fundamental components of spintronic devices, with enhance phenomena.
4) Created new multiferroics structures based on polymer piezoelectric and high magnetostrictive wires and ribbons.
5) The phenomenological model with theoretical background of domain wall dynamics in amorphous ferromagnetic microwires for application in novel magnetic memory and devices.
6) designed a sensor of external AC and DC magnetic field based on magnetoplasmonic crystal

Laboratory of X-ray optics (Team leader Anatoly Snigirev)

Papers 2016

1) M. Lyubomirskiy, I. Snigireva, A. Snigirev, *"Lens coupled tunable Young's double pinhole system for hard X-ray spatial coherence characterization"*, Optics Express, **24**, 013679, 2016.

2) N. Dubrovinskaia, L. Dubrovinsky, N. A. Solopova, A. Abakumov, S. Turner, M. Hanfland, E. Bykova, M. Bykov, C. Prescher, V. B. Prakapenka, S. Petitgirard, I. Chuvashova, B. Gasharova, Y-L. Mathis, P. Ershov, I. Snigireva, A. Snigirev, *"Terapascal Static Pressure Generation with Ultrahigh Yield Strength Nanodiamond"*, Sci. Adv., **2**, e1600341, 2016.

3) F. Wilhelm, G. Garbarino, J. Jacobs, H. Vitoux, R. Steinmann, F. Guillou, A. Snigirev, I. Snigireva, P. Voisin, D. Braithwaite, D. Aoki, J.-P. Brison, I. Kantor, I. Lyatun, A. Rogalev, *"High pressure XANES and XMCD in the tender X-ray energy range"*, High Pressure Research, doi: 10.1080/08957959.2016.1206092.

4) M. Lyubomirskiy, I. Snigireva, V. Kohn, S. Kuznetsov, V. Yunkin, G. Vaughan, and A. Snigirev, *"30-lens interferometer for high energy X-rays"*, J. Synchrotron Rad., **23**, 1104-1109, 2016.

5) M. Lyubomirskiy, I. Snigireva, G. Vaughan, V. Kohn, S. Kuznetsov, V. Yunkin and A. Snigirev, "30-lens interferometer for high energy X-rays", AIP Conference Proceedings, **1741**, 040022, 2016.

6) M. Polikarpov, I. Snigireva, A. Snigirev, "Focusing of white synchrotron radiation using large-acceptance cylindrical refractive lenses made of single - crystal diamond", AIP Conference Proceedings, **1741**, 040024, 2016.

7) K. V. Falch, C. Detlefs, M. Di Michiel, A. Snigirev, I. Snigireva, R. Mathiesen, "Correction of lateral chromatic aberrations in X-ray compound refractive lens microscopy", Appl. Phys. Lett., **109**, 054103, 2016.

8) S. I. Zholudev, S. A. Terentiev, S.N. Polyakov, S. Yu. Martyushov, V. N. Denisov, N. V. Kornilov, M. V. Polikarpov, A. Snigirev, I. Snigireva and V. D. Blank, *"Imaging by 2D Parabolic Diamond X-ray Compound Refractive Lens at the Laboratory Source",* AIP conference proceedings, **1764**, 020006, 2016.

9) M. Polikarpov, A. Barannikov, D. Zverev, S.A. Terentiev, S.N. Polyakov, S.I. Zholudev, S. Yu. Martyushov, V.N. Denisov, N.V. Kornilov, I. Snigireva, V.D. Blank, A. Snigirev, *"Laboratory and synchrotron tests of two-dimensional parabolic X-ray compound refractive lens made of single-crystal diamond*", SPIE, **9964**, 99640J, 2016.

10) M. Polikarpov, T.V. Kononenko, V.G. Ralchenko, E.E. Ashkinazi, V.I. Konov, P. Ershov , S. Kuznetsov , V. Yunkin , I. Snigireva, V. M. Polikarpov and A. Snigirev, *"Diamond X-ray refractive lenses produced by femto-second laser ablation"*, SPIE, **9963**, 99630Q, 2016.

11) D. Serebrennikov, E. Clementyev, A. Semenov, A. Snigirev, *"Optical performance of materials for X-ray refractive optics in the energy range 8 – 100keV'*, J. of Synchrotron Rad., **23**, 1315-1322, 2016.

12) M. Polikarpov, V. Polikarpov, I. Snigireva, A. Snigirev, *"Diamond X-ray refractive lenses with high acceptance"*, Physics Procedia, **84**, 213-220, 2016.

13) T. V. Kononenko. V. G. Ralchenko, E. E. Ashkinazi, M. Polikarpov, P. Ershov, S. Kuznetsov, V. Yunkin, I. Snigireva, V. I. Konov, «Fabrication of polycrystalline diamond refractive X-ray lens by femtosecond laser», Appl. Phys. A, 122, 152, 2016

14) S. Terentyev, M. Polikarpov, I. Snigireva, M. Di Michiel, S. Zholudev, V. Yunkin, S. Kuznetsov, V. Blank and A. Snigirev, *"Linear parabolic single-crystal diamond refractive lenses for synchrotron X-ray sources"*, J. Synchrotron Rad., **24**, 103-109, 2017.

15) K. V. Falch, D. Casari, M. Di Michiel, C. Detlefs, A. Snigireva, I. Snigireva, V. Honkimaki, R. H. Mathiesen, *"In situ hard X-ray transmission microscopy in material science",* Journal of Materials Science, **52**, 3437-3507, 2017.

Conferences 2016

1) A. Snigirev, "20 years of X-ray refractive optics. New promising prospectives for diffraction limited X-ray sources", International conference on X-ray optics, detectors, sources and their applications, 18-20 May, Yokohama, Japan **(invited)**.

2) I. Snigireva, A. Snigirev, "Coherent high energy x-ray microscopy for the characterization of mesoscopic materials, oral presentation XOPT4-3, International conference on X-ray optics, detectors, sources and their applications (XOPT), 18-20 May 2016, Yokohama, Japan.

3) M. Polikarpov, S. Terentiev, S. Polyakov, S. Zholudev, V. Yunkin, I. Snigireva, Y. Shvyd'ko, V. Blank, A. Snigirev, "Diamond refractive lenses as the breakthrough optic tool for high heat load flux X-ray beams", oral presentation XOPT4-2, International conference on X-ray optics, detectors, sources and their applications (XOPT), 18-20 May 2016, Yokohama, Japan.

4) A. Narikovich, I. Lyatun, D. Zverev, S. Savelyev, I. Snigireva, A. Snigirev, "Metrology of the parabolic profile of X-ray refractive lens", poster XOPTp8-2, International conference on X-ray optics, detectors, sources and their applications (XOPT), 18-20 May 2016, Yokohama, Japan.

5) P. Ershov, S. Kuznetsov, I. Snigireva, V. Yunkin, A. Snigirev, "X-ray diffractometry based on refractive optics", poster XOPTp8-18, International conference on X-ray optics, detectors, sources and their applications (XOPT), 18-20 May 2016, Yokohama, Japan.

6) M. Lyubomirskiy, I. Snigireva, S. Kuznetsov, V. Yunkin, V. Kohn, A. Snigirev, "Hard X-ray in-line interferometers fabricated by Si planar technologies", poster XOPTp8-19, International conference on X-ray optics, detectors, sources and their applications (XOPT), 18-20 May 2016, Yokohama, Japan.

7) I. Lyatun, P. Ershov, A. Goikhman, I. Snigireva, A. Snigirev, "Influence of beryllium microstructure on compound refractive lenses optical properties in X-ray microscopy", poster XOPTp8-28, International conference on X-ray optics, detectors, sources and their applications (XOPT), 18-20 May 2016, Yokohama, Japan.

8) A. Snigirev, "20 years of X-ray refractive optics: Status and New opportunities for diffraction limited X-ray sources", invited, conference Synchrotron and Free electron laser Radiation: generation and applications (SFR-2016), 4-7 July, Novosibirsk, Russia **(invited)**.

9) I. Snigireva, A. Snigirev, "Coherent hard X-ray microscopy for the characterization of mesoscopic materials", invited, conference Synchrotron and Free electron laser Radiation: generation and applications (SFR-2016), 4-7 July, Novosibirsk, Russia.

10) M. Polikarpov, I. Snigireva, S. Terentiev, V. Blank, V. Yunkin, A. Snigirev, “Diamond refractive lenses for diffraction-limited X-ray sources”, oral presentation, conference Synchrotron and Free electron laser Radiation: generation and applications (SFR-2016), 4-7 July, Novosibirsk, Russia.

11) I. Lyatun, P. Ershov, A. Goikhman, I. Snigireva, A. Snigirev, “The CRL's optical properties of beryllium grades IS-50M AND O-30-H”, poster 072, conference Synchrotron and Free electron laser Radiation: generation and applications (SFR-2016), 4-7 July, Novosibirsk, Russia.

12) D. Zverev, A. Narikovich, I. Lyatun, S. Savelyev, A. Snigirev, I. Snigireva, “Development of laboratory metrology for X-ray refractive lenses”, poster 095, conference Synchrotron and Free electron laser Radiation: generation and applications (SFR-2016), 4-7 July, Novosibirsk, Russia.

13) A. Narikovich, D. Zverev, V. Savin, V. Leitsin, A. Snigirev, “The use of laboratory-based X-ray computed tomography for the diagnostics of X-ray refractive optics”, poster 089, conference Synchrotron and Free electron laser Radiation: generation and applications (SFR-2016), 4-7 July, Novosibirsk, Russia.

14) A. Snigirev, “Hard X-ray Micro-optics for new 3d and 4th generation sources: latest developments and applications”, abstract book 38-39, Young scientists summer school “Nanocarbon for optics and electronics”, 24-29 July, Kaliningrad, Russia **(invited)**.

15) I. Snigireva, A. Snigirev, “Coherent hard X-ray microscopy for the characterization of mesoscopic materials”, invited, abstract book 50-51, Young scientist’s summer school “Nanocarbon for optics and electronics”, 24-29 July, Kaliningrad, Russia **(invited)**.

16) P. Ershov, M. Polikarpov, A. Barannikov, D. Zverev, A. Narikovich, I. Lyatun, D. Serebrennikov , A. Goikhman , P. Prokopovich , A. Borisov , I. Panormov , N. Klimova, I. Snigireva, A. Snigirev, “Laboratory based hard X-ray optics test bench”, poster, abstract book 75, Young scientists summer school “Nanocarbon for optics and electronics”, 24-29 July, Kaliningrad, Russia.

17) I. Lyatun, V. Yunkin, I. Snigireva, A. Snigirev, “Using focused ion beam systems for modification and correction X-ray optics elements, poster, abstract book 93, Young scientists summer school “Nanocarbon for optics and electronics”, 24-29 July, Kaliningrad, Russia.

18) A. Narikovich, I. Lyatun, D. Zverev, S. Savelyev, I. Snigireva, A. Snigirev, “laboratory based metrology of parabolic profile X-ray refractive lens”, poster, abstract book 96, Young scientists summer school “Nanocarbon for optics and electronics”, 24-29 July, Kaliningrad, Russia.

19) M. Polikarpov, S. Terentiev, V. Yunkin, I. Snigireva, V. Blank, T. Kononenko, V. Ralchenko, A. Snigirev, “Diamond refractive lenses for diffraction-limited X-ray sources”, poster, abstract book 102, Young scientists summer school “Nanocarbon for optics and electronics”, 24-29 July, Kaliningrad, Russia.

29) D. Zverev, A. Barannikov, I. Lyatun, P. Ershov, I. Snigireva, A. Snigirev, “The high resolution reciprocal-space mapping by refractive X-ray optics”, poster, abstract book 118, Young scientists summer school “Nanocarbon for optics and electronics”, 24-29 July, Kaliningrad, Russia.

21) M. Polikarpov, I. Snigireva, V.G. Ralchenko, T.V. Kononenko, A. Snigirev, “Diamond refractive lenses for high-power diffraction limited X-ray sources”, oral presentation, SPIE Optics and Photonics 9963 conference, 28 August - 1 September 2016, San Diego, USA.

22) M. Polikarpov, S. Terentiev, S. Polyakov, S. Zholudev, S. Martyushov, V. Denisov, N. Kornilov, I. Snigireva, A. Snigirev, V. Blank, “Laboratory test of two-dimensional parabolic X-ray compound refractive lens made of single-crystal diamond”, poster, SPIE Optics and Photonics 9964 conference, 28 August - 1 September 2016, San Diego, USA.

23) S. Terentiev, V. Blank, S. Polyakov, S. Zholudev, A. Snigirev, M. Polikarpov, T. Kolodziej, J. Qian, H. Zhou, Y. Shvyd'ko, "parabolic single crystal diamond lenses for coherent X-ray imaging", oral presentation, SPIE Optics and Photonics 9963 conference, 28 August – 1 September 2016, San Diego, USA.

24) D. Serebrennikov, E. Clementyev, A. Snigirev, "X-ray lens made from cubic boron nitride: performance and basic parameters", poster, SPIE Optics and Photonics 9963 conference, 28 August - 1 September 2016, San Diego, USA.

25) A. Narikovich, P. Ershov, V. Leitsin, V. Savin, A. Snigirev, "Laboratory-based x-ray micro-tomography for diagnostics of x-ray refractive optics", poster, SPIE Optics and Photonics 9967 conference, 28 August - 1 September 2016, San Diego, USA.

26) A. Snigirev, "Coherent X-ray optics for diffraction limited sources", invited, The International Joint School "Smart Materials and X-ray Optics 2016. Modeling, Synthesis and Diagnostics and The International Workshop "20 years of X-ray refractive optics: status and perspectives", 12-16 October, 2016, Kaliningrad, Russia **(invited)**.

27) A. Snigirev, "X-ray refractive optics: 20 years after", invited, The International Joint School "Smart Materials and X-ray Optics 2016. Modeling, Synthesis and Diagnostics and The International Workshop "20 years of X-ray refractive optics: status and perspectives", 12-16 October, 2016, Kaliningrad, Russia **(invited)**.

28) A. Barannikov, P. Ershov, M. Polikarpov, I. Lyatun, D. Zverev, A. Narikovich, D. Serebrennikov, M.Voevodina, N. Klimova, A. Sinicyn, A. Snigirev, "Micro-optics test bench based on the fine focus "Metal jet" X-ray source, poster, The International Joint School "Smart Materials and X-ray Optics 2016. Modeling, Synthesis and Diagnostics and The International Workshop "20 years of X-ray refractive optics: status and perspectives", 12-16 October, 2016, Kaliningrad, Russia.

29). Dudchik Y.I., Ershov P.A., Polikarpov M.V., Serebrennikov D.A. , Goikhman A.Y., Snigireva I.I. and Snigirev A.A, X-ray focusing and imaging with short focal length compound refractive x-ray lens", poster, The International Joint School "Smart Materials and X-ray Optics 2016. Modeling, Synthesis and Diagnostics and The International Workshop "20 years of X-ray refractive optics: status and perspectives", 12-16 October, 2016, Kaliningrad, Russia.

30) I. Lyatun, P. Ershov, I. Snigireva, A. Snigirev, "the influence of beryllium microstructure on the compound refractive lenses optical properties in coherent transmission X-ray microscopy", poster, The International Joint School "Smart Materials and X-ray Optics 2016. Modeling, Synthesis and Diagnostics and The International Workshop "20 years of X-ray refractive optics: status and perspectives", 12-16 October, 2016, Kaliningrad, Russia.

31). A. Narikovich, I. Lyatun, D. Zverev, S. Savelyev, I. Snigireva, A. Snigirev, "metrological methods for the parabolic profile of x-ray refractive lens diagnostics", poster, The International Joint School "Smart Materials and X-ray Optics 2016. Modeling, Synthesis and Diagnostics and The International Workshop "20 years of X-ray refractive optics: status and perspectives", 12-16 October, 2016, Kaliningrad, Russia.

32) M. Polikarpov, I. Snigireva, A. Snigirev, "Diamond refractive lenses with high acceptance", poster, The International Joint School "Smart Materials and X-ray Optics 2016. Modeling, Synthesis and Diagnostics and The International Workshop "20 years of X-ray refractive optics: status and perspectives", 12-16 October, 2016, Kaliningrad, Russia.

33) D. A. Serebrennikov, E. S. Clementyev, A. A. Snigirev, "Characterization of materials for refractive X-ray optics", poster, The International Joint School "Smart Materials and X-ray Optics 2016. Modeling, Synthesis and Diagnostics and The International Workshop "20 years of X-ray refractive optics: status and perspectives", 12-16 October, 2016, Kaliningrad, Russia.

34) D. A. Serebrennikov, Yu. I. Dudchik, A. A. Barannikov, A. A. Snigirev, "X-ray microscopy based on refractive X-ray lens at laboratory microfocus source", poster, The International Joint School "Smart Materials and X-ray Optics 2016. Modeling, Synthesis and Diagnostics and The International Workshop "20 years of X-ray refractive optics: status and perspectives", 12-16 October, 2016, Kaliningrad, Russia.

35) D. Zverev, I. Lyatun, A. Narikovich, M. Polikarpov, I. Snigireva, A. Snigirev, "High resolution X-ray imaging technique for refractive lens metrology", poster, v The International Joint School "Smart Materials and X-ray Optics 2016. Modeling, Synthesis and Diagnostics and The International Workshop "20 years of X-ray refractive optics: status and perspectives", 12-16 October, 2016, Kaliningrad, Russia.

36) A. Snigirev, "20 years of X-ray refractive optics- perspectives for MeV light sources", invited, Nuclear Photonics, 16-21 October, 2016, Monterey, California, USA **(invited)**.

37) A. Snigirev, "Coherent refractive X-ray optics for new diffraction limited X-ray sources", oral contribution, 1st Russian Crystallography Congress: "From Science Convergence to Nature-like Technologies", 21-25 November, Moscow, Russia.

Program 2017: Missing

Laboratory of Analytic-Numeric modeling of nonlinear phenomena (Team leader: Sergey Leble)

Papers 2016

1) Alexander Ivanov and Alexei Ivanov Diamond, Side Resonances: Influence of Isotopic Substitution of CarbonSubmitted to Phys. Lett.

2) Alexander Ivanov and Alexei Ivanov, Side resonances and metastable excited state of NV^- center in diamond; Submitted to TASK Quarterly.

3) Sergey Leble, Dmitry Ampilogov, GENERAL EQUATION FOR DIRECTED ELECTROMAGNETIC WAVE PROPAGATION IN 1D METAMATERIAL: PROJECTING OPERATOR METHOD; TASK quarterly vol. 20, No 2, 2016, pp. 131 –143

4) Stepan Botman and Sergey Leble, Bloch Wave – ZRP Scattering as a Key Element of Solid State Physics Computation: 1D Example; TASK QUARTERLY vol. 20, No 2, 2016, pp. 185 –194

5) Sergey Leble, Dmitry Ampilogov, Directed Electromagnetic Wave Propagation in 1D metamaterial: Projecting Operators Method; Phys. Lett. A. Volume 380, Issues 29–30, 1 July 2016, Pages 2271 –2278

6) A.V. Yurov, V.A. Yurov, "The Landau-Lifshitz equation, the NLS, and the magnetic rogue wave as a by-product of two colliding regular positons" (20 pages, 9 figures), submitted to Physical Review A.

7) A. Botman, S. B. Leble Electrical Resistivity Model for Quasi-one-dimensional structures. (submitted to NANOSYSTEMS: PHYSICS, CHEMISTRY, MATHEMATICS, 2017, 0 (0), P. 1{6)

8) S. B. Leble. Kolmogorov Equation for Bloch Electrons and Electrical Resistivity Models for Nanowires. (submitted to NANOSYSTEMS: PHYSICS, CHEMISTRY, MATHEMATICS, 2017, 0 (0), P. 1{6)

9) D. Verteshchagin. “Dynamics of domain wall in cylindrical amorphous microwires”. (n preparation)

10) A.A. Yurova, A.V. Yurov, V.A. Yurov, “When the supersymmetry is not enough: the parasupersymmetric algebras of the Boussinesq equations”. TASK Quaterly, 20, No.2, pp. 241-248 (2016)

11) Artyom V. Astashenok, Artyom V. Yurov, Valerian V. Yurov "The possible resolution of Boltzmann brains problem in phantom cosmology". Gravitation and Cosmology, 22, Issue 2, pp. 212-219 (2016)

Conferences 2016

a) Workshop "Waves in inhomogeneous media and integrable systems" Gdańsk University of Technology, Gdańsk, Poland; 20-22 September 2016(organized by our group):

1) Dmitry Ampilogov (Kaliningrad)
Interaction of electromagnetic polarization modes in metamaterials. Stationary solutions in elliptic functions.

2) Grzegorz Kwiatkowski (Gdansk)
Green function construction through Moutard transform.

3) Mikhail Vereschagin (Kaliningrad)
Investigation of domain wall dynamics in micro and nano wires using generalized complete integrable discrete Heisenberg chain model

4) Sergey Leble (Kaliningrad)
Kolmogorov equation in propagation problems and iteration series

5) Stepan Botman (Kaliningrad)
Electrical Resistivity Model for Quasi-one-dimensional structures.

b) XXXVI Max Born Symposium (S. Leble – co-organiser)
9th Symposium on Integrable Systems
Wroclaw, Poland, 26 - 28 June 2016

1)V.Yurov,
The construction of exact solutions to the Cauchy problem for the generalized hyperbolic Novikov-Veselov equation

2) S. Leble
Reductions of Yang-Mills equations and mass via quantum correction

3) G. Kwiatkowski
Toward semiclassical dynamics: Green function construction through

c) Mathematical challenge of quantum transport in nanosystems - PIERRE DUCLOS WORKSHOP, Conference in memory of Boris Pavlov, International Conference, Saint Petersburg, November 14 – 15, 2016

1) Sergey Leble (Invited, Kaliningrad, Russia)
Kolmogorov equation for Bloch electrons and Electrical Resistivity Models for nanowires

2) Stepan Botman (Kaliningrad, Russia)
Electrical Resistivity Model for Quasi-one-dimensional structures

d) International Workshop "Waves in inhomogeneous media and integrable systems", (Gdansk University of Technology, 20-22 September 2016)

1) V.A. Yurov

The construction of exact solutions to the Cauchy problem for the generalized hyperbolic Novikov-Veselov equation”

Program 2017

Objectives

Evolution of domain wall in amorphous microwire is three-dimensional problem relates to a propagation of the phase interface in external magnetic field. Its technical significance is well-known and experimental realization is abundant. Available theory, however, is a simple "point' dynamics via Newtonian equation with parametrized coefficients. A fundamental Heisenberg equation describing the phenomenon gives a good platform of the theory construction. The equations in its original version are three-dimensional and nonlinear that is the main challenge of its applications. So, the objective of our investigation is to build the theory using symmetry and other possibilities for the statement of problem simplification. One of known reduction of the problem already exists under the name of Landau-Lifshitz equation, we include such option in our team purposes. Other aims of activity relate to theory of nanowires conductivity, electromagnetic waves propagation in metamaterials and quantum dynamics of few body spin systems with applications to optically detected magnetic resonance in diamond.

2. Description of the activity

Spin systems in diamond. We have applied this approach to bulk diamonds and nanodiamonds, containing NV^-, P1 and ^{13}C centers. The concentration of these centers can be changed with the help of nanotechnology. The interaction of these centers substantially alters their properties, which is reflected in changes in their spectra of optically detected magnetic resonance (ODMR). We carried out calculations of the energy levels and the resonance frequencies in the ODMR spectra for combined $NV^- + P1$, $NV^- + {}^{13}C$, $NV^- + 3\,{}^{13}C$ systems. It is shown, that the properties of the spin states vary greatly in points of level-anticrossing (LAC). In some cases, this change can be attributed to the possible formation of an optically excited metastable state. In general, the calculation results agree well with the experiment.

A new method of construction of exact solutions of **Landau-Lifshitz-Gilbert** equation (LLG) for the ferromagnetic nanowires has been developed. The method is based on the known connection between the LLG and the nonlinear Schrödinger equation (NLS), and resolves an old problem: how to produce multiple rogue wave solutions of NLS. Such solutions – known as P-breathers - have been proven to exist by Dubard and Matveev, but their technique heavily relied on using the solutions of yet another nonlinear equation, Kadomtsev-Petviashvili I equation (KP-I), and on their relationship with NLS. We have shown that in fact one doesn't have to use KP-I but can instead reach the same results just with NLS solutions, provided one dresses them using not standard but binary Darboux transformation. In particular, our approach allows to construct all the Dubard-Matveev P-breathers. Furthermore, the new method can lead to some completely new, previously unknown solutions. One particular solution that we have constructed describes the two positon waves, colliding with each other and in the process producing a new, short-lived rogue wave. We called this unusual solution (rogue wave begotten after the impact of two solitons) the "impacton".

From qualitative analysis of **Heisenberg spin chain** equation and its continuous approximation and scaling procedures used in order to minimize the number of physically relevant system parameters analytic correlation between critical field value needed for magnetization switching and internal parameters of the microwire have been established. A solution corresponding to the observed motion of the domain wall (constant velocity under constant external magnetic field) is proposed for the case of constant anisotropy. Based on this solution the velocity of the domain wall is found and a family of possible shapes of the domain wall is suggested. Euler-Lagrange equations of motion for the considered problem of domain wall evolution in collective coordinates in three dimensions are derived. Several ansatzs that correspond to the expected initial configuration of the system is proposed and collective coordinates of the moving domain wall are proposed. Certain dependencies between parameters and functions that enter into the ansatz are found to satisfy the equations for collective coordinates. The work on selection of the most adequate ansatz and its parameters is started based on experimental data.

Metamaterials. The general nonlinear 1D equations for the left and right waves and two polarizations are derived. We account Kerr nonlinearity and Drude dispersion in both electric and magnetic permeability to obtain the system of generalized Shafer-Wayne equations. The wave trains reductions for linear and CNLS cases are studied. Some analytical solution for interaction of opposite and polarized waves are built.

Conductivity. The problem of a nanowire conductivity is studied from kinetic point of view for quasiclassical Bloch electrons in external field. Few statements of problems with cylindric symmetry for the integro-differential Kolmogorov equation are formulated: dynamics Cauchy problem and two stationary boundary regimes ones. The first is for empty cylinder with scattering of the conduction electrons on walls, the second accounts scattering on defects inside the wire. The integro-dierential equations are transformed to integral ones and solved by iterations. There are two types of expansions with the leading terms in the right and left sides. The iteration series are constructed and its convergence studied. Electron-impurity scattering coefficient of Bloch waves on zero-range potential for one dimensional Dirac comb potential is used for calculation of temperature

dependence of resistivity within kinetic theory. The standard averaging in velocity space is expressed by integral that is evaluated with in advanced numerical procedure.

3. Expected results.

Heisenberg spin chain
Correct description of domain wall propagation in amorphous microwire: Shape of domain wall and velocity of moving domain wall. Its dependence on external magnetic field and defects distribution. A solution corresponding to the observed motion of the domain wall is proposed for the case of constant anisotropy. Based on this solution the velocity of the domain wall is found and a family of possible shapes of the domain wall is suggested.
Spin systems in diamonds. Our proposed method for the analysis of spin states of few body systems can be used for the following application: method of enhanced sensing of internal stress in diamond.
Magnon crystal. Study of the mathematical and physical properties of new magnetic impacton solution. Generalization of binary Darboux method for the bicomponent one-dimensional magnon crystal. Generation of new solutions for the bicomponent magnon crystal, including new P-breather magnetic spin waves for the bicomponent one-dimensional magnon crystals.
Metamaterials. Construction of analytic solutions of EM wave propagation in nonlinear Drude 1D metamaterial in a conventional model of Shafer-Wayne equation level describing reflected waves with polarization account.
Conductivity. Creation of model kinetic description of conductivity of a nanowire with account of temperature and geometry dependence.

4. Three-year plan.

Spin systems. The most important direction of development of our method will use it to describe few body spin systems in external oscillating fields. This development approach will help to solve important applied problem: NV-spin polarization transfer to the P1-spin bath in diamond.
Magnon crystals. Extending our technique for the case of multicomponent one-dimensional model. Generalize our approach for two-dimensional case of multilayered ferromagnetic, using the relationship between the LLG for this system and the (2+1) generalization of NLS. Construction of P-breather solutions for magnon crystals with arbitrarily many components.
Domain walls propagation. Appropriate choice of functions and parameters of ansatz to fit the observed data. Verification of the results by means of numerical simulation. Generalization of the approach to the multi-domain case. Generalization of the approach to nanowires case.
Metamaterials. Applications of Drude model for magnetic permeability, taking absorption into account. Collaboration with experimental group of FunMagMa on reflection of EM pulses from a metamaterial. Transition to 3D description, starting with rectangular and cylindrical waveguides filled with metamaterials. Construction of solutions of nonlinear EM propagation problem in elliptic functions
Conductivity. To develop complete kinetic description of Bloch electron scattering and conductivity of nanowires in presence of magnetic field.

5. Collaborations

The project is aimed to support experimental research of the laboratory of Novel Magnetic Materials of I. Kant Baltic State University, concerning the domain wall propagation in bistable amorphous microwires, done by Ksenia Chichay, governed by dr. Valeria Rodionova (both

members of FunMagMa) The project is being developed in collaboration with prof. Sergey Leble and Dr. Grzegosz Kwiatkowski (the members of the FunMagMa Project). A collaboration with Applied Physics and mathematics (center of nanotechnology and theoretical physics department) of Gdansk University of Technology related to analytic-numerical modelling of energy and charge transport processes. On magnon crystals: Prof. Smirnov A.O; Prof. Matveev V.B., Saint-Petersburg State University of Aerospace Instrumentation, Dr. Pavlov M.V., Novosibirsk State University.

Laboratory of Magnetic resonance methods for the study of matter (Team leader: **Galina Kupriyanova)**

Papers 2016

1) G.V.Mozzhukhin, V.Z.Rameev, G.S. Kupriyanova, P.Aksu, B.Aktas. Cross- relaxation enhances NQR Ammonium Nitrite in low magnetic field. In Magnetic Resonance Detection of Explosives and illicit Materials. Springer 2014, p 45-59

2) G.V.Mozzhukhin, J.Barras, G.S. Kupriyanova, V.Z.Rameev Two-Frequency Nuclear Resonance for Line Identification. Applied Magnetic Resonance. V.45, N12 2015, p. 261-165

3) N.Ya. Sinyavsky, I.G. Mershiev and G.S. Kupriyanova. Special Features of application of the inversion –recovery method for broad NQR lines; *Russian Physics Journal, Vol. 58, No. 12, April, 2016 cmp. 1876-1878*

4) N.Ya. Sinyavsky, I.G. Mershiev and G.S. Kupriyanova. The study of polymorphic states of paradichlorobenzene by means of nuclear quadupole resonance. Solid state Magnetic Resonance. 2016 Jule http://dx.doi.org/10.1016/j.ssnmr.2016.07.002

*5)*A.Bogaychuk, N. Sinyavky, G. Kupriyanova. Investigation of polymer degradation using NMR relaxometry with inverse Laplace transformation. **J. Applied Magnetic Resonance.V.47 N12 2016 p.** 1409-1417

6)G. S. Kupriyanova, A.N.Orlova. Simulation of the FMR Line Shape. Physics Procedia (2016) pp. 32-37 DOI information: 10.1016/j.phpro.2016.05.007

7)Mershiev I.G., Kupriyanova G. S. Portable nuclear magnetic resonance. The patent for useful model. 2015100995/28, 12.01.2015

8)N.Ya. Sinyavsky, G.S. Kupriyanova, P. Dolinenkov. Distribution of times of relaxation ЯКР in rotating system of co-ordinates in microdimensional crystals. Vestnik BFU im. I. Kanta 2015, №4, 18-24

9)N.Ya. Sinyavsky, I.G. Mershiev and G.S. Kupriyanova. Application of nuclear quadrupole resonance relaxometry to study the influence of the environment on the surface of the crystallites of powder. Zeitschrift für Naturforschung 70(6) A, (2015) 451-457

10)N.Sinyavsky, P.Dolinenkov, G.Kupriyanova. T1 and T2 relaxation times distridution for 35 CL and 14N NQR in micro-composites and in porous materials. Appl. Magn. Reson. 2014, V.45 N5 p.471-482

11) Figen Ay, Bulat Z. Rameev, Ali Cemil Başaran, Galina S. Kupriyanova. **Magnetic Properties of Fe/Ni and Fe/Co Multilayer thin film. J. Applied Magnetic Resonance 2016 V.47 11 p. 1-15** DOI:10.1007/s00723-016-0849-6)

Conferences 2016

1) G.V.Mozzhukhin, G.S. Kupriyanova, I.G. Mershiev, S.V.Molchanov. Signal Processing in NMR/NQR detection on the base of pattern signal. MSMW 21-24 June 2016 Kharkiv, Ukraine.

2) A. Bogaychuk, M. Dambieva, G.Kupriyanova, S.Babak. Compare acetonitrile and solid-phase extractions for sample preparation of plasma at metabolom study by NMR. Modern Development of Magnetic Resonance. Kazan, 2016, October 31- November 4 p.119

3) S. Mamadazizov S., G.Kupriyanova. NQR relaxation distribution of 5 - aminotetrazole monohydrate. Modern Development of Magnetic Resonance. Kazan, 2016, October 31- November 4 p.155-157

Program 2017

Objectives

1)The first direction of investigations is to develop of two-frequency methods of nuclear quadrupole - nuclear quadrupole resonances (NQR-NQR) and nuclear - nuclear quadrupole nuclear magnetic resonances, (NMR-NQR) and NMR-NMR and processing of experimental results for study the solids structure and their properties. The development of NMR/NQR two-frequency methods aim at expanding the class of substances and to get the more detailed information about the structure of matter, and to study a polymorphism of matter and to identify a substance.

2)The second direction of investigations is the development of NMR and NQR relaxation spectroscopy, which allows us to investigate the dynamic processes in multispin systems to extract data about the molecular mobility in composite materials as well as materials exposed to radiation, pressure, heat and also in technical and natural liquids

Description of the activity

The follow researches were carried out in our laboratory.
1) One of the studies is related to the development of relaxation NMR / NQR spectroscopy methods and application of these methods to the study of different effects. ^{1}H NMR relaxation spectroscopy was used to study the effect of radiation on the sample, the aging processes of matter. The distributions of spin–lattice and spin–spin relaxation times of nuclear magnetic resonance are used to characterize the mobility of different parts of the polymer macromolecules and to analyze the crosslink density of the polymer chains. A change in the distribution of relaxation times is applied to detect the changes of the polymers quality caused by the influence of ozone, ultraviolet radiation, temperature cycling, and stretching deformation.

2) ^{14}N and ^{35}Cl NQR relaxation methods have been developed for the study of phase transitions and size – effects. The new results of the experimental study of the molecular crystal of

paradichlorobenzene in α - and β - phases by means of NQR - relaxometry with the inversion of Laplace transformation were obtained. The anisotropy effect of the pore space of wood on the distribution of times of the spin-lattice relaxation of p-C6H4Cl2 in the pores of pre-impregnated with the molten sample is shown. It was established that the increase in the T1 spin-lattice relaxation time of 35Cl nucleus in the wood pores (channels) is observed in the case when the radio frequency field B_1 is parallel to the tracheid's of wood. The NQR T_1 dispersion analysis of paradichlorobenzene in α- phase was carried out for the first time.

3) Some NQR/ NQR techniques were developed for the identification of substances.
Two possible modifications of two-frequency ^{14}N nuclear quadrupole resonance (NQR) technique for the identification of resonance lines in NQR spectra had been studied and applied to identify of organical substances, medications. The first one is the use of a single coil for two close frequencies, while the second one utilizes two coils for two different resonance frequencies. Two-frequency methods have been applied to the 5-aminotetrazol to identify the spectral lines and to study the polymorphism of nitrogen compounds. This work was carried out in cooperation with the Gebze Technical University, Department of Informatics, King's College London, Strand, London.

4) The second direction of our research was related to the study of magnetic nanostructures (film) by FMR (definition and magnetic crystalline anisotropy, decay constant) and the development of quality diagnostic model structures designed for the memory elements according to the angular dependence of the FMR signals in - plane and out – of-plane. Magnetic properties of ferromagnetic bilayers such as Fe/SiO2/Ni and Fe/SiO2/Co have been investigated by room-temperature ferromagnetic resonance (FMR). Standard four-point magneto-transport measurements at various temperatures have been performed. Magneto-transport measurements have shown the predominant contribution of anisotropic magnetic resistance both at room and low temperatures. FMR studies of Fe/SiO2/Ni and Fe/SiO2/Co samples have revealed additional non-uniform (surface and bulk SWR) modes, which behavior has been explained in the framework of the surface inhomogeneity model. This work was carried out in cooperation with the Gebze Technical University.

Expected results

It is expected to work out the new equipment for the registration of the double resonance signals NMR -NQR allowing to investigate NQR spectrum in a wide frequency range. It is expected to develop NQR sensors for research the substances with ^{14}N, ^{63}Cu, ^{65}Cu, $^{121,123}Sb$ nuclei by NQR-NQR methods.

The investigation the tetrahedrites (Cu12Sb4S13 and Cu10Cr2Sb4S13 Cu12Sb3.8As0.2S13 Cu11.8Au0.2Sb4S13 Cu2SeO4), to focus on establishing the relationship between the topology of the magnetic structure, the structure, the anisotropy of the electrical and magnetic properties will be carried out by NMR /NQR methods.

The study a polymorphism on the base NQR/NMR spectra of a number of substances containing ^{14}N, ^{63}Cu, ^{65}Cu nuclei will be carried out.

The distributions of spin–lattice and spin–spin relaxation times of nuclear magnetic resonance will be carried out to characterize the mobility of different parts of the polymer macromolecules and to analyze the crosslink density of the polymer chains. It is expected to continue studies polymeric structures which exposed to destruction by NMR relaxation methods.

Running projects

Grant Tubitak **05/12/2016** N **21514107-115.02-E.249070**

Collaborations

Gebze Technical University

Research and Education Center "Fundamental and Applied Photonics. Nanophotonics" (team leader: Ilia Samusev)

Publications 2016

1) Letuta S.N., Pashkevich S.N., Ishemgulov A.T., Lantukh Yu.D., Alidzhanov E.K., Sokabaeva S.S., Bryukhanov V.V. Delayed luminescence of erythrosine in biological tissue and photodynamic therapy dosimetry. Journal of Photochemistry & Photobiology, B: Biology (2016) 163, 232-236.

2)Samusev I.G., Tukhomirova N.S., Slezhkin V.A., Zyubin A.Yu., Bryukhanov V.V., Tsibulnikova A.V. Silver nanoparticles plasmonic effect on eosin and rhodamine 6G luminescence in various media. Proceedings of SPIE (2016)

3) Tikhomirova N.S., Myslitskaya N.S., Samusev I.G., Bryukhanov V.V. Plasmon enhancement of electronic energy transfer between quantum dots on the surface of nanoporous silica. Journal of Applied Spectroscopy (2016) 82, 6, 961-969.

4) Konstantinova E.I., Zyubin A.Yu., Slezhkin V.A., Samusev I.G., Bryukhanov V.V. Plasmon enhancement of Raman scattering and fluorescence for rhodamine 6G molecules in the porous glass and PVA films with nanoparticles of silver citrate hydrosol. Journal of Physics: Conference Series (2016) 737, 012037.

5) Didenko N.V., Konyashchenko A.V., Kostryukov P.V., Losev L.L., Pazyuk V.S., Tenyakov S.Y., Bryukhanov V.V. Temporal compression of pulses from a 100-kHz-repetiton-rate femtosecond ytterbium laser. Quantum Electronics (2016) 46, 8, 675-678.

Conferences 2016

1) *6th International Conference on Nanotechnology and Biosensors* (December 12 – 14, 2016, Amsterdam, the Netherlands). Tikhomirova N.S., Myslitskaya N.A., Samusev I.G., Bryukhanov V.V. Plasmon enhancement of Electron Energy Transfer between Quantum Dots on the PMMA Surface.

2) SPIE PHOTONICS-ASIA (October 12 – 14, 2016, Beijing, China). Samusev I.G., Tikhomirova N.S., Slezhkin V.A., Zyubin A.Yu., Bryukhanov V.V., Tsibulnikova A.V. Silver Nanoparticles Plasmonic Effect on Eosin and Rhodamine 6G Luminescence in Various Media.

3) XXII International Conference "Optics and Spectroscopy of Condensed Matter" (Sep. 18 – 24, 2016, KubSU, Agoy, Russia). a) Tikhomirova N.S., Slezhkin V.A., Myslitskaya N.A., Samusev I.G., Bryukhanov V.V., Petrovskaya Yu. A. Silica adsorbate Layer Structure and Temperature Effect on Rhodamine 6G Fluorescence Complex Quenching by Outer Heavy Atoms and Silver

Nanoparticles. b) Konstantinova E.I., Matveeva K.I., Slezhkin V.A., Bryukhanov V.V., Evtushenko Ya. A. Energy Deactivation Plasmonic Processes in Silver Nanoparticles Doped in Polymer Matrix. c) Tikhomirova N.S., Myslitskaya N.A., Zyubin A.Yu., Samusev I.G., Bryukhanov V.V. Donor-Acceptor Interaction in Semiconductor Quantum Dots on the Silica Surface and in PMMA film.

4)XIV International Scientific Conference "Innovations in Science, Education and Managing-2016" (May 25 – 28, 2016, KSTU, Kaliningrad, Russia). a) Konstantinova E.I., Zyubin A.Yu., Evtushenko Ya. A., Slezhkin V.A., Bryukhanov V.V. Rhodamine 6G Molecules Raman Scattering on the Glass Porous Surface Modified by Silver Nanoparticles. b) Slezhkin V.A., Bryukhanov V.V., Tsibulnikova A.V., Petrovskaya Yu. A. Silver Surface with Adsorbed R6G Molecules Refractive Coefficients. c) Tikhomirova N.S., Myslitskaya N.A., Matveeva K.I., Makhneva E.I., Samusev I.G., Bryukhanov V.V. Silver Nanoparticles Plasmonic Energy Migration near Acryflavine Molecules on the Nanoporous Silica Surface. d) Tsarkov M.V., Borkunov R.Yu., Zemlyakova E.S., Slezhkin V.A., Bryukhanov V.V. Methylene Blue Application for Solar Energy Transformation into Electrical in the Solar Cell Base on Titanium Dioxide. e) Tsibulnikova A.V., Bryukhanov V.V., Slezhkin V.A. Silver Surface with Various Porosity Ellipsometry.

2)

5)International Forum for Young Scientists "Lomonosov-2016" (April 18 – 20, 2016, MSU, Moscow, Russia). Konstantinova E.I., Zyubin A.Yu., Slezhkin V.A., Bryukhanov V.V. Sol silver Nanoparticles Raman Spectroscopy on the Glass Porous Surface.

6) *International Conference on Photonics and Information Optics* (February 3 – 5, 2016, MPhI, Moscow, Russia). Konstantinova E.I., Zyubin A.Yu., Slezhkin V.A., Samusev I.G., Bryukhanov V.V. Plasmon Enhancement of Raman Scattering and Fluorescence of Rhodamine 6G Molecules in the Porous Glass and PVA films with Nanoparticles of Silver Citrate Hydrosol.

Program 2017

Objectives

1. Organic Fluorophors and Metal Nanoparticles Photoprocesses Study in the Biological Liquid Evaporating Droplets.

2. Plasmon Energy Transfer from Silver and Gold Nanoparticles in "Quantum Dot – Porphyrin – Silver Nanoparticle" Complex Study for Porphyrine Compounds – DNA Interaction Sensor Development.

3. Research and Development of Coherence-Based Optical Methods for the Measurements and Analysis of the Dynamic Events.

4. Study of Silver Nanoparticles and Quantum Dots Photoprocesses in Perovskite-Based Photovoltaic Cells.

5. Cold Plasma Production Methods Study.

6. Investigation of the Plasmon Energy Transfer Mechanisms of the Gold and Silver Nanoparticles in CdSe Shell Quantum Dots with Porphyrin Compounds Molecules.

7. Plasmon Excitation in the Singlet-Triplet Complexes of Metal Nanoparticles with Coumarin and Xanthene Dyes in Polymer Films over a Wide Range of Temperatures.

Research Activity Description

1. Protein (HSA) and acid structuring in a biological liquid evaporating droplet (involving diffusion and capillary flow of organic compounds and silver nanoparticles) is studied in the project by means of absorption/fluorescence spectroscopy (incl. time-resolved), interferometry and Raman spectroscopy.

2. The study of semiconductor structures based on quantum dots is currently a special position due to the use of these compounds in biomedicine. Quantum dots are used as biological markers for molecular systems, i.e. in applications that require scalable, tunable wavelength optical properties. Luminescence of quantum dots can be excited by a broad range of wavelengths, therefore they can have optical fluorescent characteristics are of particular interest. The process of formation of multicomponent systems based on quantum dots is quite complex due to different exchange mechanisms arising from the contact of nanocrystal quantum dots with a molecular object. In the same context, the environment in which components are placed is of great importance. Currently, in our opinion, not all excited states of quantum dots have been studied enough, especially in combination with other objects. Thus, the project is expected to fill this gap and try to expand the physical capabilities of quantum dots in combination with the compounds of the class of porphyrins, modified with nanoparticles. The molecules of porphyrins and mesoporphyrin are a good sensitizer to generate active forms of oxygen (singlet), therefore, this dye has found its application in the field of medicine, namely to photodynamic therapy. Mechanisms of formation of various forms of porphyrin compounds is now quite well studied mainly in the framework of absorption and fluorescence analysis. Spectral studies of the properties of the complexes of these compounds with particles of zinc, silver, gold, which largely are in the nature of chemical research were carried out. In this regard, there is a need for more in-depth analysis with the determination of optical properties of porphyrin compounds in the presence of nanoparticles of noble metals:
- in the framework of the kinetic studies at various temperatures;
- in the study of Raman spectra with participation of a plasmon energy of gold nanoparticles in a wide range of wavelengths (from UV to mid-IR range) that, in our opinion, will bring many new results and provide answers to questions about the mechanisms of energy transfer in the complexes of the porphyrin-gold nanoparticles. The processes of energy transfer and quenching in the system of semiconductor quantum dots with a CdSe core and molecules of porphyrin compounds in the presence of plasmon oscillations, generated in the noble metal nanoparticles of different sizes and optical properties will be studied during the project. Methods of creating a polymer medium with embedded quantum dots, nanoparticles and porphyrins will be developed. This part of the project will deal with the special role of the plasmonic interactions of metal nanoparticles in the studied complex.

3. Different dynamic processes in the behavior of both mechanical and biological systems may significantly affect their functional characteristics and increase the deformations that lead to the destruction of these systems. There are plenty of factors such as periodic and-non periodic loading, no stationary processes, thermal influence; extreme events (destruction, high speed movements) may change the state of an object. The dynamic processes investigation is a task, which is especially important in aeronautics and space industries, as well as in applied materials technology. We propose to use the coherent optical non-destructive testing methods, which include the method of digital holographic interferometry and digital holographic microscopy. These methods are based on a comparison of the phase of two or more wave fronts are recorded and reconstructed as holographic images. The main advantage of methods is a high sensitivity to displacements and deformations of an object or to changing of the refractive index in transparent (phase) objects. The sensitivity is determined by the wavelength of the radiation used in hologram recording, and is

approximately 50 nm. However, modern digital technology reaches the sensitivity up to λ/1000 (5-10 nm). The basic task of the investigation is the development of new methods and techniques for the dynamic events investigation in solid state bodies. The results could be used for the diagnostics in microstructures and micro objects as well. In order to solve the task, the digital holographic interferometry method was chosen. Recently, this technique has a high sensitivity to the deformation and defects determination and may investigate a wide class of physical objects. The method could be combined with digital microscopy. A common approach to measuring and monitoring of dynamic processes will create conditions for the developing of measuring systems for the aerospace industry, the industry of micro- and nano-systems.

4. Photoprocesses, taking place in developed hybrid photovoltaic solar energy converter in VIS- and near IR-wavelength range based upon perovskite doped with metal nanoparticles and semiconductor quantum dots are investigated. In order to study nanoparticles plasmon energy conversion along with quantum dots electronic excitement leading to photocurrent production, spectral-kinetic methods and new types of metall-organic compounds instead of lead (Pb) are used. The development of technologies has led to the need of developing methods of synthesis of new inorganic compounds and materials with different properties based on them. Among the compounds for which there is a possibility of purposeful change of properties due to the controlled change of the composition there is highly representative family of perovskites and related perovskite-like crystals. They are characterized by a great diversity of compositions in combination with important, practical properties. Currently, the interest in perovskites is growing rapidly, new research in the framework of this topical and fast developing field of nanotechnology appear. The physical and chemical properties of nanomaterials, their production and application are widely studied. At the moment there is a need for the creation of multifunctional materials combining various properties, e.g., magnetic semiconductors, nanocomposites metal-dielectric, metal nanoparticles and quantum dots. According to the afore-mentioned, the materials with perovskite structure that possess important properties in nano sized state are very interesting and perspective. The synthesis of these nanoparticles is still labour intensive and traditional methods (Sol-gel method, hydrothermal synthesis, etc.) are accompanied by subsequent high temperature treatment leading to grain growth and assembly of particles. The development of cheaper industrial methods of producing nanoparticles, preserving their crystallinity is extremely actual. In addition to new methods of obtaining materials based on perovskites appear and new applications of this class of compounds. One of the most important tasks of modern chemistry, optics and music library is the comprehensive fundamental study of compounds, to identify the relationships in the system "composition-structure-properties-performance". Despite the fact that the perovskites are one of the largest collections in the chemistry of solids, the information about the synthesis, the study of the structure and determination of some physico-chemical properties of hybrid perovskites embedded in their composition with metal nanoparticles and semiconductor quantum structures (currently available in the scientific literature) is fragmented. The relevance of this project is reflected in the following concerns the creation of structures based perovskites:
- effective selection of the cations and anionic dyes;
- determination of the mechanism and impact of nanoparticles (including porosity, concentration and temperature) on the efficiency of energy conversion based on the experience of work on research of influence of metal nanoparticles on the singlet and reverent state of the phosphors, as well as studies of photochemical phenomena on the sorbent;
- influence of quantum dots on the efficiency of the studied cells obtained and (additional energy transferred from the quantum dots, should result in increased efficiency of the excited states of the perovskite with the generation of eximers);
- accounting for the combined influence of quantum dots and nanoparticles in the transformation of electronic energy;

- in the research process of aging of cells must be obtained original results on the study of triplet states and the influence of singlet oxygen and excited states of a cell.

5. The important research perspective is the integrated study of the physical processes leading to obtaining a jet of low-temperature plasma with low gas temperature in various electrode systems that ensure the discharges in different gases at atmospheric pressure. Studies using established mathematical models describing plasma-chemical processes in various electrode systems in gases of different varieties, will facilitate the implementation of optimum conditions and methods of obtaining the jet low-temperature plasma with a gas temperature less than 40 degrees Celsius.

6. We propose to investigate the processes of energy transfer in the system of semiconductor quantum dots CdSe core and molecules of porphyrin compounds in the presence of plasmon oscillations, generated in the noble metal nanoparticles of different sizes and optical properties. The methods of creating a polymer medium with embedded quantum dots, nanoparticles and porphyrins will be developed. The study examines the special role of the plasmonic interactions of metal nanoparticles in the studied complex.

7. The project is planned amount of works on determining the mechanisms of energy transfer in the complex of coumarin and xantene compounds under resonant photo-excitation of surface plasmons of noble metal nanoparticles using methods of spectral-fluorescence analysis, Raman spectroscopy. The feasibility of performing works with the Grodno State University for Ya. Kupala due to a rich base of laser equipment (solid, liquid and gas lasers, including technological, as well as excimer lasers, DFB lasers and tunable dye lasers of their own making) working in a wide range of wavelengths. Such opportunities will allow us to explore the mechanisms of photoprocesses in the visible region, UV, IR and provide a huge range of kinetic characteristics of the excited states of the dye molecules. That is a large range of wavelengths allows the use of selected dyes xantene and cumarin series. The use of excimer laser will allow us to investigate photoprocesses in biopolymers complexes with the dye molecules and nanoparticles. Ability of of the X-ray spectrometer use will allow to identify possible changes in the composition of the investigated complexes.

Expected Results

1. The theoretical diffusion- and capillary flows simulation will be developed in order to study the photo-processes accompanying the interaction between organic compounds and metal nanopartcles in evaporating biological liquid droplet. The experimental unit bases on interferometry and Raman spectroscopy methods will be developed to investigate the photo-processes which affected by diffusion/capillary flows in the droplet.

2. The relevance of the results that are expected to be obtained to the end of the project, is due to the current state of research on selected topics. All of the above research can be divided into three big components, the components of which are the following:
- the interaction of quantum dots with the sensitizer – porphyrin;
- the interaction of the combined system quantum dot-porphyrin with gold nanoparticles;
- interaction cluster of nanoparticles of Ag-Au system quantum dot – porphyrin;
- interaction cluster of nanoparticles Ag/Au system quantum dot – G-complex (G-quadruplex) (the third year of the project).
A new detection mode based on reversible “turn-off/on” fluorescent change of quantum dots enhanced by plasmon transfer from silve/gold nanoparticels will be established to study the interaction between porphyrin TMPyP and G-quadruplex. In addition, it will be clarified that the fluorescent probes can be used for the study of spatial factors, especially the different G-quadruplex structures. The results will show that this reversible fluorescent “turn-off-on” mode is a promising

approaching for the design of highly sensitive G-quadruplex probe and for the future study of the interactions between anti-cancer drug molecules and complex-structured DNA.

3. Novel approaches will be found along with the spatial scale methods of dynamic processes in physical objects study will be obtained during the research work:
- Methods of registration and study of multi-frequency resonant oscillatory processes in mechanical systems for related and unrelated vibrations.
- The method of direct phase recovery for reconstruction of the object points displacements for complex multi-frequency oscillatory process.
- Frequency components of the composite oscillations separation algorithm with the possibility of reconstruct the displacement surface deployed in time (4D view). Quantitative data on multi-oscillatory processes obtaining (values of displacements and amplitude).
- Critical mechanical processes registration and research methods: rupture, delamination, impact excitation. Localization of such processes and the displacements and (or) the object deformation in critical points values identification. Determination of deformed state quantitative values (displacement, deformation, residual stresses).
- With the use of the digital holographic interferometry and digital holographic microscopy methods, a diagnostic method for microstructural investigation of small spatial scale object dynamic states will be proposed, including critical stresses conditions.
- Proposed and developed methods and algorithms testing results in composite materials research (biocompatible ceramics) and structural materials under dynamic stresses.

4. As a result of the work program implementation on the project will have to achieved the following scientific and technological results:
- first in the North-West of Russia, research group on the development and study of hybrid solar converters with powerful modern spectral instrument base (list attached) will be organized in the Baltic Federal University;
- combined optical-electronic unit with non-monochromatic spectral excitation (analogous to the solar spectrum) and selective laser-pulse photoexcitation at seven wavelengths with nanosecond, picosecond and femtosecond excitation, including low-temperature cryostat and all optical and electronic devices required to achieve project objectives will be created;
- the technology of obtaining nanoparticles of metals (silver, gold, copper) the set of optimal (and scientifically proved) of the amount by chemical synthesis and femtosecond laser ablation in liquid environment to control the radii of the nanoparticles on the installation photo correlation spectroscopy will be developed;
- the original technology of deposition of silver clusters on the surface of the porous perovskite and titanium oxide at high temperatures with the purpose of reception centers plasmon energy near the electronic States of semiconducting perovskite and strengthening the processes of giant impacts on these conditions, increasing the efficiency of generation of excitons will be developed;
- the method of production of inexpensive quantum dots by laser ablation of ZnO crystals in organic solvents will be developed;
- the method of assembling the single cells on the basis of the classical perovskite structure will be mastered.
In the first series of experimental studies assemblage (collected design) converters of the Swiss company Solaronix will be studied. The study of the processes of transformation of stationary and pulsed radiation of the near UV, visible and near IR ranges on the samples Solaronix will be determined by the conversion efficiency at standard, manufactured for scientific labs solar converters. The technique of research of standard samples of cells to determine their topographic conversion efficiency of light energy at different points of the cell, studied the spectral and kinetic features of the conversion of the radiation at these points, the kinetics of photocurrent rise and fall times, efficiency, etc. features that are not available to researchers hybrid converters who wish to

work in this field of science and technology will be perfected. Based on the research strategy, further cells to the project will be determined. This study is important also from the metrological point of view, since currently, such standards do not exist. The obtained characteristics of modern single-channel converter will allow scientists to determine weaknesses and to identify ways to improve by hybridization of the cell. Assembly-based Solaronix compounds experiments will be carried out with the introduction into the cells of the dyes of anionic and cationic type, which will serve as transformers of light energy to electronic energy transfer at semiconductor - particles of perovskite (in the use of organic-metallic complexes of iodide of lead type perovskite structure, hereinafter referred to as perovskite), in the long wavelength region of the spectrum (it is known that perovskite, a decrease in absorptivity long-wave spectral region, therefore, additional "transformers" for the transfer of the scattered radiation on the perovskite). As a result of optoelectronic research at room temperature will be achieved the following:
- the sorption isotherms of dyes on porous perovskite, analyzing the quantitative characteristics of sorption in the reflection will be determined;
- dyes absorption and fluorescence spectra, their Raman spectra will be obtained and studied in order to investigate the processes of complexation;
- reflection spectra and luminescence will be determined the spectral and energetic characteristics of dyes and their changes during adsorption will be obtained and studied;
- the processes of nonradiative transfer of electronic energy from the dyes in the perovskite will be studied, according to the theory of Förster and filters in selective excitation, will be defined by constants of fluorescence quenching and reduced quantum yield of luminescence of the dye; simultaneously, determining the amplitude and kinetics of increase of the photocurrent will be the efficiency of the use of certain sensitizers; the database will be created on the energy characteristics of the process.
Data on the effectiveness of the application of dyes should have international level of efficiency. The results raise the question of the choice of the sensitizer with the following parameters to the next phase of the project was expected to be the highest plasmon enhancement effect on the sensitizer in the energy transfer in perovskite: resonant absorption, the greatest overlap of the absorption spectra and emission. Priority research results on photonics of enhance the generation of excitons in the hybrid cell on the basis of direct and indirect plasmonic amplification of the photocurrent via impact on the process and perovskite sensitizers will be produced. For the first time the spectral and kinetic results for the energy transfer from the perovskite sensitizers under excitation in different spectral ranges with the registration of the kinetics of the photocurrent will be obtained.

5. Under the proposed project the results of scientific activities will be the following: the original software for the numerical calculations of main parameters of the plasma-chemical processes occurring in the streams of inert gases and air; developed an experimental design for the generation of streams of cold plasma with variations in different parameters of the electrode system, voltage pulses of the excitation source of the discharge and flow of gases at a controlled rate of flow; design the layout of the stream source of low-temperature plasma with the optimal design of the electrode system and the power source from the point of view of the maximum length of the plasma torch and the minimum gas temperature, minimum consumption of gases, where the work will be used helium, argon, or air; the prototypes are designed sources of low-temperature plasma with parameters of the jet are suitable for the therapy; results of research of influence of streams of cold plasma on living cells in the human body; the results of studies of the rate of inactivation and resistance of pathogenic microorganisms, such as Pseudomonas aeruginosa, Staphylococcus aureus, etc., in the processing flow of the cold plasma methods of treatment of purulent wounds of various pathologies with the help of the developed devices; the results of studies of the condition of human skin after treatment with streams of cold plasma; developed methods for treating dermatological disorders using the developed devices.

6. The obtained results on the optical characteristics of the interacting components of the system will determine ways to enhance the efficiency of transfer of electronic energy in a binary system. Study of the optical properties of synthesized bass will allow you to pick the optimal size of nanoparticles for further studies.

7. The result of the research will generate new scientific knowledge in the study of photophysical processes in the complexes of coumarin dyes with noble metal nanoparticles. The first series of experiments will be processed by the method of manufacture of polymer films with nanoparticles and molecules of coumarin and xanthenes dyes. The obtained samples will be studied by the methods of fluorescence spectroscopy. Resulting optical performance of the dye molecules with nanoparticles in conditions of resonant photo-excitation of surface plasmons by the nanoparticles. The fluorescent characteristics of singlet and triplet states of molecules of coumarin and xanthenes dyes under impulse of nanosecond and picosecond excitation will be obtained. Methods of Raman spectroscopy will allow to obtain Raman spectra, which will give a complete picture of the intra-molecular transitions in complex with nanoparticles of metals. Low-temperature (77 K) measurements will allow to identify the degradation mechanisms of electronic excitation energy of the long-lived states of the dye molecules in the presence of the plasmon energy of nanoparticles.
It is known that coumarin compounds K120, K7 have an intense fluorescence in the visible region even at low concentrations, it is therefore of interest to measure the quantum yield of fluorescence. These data together with kinetic results on the duration of the existence of excited states of the dye molecules will allow us to calculate the energy deactivation rates in the complex in the presence of the plasmon energy of nanoparticles. Since coumarin dyes are widely used in medicine (in the study of the activities of individual proteins), studies of the optical characteristics of this class of dyes in the presence of the plasmon energy of nanoparticles will allow to identify mechanisms of amplification and conversion efficiency of the exciting radiation into the energy of surface plasmons in complex coumarin – nanoparticle. The information acquired can be used in medical studies.

Running Projects and Applications to be Submitted

1. “Organic Fluorophors and Metal Nanoparticles Photoprocesses Study in the Biological Liquid Evaporating Droplets” (Ministry of Education and Science of Russian Federation Assignment, 2017 – 2019, running project).

2. “Cold Plasma Production Methods Study” (Ministry of Education and Science of Russian Federation Assignment, 2017 – 2019, running project).

3. “Plasmon Energy Transfer from Silver and Gold Nanoparticles in "Quantum Dot – Porphyrin – Silver Nanoparticle" Complex Study for Porphyrine Compounds – DNA Interaction Sensor Development (2017 – 2019, *Application in Russian Scientific Found is under consideration*).

4. “Research and Development of Coherence-Based Optical Methods for the Measurements and Analysis of the Dynamic Events” (2017 – 2019, *Application in Russian Scientific Found is under consideration*).

5. “Investigation of the Plasmon Energy Transfer Mechanisms of the Gold and Silver Nanoparticles in CdSe Shell Quantum Dots with Porphyrin Compounds Molecules” (2017 – 2019. *Application in Russian Found for Fundamental Research is under consideration*).

6. “Plasmon Excitation in the Singlet-Triplet Complexes of Metal Nanoparticles with Coumarin and Xanthene Dyes in Polymer Films over a Wide Range of Temperatures” (2017 – 2018, *Application in Russian Found for Fundamental Research is under consideration*).

Collaborations

1. Grodno State University (Grodno, Belarus)
2. Saratov State University (Saratov, Russia)
3. Stuttgart Institute for of Technical Optics (Stuttgart, Germany)
4. Tomsk State University (Tomsk, Russia)
5. Kaliningrad State technical University (Kaliningrad, Russia)
6. Smolensk State medical University (Smolensk, Russia)

Other Activities (Conference Organization)

XXX School – Symposium on Holography, Coherent Optics and Photonics (October 2 – 6, 2017, “Fabrika”, IK BFU, Kaliningrad, Russia).