FRANK LABORATORY OF NEUTRON PHYSICS

In 2011, the FLNP scientific programme was realized under four research themes of the JINR Plan for Scientific Research and International Scientific and Technical Cooperation and was aimed at obtaining new results in condensed matter physics (theme 04-4-1069-2009/2014 «Investigations of Nanosystems and Novel Materials by Neutron Scattering Methods» headed by V. L. Aksenov, A. M. Balagurov and D. P. Kozlenko) and neutron nuclear physics (theme 03-4-1104-2011/2013 «Investigations in the Field of Nuclear Physics with Neutrons» headed by V. N. Shvetsov and Yu. N. Kopatch). To effect scientific research, work was continued to develop and modernize the FLNP basic facility, the IBR-2 (theme 04-4-1105-2011/2013 «Development of the IBR-2 Reactor with a Complex of Cryogenic Moderators of Neutrons» headed by A. V. Belushkin and A. V. Vinogradov) as well as the IBR-2 spectrometer and computation complex (theme 04-4-1075-2009/2014 «Novel Development and Creation of Equipment for the IBR-2 Spectrometers Complex» headed by V. I. Prikhodko and S. A. Kulikov).

CONDENSED MATTER PHYSICS

In the first half of 2011 during the physical start-up of the IBR-2 modernized reactor, the scientific experimental activities conducted by the personnel of the FLNP Department of Neutron Investigations of Condensed Matter (NICM) were carried out in neutron and synchrotron centers in Russia and abroad. This work was performed in accordance with the existing cooperation agreements and accepted beam time application proposals. In the second half of 2011 during the power start-up of the reactor, the first instrument-comissioning and experimental activities were started on the IBR-2 spectrometers. Also, the work to modernize the available spectrometers and to develop and construct new instruments was conducted in accordance with the modernization programme plan for the spectrometers.

Scientific Results. Using neutron diffraction, the structural disorder effects have been studied in the samples of fine-grained HTSCs $YBa_2Cu_3O_y$ with various average grain sizes $\langle D \rangle$ in the range of 0.4–2 μm and the oxygen content $y = 6.93 \pm 0.03$, having approximately similar $T_C \approx 92$ K (Fig. 1) [1]. It has been found that with a decrease in the grain sizes (i.e., an increase in the degree of nonequilibrium in the synthesis conditions) the oxygen content in the O(5) position increases several times as compared to the equilibrium coarse-grained state. The obtained results have made it possible to explain the unusual physical properties of fine-grained $YBa_2Cu_3O_y$, in particular, the effect of coexistence of high values of superconducting transition temperatures T_C and significantly low values of magnetization in strong magnetic fields at $T < T_C$. It has been shown that in the fine-grained $YBa_2Cu_3O_y$ samples with the optimum oxygen content the nanoscale structural inhomogeneity takes place leading to the changes in the fundamental superconducting parameters — magnetic penetration depth and coherence length.

The atomic and magnetic structures of multiferroic $BiFeO_3$ have been studied at high pressures up to 9 GPa [2]. A structural phase transition from the rhombohedral R3c (ferroelectric) phase to the orthorhombic *Pbam* (antiferroelectric) phase was revealed at $P \sim 3$ GPa. The G-type AFM state remains stable under pressure, however its character changes from a noncollinear (propagation vector $k = (\delta, \delta, 0)$, $\delta \sim 0.004$) to a collinear one ($\delta \sim 0.0$).

The crystal structure of crystal phosphors $Y_3Al_5O_{12}$:Ce^{3+}/Lu_2O_3(Lu_2O_3:Ce) produced by the colloid-chemical method and the influence of the way

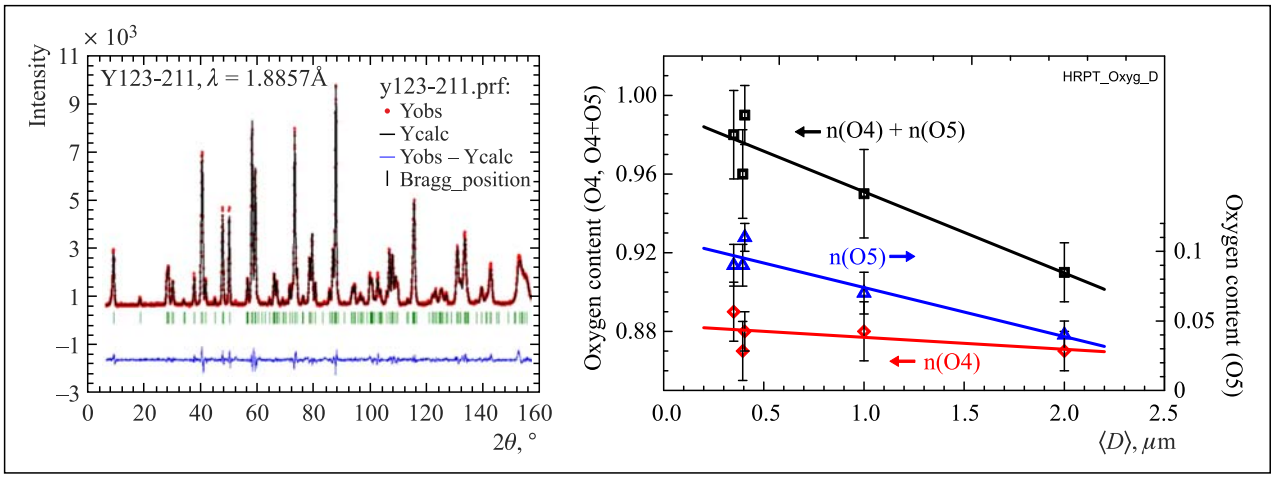

Fig. 1. Left: diffraction spectrum of $YBa_2Cu_3O_y$ sample (annealed at 930 °C with an average crystallite size $\langle D\rangle = 2$ μm) obtained on HRPT (PSI, Switzerland) and treated by the Rietveld method. Right: site occupation factors for O(4) (left scale), O(5) (right scale) and their sum (left scale) as a function of the average crystallite size. Statistical errors of the points are indicated. Lines are drawn by the least squares method

of introduction of Lu_2O_3 into the system on the structure and spectral-luminescent properties of the samples have been studied at room temperature using the neutron diffraction technique. The study has demonstrated that in the spectra of the samples obtained under the most nonequilibrium conditions, a Stokes shift and high intensity of photoluminescence are observed, which is caused by the disorder of their crystal structure due to the formation of stable associate-defects.

In the frame of the research of nanoparticles for biomedical applications, the powders of magnetic nanoparticles coated with block-copolymers (based on substituted pyrrols for increasing biocompatibility) have been studied by means of small-angle neutron scattering [3]. It has been found that the structure of the formed precipitate depends strongly on the type of the stabilizing shell in the initial magnetic fluid. For the systems initially stabilized with dodecylbenzenesulphonic acid (DBSA), the scattering in the final samples comes from separate polydisperse particles with irregular surface. For the systems with the initial stabilization by means of lauric acid (LA), the experimental curves are additionally modulated by the scattering from a quasi-crystalline structure with the characteristic correlation length of 10 nm. The differences in the structural organization of the studied powders are explained by a different rate of the polymeric coating of magnetic nanoparticles, which is determined by the adsorption properties of surfactants in the magnetic fluids in respect to particle surface.

The complex investigations of the solution C_{60}/N-methyl-2-pyrrolidone (NMP) and its mixtures with the solvents of various polarities have been carried out using small-angle neutron scattering, UV-Vis spectroscopy and mass-spectrometry. It has been shown that the main contribution into the temporal solvatochromism in C_{60}/NMP (change in the absorption spectrum with the age of the solution) is determined by the variation of donor-acceptor complexes fullerene-solvent with time. Nevertheless, the formation of fullerene clusters in the given system with time is reflected indirectly in solvatochromism and other effects. In particular, it influences the content of residual NMP in the precipitate obtained by the evaporation of the solution at different stages of its evolution after the preparation. The theoretical description of the kinetics of the cluster growth in C_{60}/NMP has been proposed [4]. The developed model takes into account the processes of fullerene dissolution, the formation of complexes C_{60} with the molecules of the solute (NMP), as well as a slow growth of clusters from the new complexes.

The ultrastructure of the inner mitochondrial membrane and the formation of supercomplexes of oxidative phosphorylation enzymes in it, as well as the influence of the tonicity of the incubation medium have been studied [5]. The search for supercomplexes and the conditions of their formation from oxidative phosphorylation enzymes (ATP-synthetase, respiratory chain enzymes, nucleotide translocator) has been conducted using the double inhibitor titration (DIT) technique. The formation of enzyme complexes in mitochondria has been detected.

The investigation of biogenic ferrihydrite nanoparticles produced by bacteria *Klebsiella oxytoca* has been continued. The ultrasound-treated diluted samples of water suspensions of biogenic nanoparticles have been studied by the SAXS technique. It has been found that the nanoparticles have an elongated shape with the radius of gyration of 6.73 ± 0.16 nm. The results obtained with the ultrasound-treated samples are close to the structural parameters determined earlier (using SAXS, high-resolution electron microscopy and magnetic granulometry) with the concentrated samples. This fact al-

lows us to suggest that the ultrasound treatment does not affect the physical and chemical properties of the particles and only helps to minimize the effect of aggregation.

The phenomenon of neutron magnetic resonance in neutron reflection from a 0.5 μm-thick permalloy film (80% Ni + 20% Fe) has been studied. A static magnetic field of 20 Oe and an oscillating magnetic field of 10 Oe perpendicular to it were applied to the film in its plane. At a frequency of the oscillating magnetic field of 26.2 MHz, the intensity of the specularly reflected neutron beam decreased and off-specular reflection appeared. Resonance, as is well known, occurs when the frequency of an oscillating magnetic field coincides with the frequency of precession of the neutron magnetic moment (neutron spin) around the magnetic induction vector. The induction value of 0.899 T corresponds to the frequency of 26.2 MHz. The magnetometric measurements have demonstrated that this induction value corresponds to the saturation induction, which exists in domains. Thus, it has also been shown that by means of neutron scattering it is possible to simultaneously measure the average value of the induction vector determined by the angular distribution of its direction in domains and the saturation induction.

The experiments to study the microstructure of a single crystal turbine blade made of heat-resistant nickel alloy ZhS-32 have been carried out. Single crystal turbine blades of various materials are used in the aircraft engines produced by the NPO «Saturn» (Rybinsk, Russia). The prototype of a turbine blade was studied at the FSD diffractometer of the IBR-2 reactor and the radiography station of the IR-8 reactor in NRC KI. A rather complex topology of the diffraction-peak regions and the presence of a «parasitic» single crystal grain outcropping at the blade surface with different (compared to the basic matrix) orientation have been revealed (Fig. 2). The obtained diffraction data are in good agreement with the results of neutron radiography and topography performed in NRC KI.

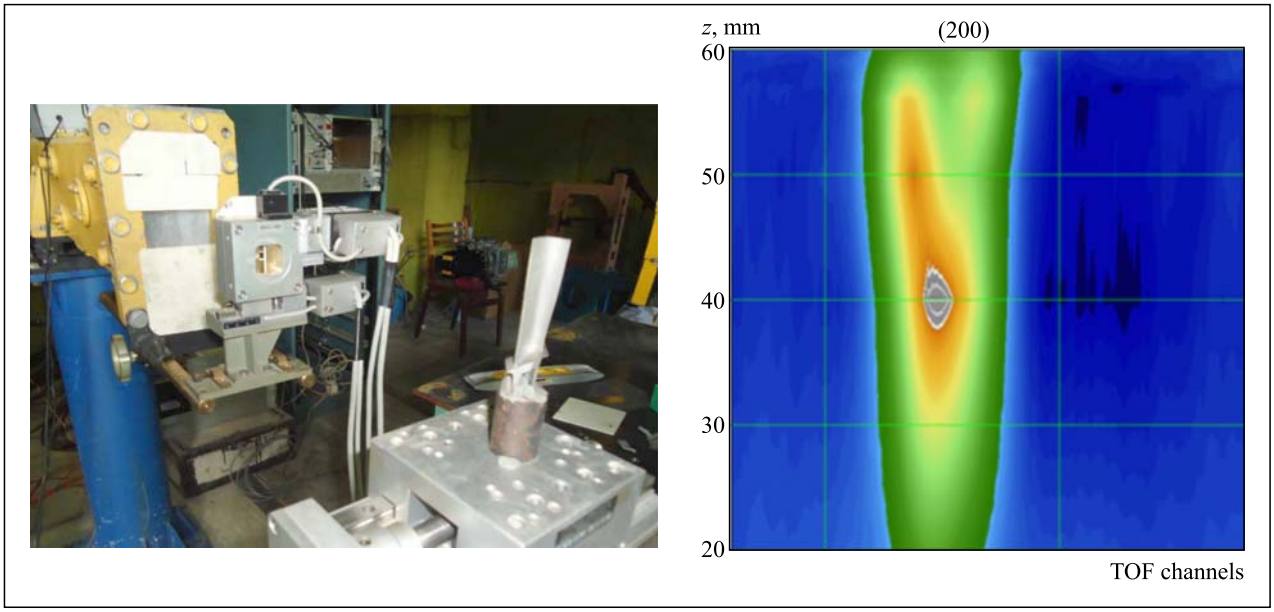

Fig. 2. Left: a turbine blade fixed on the goniometer of the FSD diffractometer for the experiment on the analysis of its microstructure. Right: 2D cross section of the region of the diffraction peak (200) revealing its complex topology. In particular, the presence of a grain with different (compared to the basic matrix) orientation can be seen

The comparison of the results of the neutron texture analysis and laboratory acoustic measurements with the seismic borehole logging data has been continued for the biotite gneiss samples from the research Outokumpu borehole (Finland). It has been suggested that the reason for the increased seismic reflection zones on the contacts between biotite gneisses and pegmatic granites found at a depth of 1500 m is the preferred orientation of biotite grains in biotite gneisses. Texture measurements at the modified SKAT diffractometer (FLNP) with a large series of samples including those from the increased seismic reflection zones of the Outokumpu borehole will help to support this suggestion.

The phonon spectra of lanthanum cobaltite $LaCoO_3$ have been studied in the temperature range of 4–120 K using the inelastic neutron scattering technique [6]. First-principles quantum-chemical calculations of the phonon spectrum have been performed to analyze the experimental data. Good agreement has been obtained for the calculated and experimental values of the frequencies of the phonon modes. The behavior of the phonon state density in the spin transition region has been studied. The anomalies in the temperature dependences of the frequencies of the optical phonon modes have been revealed in the spin-transition region.

On the basis of the experimental data obtained at the DIN-2PI spectrometer, the frequency spectra of uranium mononitride (UN) (nuclear fuel for reactors) have been determined and used for calculating its thermodynamic parameters. The obtained temperature dependences of heat capacity, enthalpy and entropy of UN in a temperature range of 293-1400 K have been compared with the macroscopic experimental data. Good agreement between the calculations and experiment has been observed.

Instrument Development. Since the power start-up of the modernized IBR-2 reactor, the spectrometers YuMO, HRFD, REMUR, REFLEX, FSD, DN-12, DIN-2PI have been put into operation after the planned modernization. The first instrument-comissioning and experimental work has been performed at these spectrometers.

The work on the construction of the new diffractometer DN-6 (beam 6B at the IBR-2 reactor) for studying microsamples has continued. The beam chopper has been installed at its regular place. The manufacturing of mirrors for the tail part of the neutron guide has been completed. The assembling of this part is planned to be completed by the end of 2011. The manufacturing of the mechanical units of the diffractometer is nearing completion. A gas PSD detector for the DN-6 diffractometer has been designed at the Spectrometers' Complex Department.

The work on the construction of the new multifunctional reflectometer GRAINS (beam 10 of the IBR-2 reactor) has continued. The background chopper of the drum type (horizontal aperture) has been manufactured and assembled at its regular place in the experimental reactor hall. The beam-forming system (including automatic apertures, mirror deflector, mirror polarizer, leading magnetic system) has been assembled at its regular place. The autonomous vacuum system of the reflectometer has been designed. The first spin-flipper has been manufactured. The antivibration platform for the sample table has been purchased. The work on the manufacturing of the platform for the detector unit and of the liquid-containing cell for reflectometry measurements has started.

The complex modernization of the REFLEX reflectometer (including the start-up of the new control system and data acquisition and accumulation electronics) has been carried out. The work on the analytical description of the operation of the spin-echo instrument with rotating magnetic fields has started.

NEUTRON NUCLEAR PHYSICS

An experiment has been carried out to measure the probability of quasi-elastic UCN scattering («weak heating» of UCN) following their reflection from the surface of hydrogen-free fomblin grease. The temperature dependence of this probability has been measured. Nowadays, there are two hypotheses explaining this phenomenon — UCN scattering by capillary waves and UCN scattering by nanodrops formed near the liquid surface. It is possible that the obtained data might be sufficient to unambiguously establish the reason for the phenomenon of quasi-elastic UCN scattering by a liquid surface. To do this would require additional calculations of the temperature dependence of UCN scattering by capillary waves. It has been demonstrated that certain corrections connected with the quasi-elastic UCN scattering should be introduced in a number of experiments on the measurement of the neutron lifetime [7].

The measurements of the P-odd asymmetry in the radiative cross section of natural lead have been performed at the PF1B cold polarized neutron beam facility in ILL (Grenoble, France). The experiment was conducted to obtain additional information to explain the anomalously high value of the neutron spin rotation in the measurements of transmission of transversely polarized neutrons through a sample. To decrease the effect of the reactor power fluctuations, an integral method was used at neutron polarization switching frequencies (8.3 Hz) higher than the frequencies of the main spectrum of the neutron noise of the reactor. The measurements with the sample lasted for 10 days, the «zero» experiment — for 6.5 days. Taking the «zero-test» into account the asymmetry effect was found to be $a_\gamma(^{\mathrm{nat}}\mathrm{Pb}) = (2.3 \pm 3.5) \cdot 10^{-7}$ or $\alpha_\gamma \leqslant 8.1 \cdot 10^{-7}$ at the 90% CL. The achieved accuracy is still insufficient to perform the combined analysis [8].

The investigations of the spontaneous nuclear fission induced by fast neutrons have been carried out in cooperation with the EC-JRC-IRMM and LIT JINR. The calculations of electrostatic fields between the electrodes of a twin ionization chamber with Frisch grids have been made in order to study the fission fragment signal formation. These calculations have made it possible to modify the digital signal processing procedures. As a result, we have managed to obtain more detailed data on the vibration resonances in the $^{234}\mathrm{U}(n, f)$ reaction and more accurate information on the emission of prompt fission neutrons in the reaction $^{252}\mathrm{Cf}$ (sf) [9].

In the framework of the collaboration between JINR and Czech Technical University in Prague a number of experiments have been conducted to study the properties of silicon pixel detectors of the Medipix family and the possibilities of their application for measuring heavy charged particles, specifically for searching and studying rare nuclear fission modes. The measurements of

fission fragments and alpha-particles in the spontaneous fission of ^{252}Cf have been performed using several detectors Timepix and Medipix-2 included in the coincidence circuit, and in particular, using a start module specially developed for these measurements. The possibility of measuring ternary fission by means of this method has been demonstrated, a spatial image of the source of fission fragments with a resolution of several tens of microns has been obtained [10].

The experimental and theoretical investigations of the reactions (neutron, charged particle) induced by fast neutrons have continued. The experiments are carried out at the Van de Graaf accelerators EG-5 in FLNP, JINR and EG-4.5 of the Institute of Heavy Ion Physics of Peking University. Data on the neutron reactions with the emission of charged particles induced by fast neutrons are of much interest for studying the mechanisms of nuclear reactions, atomic nuclear structure, in choosing construction materials and in performing calculations in the development of new facilities for nuclear power engineering. The measurements of the $^{\mathrm{nat}}\mathrm{Mg}(n,\alpha)$ reaction at $E_n \sim 4.0{-}6.5$ MeV have been performed. The treatment of data from the measurements of the $^{149}\mathrm{Sm}(n,\alpha)^{146}\mathrm{Nd}$ reaction carried out in the neutron energy range between 4.5 and 6.5 MeV has been completed. The data on the cross sections and angular distributions for this neutron energy range have been obtained for the first time; a comparison with the available estimates and theoretical models has been made (Fig. 3) [11].

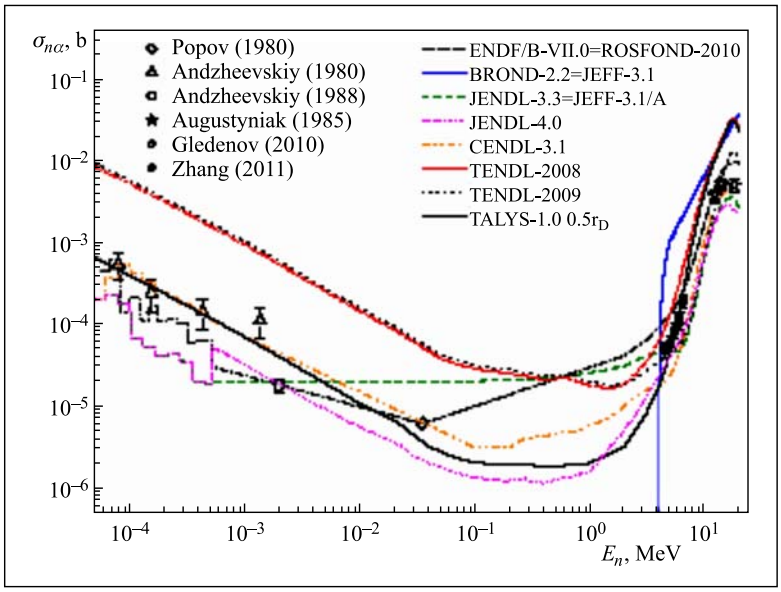

Fig. 3. Cross section of the $^{149}\mathrm{Sm}(n,\alpha)^{146}\mathrm{Nd}$ reaction in comparison with the estimates available in the nuclear data libraries and the calculations performed using the TALYS-1.0 software package

In the framework of a broad international collaboration on the basis of the JINR facilities, the research project «Energy and Transmutation of Radioactive Wastes» («E&T RAW») is carried out. In 2011, using a new subcritical assembly «QUINTA» consisting of 500 kg of natural metal uranium, the distributions of neutron fluxes, fission rates, and ^{239}Pu recovery as well as the time dependence of the delayed neutron yield after irradiation of the assembly with a pulsed deutron beam of the JINR nuclotron were measured in the energy range of $E_d = 2{-}6$ GeV. The tendency of the average energy of neutrons $\langle E_n \rangle$ inducing fission of ^{238}U inside the assembly to grow with an increase in the energy of incident deutrons (discovered in the experiments in 2010) has been confirmed. The value of $\langle E_n \rangle$ ran as high as ~ 30 MeV at $E_d = 6$ GeV. It has been found (with an error of 10–15 %) that the integral number of fissions in the assembly grows, at least linearly with increasing E_d, whereas the relative total yield of delayed neutrons generated in the fission of the assembly nuclei increased approximately six times as the value of E_d grew from 2 to 6 GeV [12].

Possible neutron experiments to search for new short-range spin-dependent forces have been considered. The spin-dependent nucleon–nucleon interaction between neutrons and nuclei may be responsible for various effects: phase shift of a neutron wave in neutron interferometers of different types, in particular of the Lloyd mirror configuration, neutron spin rotation in a pseudomagnetic field, and transverse deflection of a polarized neutron beam by a layer of substance. The sensitivity assessment of these experiments has been made [13].

At the IREN pulsed resonance neutron source, the activities on the development and application of the methods of elemental and isotope analysis using neutron spectroscopy, have been carried out. The analysis of the boron content in ceramics of nanocomposite materi-

als prepared in the Belorussian State University (Minsk) has been performed by measuring neutron transmission. In cooperation with the Sternberg Astronomical Institute MSU the objects of presumably extraterrestrial origin have been investigated by means of the resonance spectroscopy method. In the samples from bottom sediments of a brook in an Altai mountain glacier, a rather high iron content has been found. The works are in progress [14].

At the beams of charged particles of the EG-5 accelerator (FLNP), the systematic studies of the depth profiles of the elements in the near-surface layers of the construction materials with the depth resolution of about 10 nm have been performed. In cooperation with MCSU (Lublin, Poland), the research of the influence of the ion implantation on the optical properties of the natural oxide layer covering the silicon surface has been conducted [15]. In cooperation with IEE SAS (Bratislava, Slovakia), the investigations of the content of light elements (including hydrogen) in layered structures produced on the silicon surface by means of PECVD (plasma-enhanced chemical vapor deposition) have been performed [16]. In cooperation with VSU (Voronezh), the studies of various layered structures for the technical use by means of the back-scattering of helium ions have continued.

In 2011, the activities on the improvement of the radioanalytical complex REGATA were completed. In the period of two reactor cycles after the modernization of IBR-2, a significant amount of the planned research in the framework of the projects with the JINR Member States has been performed. In cooperation with the Andronikashvili Institute of Physics, Tbilisi, Georgia, and the Moscow Branch of the Dutch firm «Systems for Microscopy and Analysis», the work on the visualization of silver and gold nanoparticles produced in the process of biosynthesis by *Streptomyces glaucus* 71 MD and *Artrobacter globiformis* 151T bacteria, as well as blue-green microalgae *Spirulina platensis* has been done [17]. The preliminary data on the quantitative assessment of the silver and gold synthesis and its influence on the change in the elemental composition of the biomass of the studied objects were obtained at the SAFARI-I reactor (NECSA), RSA, in June, 2011 and the IBR-2 reactor in November, 2011. The programme for investigating the distributions of ^{137}Cs and ^{210}Pb isotopes in mosses-biomonitors collected on the territory of Belorussia and Slovakia 23 years after the Chernobyl accident has been completed. Gamma-spectroscopy of the moss samples was made in the low-background laboratories at the Comenius University in Bratislava, Slovakia, and at the Nuclear Energy Corporation of South Africa (NECSA). In cooperation with the Slovakian and Norwegian researchers, the data on the season variations of ^{137}Cs and ^{40}K isotopes in the ground air were analyzed. It is the authors' opinion that such variations are the result of soil resuspension. In cooperation with the Bucharest University, Romania, and the Geological Institute of RAS, the multielemental analysis of bottom sediments and rocks of two semi-closed ecosystems of the glacial lake Balea (Fagaras mountains) and the crater lake St. Ana (Harghita mountains) has been carried out at the reactor of MEPHI in Moscow. The obtained results are of great interest for practical geology. A report for the Black Sea Economical Council and a publication in the international journal have been prepared on the results of the international project between Black See countries (BSEC-PDF) «Revitalization of Urban Ecosystems with the Help of Higher Plants» completed in 2010 with participation of Russia (JINR), Bulgaria, Greece, Serbia, Romania, and Turkey [18].

THE IBR-2 PULSED REACTOR

In 2011, the activities on the IBR-2 research reactor were carried out in accordance with the tasks of the theme «Development of the IBR-2 Reactor with a Complex of Cryogenic Neutron Moderators» with the maintenance of the regular operation of all reactor systems. Upon the completion of modernization of the IBR-2 reactor in 2010, during 2011, the physical start-up was conducted in steady-state and pulsed modes followed by a successful power start-up with the achievement of the designed power of 2 MW. In November–December, two cycles of test physical experiments were performed on the extracted neutron beams at the reactor power of 2 MW in order to obtain more accurate and specific user characteristics of the modernized reactor. Also, a set of documents necessary for obtaining the Rostechnadzor license for the regular operation of the reactor has been prepared.

In 2011, the work to develop and construct a complex of cryogenic moderators was carried out in two main directions:

1. More than 30 cooling cycles with and without loading mesitylene beads to the simulation chamber were carried out on the test stand installed on channel 3 in the IBR-2 experimental hall. Using the results of these experiments:

a) the technology of full loading of mesitylene beads to the simulation chamber for 3–5 hours has been developed;

b) hydrodynamical and thermophysical properties of the pneumatic conveying system have been studied,

which is necessary for designing real units of pneumatic systems for transporting beads to the moderators;

c) the bead movement monitoring system on the basis of differential pressure diaphragm sensors has been developed;

d) the technical documentation necessary for installation of the cryogenic moderator on its regular place has been worked out.

2. Starting-up and adjustment works were continued on the refrigerator facility KGU-700/15.

NOVEL DEVELOPMENT AND CONSTRUCTION OF EQUIPMENT FOR IBR-2 SPECTROMETERS COMPLEX

Development of the Complex of Neutron Moderators. The research activities carried out within the framework of the theme on the development and construction of a cryogenic moderator for IBR-2 beams 7, 8, 10, 11 included two large blocks:

- Development and research of technological schemes of the complex of moderators (preparation and loading of beads, transport pipelines, cryogenic equipment, control systems, etc.); construction of a full-scale test stand of the cryogenic moderator.
- Monitoring of the manufacturing and assembling of the complex of moderators, starting-up and adjustment activities.

In 2011, a number of experiments on loading the simulation chamber were carried out with the cryogenic moderator prototype, which allowed us to select the optimum temperature operation mode and appropriate helium flow rate, to adjust and debug the bead movement monitoring system, and to develop the technology of full loading of mesitylene beads to the simulation chamber. At the same time during the experiments with the prototype, a number of shortcomings in the design of the technological scheme were revealed, first of all this refers to the bead counting method. As a result, an alternative method of monitoring the loading of the chamber and the moderator operating parameters has been developed. The process of filling the chamber with beads on a real moderator is suggested to be monitored by taking a neutron image of the moderator chamber by a 2D PSD using an obscure chamber method. In addition, the monitor will also permit us to solve the following problems: to obtain local neutron spectra; to control the local «point» temperature of beads in a dynamic mode of mesitylene heating for melting the beads; mesitylene discharge control.

The manufacturing of a combi-moderator for beams 7, 8, 10, 11 with a «small» trolley for installation at the reactor core has been completed; the test installation has been carried out. The necessary industrial equipment (cryostats-heat-exchangers, helium supply tubes, pneumatic bead conveying pipes) has been purchased and installed in the ring corridor. The starting-up and adjustment works on the refrigerator facility KGU-700/15 are nearing completion with the help of the specialists of the Scientific Production Association «Geliymash».

Calculations and Simulation of Spectrometers. In 2011, special VITESS (Virtual Instrument Tool European Spallation Source) modules were developed (in cooperation with JCNS-Munich) that allow the simulation of the neutron spin behavior in arbitrary magnetic fields; and the simulation of several variants of a small-angle neutron scattering spectrometer on the basis of the spin-echo technique with time-dependent magnetic fields at the IBR-2 reactor was performed.

Reconstruction of Neutron Guides on Beam 7 of IBR-2. In cooperation with the German institutes and PNPI (Gatchina), the activities on the reconstruction of the neutron guides on beam 7 of IBR-2 and the modernization of the EPSILON and SKAT diffractometers continued in accordance with the plan-schedule of the BMBF-JINR project. Support pillars and 92 vacuum casings of the curved neutron guides have been manufactured and assembled; vacuum sealing of the 200-meter flight path of the EPSILON and SKAT neutron guides has been done. Similar work has been carried out for the NERA-PR neutron guide ($\sim 30\%$ of the total amount of work has been completed). A background chopper and 3 drum λ-choppers with control systems for the EPSILON, SKAT, and NERA-PR spectrometers have been manufactured and their characteristics have been measured in the phase stabilization mode.

The activities on the installation of a biological shield, the equipment for the new **high-resolution Fourier diffractometer** based on the units of the FSS spectrometer (GKSS, Geesthacht), and the equipment for the **test beam** on channels 13–14 of IBR-2 have to be postponed, since the organizational and financial problems connected with the transportation of the FSS equipment from Geesthacht to St. Petersburg and then further to Dubna have not been solved yet. At present, the physical equipment of the FSS spectrometer at the FRG-2 reactor has been dismantled and the disassembling of its neutron guide has started. The preparatory work on beams 13 and 14 of IBR-2 is in progress.

In 2011, we continued the course towards unification of the equipment and electronics of **actuating mechanisms and sample environment systems** of the

IBR-2 spectrometers. In the framework of this direction, the following activities have been conducted: the control systems of a goniometer and a platform with a detector on the REMUR spectrometer have been modernized; the control system of a device for producing pressure at a sample has been put into service on the YuMO spectrometer; seven new variable-frequency drives for neutron beam choppers have been installed and put into operation; the control system of drum-type DC-motor-based choppers has been installed and adjusted on beams 6 a and 6 b; new control systems of a physical instrument (status of shutters, choppers, etc.) have been made and adjusted for the SKAT, EPSILON, and NERA-PR spectrometers.

Detectors. In 2011, on the basis of the results of the trials of the ring-shaped multisection gas detector test module for the DN-6 diffractometer, the electrode system was improved and all mechanical units of the detector were manufactured in the SPA «Atom». At present, the following activities have been carried out: the soldering of the input stages of the preamplifiers; complete assembling of the detector, degassing, vacuum sealing and filling of the detector with a test gas mixture. On the test stand, the preliminary tests of the detector with a ^{252}Cf source have been performed; amplitude spectra and counting characteristics have been measured. All blocks of 96-channel data acquisition and accumulation electronics have been manufactured and at the present time are being adjusted and debugged (Fig. 4). In December the detector was successfully tested on beam 12 of IBR-2.

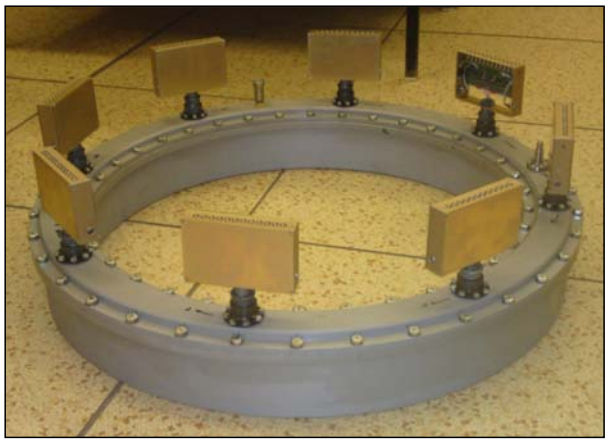

Fig. 4. The ring-shaped detector with 12-channel signal-shaping amplifiers mounted on its case

A 2D PSD for the GRAINS spectrometer has been handed over to the physicists. Detectors of a similar design for monitoring the operation of the cold moderator and for the DN-2 diffractometer have been manufactured and at present are at the testing stage.

In view of a high cost and problems with the purchase of helium-3, the pace of work on the construction of a helium-3 purification facility has been intensified in order to put it into operation in 2012.

Electronics. A DE-LI-DAQ2 block for PSD has been adjusted and started to be tested. Three sets of MPD blocks for data acquisition and accumulation from the point detectors of the EPSILON, DN-6, and HRFD spectrometers have been manufactured and adjusted. A 16-channel data acquisition block has been put into operation at the REFLEX spectrometer.

A plan-schedule of transition of the IBR-2 spectrometers to a new generation of data acquisition and accumulation electronics (MPD and DE-LI-DAQ2 blocks) has been worked out. The planned pace of work is 2–3 spectrometers a year. The replacement of electronics also involves abandoning the VME standard and a transition to the application of the Sonix+ software package.

In connection with the reactor start-up, a large amount of work on routine maintenance and repair of electronic equipment of the IBR-2 spectrometers has been carried out.

Software. For the new DAQ controller the list-mode functions have been introduced into the driver and tested. These functions are intended to be used in the software for the Fourier diffractometers (HRFD and FSD) and the EPSILON spectrometer. The working versions of the software (Sonix+) for the SKAT and EPSILON spectrometers have been prepared with regard to the available equipment. Upon completion of modernization of the detectors and sample environment systems of these spectrometers, the software is to be modified as well. For the EPSILON spectrometer the work on the adjustment programme based on Mathplotlib, PyQt, and QT has been started. The widgets for visualization of 1D and multidimensional data, as well as the prototype of the whole programme have been created out.

Significant modifications of the software of the WebSonix system have been made. A new data exchange protocol for exchanging information between the site and control computers has been proposed and realized to enhance the exchange reliability and to accelerate the measurement protocol transfer. The help information on the Sonix+ software package has been updated, in particular, «help» modules in Russian and English have been created.

Local Area Network. The first stage of transition of FLNP LAN to rates of 10 Gbit/s is nearing completion. At present, bldg. 119 (FLNP Central Computing Complex, offices of employees) and bldg. 117 (experimental halls No. 1 and No. 2, IBR-2 reactor control services) are connected to the 10 Gbit/s network backbone. This makes it possible to provide the end users with the rate of up to 1 Gbit/s. To accomplish this stage, the purchase of the necessary switching equipment and the installation of single-mode fiber-optic cable network between buildings 119, 117, 117/2, the IBR-2 reactor control room and experimental halls have been financed out of the BMBF funds.

CONFERENCES AND MEETINGS

Three scientific schools for advanced training of young scientists were organized by or in collaboration with the Frank Laboratory of Neutron Physics in 2011: the IV Higher Courses of CIS Countries for young researchers, Ph.D. students and graduate students on modern methods in investigations of nanosystems and materials «Synchrotron and Neutron Investigation of Nanosystems» (SYN-NANO-2011) (July 10–23, Moscow–Dubna), the III International Neutron School for Young Scientists and Students «Modern Neutron Diffraction Studies: Interdisciplinary Research of Nanosystems and Materials» (October 31 – November 4, Dubna) and the II International Scientific School for Young Scientists and Students «Instruments and Methods of Experimental Nuclear Physics. Electronics and Automatics of Experimental Facilities» (November 7–9, Dubna). These Schools continued the tradition of the FLNP Schools for young scientists devoted to the fundamental and applied aspects of neutron research in the fields of condensed-matter physics, materials science and related topics in order to attract young scientists in farther development and exploitation of FLNP facilities.

The 19th edition of the traditional International Seminar on Interaction of Neutrons with Nuclei: «Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics» took place in May 25–28. Papers presented covered a wide range of issues of fundamental and applied nuclear physics and ecology, studied with neutrons. The first physical results obtained at the new neutron source IREN, JINR, were reported.

The SANS-YuMO User Meeting was devoted to the 75th anniversary of Professor Yuriy Mechislavovich Ostanevich (1936–1992), an outstanding physicist, who specialized in the area of neutron physics and who was the founder of small-angle neutron scattering (the field, the group and the instrument) at Frank Laboratory of Neutron Physics of Joint Institute for Nuclear Research, JINR in Dubna on May 27–30, 2011.

The international conference «Stress and Texture Investigations by Means of Neutron Diffraction 2011» (STI-2011) organized jointly by the GFZ German Research Centre for Geosciences (Potsdam) and Karlsruhe Institute of Technology (KIT) was held at the Frank Laboratory of Neutron Physics (FLNP), JINR on June 6–9, 2011.

The objective of this conference was coordination of activities going on at the specialized diffractometers SKAT, EPSILON and FSD at IBR-2 that are designed for neutron spectra measurements of bulky geological and constructional materials. These spectrometers have been thoroughly upgraded during the reactor outage. The project of modernization of EPSILON and SKAT was substantially financed by the Federal Ministry of Education and Research, Germany (BMBF).

The 3rd joint seminar JINR-Romania on neutron physics for investigations of nuclei, condensed matter and life sciences was organized by FLNP in collaboration with Valahia University of Targoviste, Romania on July 24–30 and supported by a grant of the Plenipotentiary of Romania at JINR.

The last three mentioned meetings were organized in order to present the FLNP user programme to the world scientific community and to invite scientists to submit research projects within the framework of the first call for proposals announced after the modernization of the IBR-2 reactor.

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