FRANK LABORATORY OF NEUTRON PHYSICS

In 2012, 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 the 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-2M 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-2M Spectrometers Complex» headed by V. I. Prikhodko and S. A. Kulikov).

The most important results in 2012 were the obtaining of the license for regular operation of the IBR-2M reactor, resumption of the user program and successful start-up of the cold neutron moderator at the IBR-2M reactor. Both of the main neutron sources of FLNP, the IBR-2M reactor and IREN facility, operated for about 1500 h for physical experiments.

CONDENSED MATTER PHYSICS

In the first half of 2012, until the license for regular operation of the IBR-2M reactor was issued, 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 centres in Russia and abroad. The work was performed in accordance with the existing cooperation agreements and accepted beam time application proposals.

A total of 163 proposals from 17 countries have been submitted during the first call for proposals for experiments at the modernized IBR-2 reactor. The received proposals covered the broad spectrum of neutron research in physics (35%), materials science (25%), chemistry, geosciences, biology and applied sciences (constituting the rest 40%). 119 experimental proposals have been accepted to be conducted at the IBR-2M spectrometers with 93 of them realized in 2012.

Starting from May, 2012, the research activities at the IBR-2M reactor were resumed in accordance with the FLNP user program. Also, the work to modernize the available spectrometers and to develop and construct new instruments was conducted in accordance with the development programme plan for the IBR-2M spectrometers.

Scientific Results. The crystalline and magnetic structures of deuterated herbertsmithite $ZnCu_3(OD)_6Cl_2$ have been studied by means of neutron powder diffraction and magnetic susceptibility measurements in a wide range of temperatures (1.5–300 K) and pressures (0–10 GPa) [1]. The given compound exhibits the most ideal (among crystalline structures) realization of the 2D magnetic Kagome lattice of Cu ions with a spin $s = 1/2$ which has a ground state of a quantum spin liquid. It has been found that the application of pressure $P = 2.5$ GPa induces a phase transition from a quantum-disordered spin-liquid state to an antiferromagnetic ordering with the Néel temperature $T_N = 6$ K and magnetic elementary cell $\sqrt{3}a \times \sqrt{3}a$. The anomalies in the pressure behavior of Cu–O bond length and Cu–O–Cu, Cu–Cl–Cu bond angles have been revealed in the phase transition region. Possible mechanisms of these phenomena have been analyzed.

Diffraction real-time *ex-situ* and *in-situ* experiments have been conducted on the HRFD diffractometer for the first time to study the structural changes that occur

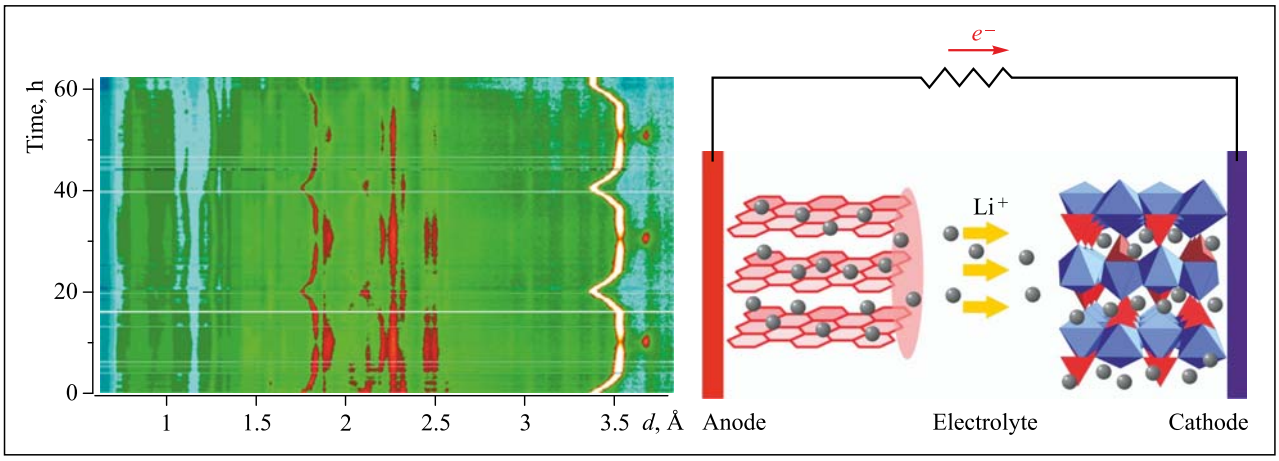

Fig. 1. At the left: evolution of neutron diffraction spectra from lithium-based electrical current source in the process of three charging/discharging cycles. Each full charging/discharging cycle takes about 20 hours. An intense peak at $d \approx 3.5$ Å is from graphite anode; peaks in the region of 2–2.5 Å are from olivine. At the right: illustration of the lithium ion migration during a charging/discharging cycle for a $LiFePO_4$-based Li-ion battery (cathode is at the right). During the charging process, lithium ions are intercalated into the graphite lattice making it to expand; and vice versa, during the discharging process lithium ions leave the graphite lattice and their standard structural parameters are restored. From Janina Molenda and Marcin Molenda (2011)

in chemical sources of electric current (lithium accumulators) with working substance of olivine doped with vanadium ($LiFePO_4 + x$V, $x = 0$, 0.75, 2, and 5%) in the course of their charging/discharging (redox-processes) in a high-resolution mode ($\Delta d/d \sim 0.001$). The ultra-low doping with vanadium makes it possible to significantly improve the properties of olivine ($LiFePO_4$) as a cathode material — electrical conductivity increases 108 times and the capacity grows by 33%. Two batteries, in one of which $LiFePO_4$ was doped with 0.75% of vanadium, were studied in the *in-situ* mode in the course of charging/discharging. During the charging of a battery, a graphite unit cell (serves as an anode) enlarges because of the penetration of lithium ions into the structure of graphite and vice versa, diminishes down to standard sizes in the course of discharging and, correspondingly, migration of lithium ions back to a $LiFePO_4$ electrode (Fig. 1). The enlargement and restoration of a crystal lattice of graphite, as well as the number of embedded lithium ions in Li_xC, affect the position and intensity of some diffraction peaks of graphite. Phase transition $LiFePO_4 \leftrightarrow FePO_4$ was clearly observed: at $d \sim 2.4$ Å in the charged accumulator there appear two intense diffraction peaks that are characteristic of the $FePO_4$phase. After several cycles of battery charging/discharging, no degradation of the crystal structure of working electrodes was revealed.

Small-angle neutron scattering has been applied for studying solutions of magnetoferritin — artificial biological complex on the basis of apoferritin in whose cavity the synthesis of iron oxides is initiated by chemical methods. By means of the contrast variation, the mean scattering length density of magnetoferritin and its relative composition has been determined depending on the loading factor LF, which is the mean number of iron atoms per one apoferritin complex. The measurements have revealed a significant shift in the match point of magnetoferritin with increasing (LF), which is probably related to a partial distortion of the apoferritin shell [2].

At the first stage of the complex investigation of the influence of magnetic nanoparticles on the conformation of amyloids, the structure analysis of amyloidal fibrils of hen egg white lyzosyme stabilized in an acidic medium has been carried out by means of small-angle neutron (SANS) and small-angle X-ray (SAXS) scattering from aqueous solutions, as well as by atomic force microscopy with the adsorption of fibrils on a mica surface [3]. It has been shown that the obtained small-angle scattering curves are consistent with the helical structure of protofilaments forming amyloidal fibrils. For the analysis, a simple approximation has been proposed, which makes it possible to find out the period of repetition (pitch) and mean diameter of the helix, as well as the effective radius of their basic structural units. Some kind of «isotope effect» on the helical structure was observed when using a heavy component in the solvent (H_2O/D_2O mixtures), which showed a significant increase in the helix diameter for the solutions with the dominant fraction of D_2O (Fig. 2).

The formation of micelles of photosensitive surfactant azobenzene trimethylammonium bromide (AzoTAB) has been studied by means of small-angle neutron scattering. In the trans-conformation, the AzoTAB molecule forms charged ellipsoidal micelles. The micelle size and aggregation number increase with growing AzoTAB concentration. The temperature increase results in a decrease in these parameters. In contrast, the degree of dissociation of bromine ξ drops when the AzoTAB concentration increases and rises with increasing temperature. Under the ultraviolet irra-

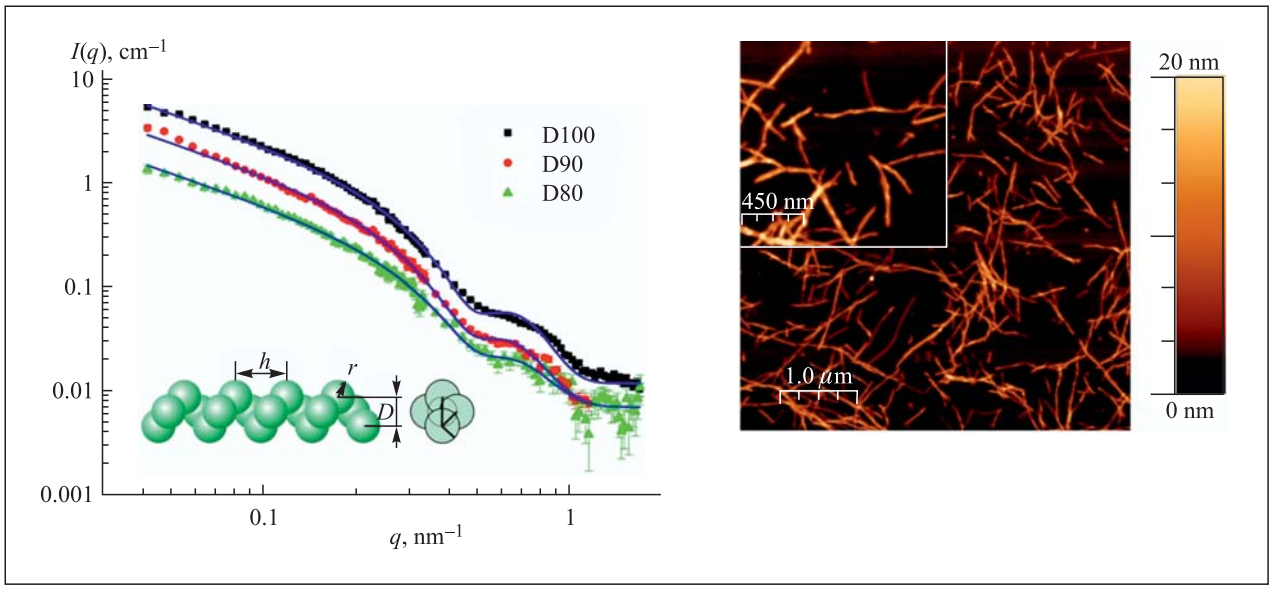

Fig. 2. Small-angle neutron scattering curves (SANS-II, PSI) from fibril amyloidal aggregates of hen egg white lyzosyme at different content of D_2O in solution. The curves are approached by the model «helix from homogeneous spheres» whose parameters are illustrated in the inset. At the right, the AFM image (IEP SAS) is shown for analogous aggregates adsorbed on the mica surface from D_2O

diation the shape of the scattering curves changes sharply in the covered range of the momentum transfer q, which is indicative of reorganization of AzoTAB aggregates. It is possible that in this case AzoTAB forms strongly anisotropic objects. It has been shown that the addition of the photosensitive surfactant to nucleic acids causes their compaction. Along with this, the compaction effect is also photosensitive. It is explained by the change in the surfactant conformation depending on the irradiation wavelength. Thus, the irradiation of the system by ultraviolet light causes the transition of the AzoTAB molecule from trans- to cys-conformation, which promotes the isolation of AzoTAB from RNA/DNA and decompaction of polynucleotide chains.

In collaboration with the State Centre for Machine-Building Technology (TSNIITMASH), the processes of formation and decomposition of martensite after normalizing at 1050 °C and further annealing in the temperature range of 500–840 °C have been studied for heat-resistant ferritic-martensitic steels 10Х9К3В2МФБР and P91 (Russian notation). A strong anisotropy of the diffraction peak width caused by a high dislocation density (as a result of martensite transition) was observed; the values of microdeformations and the dislocation density, as well as their decrease with increasing temperature and annealing time, were determined (Fig. 3). The measured SANS spectra showed the strong surface fractal scattering in these martensites. At the annealing temperature of 600 °C, the intense precipitation of fractal particles of carbides and nitrides was observed during 1 h. At further annealing, the carbides were aggregated up to sizes out of the limits of the SANS method. At the same time the scattering from surface fractals reappeared up to the highest annealing temperatures.

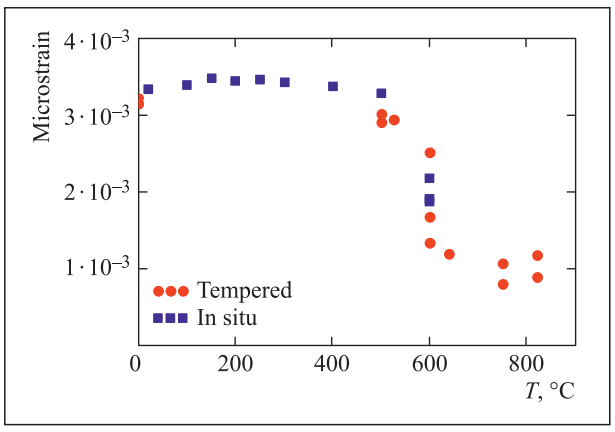

Fig. 3. Relaxation of microstrains in steel 10Х9К3В2МФБР with increasing annealing temperature

A new comprehensive approach to the study of physical properties of layered textured rocks has been realized. It is based on the fabrication of model samples with specified characteristics, which are close in their internal structure and crystallographic texture to the real objects formed under natural conditions of the Earth's lithosphere. For this purpose, the velocities of quasi-longitudinal elastic waves propagating through two-phase layered model samples in the shape of a ball made of mineral powder fillers (muscovite, quartz) and binding layered epoxide have been measured in cooperation with the Institute of Geology, Academy of Sciences of the Czech Republic (Prague, Czech Republic). It has been revealed that samples with muscovite and quartz fillers have different relations between the lay-

ered structure and the spatial distribution of the velocities of quasi-longitudinal elastic waves, which is due to the process of fabrication of the models (deposition) [4].

The quantum-chemical calculations of the lattice dynamics of vanadium oxide in polymorphic phases α-V_2O_5 and β-V_2O_5 have been performed [5]. Vanadium oxides are widely used in thin film electrochemical devices and as cathodes of lithium batteries due to their high energy density and retention capacity upon cycling. The model vibrational spectra showed satisfactory agreement with the experimental Raman spectra. Their analysis permitted a reliable description of all observed spectral features, and made it possible for the first time to establish «structure-spectra» relationship for the two polymorphs of vanadium pentoxides. The activation energy of the phase transition α-$V_2O_5 \rightarrow \beta$-V_2O_5 has been estimated together with the additional calculations aimed at revealing possible mechanisms of the transition.

Instrument Development. The work on the basic configuration of the new DN-6 diffractometer for studying microsamples on beam 6B of the IBR-2 reactor has been completed. The main elements of the diffractometer (mirror vacuum neutron guide, mechanical part, detector system) have been installed at beam 6B. First scientific and methodological experiments have been carried out and showed a one-order increase in the neutron counting rate compared to that of the analogous DN-12 diffractometer (Fig. 4).

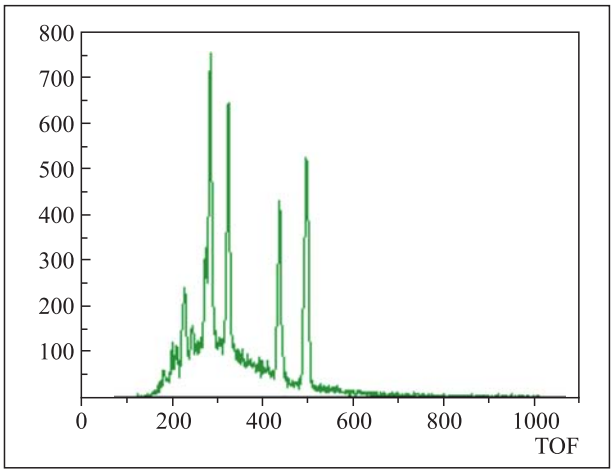

Fig. 4. Spectrum of a standard Ni sample at DN-6 spectrometer

A large-scale modernization of the SKAT/Epsilon and NERA-PR diffractometers on beams 7a-1, 7a-2, 7-b aimed at the replacement of mirror neutron guides, installation of beam choppers and λ-choppers, modernization of the detector system, accumulation and sample environment electronics has been completed. On the NERA-PR spectrometer the integrated neutron flux at a sample position has approximately doubled and in the cold neutron range it has increased 4 times (in the operation mode with a cryogenic moderator) (Fig. 5). The analogous data for the SKAT/Epsilon are to be obtained. The instruments have been put into operation. A high-pressure cell (Paris-Edinburgh type) has been purchased to extend experimental capabilities of the Epsilon diffractometer.

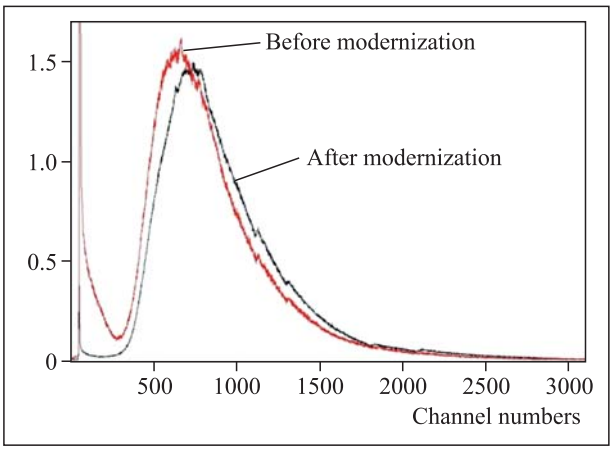

Fig. 5. Incident neutron spectrum obtained for a vanadium sample at the NERA-PR spectrometer before and after modernization

The reconstruction of the DN-2 diffractometer into a diffractometer for real-time measurements continued. A beam chopper, mirror neutron guide, 2D PSD with an active area of 200 × 200 mm have been installed. First test measurements were started.

The work continued to construct a new multifunctional reflectometer GRAINS on beam 10 of the IBR-2M reactor. The improvement of the beam-forming system units was carried out in order to eliminate the revealed design flaws. The final stage of the work on the design and construction of the reflectometer biological shielding has been completed. The electrical work necessary to prepare the spectrometer for commissioning is underway.

The creation of neutron beam infrastructure for the FSS diffractometer (moved from GKSS) and a prototype of neutron radiography facility has started at channels 13 and 14 of IBR-2M. A biological shield has been built; the electrical work is nearing completion.

A significant progress has been made in the development of neutron probe microscopy. The experiment was performed with a polarized neutron (4 Å) beam 2 μm wide formed by a layered waveguide, which was directed to an amorphous magnetic wire $(Co_{0.94}Fe_{0.06})_{72.5}Si_{12.5}B_{15}$ 190 μm in diameter with two types of magnetic domains. As a result of scanning in the direction perpendicular to the neutron beam, a cross sectional profile of a neutron spin precession angle was measured for the wire, thus making it possible to analyze its magnetic microstructure (distribution of magnetic induction). It has been experimentally demonstrated that statistically sufficient data on the magnetic microstructure can be obtained for a reasonable measurement time (of the order of 10 h).

At the IREN pulsed resonance neutron source, the analysis of the boron content in the samples of the materials on the basis of phosphate compositions has been performed by the neutron spectrometry methods. The samples were synthesized at the Belorussian State University (Minsk). These new multifunctional materials combine efficient neutron shielding properties with high heat resistance and mechanical strength [6].

In cooperation with Gettysburg College (Gettysburg, Pennsylvania, USA), the final stage of the analysis of data from the first direct neutron–neutron scattering experiment aimed at studying the charge symmetry of nuclear forces and carried out at the JAGUAR pulsed reactor has been performed. It has been shown that the observed abnormally strong effect of an increase in the scattering intensity with increasing JAGUAR pulse energy can be explained by radiation desorption of hydrogen from the surface of the aluminum channel of the facility induced by a powerful dose of gamma radiation during the reactor pulse. The obtained value of the desorption coefficient, $\eta(\gamma) = 0.02$, is in agreement with the data from other experiments. The performed analysis of literature on metal surface treatment methods suggests that $\eta(\gamma)$ can be reduced down to the value that would be acceptable for nn scattering cross-section measurements [7].

A new method to measure polarization of cold/thermal neutrons using P-even asymmetry in nuclear reactions induced by polarized neutrons has been proposed. A scheme based on a large correlation of the neutron spin and the circular γ-quantum polarization in the reaction (n, γ) of polarized neutrons with nuclei has been analyzed. This method could be used, for instance, to measure the neutron-beam polarization in experiments with frequently varying configuration. It has been demonstrated that high accuracy and reliability of measurements could be expected [8].

Angular correlations between the direction of prompt neutron escape and fission fragment spins have been studied in the experiment carried out in the framework of a wide international collaboration using DEMON neutron detectors. For this purpose triple fragment–neutron–neutron correlations were investigated, for which angular correlations of the escape of two neutrons relative to each other were observed by choosing a dynamic coordinate system aligned with the direction of fragment escape. The existence of such correlations was predicted theoretically and observed for the first time in the experiment [9].

A new method of determination of prompt fission neutron energy that is applicable to single events with measured neutron time of flight has been developed and applied to study spontaneous fission of ^{252}Cf [10]. In the course of the analysis of experimental data, a new method of separation of prompt neutrons and γ quanta has been developed. The digital realization of the correlation algorithm made it possible to enhance the suppression factor for prompt fission γ quanta by more than an order of magnitude. An important advantage of the method is that it has only one parameter for the event selection criterion [11].

The analysis of the experimental data collected in FLNP on the intensities of two-quantum cascades of neutron radiative capture by nuclei in the mass range from ^{39}K to ^{199}Hg continued. A hypothesis on the form of the relation between the partial width of γ transitions, between the excited levels of the above-mentioned nuclei and the structure of the wave function of the excited level has been tested. It has been demonstrated that the introduction of the dependence of the specified width on the density of levels excited by γ transitions ensures a high-quality reproduction of experimental intensities of two-quantum cascades in all ~ 40 nuclei studied so far. This result opens up a possibility of developing new-generation models of cascade γ decay of compound states that provide a significant improvement of the accuracy in the calculation of parameters of this process and factors that determine it [12].

For the massive (500 kg, $\varnothing\, 30 \times 65$ cm) uranium target assembly QUINTA irradiated at JINR Nuclotron by accelerated deuterons with energies from 1 to 8 GeV, the time spectra of fission delayed neutrons (DN) measured using the IZOMER-M detector as well as spatial distributions of ^{238}U fission rates were simultaneously obtained for the first time. In addition, using DEMON liquid scintillation detectors, the first direct measurements of energy spectra of leakage of prompt neutrons produced in the target assembly were carried out, which pointed to the presence of a considerable high-energy neutron background. Contrary to the existing theoretical predictions, the analysis of the results from the measurements in 2012 has showed that for a deeply subcritical natural uranium target the total number of fissions increases linearly depending on the energy of incident deuterons in the deuteron energy range studied. The group analysis of DN time spectra indicates a growth of the average energy of the neutrons initiating fission of ^{238}U target nuclei with an increase in the energy of incident deuterons [13].

A new effective analytical approach to describe electromagnetic waves in anisotropic media has been proposed. An analytical description of the refraction and reflection at an interface between isotropic and anisotropic media has been demonstrated. Beam splitting upon reflection and refraction as well as surface wave generation have been studied. D'yakonov surface waves and methods of their observation are under discussion. Analytical and numerical calculations of

the reflection and transmission of plane-parallel uniaxial plates have been demonstrated [14].

An oxygen depth profile of a TiO\Pt\Si sample has been studied by employing a resonance in the elastic scattering of helium ions with the energy of 3.045 MeV from oxygen atoms. Three 10–30 nm-thick layers with an oxygen content of 50–60–67 at. % and one layer with an oxygen concentration of 10 at. % were detected by scanning over the energy range near the resonance. The oxygen content was measured with an accuracy of 2 at. % [15]. The effect of irradiation with fast neutrons at a dose rate of $1.4 \cdot 10^{14}$ n/cm^2 on the properties of SiC and SiC(N) films has been studied using nuclear analytical RBS and ERD techniques. A 100-fold change in the conductivity of layers was found while the element content and layer thickness in the samples experienced no noticeable changes [16].

The limits of analytical possibilities of the RBS and ERD techniques for charged particle (protons and helium ions) beams have been considered. The combined application of both techniques has been demonstrated to provide full information on the content of all elements in the surface layer of a sample. The sequential analysis of one and the same sample using a proton and helium ion beam makes it possible to improve the accuracy of determination of light element concentration and to increase the depth of the analysis [17].

In 2012, within the framework of the International Programme «Atmospheric Deposition of Heavy Metals in Europe — Estimates on the Basis of the Analysis of Mosses-Biomonitors», the data analysis was completed and a number of papers [18–21], which reflect the contribution of the NAA Sector to the European Atlas of Heavy Metal Atmospheric Deposition for Macedonia, Bulgaria, Croatia, and Serbia, were published. In 2012, in cooperation with the biophysicists of the E. Andronikashvili Institute of Physics, I. Javakhishvili Tbilisi State University and I. Chavchavadze State University (Tbilisi, Georgia), the studies on the development of methods for synthesis of silver and gold nanoparticles by some new strains of bacteria and blue-green algae *Spirulina platensis* continued [22].

THE IBR-2 PULSED REACTOR

1. Rostechnadzor license No. GN-03-108-2614 of 27.04.2012 was obtained for the regular operation of the IBR-2 reactor.

2. In accordance with the license requirements, during the year, specialized organizations together with the IBR-2 personnel have been performing the scheduled work on the technical evaluation and the assessment of the remaining life of the technological reactor equipment.

3. The modernization of the cooling system of the movable reflector MR-3 jacket has been carried out: The scheme of pump unloading has been changed over to partial discharge of water directly to a distillate tank and the pumps of the cooling system of the movable reflector MR-3 jacket have been replaced.

4. Since May 2012, regular IBR-2 cycles of physical experiments have been carried out at a power of 2 MW with the CM-202 moderator operating either in a water or cryogenic mode depending on the schedule of the physical start-up of the cold moderator.

The working parameters of the reactor during the cycles are presented in the Table.

An additional one-day run of the reactor at a low power was performed on July 10 in order to test the cryogenic system.

Data on the IBR-2 operation for physical experiments

No. cycle	Period	Moderator type	Reactor power, MW	Reactor operation at power, h	Reactor operation for physical experiments, h
1	May 21 – June 1	Water	2	247	241
2	June 18 – June 29	Water	2	272	264
3	September 24 – September 28 October 3 – October 9	Cryogenic Cryogenic	2	244	201
4	October 22 – November 1	Water	2	179	171
5	November 12 – November 24	Water	2	290	281
6	November 28 – December 4	Cryogenic	2	171	131
7	December 13 – December 21	Cryogenic	2	189	182
			Total:	**1592**	**1471**

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

The start-up of the first CM-202 cold moderator at the modernized IBR-2 reactor at a maximal power of 2 MW has been successfully done in the framework of the project of the development of a complex of cryogenic moderators. All systems of the moderator worked properly throughout the whole cycle and the moderator chamber was fully charged with mesitylene beads. A «pinhole-camera» method was used for monitoring the charging process by taking 2D neutron images of the moderator chamber (Fig. 6) by a two coordinate PSD. At the end of the reactor cycle, which lasted for 5.5 days, it was found that the cold neutron flux from the surface of the cryogenic moderator had increased by a factor of up to 13 as compared to that from the surface of a water moderator. In 2012, the automated system of acquisition and registration of control and measuring data from the sensors of the monitoring system of the cold moderator was modernized as well.

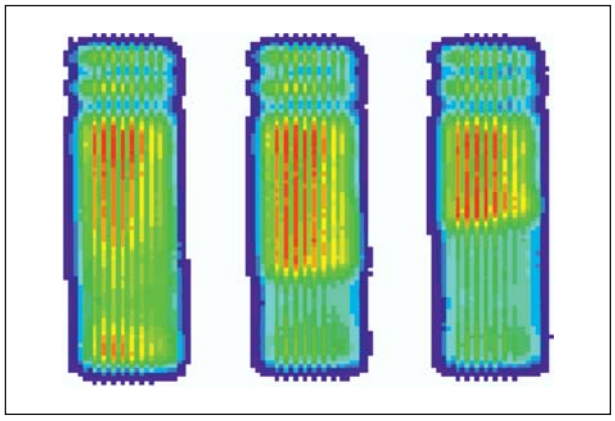

Fig. 6. Neutron images of a part of the complex of moderators CM-202 with a cryogenic moderator located in the bottom half at different bead filling levels: empty chamber (at the left), 2/3-filled (at the centre) and full chamber (at the right)

The work to design and construct a helium-3 purification facility has been completed. The facility is intended for purification and preparation of He^3 for reuse in neutron detectors. A gas He^3-containing mixture from the detectors is stored in the tanks of the facility and, using cryogenic and pumping-over systems, helium is separated from other gases. Then, by means of a special cryogenic pump, He^3 is compressed to a pressure of 80 bar, which is sufficient to fill new detectors. The facility has undergone precommissioning tests and has been put into operation.

The development of the VITESS software package continued. In 2012, special VITESS modules that allow the simulation of the neutron spin behaviour in arbitrary magnetic fields were improved, and the first stage of a novel project — the immersion of VITESS modules in a magnetic field — was fulfilled. The module «polarizing mirror in a magnetic field» has been developed and tested, and is planned to be included in the next VITESS version. Four new VITESS modules that make it possible to simulate and calculate the time focusing surface for time-of-flight spectrometers on pulsed neutron sources have been developed and are being tested. In addition, a module from the MCSTAS programme for simulating a gas PSD has been introduced and adapted for the VITESS package.

On beam 7 of the IBR-2 reactor, the construction and installation of an 80-m neutron guide for the NERA-PR spectrometer have been completed. The adjustment of optical elements has been performed. An adjustable diaphragm for neutron beam focusing has been manufactured. The diaphragm is controlled by stepper motors connected to PC via CAN/USB controller and converter. The modernization of a multicounter detector for NERA-PR has been carried out as well. A control system of detector collimators and goniometer (Huber) has been put into operation at the EPSILON spectrometer. At present, at these spectrometers new DAQ systems for point detectors have been installed; the adjustment work is nearing completion and test measurements are being made. The automation system of these instruments also monitors the status of choppers, shutters, and the readings of vacuum sensors and other elements of the spectrometers. Sets of equipment for automation systems and data acquisition systems have been adjusted at a test-stand and are ready to be installed at the SKAT, GRAINS, and DN-2 (RTD) spectrometers. Two polarizers and two diaphragms have been assembled and tested for GRAINS, and drawings of a beam collimation system for DN-2 have been developed.

At present in addition to the above-mentioned instruments, new DAQ-systems for point detectors have been put into service at the FSD, DIN-2PI, DN-6, and REFLEX spectrometers.

The work continued on the construction of a new high-resolution Fourier diffractometer on the basis of the units of the FSS spectrometer (GKSS, Geesthacht, Germany) on beam 13 of the IBR-2 reactor. In connection with the construction of a test bench for neutron imaging on the adjacent beam 14, a draft layout of the equipment was corrected and a new arrangement of biological shielding of beams 13 and 14 was developed, drawings were made, shield elements were manufactured and assembled. On the FSD diffractometer, the tests of a «List Mode» analyzer for accumulation of «raw» data in the list mode (MPD module) and the debugging of processing programmes are in progress.

The project of creation of a gas ring-shaped multisection detector for the DN-6 diffractometer has been

completed. In 2012, the following main activities were conducted within the framework of the project:

— Mechanical units for fastening and adjustment of the detector were developed and manufactured, and its background shield was mounted.

— The 96-channel data acquisition and accumulation electronics were checked out and debugged.

— Programmes for testing the detector were written, data accumulation software was upgraded, and a new programme interface was developed.

— Test trials of the detector were conducted on beam 6b of IBR-2 with working gas mixtures at different pressures of He^3.

The detector has been handed over to the physicists for further testing and working measurements.

Inoperative position-sensitive detectors on HRFD and REFLEX have been replaced. Two detector systems that comprise 2D PSD, detector electronics, data acquisition and accumulation electronics as well as software have been made and transferred to the Nuclear Research Institute (NRI) in Řež (Czech Republic). On the DN-2 (RTD) diffractometer, a detector system with 2D PSD (active area of 225×225 mm^2) has been put into operation and a ring-shaped helium back-scattering detector has been manufactured, assembled, and tested on the test stand. An ND-screen-based scintillation counter with light collection using wavelength shifting fibers has been made and tested. The preparation for production of scintillation counters for the «Aster» detector has begun. A number of measures to upgrade the clean room have been taken; its area has increased to 10 m^2.

Neutron beam profiles have been measured on beams 2, 4, 6a, 6b, 7, 9, 11, 12 of the modernized IBR-2M reactor. The measurements were carried out in the beam extraction areas using a 2D thermal neutron PSD-monitor. An average intensity, coordinate and time distributions of neutron fluxes were measured for each beam.

A large amount of work has been carried out on the development and maintenance of the Sonix+ software package on the IBR-2M spectrometers:

— Sonix+ versions were prepared and put into trial operation on the spectrometers where new DAQ-systems have been installed (NERA-PR, EPSILON, DIN-2PI, DN-6, RTD). Sonix+ versions for SKAT and DN-2 (RTD) were prepared and tested on a test stand.

— Variants of adjustment software were developed for the YuMO, REMUR, and REFLEX spectrometers.

— A new variant of user interface on the basis of PyQT and Matplotlib was designed and implemented.

The main task of the current year in the development of LAN — to provide the end-user with the rate of up to 1 Gb/s in the main network segments (bldg. 42, 42a, 43 (IREN), 44, 117, 119) — has been successfully fulfilled. A trouble-free operation of all network equipment has been maintained both on the IBR-2 spectrometers and in the offices of the Laboratory.

Because of an increase in the amount of data coming from the IBR-2 spectrometers, a subnet has been allocated to the IBR-2 network segment and connected directly to the FLNP switch to provide a throughput of up to 10 Gb/s.

A new SuperMicro 6047 server intended, first of all, for data storage has been purchased and installed. The server disk memory capacity is 72 TB.

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 2012: the V 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-2012) (17 June – 5 July, Moscow–Dubna); the III International Scientific School for Young Scientists and Students «Instruments and Methods of Experimental Nuclear Physics. Electronics and Automatics of Experimental Facilities» (September 8–12, Dubna), and the IV International Neutron School for Young Scientists and Students «Modern Neutron Diffraction Studies: Interdisciplinary Research of Nanosystems and Materials» (September 24–28, 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 20th edition of the traditional International Seminar on Interaction of Neutrons with Nuclei: «Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics» took place on Alushta, Ukraine in May 21–26. Papers presented covered a wide range of issues of fundamental and applied nuclear physics and ecology, studied with neutrons.

On the initiative of the Romanian representative in ENSA, the international neutron centre FLNP JINR (Dubna) was chosen to be the venue for the 39th European Neutron Scattering Association (ENSA) Meeting (October 8–9, 2012).

The International Summer School and Workshop «Complex and Magnetic Soft Matter Systems: Physico-Mechanical Properties and Structure» (CMSMS'12) was held in Alushta, Ukraine in September 3–7. The School-workshop was organized by FLNP JINR together with West University of Timisoara, Institute of Continuous Media Mechanics of Ural branch of Russian Academy of Sciences (Perm), Institute of Physics and Nuclear Engineering «Horia Hulubei» (Bucharest) and Romanian Society of Physics.

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