FRANK LABORATORY OF NEUTRON PHYSICS

In 2003, the FLNP scientific programme was realized under the auspices of five research themes of the JINR Plan of Scientific Research and International Scientific and Technical Cooperation (PSRISTC). It was aimed at obtaining new results in condensed matter physics (theme «Neutron Investigations of Structure and Dynamics of Condensed Matter», 07-4-1031-99/2003, headed by V. L. Aksenov and A. M. Balagurov) and neutron nuclear physics (theme «Nuclear Physics with Neutrons — Fundamental and Applied Investigations», 06-4-1036-2001/2004, headed by W. I. Furman and V. N. Shvetsov). To effect scientific research, work to develop, modernize, and construct the FLNP basic facilities, IBR-2 (theme «Upgrade of the IBR-2 Complex», 07-4-0851-87/2007, headed by V. D. Ananiev) and IREN (theme «IREN Project», 06-4-0993-94/2004, headed by W. I. Furman and I. N. Meshkov) as well as the IBR-2 spectrometry and computation complex (theme «Development of the IBR-2 Spectrometer Complex and Information-Computation Infrastructure», 07-4-1012-96/2003, headed by A. V. Belushkin and V. I. Prikhodko) continued.

Current topics of the investigations, carried out in collaboration with leading nuclear research centres, were considered and discussed at the XI International Seminar on Interaction of Neutrons with Nuclei and the XII International Conference on Selected Problems of Modern Physics.

CONDENSED MATTER PHYSICS

Diffraction. At HRFD, new experimental results on the magnetic and nuclear structures of manganites with a colossal magnetic resistance were obtained. In particular, two series of samples of the type $(La_{1-y}Pr_y)_{0.7}Ca_{0.3}MnO_3$ (LPCM), each enriched with the oxygen isotope ^{16}O or ^{18}O, were investigated in detail over a wide interval of Pr concentrations. Qualitative coincidence of phase diagrams for the two series, though with a shift in Pr concentration, was established. This means that strong influence of isotopic replacement on LPCM macroscopic properties in the region of mixed metallic and dielectric states, which was observed earlier, is, in the main, a percolation effect rather than the result of appearance of some principally new state [1]. Neutron diffraction was used to investigate the oxygen and fluoridated layered manganese oxides $Sr_2GaMnO_{5-x}F_{1+x}$ with a structure of the brownmillerite type. In such compounds, the number of Mn^{3+} and Mn^{4+} ions, which affects the extent to which the mechanism of «double exchange» demonstrates itself, depends on the concentration of oxygen and fluorine and can be easily changed. The type of magnetic ordering in brownmillerites depends on the structure of the buffer layer $Ga(O,F)_6$ and on the Mn orbital configuration. The crystalline and the magnetic structures of the compound $Sr_2GaMnO_{4.8}F_{1.2}$, where the Mn mean charge is +3.8, were determined (Fig. 1).

At the DN-12 diffractometer for high pressures, the structure of the pseudobinar system of mercury chalcogenites $HgSe_{0.7}Se_{0.3}$was investigated at 9 GPa. A phenomenological model of the phase transition from cubic structure of the blende type to hexagonal structure of the cinnabar type observed in the compound under pressure has been suggested. The effect of high pressures, up to 4 GPa, and low temperatures, from 16 to 300 K, on the MnAs atomic and magnetic structure was investigated (Fig. 2). It is found that in MnAs in the region of high pressures and low temperatures there exists a new

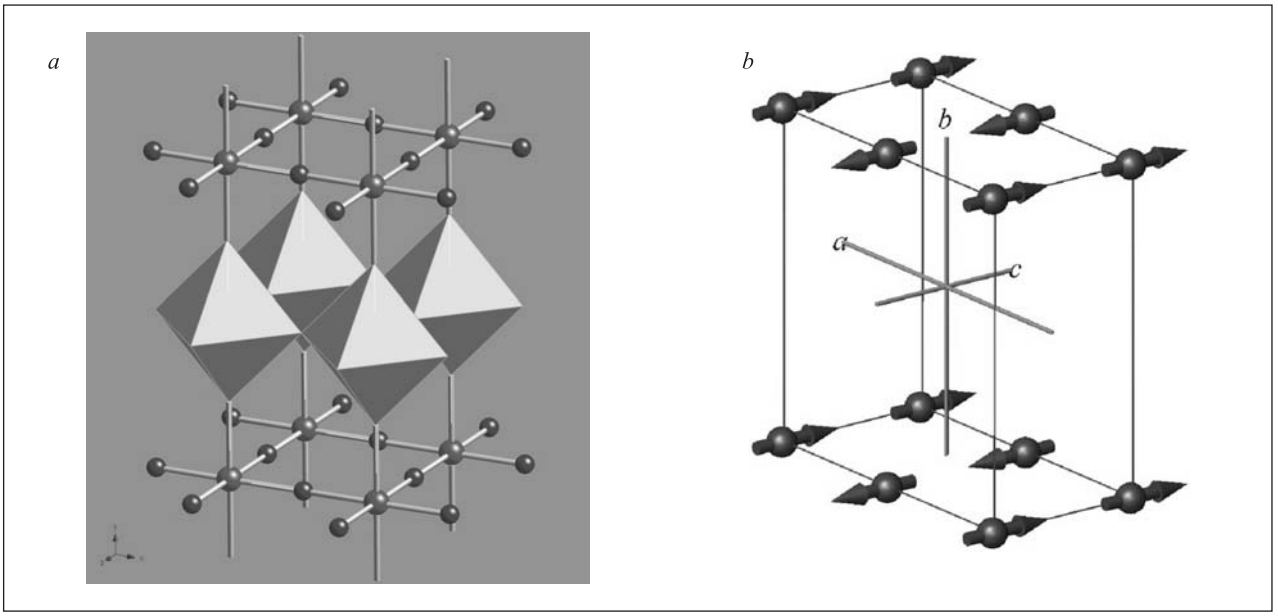

Fig. 1. The crystalline structure of $Sr_2GaMnO_5F_1$ (*a*). The MnO_2 planes and the $Ga(O,F)_6$ octahedra are shown. The spin configuration in $Sr_2GaMn(O,F)_6$ (*b*). Only the manganese are shown

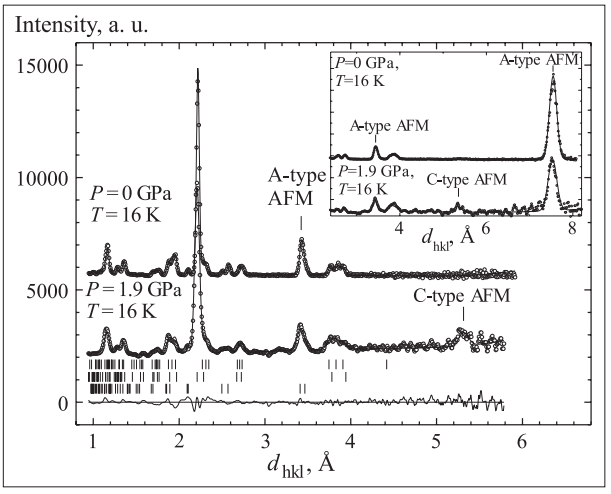

Fig. 2. Neutron diffraction patterns of $Pr_{0.44}Sr_{0.56}MnO_3$ measured at $P = 0$ and 1.9 GPa, $T = 16$ K at scattering angles $2\theta = 90$ and 45.5° (inset) and processed by the Rietveld method. A coexistence of the initial A-type AFM orthorhombic phase with a pressure-induced C-type AFM tetragonal phase was observed

orthorhombic magnetic phase. Investigations of the atomic and magnetic structure of the manganites $Pr_{1-x}Sr_xMnO_3$ ($x = 0.50,\ 0.56$) was conducted at 0–5 GPa and 16–300 K. It has been discovered that in the region of high pressures and low temperatures a new tetragonal phase, which coexists with the initial orthorhombic phase, arises in $Pr_{0.5}Sr_{0.5}MnO_3$ and $Pr_{0.44}Sr_{0.56}MnO_3$. This pressure-induced tetragonal phase has an antiferromagnetic structure of the C-type in $Pr_{0.44}Sr_{0.56}MnO_3$ and exhibits no sign of magnetic ordering in $Pr_{0.5}Sr_{0.5}MnO_3$ [2].

Polarized Neutrons and Neutron Optics. At the REMUR reflectometer, a spatial magnetization distribution at the V(650 Å)/Cr bilayer interface, where an effective ferromagnetic layer was discovered to exist, was measured. The data from reflectometric measurements of the magnetization profile in periodic Fe/V structures were analyzed to determine the magnetic ordering type of vanadium atoms in the vicinity of the interface. To analyze the experimental data, a program for the calculation of reflection coefficients involving a particular type of gaussian nonideality of the interface structure has been developed [3].

Inelastic Neutron Scattering. At the NERA-PR spectrometer, a series of experiments on neutron diffraction and neutron inelastic scattering was carried out using a set-up for the investigation of phase transitions and dynamics of solid mesitylene. The obtained results were used to calculate its moderating properties. It is shown that solid mesitylene can occur in different crystallographic modifications depending on the degree of cooling and thermal processing. The generalized phonon density function of different mesitylene phases has been obtained and analyzed.

Small-Angle Scattering. At the YuMO instrument, complex small-angle neutron scattering investigations of a number of nanodimensional systems were carried out. In particular, experiments on the small-angle scattering of neutrons on colloid C_{60} fullerene water solutions were conducted and analyzed. The specific parameters of colloid particles (size, polydispersivity, density, etc.) and their dependence on the fullerene concentration were determined. A number of models of the particles have been suggested based on the obtained data and some complementary methods.

Small-angle neutron scattering experiments on the solution C_{60}/carbon bisulphide were repeated confirming the existence of cluster-like formations in the solution. From the scattering curves, size distributions of the formations were obtained and it was determined how the temperature and fullerene concentration affected them. In the framework of the nucleation theory, equations for a kinetic formation of clusters in the studied system were investigated. It is shown that a series of simple expressions for the binding energy as a function of the number of particles in the cluster corresponding, in particular, to the drop model of the cluster do not describe the cluster state of fullerene in carbon bisulphide if the nucleation theory is used.

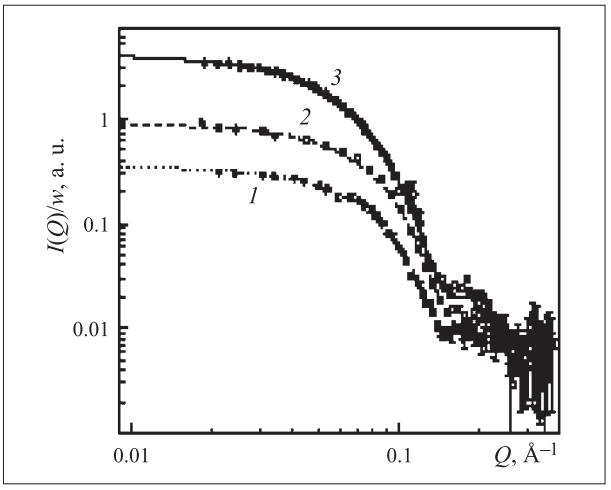

Fig. 3. SANS curves for G(3)7 dendrimers in chloroform-*d* (*1*) and in benzene-*d*6 (*2*), and for G(4)7 dendrimers in benzene-*d*6 (*3*). $w = 4$ wt.% (*1, 2*) and 1 wt.% (*3*). The fits are made using uniform ellipsoid model

In the framework of investigations of ferroliquids a simple method of testing industrial ferroliquid samples, based on the analysis of small-angle neutron scattering intensities, has been suggested. The method allows aggregations in ferroliquids to be identified with a good confidence and their stability under different magnetic loadings to be judged [4].

The basic parameters of polycarboxyl dendrimers with different molecular architectures were obtained (Fig. 3). At the same time, it was found that the solvent penetrates into the dendrimer structure in the amount up to 30% by volume [5]. Analytical models for the determination of the structural parameters of the protein RecA that forms filament complexes with DNA were investigated. It has been shown that the structure of filaments is formed of two RecA proteins. The effect of the n-decane on the thickness of the lipid bilayer in a unilamellar vesicle was investigated. Precision measurements of small-angle neutron scattering curves have made it possible to discover, in particular, that the bilayer thickness increases by 2.4 Å. In addition, these data together with those from differential scanning calorimetry allowed explaining of nonmonotonous temperature dependence of the structural parameters of polyethylene oxide/polypropylene oxide copolymers in water solutions [6].

Applied Research. In the framework of studies on «the physics of seismic foci and physics of rock failure», theoretical and experimental investigations of anomalous physical properties of minerals and rocks were conducted at high temperatures and pressures. At the SKAT–TKOS experimental complex, measurements of the structure, texture as well as elastic, deformational and thermal properties of polycrystalline quartzite were conducted under simultaneous action of a deforming force and temperatures, from 20 to 620 °C, making it possible to perform an analysis of the temperature dependence of intra-lattice stresses. To elucidate the nature of the anisotropy of seismic waves at different depths in the lithosphere, a complex investigation of rocks from different lithosphere depths at high all-round pressures and with an instrument creating triaxial stresses at temperatures up to 600 °C was first conducted. It is established that the key factor that controls the elastic properties anisotropy of olivine-bearing mantle rocks at high all-round pressures (over 200 MPa) is the crystallographic structure of olivine. The influence of the form texture (oriented microcracks, pores, intergrain boundaries, etc.) on the elastic anisotropy of olivine rocks has been determined [6].

The research programme for EPSILON/SKAT focused on the following directions: investigations of applied and residual stresses in polycrystalline materials (rocks and other materials); texture analysis of materials (mainly geological), and obtaining of anisotropic physical properties of rocks from their crystallographic textures. The investigated samples were dolomite and anhydrite compositions, construction marble materials, rocks from the Eastern Alps, etc. [7].

At the HRFD diffractometer, measurements of residual stresses in bimetallic (hardened steel/zirconium alloy) uses in RBMK neutron reactors continued. The work was carried out together with research institutes of Minatom, RF. The instrument was also used to study TiNi alloy-based materials under external nonaxial loading at different temperatures. The dependence of the martensite transition temperature on the loading was obtained. The formation and growth of the austenite phase with a characteristic distribution of stresses between the two phases depending on external loading have been observed. A difference between the lattice parameters of the martensite phase in freshly prepared samples and those used has been discovered [8].

By means of neutron diffraction at the DIN-2PI instrument, the structure of liquid lead/potassium alloys was investigated. An analysis of neutron diffraction patterns as a function of relative lead concentration points to the absence of specific Zintl clusters in alloys. This means that the investigated alloy has much lower corrosion properties than pure lead and may be looked at as

a possible candidate for the role of an effective cooling agent in nuclear power stations [9].

Principal Methodological Results. Tests of a new head part of the REMUR spectrometer were conducted on the neutron beam. The tests have proved that the choice of a concept of a head part with two different neutron sources is right. Physical and technical proposals for the modernization of the platforms for the polarizers, the shielding of the spectrometer's detector, and the creation of the new movable collimators were developed.

The reflection of neutrons from layered spin-precessors was investigated. A new magnetic system, which allowed the realization of a spin-precessor with rotating current planes, has been created. A two current $\pi/2$ rotators–based spin-precessor was investigated. It has been experimentally shown that the neutron spin precession phase changes as a function of beam divergence and rotation angle of the current planes of the rotators. It is found that with such a precessor the beam cross section 10×25 cm can be used and objects with a correlation length in the range $10^2 - 10^4$ Å can be investigated [10].

The possibility of construction and draft project development of a polarized neutron reflectometer with a vertical scattering plane on the second beam of the REFLEX reflectometer was investigated. The instrument is expected to have a resolution of several percent, working wavelength interval of $1-10$ Å and a spectrum-averaged polarization of the incident beam on the level not lower than 95%. The main objects of investigation with the new reflectometer will be surface films on liquids.

At the REFLEX II spectrometer, a measuring technique using polarized neutrons that employs larmor precession of neutron spin and is based on the use of current foils has been tuned. The technique has been developed to be used at the time-of-flight reflectometer. The larmor precession technique combined with the time-of-flight method is a new direction that extends essentially the experimental possibilities of the instrument.

At the DN-12 diffractometer for high pressures, a collimation system for detectors has been developed and tested. The effect-to-background ratio has been increased three times. A project of a cooled beryllium filter for experiments on inelastic neutron scattering at high pressures has been developed.

At the EPSILON instrument a system of nine radial collimators, each equipped with nine detectors, has been adjusted. A total of 42 new detectors are installed and, as a result, the total number of detectors is 78 today. In the course of measurements, the diffraction spectra registered by the detectors are added up by means of time focusing based on varying of the channel width depending on the detector position. All the necessary calculations (recalculations) are performed in parallel. To raise the quality of experimental determination of materials' elastic properties, the effect of the number of grains in a polycrystalline sample and of the volume distribution of grains on the accuracy of the obtained elastic property parameters was studied. The new proposed model of calculation of the elastic properties of polycrystals was applied for the investigation of important technological materials, such as copper, graphite, zirconium, etc.

At the YUMO instrument, the two-detector system started to operate effectively: sample environment possibilities are widened, the project for creation of a facility with a magnetic field is going on successfully, a number of new experimental data procession programs were written and tested. The project of a small-angle X-ray diffractometer is being developed successfully [11].

At the DIN-2PI spectrometer, works were carried out to complete the experimental base for neutron physics investigations of matter over the temperature region up to 3000 K. Heating of the sample and keeping its temperature on the specified level during the course of measurements are executed with the help of the TS-3000 thermostat installed in the vacuum chamber of the spectrometer. The thermostat was designed and produced in Romania in accordance with the technical proposal developed by FLNP and PSI. The thermostat was tested in the working conditions. The new experimental possibilities of neutron physics investigations of matter at temperatures up to 3000 K allow intensification of research in: atomic structure and dynamics of advanced reactor materials under working or extreme temperatures in nuclear power facilities; superionic conductors with a fluorite structure (of the CaF_2 type) in the region of the superionic transition; advanced materials for thermonuclear reactors in the temperature region up to 3000 K, peculiarities of the structure and dynamics of liquid-metallic systems with admixtures of carbon or carbon modifications in the region of high temperatures, etc.

NEUTRON NUCLEAR PHYSICS

In 2003, the FLNP experimental investigation programme in neutron nuclear physics included traditional directions of fundamental and applied research carried out on the IBR-2 and EG-5 beams and in collaboration with nuclear centres in Russia, Bulgaria, Poland, Czechia, Germany, the Republic of Korea, France, the USA, and Japan.

Experimental Investigations. Early in 2003 in the course of two operation cycles on beam 1 of the IBR-2 reactor, experimental work to elucidate the nature of the spatial parity-violation effect in the interaction of polarized thermal neutrons with plumbum nuclei was completed [12]. As a result, it has been shown that the spin rotation effect responsible for spatial parity violation may be due to the isotope ^{207}Pb rather than to ^{204}Pb, as was earlier obtained by an ITEP group. This is based on the discovery of a p resonance in ^{207}Pb, which may explain the parity-violation effect.

On the IBR-2 beam 11b the experiment to measure the scattering anisotropy of neutrons on gaseous argon at 50 atm and on vanadium or cadmium metallic plates was completed [13]. The objective of the measurements was the ratio between neutron scattering intensities into the front and into the back hemisphere $R = I(30^\circ)/I(150^\circ)$ for the neutron energy $E = 0.002{-}0.07$ eV. For argon, a distinct diffraction pattern was observed well corresponding to the data on the argon structural factor in the literature. The pattern, after being reduced 50 times, has led to two important conclusions: 1) even at low pressure diffraction there is a serious obstacle to a reliable measurement of the n, e-scattering length b_{ne}; 2) the situation is much better at $E > 0.1$ eV, at which measurements should be taken. Vanadium frequently used as an isotropic scatterer has first demonstrated a weak anisotropy $(R = 0.97{-}1.06)$ as predicted by J. Mayers (Nucl. Instr. Meth. 1984. V. 221. P. 609). The measurements with cadmium demonstrated that cadmium has an appreciable reflectivity ($\sim 10^{-3}$) described well by a simple formula. The value of $R$is on the order of 0.02–0.03.

In 2003, the processing of the data from a Dubna–Karlsruhe joint experiment to measure the neutron capture cross section of the isotope ^{147}Pm being an important branching point on the s-process pathway, which was carried out for neutron energies characteristic of stellar conditions, was completed [14]. On the basis of the newly obtained data an analysis of s-process branching at $A = 147/148$ was performed and neutron densities in the stage of pulsed layer burning of helium in small-mass red giants were estimated.

As part of the preparation of the experiment on direct measurements of the neutron-neutron scattering length at the JAGUAR reactor at VNIITF (town of Snezhinsk), background calculations for the lower part of the experimental channel were carried out. These allowed the optimization of the geometry of the channel, of the collimators, and of the shielding under the reactor to satisfy the condition: the number of the registered background events per pulse is not larger than 1% of the number of the registered useful events. It is found that the main contribution to the background is that of fast neutrons with energies from 100 keV to 5 MeV. The FLNP–VNIITF–Triangle University international collaboration with a financial support from RFBR, ISTC, and Minatom, RF, completed the modernization of the JAGUAR reactor environment: a 10 meter deep under-reactor mine was built and openings in the over-reactor cover were made.

The processing of the earlier data on the process of cascade gamma decay of compound states of nuclei with a high level density by the method of summation of coinciding pulse amplitudes was continued. Under the programme, the most detailed and precise data on the properties of excited states of the spherical ^{118}Sn [15] and deformed ^{185}W compound nuclei for energies up to their neutron binding energy B_n have been obtained. The data in the form of spectra that are extremely simple and most convenient for the determination of the most probable level densities and radiative strength functions were obtained for more than half total intensity of all probable primary gamma transitions in the two investigated nuclei. No other experimental technique known today can produce comparable information about nuclei with similar parameters above the excitation energy about 1–3 MeV. As for the nuclei studied before, the parameters of the cascade gamma decay of both ^{118}Sn and ^{185}W in the excitation energy region around the neutron binding energy cannot be reproduced without accounting for a sharp change in the structure of the nucleus at least in the selected excitation energy region. The conclusion is arrived at not only because of the existence of a step-like structure in the dependence of the level density on the excitation energy around $0.5B_n$, but also because of a quite appreciable increase in the total cascade population of levels in a number of nuclei below that very excitation energy. In the framework of available developments of a model description of level densities by Obninsk theoreticians, a qualitative description of the observed effects can be done under the assumption of breaking of one or several Couper pairs of nucleons at an effective excitation energy in the deformed nuclei of the order of 3 MeV and a somewhat higher energy in the spherical nuclei belonging to the region $A = 100$. This is also what the transition of the nucleus from excitations with dominance of vibrational components of level wave functions to dominance of multiquasiparticle levels is connected with.

In the field of **Theoretical Physics**, investigations in the physics of fission, fundamental properties of the neutron and high-excited states of compound nuclei were performed.

Within the framework of the new approach to the description of induced fission developed by Barabanov and Furman on the basis of helicity representation and R-matrix formalism, an analysis of the experimental data on P-even and P-odd angular correlations of fission fragments from resonance neutron induced fission was completed [16]. The approach has made it possible to describe such interference effects in the differential fission cross section as the anisotropy of «forward–backward» separation of fragments on the unpolarized neutron beam and their «left–right» anisotropy on the polarized beam, as well as spin–opposite spin

anisotropy caused by a contribution of the weak nucleon–nucleon interaction. The R-matrix formalism allows a more complete and rigorous description of the contribution of the interference of s, p resonances to the observed angular correlations. At the same time, an important role of interresonance interference in the energy structure of the observed effects is indicated. This is what makes the new approach essentially different from the Sushkov–Flambaum simplified approach proposed back in 1982. In contrast to the Sushkov–Flambaum approach, the structure of the parity-violating cross section is related to s resonances and, correspondingly, the matrix elements of the weak interaction as a superposition enter into «impurity» fission width of s resonances.

Applied Research. On the IBR-2 beam 6b, measurements of sample filters from reactor construction materials such as Mo, Pb, Ti, W, and Zr to measure their thermal neutron cross sections were conducted using a chopper-monochromator [17]. The 0.1–200 keV time-of-flight spectra from Mo, Rh, Ho, and W measurements were analyzed and total/capture cross sections and transmissions were obtained with an accuracy of 0.2–0.5% (transmission) and of 2–10% (cross sections). For Nb, Mo, and Pb, the resonance blocking coefficients in capture and scattering cross sections were determined in a similar energy region. The obtained data will be included in the nuclear data libraries used in the calculation of nuclear facilities.

NEUTRON SOURCES

The IBR-2 Pulsed Reactor. In 2003, the IBR-2 reactor operated in accordance with the approved working schedule. It has operated ~ 681 hours in two cycles with the power $W = 1.5$ MW.

Modernization of IBR-2 was carried out in the following directions:

- MR-3 — chief goal of the year: test assembling of MR-3 without a jacket on the FLNP testing stand is performed; MR-3 startup in the air at a rate of up to 360 rot/min (60% of nominal rate) is conducted; vibration level is checked; manufacturing of the jacket is completed at NIKIET; test assembling of MR-3 with a jacket is under way.
- New fuel loading: manufacturing of TVELs is in the stage of completion at the industrial enterprise «Mayak»; components of fuel element assemblies (TVS) are manufactured and supplied; GSPI project of TVELs assembling into TVS started.
- Basic reactor equipment: manufacturing of the new reactor jacket continued; work to execute design plans and documentation for roll-away shieldings and stationary reflectors continued.
- Control and emergency system (SUZ): agreement with SNIIP Systematom for the development and manufacturing of SUZ electronic equipment is signed; development of SUZ executive mechanisms continued at NIKIET.
- Helium facility: development of the new Cold Helium Facility (CHF) completed.

The IREN Project. The main task of the IREN project in 2003 was decommissioning of the IBR-30 reactor. It is a mandatory condition to get a license for construction of the IREN facility. JINR Directorate assigned nominally a special grant ($80 000) for decommissioning of the IBR-30 reactor and a separate grant ($50 000) for the project itself.

The first one allowed fulfilling of the task in principle. But, actually, in spite of much effort to realize the special JINR Director's order and the respective time-table, the decommissioning of IBR-30 was not finished in 2003. Meanwhile, most of items of this timetable were realized (bld. 117/6 for storing of activated constructions of the reactor is completed and technically equipped, all devices necessary for dismantling of the reactor are manufactured and tested, all containers intended for transportation and storing of reactor fuel load are manufactured and obtained, the first stage of personnel training is completed), the absence of some dosimetric equipment and debts for construction of bld. 117/6 did not permit us to get license for exploitation of this storage and for its use for some operation with fuel load. So the dismantling of IBR-30 will not start before the summer of 2004, provided that dosimetric equipment is paid, delivered, and installed in the first quarter of 2004 and the license for storage is received before starting of the work. The work on dismantling of the reactor is permitted to carry out only at warm time. It is essential to note that the present license for decommissioning of the IBR-30 will expire 31.12.2003, so now we have sent an application to get a new license from Russian Gosatomnadzor.

The second main task of the IREN project was to complete working-out of the first part of the technological project of the facility. It was fulfilled with large delay by the Moscow design institute GSPI. We have recently obtained the part of the general project necessary for approving by the respective Russian authorities. The activity aimed at getting permission for siting of the IREN source at JINR is started on the basis

of the obtained project. But we did not obtain from NIKIET, Moscow, the technological drawings of the multiplying target necessary to claim a tender for manufacture of the hardware of this target. This documentation is practically ready but it could not be delivered to JINR without the respective payments. A very similar situation is with the technical project of the control system of the IREN source. It has been completed by a special Moscow organization OKSAT NIKIET on credit.

DEVELOPMENT OF THE IBR-2 SPECTROMETER COMPLEX AND INFORMATION-COMPUTATION INFRASTRUCTURE

In 2003, work under theme 1012 was carried out in the following main directions:

— creation of neutron detectors;

— development of sample environment systems;

— development of data acquisition systems and network infrastructure;

— current modernization and routine maintenance of the IBR-2 spectrometer complex.

Creation of Neutron Detectors. ***Gas detectors***. *Infrastructure*. A large amount of work to create technological and electronic infrastructure for manufacturing and testing detectors has been performed:

- Preparation for commissioning of a clean room is being completed. Work on assembling the detector elements is under way in it.
- A stand for creating anode and cathode planes for neutron detectors on the basis of multiwire proportional chambers (MWPC) was created, and the manufacturing of electrodes for the MWPC detectors with individual signal readout from each wire and with delay line data readout started.
- An electronic stand for testing two-coordinate detectors with delay line data readout was assembled. It includes an amplitude analyzer and NIM crate with five-channel constant fraction discriminator, blocks of controlled delays and a high-voltage power supply. The structure of the stand also comprises a personal computer with a built-in data acquisition (DAQ) and accumulation card developed in cooperation with HMI, Berlin [18]. All the mentioned equipment was adjusted, and the first test measurements with ^{252}Cf source on a real detector manufactured in ILL, Grenoble, were performed.

Development and Manufacturing of detectors [19]. An original design of MSGC detector with a «virtual» cathode was developed, and the prototype of the detector was manufactured; readout electronics was adjusted, and measurements were carried out. At present, the stability of detector operation is being checked. Electronics for a coordinate microstrip detector with determination of coordinates by the charge division method was assembled and prepared for testing.

An MWPC detector with a sensitive area 20×20 см and planned coordinate resolution of 2.5 mm was developed and manufactured. Determination of coordinates is realized by wire number coding. Together with the University of Magdeburg, a principal electric circuit of the block for calculation of the centre of mass of the event cluster in the detector space (64×64 wires) was developed and simulated in FPGA environment. The accuracy of determination of the centre of mass is 0.5 pixels. A simplified version of the encoding block (24×24 pixels) was developed and manufactured.

The same casing will be used for creation of a two-coordinate detector of 20×20 cm with delay line data readout. Cathode planes with delay lines, anode planes and preamplifiers are in the manufacturing stage. The manufacturing of the casing and assembling of the detector, as well as the beginning of test trials with DAQ electronics, are scheduled for I–II quarters of 2004.

Scintillation detectors. Work in this direction has been successfully carried out for several years. In 2003, the following results were obtained:

- At the FSD diffractometer, to reduce the cost of detectors, investigations were conducted and the construction of scintillation counters was elaborated, which provided a change-over to domestic photomultipliers. The main elements and units of two sections (16 working modules) of the ASTRA wide-aperture scintillation (ZnS) 90° detector with time focusing were manufactured. In cooperation with the State Optical Institute (St. Petersburg), the first stage of investigations of new scintillation ZnS-based materials was completed. These materials will make it possible to improve characteristics of scintillation ZnS screens, as well as to abandon expensive purchases of ZnS screens abroad.
- A prototype of the module for the scintillation (ZnS) 90° detector of the DN-12 spectrometer was manufactured and tested on channel 12 of the IBR-2 reactor. The prototype was designed on the basis of the «rough» time focusing method, which allows a considerable increase in a solid observation angle, using scintillation plates of small area. The tests demonstrated a complete compliance of

the detector parameters with the calculated values. According to the results of the tests, the 90° detector assembled entirely of modules of a new type (ring of 16 modules) will provide an eight-fold increase in statistics gathering rate as compared with the available ring 90° detector on helium counters working on channel 12.

Development of Sample Environment Systems. A microcontroller block for controlling step motors was developed to create multichannel control systems of actuating mechanisms of spectrometers on the basis of PC. The system comprises: controller, commutators-amplifiers of step motors SMD-D2A and a power supply unit for motors $32B \cdot 2A$. Communication with PC is carried out using RS232 protocol.

For the DSD spectrometer of the IVV-2M reactor (Sverdlovsk branch of NIKIET) a central platform of stress-diffractometer with a linear scanner was manufactured. The central platform provides rotation of the linear scanner as a single whole around a vertical axis and rotation of a rotary platform with the detector around the same axis. All control systems are constructed on the basis of step motors and controlled by the experimental program.

A top loaded cryostat was developed for carrying out diffraction experiments on thermal neutron beams in the temperature range from 8 to 300 K. In the cryostat the closed cycle refrigerator of Leybold firm is used on the basis of cold head CoolPower 5/100T and compressor CoolPak 6000. The replacement of a sample does not demand the removal of the cryostat casing or disassembly of the cryostat. The shaft whose bottom end is connected by means of a heat exchanger to the second stage of the refrigerator, is intended for sample changing. The sample volume — a vanadium glass is shunted by a copper heat conductor, which equalizes temperature across its volume. A drift diameter of the shaft is 19.2 mm; however, at the level of the heat exchanger it is tapered to 18.1 mm. The greatest possible diameter of a sample is limited to a diameter of 17 mm.

A self-contained sorption refrigerator for working at a temperature of 0.3 K was developed [20]. The refrigerator is designed as an insert 80 mm in diameter, which is submerged in a helium cryostat. It keeps the temperature of a sample at 0.31 K for 20 h after condensation of ^{3}He at a useful heat load of 10 μW. Recondensation time is 0.5 h.

Work to modernize the microcontroller-based control systems of choppers for the NERA-PR, SKAT and DIN-2 spectrometers (three choppers) was conducted [21]. The software of chopper control systems was significantly modernized.

Development of Data Acquisition Systems and Network Infrastructure. In the FLNP local area network, Access Control Module Catalist 8510 for controlling and analyzing traffic as well as a new mail server based on two Intel compatible processor with OS Solaris were installed and put into operation.

Work to develop FLNP Web-server and HIPNS information system (hypertext information system on neutron sources and neutron instruments) continued. HIPNS provides users with data about neutron sources and spectrometers, as well as about investigations carried out on these sources [22]. The XML version of the HIPNS system using the Apache Cocoon technology was realized. Required pages are automatically generated from the database, which was created for several IBR-2 spectrometers. In 2003, a new two-processor PC Web-server was purchased and installed.

In cooperation with HMI, Berlin, testing of DAQ electronics for MWPC detector with delay lines was completed. The changes improving speed of operation and time resolution were made in the electric circuit, and 10 boards for JINR and HMI were manufactured in the ILFA firm, Hamburg. The first version of software for the board was developed. It includes event selection algorithms (realized in FPGA), programs for controlling data flows in various operating modes of the board (these programs are run by a digital signal processor installed on the board), program driver of the board, programs of preliminary processing and user programs on PC. Electronics and software were successfully tested with a real detector using a source (at HMI and at FLNP) and on the BER-II reactor at HMI. The analysis and visualization of data were carried out using ROOT and PV-WAVE packages [23]. At present, works on optimization of the programs are conducted.

The combined control system of the NERA-PR spectrometer (graphic interface on PC with retention of control programs in VME) was given to users for operation testing from the end of October, 2002, till February, 2003. This operation testing has demonstrated stable work of the hardware, Windows XP operating system, and the created software [24]. Work to adapt all control programs to Windows is in the completion stage [25]. Simultaneously at the SPN (REMUR) spectrometer a similar problem of changing over to a new control system on the basis of VME-PCI adapter is being solved [26]. The scheduled completion date of works is the end of I quarter, 2004.

The SONIX software complex was adapted for work at the FSD spectrometer, installed, tested and put into operation [27]. Works to install the adapted SONIX software complex at the HRFD spectrometer were started as well.

During the reported year a number of digital and analog electronic blocks for the IBR-2 spectrometers (spin-flippers for the SPN spectrometer, preamplifiers, spectrometric amplifier, etc.) were developed and manufactured [27]. On demands of users works on current modernization and repair of the equipment, as well as on optimization and routine maintenance of the software, were carried out [28].

To maintain trouble-free operation of the spectrometers during the IBR-2 cycles and preventive servicing

during the reactor shut-down required a great deal of effort.

Within the framework of main directions of works under theme 1012 (detectors, sample environment systems, data acquisition systems, local area network), long-term development projects for 2004–2008 were prepared [29].

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