A. V. Belushkin

SCIENTIFIC PROGRAMME OF THE FRANK LABORATORY OF NEUTRON PHYSICS

Report on FLNP activity within 2003–2009 R&D scientific programme of JINR and short report for 2009

Report to the 107th Session
of the JINR Scientific Council,
February 18–19, 2010

Dubna 2010

JOINT INSTITUTE FOR NUCLEAR RESEARCH

2010-5

A. V. Belushkin

SCIENTIFIC PROGRAMME OF THE FRANK LABORATORY OF NEUTRON PHYSICS

Report on FLNP activity within 2003–2009 R&D scientific programme of JINR and short report for 2009

Report to the 107th Session
of the JINR Scientific Council,
February 18–19, 2010

Dubna 2010

INTRODUCTION

In 2009, the FLNP scientific program 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 04-4-1069-2009/2011 "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 06-4-1036-2001/2010 "Nuclear Physics with Neutrons – Fundamental and Applied Investigations" headed by V.N.Shvetsov and Yu.N.Kopatch). To effect scientific research, work to develop and modernize the FLNP basic facility, the IBR-2 (theme 07-4-0851-87/2010 "Upgrade of the IBR-2 Complex" headed by A.V.Belushkin and A.V.Vinogradov) as well as the IBR-2 spectrometry and computation complex (theme 04-4-1075-2009/2011 "Novel Development and Creation of Equipment for IBR-2M Spectrometers Complex" headed by V.I.Prikhodko and S.A.Kulikov) continued.

This report contains a report on the FLNP activity within the framework of the JINR's Scientific Research and Development Programme for 2003-2009. A brief account of 2009 scientific results is also included. The FLNP Annual Report for 2009 will give a more detail account of the results in 2009.

1. THE FLNP ACTIVITY WITHIN THE FRAMEWORK OF THE JINR'S SCIENTIFIC RESEARCH AND DEVELOPMENT PROGRAMME FOR 2003-2009

1.1. Nuclear Physics

Within the framework of cooperation with the Space Research Institute of RAS the development, physical and mathematical simulation, as well as physical calibrations of research devices for space vehicles have been carried out. The physical calibrations of the second flight sample of the High Energy Neutron Detector HEND, whose first flight sample has been successfully operating in Mars orbit as an element of the Gamma Ray Spectrometer suite since the beginning of 2002, have been completed. In 2004-2009 the simulation and calibration of the neutron detector LEND (Lunar Exploration Detector) intended to measure neutron fluxes from the lunar surface with high spatial resolution aboard the space vehicle LRO (Lunar Reconnaissance Orbiter) that was launched in 2009, were conducted. The calculations to optimize neutron collimators and the calibrations of laboratory and two flight samples were performed.

The main result achieved within the framework of activities on the preparation and carrying out of an experiment on the direct measurement of the neutron-neutron scattering cross-section at the JAGUAR reactor (RFNC-VNIITF, Snezhinsk) is the

development and construction of a neutron detector meeting all requirements of the experiment. Never before there have been neutron detectors that can combine a high counting rate (~10^6 s^{-1}), ~100 % neutron registration efficiency, high energy resolution (no worse than 10 %) and low sensitivity to γ-quanta (~10^{-9}). The detector has been mounted on the experimental facility and has been successfully tested in calibration measurements with gases in a pulsed operating mode of the JAGUAR reactor.

A series of fundamental investigations has been carried out in the field of neutron optics. In particular, a test of the weak equivalence principle for the neutron as an elementary particle has been performed, i.e. the ratio of inertial and gravitational masses $\gamma = m_g / m_g a$ has been measured and the value $1 - \gamma = (1.8 \pm 2.1) \cdot 10^{-3}$ has been obtained. Also, a new experiment to study the effect of a refracting medium in neutron optics has been carried out. The effect of an accelerating medium consists in a change in the frequency of the wave upon passing through a refracting sample moving with acceleration. Though the effect is of quite universal nature, it has been observed, however, only for neutron waves. In the experiment in 2007 new convincing data were obtained, thus allowing us to speak with full confidence that the existence of the effect is proved.

The construction of the "Big Gravitational Spectrometer" has made it possible to study rare processes (with a probability of up to 10^{-8}) of small energy transfers as a result of interaction of UCN with the matter surface in a wide temperature range. The performed investigations suggest that the small energy transfer processes are the result of interaction of UCN with surface nanoparticles and may be responsible for additional losses of UCN from traps introducing systematic corrections into the results of precision experiments with UCN.

Several series of studies have been carried out on the basic properties of nuclear fission. The properties of ternary and quaternary fission have been studied, angular correlations of fission products have been measured, a search for exotic fission modes has been conducted. In particular, in the experiment to study neutron-induced fission of ^{235}U performed on the IBR-2 reactor within the framework of the FLNP-FLNR collaboration some evidence of the possible existence of ternary collinear decay in fission has been found.

In FLNP a correlative high-resolution gamma-spectrometer COCOS has been developed and constructed. Using the COCOS spectrometer a number of studies have been carried out to search for a negative neutron p-resonance in lead, which is responsible for spin rotation observed in a classical experiment to study the space parity violation effects.

Within the framework of the work to obtain nuclear data with the "ISOMER" facility on the IBR-2 reactor the data on delayed neutron yield at the fission of ^{237}Np and ^{245}Cm isotopes have been obtained.

Within the framework of the determination of a root-mean-square charge radius of the neutron in the n,e interaction, a new approach has been suggested to the measurement of the n,e-scattering length, which is based on the measurement of angular anisotropy of neutron scattering by noble gases. A facility has been constructed; an experiment is planned on the IBR-2M reactor.

Full-scale measurements with the UGRA instrument have not been realized because of the delay in the startup of the IREN facility.

Within the framework of the KaTRIn project the technology of construction of gas targets and the technique for measuring nuclear polarization on neutron beams have been developed. For 3He targets it has been possible to achieve the degree of nuclear polarization of 0.63±0.01. We failed to attain significant polarization of 131Xe experimentally. The project, however, has not yet received support for its realization on JSNS (a beam has not been allocated in the context of preferred orientation toward the condensed matter physics research).

The POLYANA project has not been realized because of the delay in the startup of the IREN facility. What is more, the detailed calculations have shown that the realization of the declared theme even if the full-scale project of the neutron source is realized, will be complicated.

1.2. Condensed Matter Physics

In the period of realization of the seven-year Scientific Research and Development Programme of JINR within the theme "Condensed Matter Physics" the basic directions of investigations on the complex of spectrometers of the FLNP basic facility – IBR-2 reactor – and within the framework of cooperation with other scientific centers of the JINR Member States were as follows: magnetism and strongly correlated electron systems, crystal structures and excitations, non-crystalline materials and liquids, biology and pharmacology, chemistry and polymer physics, geophysics, constructional materials. These research objectives have been successfully accomplished and a number of important results on the above-listed scientific directions have been obtained.

The systematic neutron diffraction studies of the atomic and magnetic structure of complex manganese and cobalt oxides R1-xAxMO3-d (R – rare earth element, A – alkaline earth element, M=Mn, Co) have been carried out in a wide range of temperatures and pressures. The obtained results are of importance for understanding the mechanisms of the appearance of the unique physical phenomena revealed in these compounds at the level of structure organization – colossal magnetoresistance, insulator-metal transitions, orbital and charge ordering, magnetoelectric effect, spin state transitions and ordering, etc. It has been found that by applying high pressures to the orbital degrees of freedom of manganese ions surrounded by oxygen octahedra, it is possible to change the character of magnetic

state of manganites in a controlled way.

Low temperature studies of the proximity effects in layered superconductor-ferromagnet heterostructures of two types: n×[Fe/V]Fe/V(40 nm) and n×[Mo/Si]Fe/Nb(40 nm) have been conducted by the neutron reflectometry technique. For the first structure at the transition of V (40 nm) layer to the superconducting state, the antiferromagnetic ordering of vanadium sublayers as well as the demagnetization of the cluster structure at the iron-vanadium interface have been revealed. For the second structure at the transition of Nb (40 nm) and n×[Mo/Si] layers to the superconducting state, a decrease in the average magnetization of Fe layer and in the saturation magnetization in the domain of Fe layer has been observed.

The structure and properties of colloidal magnetic fluids based on magnetite nanoparticles and organic non-polar short-chain monocarboxylic acids (lauric, $C_{12}H_{24}O_2$, myristic, $C_{14}H_{28}O_2$, saturated acids and oleic, $C_{18}H_{34}O_2$, unsaturated acid) have been studied by small-angle neutron scattering. Great differences have been revealed in the size distribution function of the stabilized magnetite, namely a decrease in the mean particle radius and polydispersity index when short-chain acids are used instead of oleic acid. The origin of the observed size regulation effect is connected with different acid organization on the magnetite surface, which determines elastic properties of the stabilizing shell.

A series of studies on experimental determination of the universal constant of the interaction of fluctuating surfaces has been carried out. A new approach to study undulation forces and to determine the universal constant based on the investigation of temperature dependence of intermembrane interactions by means of complementary use of small-angle neutron scattering and synchrotron radiation diffraction has been developed. In particular, the interaction constant value of $3\pi^2/256$ has been obtained, which coincides with the theoretical predictions. In addition, for the first time the absolute value of undulation forces has been determined. It has been revealed that they really make a considerable contribution to the balance of intermembrane interactions, and what is more, become dominating at intermembrane distances larger than 20 Å.

The investigations of the dynamics of molecular organic compounds of pentane and butane have been performed by inelastic neutron scattering. A difference between the intramolecular vibration spectra of the crystal and glassy phases has been shown for 2,3-dimethylbutane. The comparison of the spectra calculated using the density functional theory (DFT) and the measured spectra for 2,3-dimethylbutane shows that the phase transition from the orientational glass state to the crystalline phase is accompanied by changes in molecular conformation. This implies low potential barriers for internal rotations of molecular groups $CH(CH_3)_2$.

The classification of the crystallographic textures of mono-mineral and multi-

phase rocks has been made. Various types of crystallographic textures of quartz mineral associations have been revealed and classified. The texture analysis by means of neutron diffraction has made it possible to distinguish four types of the crystallographic texture of quartz in quartzites and sandstones. Models of pole figures for main crystallographic directions of quartz have been developed. Particularly, for the samples from the Kola superdeep borehole (SG-3) and the surface crust of the Kola Peninsula common regularities in a preferable orientation of quartz are observed. Thus, in amphibolites from various depths of the SG-3 quarry and in selected analogues from the surface crust two quartz texture types have been revealed. The given texture kind is typical for samples with different mineral composition and percentage of quartz, which evidences in favour of the same orientation mechanism that produced quartz textures.

The investigation of distribution of internal stresses in constructional materials and industrial products has been performed for atomic industry. A typical example of the performed work is the study of internal stress distribution in the natural template of the VVER-1000 reactor vessel, namely in a stainless facing (austenite phase) and ferrite steel depending on the distance from the facing. Much attention has been given to the properties of martensite-ferrite nitrogen steels, a new promising material for reactor vessels and core units. The studies have revealed a significant increase of microstresses in martensite-ferrite steels as compared to austenite steels, which can be one of the reasons for a decrease in their radiation-induced swelling and higher corrosion resistance. For the steel EK-181, a promising material of the ferrite-austenite composition class Fe-12Cr-2W-V-Ta with admixtures of carbon and boron and distinguished for fast radioactivity decay, the detailed data on its behavior in a wide temperature interval (4-100 K) have been obtained.

Particular attention has been given to the modernization of the complex of spectrometers of the IBR-2 reactor. During 2002-2008 a large-scale modernization of the REMUR reflectometer was completed. Work to develop and construct a diffractometer for studying internal stresses (FSD) has been carried out. The modernization of the YuMO small-angle spectrometer has been conducted. A two-detector system for detecting scattered neutrons has been realized, which makes it possible to increase the dynamic range of momentum transfer and to significantly reduce the experimental data acquisition rate. Since 2007 work has been carried out on the realization of the new top-priority projects of development and construction of the DN-6 diffractometer for studying microsamples, the multipurpose reflectometer GRAINS and the modernization of the SKAT/EPSILON spectrometers for geophysical research.

1.3. Development and creation of elements of neutron spectrometers for condensed matter investigations

Development of data acquisition, accumulation and analysis systems for the IBR-2 spectrometers

During the reporting period the work to develop and construct new-generation data acquisition (DAQ) systems has been carried out. Its main direction – the integration of PC into VME DAQ-systems at the first stage, and later on the total abandonment of electronic standard VME. It is achieved by means of developing unified electronic blocks based on field-programmable gate arrays (FPGA), digital signal processors and very large scale integration circuits. A DAQ system for any spectrometer may consist of 1-2 basic blocks, one of which processes and accumulates data from 1-D and 2-D PSD, and the other – from an array of point detectors (up to 256 counters). These are identical (from the viewpoint of hardware) electronic blocks, in which all functions, both common (encoding of the detector number, registration of time of flight) and specific to each concrete spectrometer (e.g., time focusing) are realized on the level of microprograms, which are executed in FPGA of a respective block.

The blocks have 1GB internal memory, built-in interface USB-2 and can be connected to PC via fiber-optics communication lines. Data processing programs are stored and executed in FPGA of these blocks. These blocks have provision for various modes of data accumulation – integral (monitor counters), histogram (on-line sorting and accumulation of spectra in the block memory), "list" (accumulation of raw data followed by processing and sorting in PC). In the latter case in order to control the experiment, the histogramming of all or a specified part of registered events is performed in parallel directly in the DAQ block.

At present, a new-generation DAQ-block built in PC is used in all developed in FLNP detector systems with PSD and also in Helmholtz-Zentrum, Berlin, with detectors of other manufacturers. The second version of this block with a counting rate of no less than 10^6 events/s has been constructed and is being tested at the moment. Under the contract with PNPI, Gatchina, a prototype of a DAQ-block for 128 counters has been developed and debugged. The final version of the unified DAQ-block for point detectors is in the development stage.

In control electronics for executive mechanisms of the spectrometers a change-over to industrial standard CAN is carried out, thus making it possible to minimize our own developments and to widely use purchased blocks.

Development of detector systems for spectrometers

Investigations and developments in the field of construction of neutron detectors were conducted in several directions in order to find an optimal and economically sound solution, which would take into account the characteristics of the IBR-2 reactor beams, experimenters' requirements, availability of materials and

technologies, capabilities of electronics, etc. In each direction the prototypes of detectors were developed, constructed and tested. As a result, two basic directions were chosen:

- development and construction of position-sensitive detectors (PSD) based on multiwire proportional chambers with delay line data readout;
- development and construction of multichannel detector systems with wide-aperture neutron counters based on ZnS/^{6}LiF scintillation screen.

Within the framework of the first direction a corresponding infrastructure for the development and construction of gas PSD ("clean" room, gas and test stands, winding machine, etc) has been created; a line of PSD detectors has been developed, which includes 1D PSD with an active area of 200×80 mm^2 and resolution of 2 mm, 2D PSD (200×200 mm^2, 2 mm^2) and 2D thermal neutron monitor (100×100 mm^2, 4 mm^2). Unified electronic blocks for data acquisition and accumulation from the specified PSD, PC interface and software have been developed and constructed as well. In essence, these detector systems are independent elements of spectrometers and can be easily built into any experiment control system.

Within the framework of the second direction the methods of calculation and the technology for producing wide-aperture scintillation counters with time focusing for high resolution diffractometry, as well as registering electronics and software have been developed. The prototypes of the detector modules of various designs have been made and tested.

All the above-mentioned detector systems or their individual elements have been made in several copies and are used in FLNP JINR (HRFD, REFLEX, REMUR, YuMO, FSD spectrometers), and in other neutron centers of Russia (Karpov Institute of Physical Chemistry, Obninsk; RRC «Kurchatov Institute», Moscow; Institute of Metal Physics, Ural Division of RAS, Yekaterinburg) and Germany (H-Z, Berlin). At present, the manufacturing of PSD for the DN-2 and GRAINS spectrometers is nearing completion. Using the same technology, for the DN-6 diffractometer the development of a ring-shaped gas multi-section detector with up to 192 measuring channels in one ring has started.

1.4 IREN facility

In accordance with the decision of the JINR Directorate to realize the IREN project in several stages, the construction of the electron accelerator and the nonmultiplying neutron-producing target complex has been completed. Since the beginning of 2009 the carrying out of experimental investigations on newly constructed source has been started.

1.5. The IBR-2 reactor

The IBR-2 modernization work schedule announced in the JINR's Scientific Research and Development Programme for 2003-2009 and the updated results.

Activities	Planned date	Updated schedule
IBR-2 operation for physics experiments	2004-2006	2004-2006
MR-3 start-up	2003	2003
Creation of fuel loading for IBR-2M	2005	2005
Development of design documentation	2004	2004
Production of major IBR-2 equipment: jacket rolling shields, stationary reflectors, CES mechanisms	 2006 2006	 2008 2006
Development and production of CES electronics	2008	Spring 2010
Construction of cryogenic helium station for CM	2005	2005-2007
Development and production of new water moderators for IBR-2	2007	2007-2009
Upgrading of technological equipment	2007-2008	2007-2009
Dismantling of IBR-2 used-up equipment	2007-2008	2007-2009
Assembly and adjustment of new IBR-2M equipment	2008-2009	2008-2010
IBR-2M physical start-up	2009	2010

Development of complex of neutron moderators

The prime objective of the project was to develop a concept of the composition and layout of neutron moderators around the modernized IBR-2M reactor. The main requirement to the moderators is to ensure the most efficient use of the spectrometers. The central problem of the task lay in the fact that the available spectrometers, each operating in its own neutron wavelength range, should remain in their places on the modernized reactor.

The essence of the developed concept was the application of the so-called combined moderators ("combi"-moderators), which was a new approach to the design of slow neutron sources. A combi-moderator is a complex system of chambers (compartments) where there is either a hydrogen-containing substance cooled down to low (20-100 K) temperatures or plain water at room temperature, or void space, or a scattering nonabsorbing substance. A special feature of this moderator is a significant dependence of thermal neutron spectra on the direction of neutron escape and/or the place of neutron escape. A combi-moderator is designed in such a way as to ensure the most favourable spectrum for each respective neutron spectrometer.

Such combi-moderators have been designed for three beam directions of the IBR-2M reactor. For each direction the composition of chambers (warm and cold compartments) and their shape are different. The optimization of the sizes and shape of combi-moderator chambers has been performed using the MCNP program. In the combi-moderators all well-known techniques are used to increase the neutron yield (grooved structure of the radiating surface, reflectors and neutron "guns" – extraction of neutrons from deep within the moderator volume).

An innovative decision has also been taken in designing the cold moderating chambers of the combi-moderators – to use a mixture of frozen aromatic hydrocarbons - 1,3,5-trimethylbenzene (mesitylene) and m-xylene as a moderator material in the form of solid beads cooled by helium gas down to the temperature of 20-30 K. It has been experimentally shown that such a pelletized moderator 20 times more radiation-resistant than a traditional solid-methane moderator. This allows the cold moderator chamber to be charged once in a two-week reactor operating cycle. The gain due to the application of cold mesitylene has been verified experimentally, the technology for producing beads has been perfected as well, and the technique of bead delivery to the moderator chamber by pneumatic conveying has been substantiated using prototypes.

Such a moderator installed at the IBR-2M reactor will provide differential cold-neutron flux density of no less than $3 \cdot 10^{13}$ n/cm^2/s/sr/eV for a wavelength of 0.4 nm (it is equal to the same value for the cold moderator of the ISIS "second" target station being constructed in the UK) with the thermal neutron flux density 4-8 times greater than that of the ISIS neutron source.

At present, the detail design of the moderator complex for IBR-2M has been completed, one of the three combi-moderators has been manufactured, a cooling helium pipeline system has been made and a full-scale model of the system for delivering beads to the moderator chamber has been constructed.

2. 2009 SCIENTIFIC RESULTS

2.1. Condensed Matter Physics

In view of the IBR-2 reactor shutdown for reconstruction, the scientific and experimental work of the personnel of the Department of Neutron Investigations of Condensed Matter was carried out in neutron and synchrotron centers in Russia and abroad under the existing cooperation agreements and in accordance with the accepted beam time application proposals. The work on the IBR-2 reactor was conducted according to the plan of the modernization program for the spectrometers.

I. Scientific results

Neutron diffraction studies of the atomic and magnetic structure of 314-

cobaltites Sr3YCo4O10.5+δ (or Sr0.75R0.25CoO2.625+δ/4) wherein A-positions are perfectly ordered have been continued. For these compounds it has been revealed that Co atoms occupying different positions in a unit cell have different magnetic moment magnitudes correlating with the oxygen surrounding of the atom, i.e. for the first time the direct correlation between the charge and spin states of the Co atoms has been revealed for perovskite-like cobaltites. The compounds with different oxygen contents have been found to have AFM structure of G-type without any sign of the presence of the ferromagnetic component of the moment. In 2009, the compounds with partial substitution of Ca for Sr, namely $Sr_{0.75-x}Ca_xY_{0.25}CoO_{3-y}$ with $x \approx 0.30$ and $y \approx 0.35$ were studied, for which from indirect data some evidence was found for the partial stabilization of ferromagnetism due to the effect of Ca on the charge state of Co. To test this model, on the HRPT diffractometer (PSI) neutron diffraction spectra were obtained in the temperature range from 1.5 to 300 K. The preliminary analysis showed the presence of magnetic phase transition at $T \approx 260$ K with the appearance of the AFM structure and a possible small FM component.

The studies of high pressure effects on the crystal and magnetic structures of complex anion-deficient cobalt oxides have been continued in a wide temperature range. In the $Sr_{0.7}Y_{0.3}CoO_{2.62}$ compound a pressure-induced change in the spin configuration for Co^{3+} ions has been revealed, which results in a modification of the symmetry of the antiferromagnetic state.

The structural characteristics of optically active nanostructured materials ($0.95GeO_2$-$0.05Eu_2O_3$, $0.949GeO_2$-$0.05Eu_2O_3$-0.001Ag and $0.999GeO_2$-0.001Ag) annealed in air at T = 900°C have been investigated by small-angle neutron scattering and X-ray diffraction. It has been found that a considerable change in the relative intensity of luminescence excitation bands of Eu^{3+} ions by doping with Ag correlates with a decrease in the characteristic sizes of polydisperse clusters formed during annealing.

Complex investigations of the size regulation effect for magnetite nanoparticles in ferrofluids with non-polar organic carriers and stabilization by monocarboxylic acids, have been completed. The studies have been performed using the static magnetization analysis, transmission electron microscopy, diffraction and small-angle scattering of synchrotron radiation and small-angle scattering of polarized neutrons. It has been confirmed that the replacement of non-saturated oleic acid (C_{18}) used in the classical stabilization procedure with saturated acids from a series of lauric (C_{12}), myristic (C_{14}), palmitic (C_{16}), stearic (C_{18}) acids results in a decrease in the effective size of stabilized magnetite.

The structure of the aggregates of nanodiamond particles (detonation) dispersed into polar liquids (water, DMSO) by a special wet milling procedure has been determined with the use of small-angle neutron scattering. The size and fractal characteristics of the aggregates, as well as the structural features of the nanodiamond particles (size, surface character) have been obtained. The comparison

with the aggregate structure in initial nanodiamond powders has been performed. The analysis of the structure factor as a function of the number of particles points to the cluster interpenetration upon concentrating dispersions. The contrast variation with the use of mixtures of protonated and deuterated solvents allowed us to determine the mean density of the particles composing the cluster, and thus to conclude about the existence of a non-diamond component on the nanodiamond surface.

The micellization of sodium dodecyl(sulfophenoxy)benzene sulfonate and nonyl benzene deca(ethylene oxide) has been investigated in neutral and alkaline electrolyte solutions of different concentrations by small-angle neutron scattering. The micelles formed in the solutions have been found to possess a cylindrical (ellipsoid) shape. The characteristic sizes of the micelles have been determined as functions of surfactant and added electrolyte concentrations. The correlation of the data obtained with the geometry of track nanopores and the dynamics of their etching in surfactant-containing solutions has been revealed and the model of the influence of surfactants on the formation of pores with specific geometry has been developed.

The experimental investigations concerning the problem of coexistence of ferromagnetism (F) and superconductivity (S) have been continued. The magnetic state of the Fe/V bilayer has been studied using a neutron wave resonator MgO/V/Cu. The behaviour of the bilayer in reality corresponded to the behaviour of a three-layer F/F-S/S structure in which the intermediate F-S layer was a mixture of vanadium and iron atoms. The direct and inverse proximity effects were observed. The direct effect consisting in the appearance of the superconducting order in ferromagnetic F-S manifested itself at the transition of the vanadium layer (S) into the superconducting state ($T = T_c$) as a decrease in the magnetization vector and its approach to the direction of the external magnetic field. The inverse proximity effect, i.e. the appearance of ferromagnetic order in the superconductor F-S was observed at a temperature of $0.6T_c$ and involved an increase in the magnetization vector and its deviation from the direction of the magnetic field.

The X-ray diffraction technique was applied to study water solutions of multilayer vesicles of multicomponent membranes modeling the mucous membranes of the human oral cavity (Oral Stratum Corneum, OSC) and the membranes comprising the mixture sphingomyelin /dipalmitoylphosphatidylcholine/dipalmitoylphosphatidylethanolamine (SM/DPPC/DPPE). The systems of the SM/DPPC/DPPE mixture (mass ratios of 1/1/1, 1/2/1) are characterized by a lamellar structure. As the mass fraction of DPPE increases, a part of the lipid forms a separate lamellar phase (d ~ 56 Å) and a reverse hexogonal phase (a ~ 56 Å). The multicomponent OSC membranes based on ceramide 6 and ceramide 3 are complex multiphase systems coming into phase equilibrium in a few days after the sample preparation.

Using the neutron diffraction data the texture of special steels, graphite,

zirconium niobate (various processes of manufacturing) has been determined. The crystallite orientation distribution function (ODF) has been determined; the simulation of volume elastic properties of these constructional materials has been performed. It has been shown that the austenitic facing of the VVER-1000 reactor vessel has a sharp radial texture (rotation of grains around the normal to the steel plane (002)), which results in a complex distribution of residual stresses in it, and in this case the minimal values of the Young's modulus are attained in the direction of the normal to the surface of the reactor vessel.

The investigations of texture and internal stresses of rock samples from the Central Alpes (Switzerland) in the region of the Gotthard Base Tunnel have been carried out. The obtained results are important to estimate the influence of the tunnel excavation work on the geomechanical conditions of the mountain ranges surrounding the tunnel.

The inelastic neutron scattering method has been applied to study vibrational spectra of hexane and isomers of hexanol. The theoretical simulation of the vibrational spectra using the density functional theory has been performed. It has been found that to describe the dynamics of hydroxyl groups, the formation of hydrogen bonds between hexanol molecules should be taken into account.

II. Instrument developments

The manufacturing of the head part of the mirror vacuum neutron guide has been completed and its installation on beam 6b of the IBR-2M reactor has been carried out within the framework of realization of the project of construction of the DN-6 diffractometer for microsample investigations. The manufacturing of a vacuum casing for the tail part of the neutron guide has continued. The designing of a gas position-sensitive detector has started.

The manufacturing, vacuum testing and installation of the head part of the GRAINS reflectometer on the reactor have been completed. The manufacturing of the rail support and the casing for the beam-forming system has started. The components of the given system (variable slits, beam-deflecting mirrors) have been tested. The technical documentation on the manufacturing of a mechanical drum chopper has been prepared.

Work to prepare a working platform for the installation of a mirror neutron guide on the DIN-2PI spectrometer has been carried out. Mirror segments, materials for effective biological shielding of the neutron guide of the first flight path of the spectrometer and mechanical units for positioning the neutron guide have been purchased. The processing of the experimental data on the simulation at the DIN-2PI spectrometer of a model of a cryogenic moderator to be installed at the IBR-2M reactor has been completed.

A schematic design of a new backscattering detector for the HRFD

diffractometer has been developed on the basis of ZnS-elements. The solid angle of the new detector is ~10 times that of the available detector, which will make it possible, in case of realization of the project, to significantly improve conditions for conducting structural experiments on HRFD.

2.2. Neutron Nuclear Physics

The physical start-up of the first stage of the IREN facility has been carried out at FLNP JINR. The future full-scale IREN facility will comprise a 200-MeV linear accelerator LUE-200 with a beam power of 10 kW, a subcritical multiplying target and beam infrastructure with experimental pavilions as well as technological, control, safety and service systems. The characteristics of the full-scale IREN facility (integral neutron yield – 10^{15} n/s, pulse width – 0.6 μs) will allow it to rank among the best resonance neutron sources in the world such as GELINA (Belgium) and ORELA (USA). The IREN first stage includes one section of the electron accelerator and a nonmultiplying tungsten target. The achieved parameters are: peak electron beam current – 2.0 A; electron energy – 30 MeV; pulse width – 100 ns; repetition rate – 25 Hz; integral neutron yield – $(3\div5)\cdot10^{10}$ n/s. The indicated parameters already make it possible to carry out experiments, which require high energy resolution in the energy range from fractions of eV to hundreds of eV.

At the IBR-2 pulsed reactor the construction of the "Kolkhida" setup intended for studies of neutron optics phenomena in interactions of polarized neutrons with polarized nuclei has been completed. In particular, studies of nuclear precession of neutron spin in a wide energy range from thermal to neutron resonance energies are planned. The setup also makes it possible to investigate magnetic properties using polarized neutrons. The computer simulation of an experiment on neutron paramagnetic resonance shift has been performed.

The investigations of P-odd secondary particle emission asymmetry in the reactions of polarized cold neutrons and light nuclei of ^{6}Li and ^{10}B have been continued. The measurements are carried out in ILL (Grenoble) in an effort to study neutral weak currents in nucleon-nucleon interactions. At present, the results are as follows: the triton emission asymmetry in the $^6Li(n,\alpha)^3H$ reaction is $\alpha^{6Li}{}_{P-odd} = -(8.8 \pm 2.1)\cdot10^{-8}$; the γ-ray emission asymmetry in the nuclear reaction $^{10}B(n,\alpha)^7Li^* \rightarrow \gamma \rightarrow {}^7Li(g.s.)$ is $\alpha^{10B}{}_{P-odd} = +(0.8 \pm 3.9)\cdot10^{-8}$. Using these values in the framework of the cluster model the weak neutral current constant was estimated to be $f_\pi^{6Li} \le 1.1 \cdot 10^{-7}$ and $f_\pi^{10B} \le 2.4 \cdot 10^{-7}$ (at 90 % confidence level). Both these values contradict "the best" DDH value $f_\pi^{DDH} = 4.6 \cdot 10^{-7}$.

In October-November, 2009, a new experiment to measure $\alpha^{10B}{}_{P-odd}$ was conducted. The 50-day measurement was carried out on the polarized cold neutron beam at ILL. The main difference between this experiment and the previous ones is the improved geometry: earlier a boron target had been right in the air in the neutron

beam in front of the detectors, in the last experiment it was placed in the helium filled neutron guide. That made it possible to reduce the background and to improve the precision (1.8×10^{-8} instead of 3.9×10^{-8}). A «zero»-experiment was performed as well.

On the cold neutron beam in ILL the FLNP specialists in collaboration with the French scientists have measured the concentration of hydrogen atoms in diamond nanopowder before and after degassing, total scattering cross-section for hydrogen (not removed by degassing) and its temperature dependence. The concentration was found using the measurement of relative flux intensity of characteristic γ-quanta in the n(p,d)γ reaction from the samples under study and a polyethylene sample. It has been revealed that the amount of hydrogen in the nanopowder before and after degassing can be expressed by the ratios C_8H and $C_{15}H$, respectively. The total scattering cross-section for a hydrogen atom in the degassed powder is ~120 barn. The variation of this cross-section as the temperature changes from 500 K to 80 K does not exceed 3 %. Thus, an increase in the reflection probability from a powder of diamond nanoparticles, which is of interest as a reflector for very cold neutrons, is possible either by removing/replacing hydrogen or by suppressing the channel of inelastic losses by cooling the powder to liquid helium temperatures. The measurement of the reflection probability in this case is possible, for example, by deep cooling of a trap of very cold neutrons.

The studies of properties of nuclei in the neutron binding energy range have been continued. The main objective of these investigations is to study the extent to which the superfluid phase of nuclear matter affects the density of excited levels of various nuclei and, in particular, the probabilities of gamma-quantum emission in nuclear reactions. It has been demonstrated that the main obstacle in obtaining reliable information on this process is serious methodical errors in the analysis of data from multiparameter experiments by some groups of physicists.

The investigations of the (n,p), (n,α) reactions induced by fast neutrons have been continued. The experiments are carried out at the Van de Graaf accelerator EG-5 in FLNP JINR (Dubna, Russia) and EG-4.5 of the Institute of Heavy Ion Physics of Peking University (Beijing, China) in collaboration with the University of Lodz (Poland), the National University of Mongolia (Ulaanbaatar, Mongolia) and the Oak Ridge National Laboratory (USA).

Data on neutron reactions with emission of charged particles induced by fast neutrons are of much interest both for the creation of constructional materials for nuclear power engineering and for studying mechanisms of nuclear reactions and for determining the parameters of an optical potential. The analysis of the available experimental data for ^{147}Sm, ^{143}Nd, ^{95}Mo isotopes shows that for the most part measurements were made at thermal and resonance energies, as well as for 14 MeV neutrons. At the same time there are scarcely any experimental data for the MeV

neutron energy region. As a result, there are significant discrepancies between the cross section estimates given by different evaluated nuclear data libraries. Within the framework of joint investigations at the EG-4.5 accelerator of the Institute of Heavy Ion Physics of Peking University (Beijing, China) the measurements of the parameters of the ^{143}Nd(n,α)^{140}Ce and ^{95}Mo(n, α)^{92}Zr reactions at E_n=4.0, 5.0 and 6.0 MeV and the ^{147}Sm(n, α)^{144}Nd reaction at E_n=5.0 and 6.0 MeV have been carried out. The energy spectra of charged particles have been obtained. The data treatment and theoretical calculations were completed in 2009. Our experimental data were compared with the available data, evaluations and model calculations. It should be pointed out that the analysis of new data on fast neutron cross sections was performed along with the analysis of the available data on these reactions induced by resonance neutrons.

In 2009, in the Neutron Activation Analysis Sector (FLNP JINR) the RFFI-Romania project «Geochronology and retrospective study of pollution of unconsolidated sediments from oxygenated and anoxic territories of the Western Black Sea» was completed. The results of the performed investigations were printed in 5 scientific publications in international peer-reviewed journals, two of which being of special interest for geology. In 2009, the State Prize of the Government of the Republic of Macedonia was awarded to the research work conducted in the NAA sector in collaboration with the Macedonian specialists on the creation of the geochemical Atlas of one of environmentally unsound areas in Macedonia.

The dependence of electrical characteristics of SiCN-films on silicon substrate produced using the plasma-enhanced chemical vapor deposition (PECVD) technique on their chemical composition has been studied. The concentration of silicon, nitrogen and carbon in the films was measured using the Rutherford backscattering technique. The concentration of hydrogen in the films and their thickness were determined by recoil proton technique on the helium ion beam of the EG-5 electrostatic generator. The possibility of accurate determination of concentration of all elements in the three-element film was realized through the application of simultaneous measurements of the Rutherford backscattering and recoil proton spectra.

3. NEUTRON SOURCES

3.1. The IBR-2 Pulsed Reactor

Starting in December 2006 after the reactor shutdown the modernization of IBR-2 was conducted in accordance with the "Program of activities on the IBR-2 reactor during its temporary shutdown (2007-2010)" in compliance with the quarterly plans approved by the FLNP chief engineer.

Activities completed in 2009

1. Installation of the reactor vessel at its work site and of in-vessel components. Loading of dummy fuel assembly cartridges into the reactor core.
2. Installation of the movable reflector MR-3 in the operative position.
3. Replacement of a cold trap for purifying sodium coolant in loop "A" of the second reactor cooling circuit.
4. Installation of stationary reflectors and water moderators on the trolleys of the rolling shields.
5. Installation of executive mechanisms and control units of the reactor.
6. Manufacturing and installation of an additional storage facility for the IBR-2 used fuel in the reactor hall.
7. Installation of equipment of the cryogenic helium refrigerator KGU-700/15 and helium pipelines between the cryogenic refrigerator and the rolling shields.

Activities still in progress according to the plan

1. Installation and stage-by-stage adjustment of the operator console on the main control panel of the reactor.
2. Installation and adjustment of communications and power electrical equipment of the reliable power supply system, of the power supply system of the standby control board and the heaters of the IBR-2M cooling circuits from the standby power supply system.
3. Installation of equipment and switching lines of the technological parameters control system (TPCS) and the automatic safety and control system (ASCS-12R).
4. Preparation to the filling of the reactor cooling circuits with a liquid sodium coolant.
5. Manufacturing of a cryogenic moderator for beams 7-11 (CM 202).
6. Installation of an experimental stand for testing transportation modes of mesitylene balls to the cryogenic moderator.

Problems

There was an unforeseen delay in the delivery of electronic equipment of the automatic safety and control system (ASCS-12R). The designer and manufacturer of the given equipment failed to fulfill contractual obligations to deliver the equipment by September 01, 2009 and postponed the final delivery of the certified complex ASCS-12R by 9 months, until the end of June, 2010. For this reason the beginning of work on the physical start-up of IBR-2M is scheduled for September, 2010.

Building and construction activities to ensure safe operation of the reactor

1. The greater part of the work to prepare the territory in the immediate vicinity of IBR-2 to make a local protected zone for physical protection of the reactor has been fulfilled.

2. The repairs of the rooms and the roof of the reactor cryogenic area have been completed.
3. Construction works in the rooms for a reliable power supply system have been completed.
4. The repairs to the rooms for the primary and standby control panels of the reactor as well as to the rooms for the measuring equipment of the reactor diagnostics system have been finished.

Financing in 2009

In 2009 the financial plan allowed for 1380 k$ on the reactor modernization. The real financing of works on the modernization project corresponded to the approved plan.

In 2010 the planned expenses on modernization will be 960 k$. In addition, a total of 1246 k$ is planned to be allocated on the creation of the system of physical protection of IBR-2M.

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

In 2009, work in the framework of the theme was focused on several activities connected with the construction and modernization of the equipment, electronic data acquisition and accumulation systems as well as the information-computational infrastructure of the IBR-2M spectrometers complex.

Cryogenic moderators

The conceptual design, development of technical documentation, manufacturing and mounting of the main parts of a full-scale stand of the technological system of the cryogenic moderator (CM) have been accomplished. The stand is a full-scale model of the future CM system with a copy of the CM camera, technological system and the system for delivery of mesitylene beads. The stand cooling system comprises two coolant loops connected by a heat exchanger. In the first coolant loop, helium is driven by a helium blower through the heat exchanger and the CM chamber. In the second coolant loop, helium is forced through the heat exchanger by a helium refrigerator (500 W, 15 K). As a result of simultaneous operation of the helium refrigerator and the helium blower in the CM chamber the required temperature is achieved and mesitylene beads are transported by the flow of gaseous helium from the charging device to the CM chamber.

In the FLNP Department of Spectrometers Complex a special integrated control system for monitoring different parameters of the stand and the respective software complex have been developed. The system includes various sensors (15 pieces altogether), a gas blower motor drive controller and a controller of the step motor of the dispenser of balls into the system. The system makes it possible to

control the main parameters of the moderator stand:

- transport of balls through a pneumatic conveying pipe (controlled by an original method based on gas-dynamic effects);
- filling of the moderator chamber with beads (monitored with a web-camera through quartz glasses);
- gas flow rate;
- pressure and temperature of helium.

At present, the manufacturing of the elements of the stand has been completed and the process of assembling and testing has started.

Test beam

The technical project of construction of a test beam on channel 13 of IBR-2M has been developed, the assignments for development of the channel equipment units have been given to the Design Department. The design specification for a biological shield has been prepared as well.

Neutron beam-forming systems

In cooperation with the German Institutes and PNPI (Gatchina) within the framework of the project aimed at constructing curved mirror neutron guides for the EPSILON and SKAT spectrometers on beam 7a of the IBR-2 reactor the work to design and manufacture mechanical and optical units of the neutron guides has continued. In particular, the designs of a vacuum system and a background shield of the EPSILON and SKAT spectrometers and of a docking part of the neutron guide of the NERA-PR spectrometer have been developed, the documentation has been worked out and the manufacturing of the disk background chopper and three drum λ-choppers is nearing completion.

The reconstruction of the supporting column of IBR-2 in bldg. 117 and a biological shield of the head part of beam 7 to accommodate three neutron guides on the channel has been completed. The equipment from the embedded pipe of the ring corridor wall has been dismantled. In NPO «Atom» the posts and beam-positioning support pillars of the neutron guide head part have been produced. In JSC «Komtrast» the manufacturing of 92 vacuum casings for the curved neutron guides for the EPSILON and SKAT spectrometers is in progress. At present, the assembly of the head part (splitter) of beam 7 and the adjustment of mechanical units of the choppers have started.

Cryogenic stand

A test cryostat for work with closed cycle cryocoolers has been developed. The manufacturing of a control panel of the helium circulation system for additional refrigerators that can be placed in this cryostat is in progress. The cryogenic stand is used to test and adjust cryogenic systems. At present, the modernization of the cryostat for the inelastic neutron scattering spectrometer (beam 7b, IBR-2) is under

way. The cryostat shaft (70 mm in diameter) allows for fast cold sample change. The expected final temperature is 4.5 K.

Development of control systems of choppers

In FLNP the control system of choppers based on the VFAS1-series variable-frequency electric drives from Toshiba has been developed, manufactured and debugged for the disk background chopper and three drum λ-choppers of the EPSILON, SKAT and NERA-PR spectrometers. The electric drive has a built-in microprocessor, which realizes the control algorithm according to the speed of rotation and the moment of rotation on the motor shaft. An incremental magnetic coding sensor for measuring speed, accelerating the disk and forming signals carrying information on an opened state of the chopper is installed on the motor axis. A phase controller CC-07 enables a chopper disk (drum) window position phase to be regulated with respect to the reactor start. The control system of choppers based on microcontrollers with CAN interface has been developed. As a result, control over each chopper is exerted by a computer of the respective spectrometer. The performed development work and tests have demonstrated the possibility of using variable-frequency VFAS1 drives and control systems to replace outdated EKT2 on the choppers of other IBR-2M spectrometers.

Calculations of spectrometers

Calculations of neutron spectra and optimization of beam geometry from moderator to sample for the EPSILON-SKAT spectrometer (beam 7a) have been completed. This will allow the neutron flux at the sample position to be increased by 20-30%. Preliminary calculations for beam 10 (GRAINS) have been made as well. The simulation of the instrument and its elements has been performed and recommendations to increase the neutron flux have been given. Two new modules for the VITESS software package have been developed.

Detectors

The anode and cathode electrodes have been manufactured, the position-sensitive detector for the GRAINS spectrometer has been assembled and filled with a gas mixture. The tests of the detector and the measurement of its characteristics have been carried out on beam 5 of the IR-8 reactor in the RRC «Kurchatov Institute». A series of measurements with pin-hole and slit cadmium masks has been made at various values of anode voltage and different levels of discrimination of input signals. The PSD counting characteristics were measured with the pin-hole and slit exposure of the detector. Optimum operating modes of the detector were chosen and its main characteristics were measured. Also, the profiles of beam 5 of the IR-8 reactor and the IREN facility were obtained.

A new high-speed neutron counter with a peak load of up to $3 \cdot 10^6$ n/s has been developed. The counter is a rectangular parallelepiped made of duraluminium of dimensions 250×80×40 mm^3 and with internal working volume 150×30×20 mm^3. The anode is a multi-wire frame coupled to the common electrode brought out

through a vacuum connector outside. The pressure-optimized mixture of ^3He и CF_4 is used as a working gas. The DAQ electronics, PC interface and the software for the counter have been developed as well. The counter has been tested on the SuperADAM reflectometer (ILL, Grenoble, France).

The development of a new ring-shaped multi-section MWPC-based detector for the DN-6 diffractometer has started. At the first stage it is proposed that one ring-shaped detector be constructed and installed at a scattering angle of 90°. The advantages of the new ring-shaped gas multi-section detector as compared to the previously used ring-shaped detector based on SNM-17 gas counters are: large size of the detector working volume will allow the count rate of scattered neutrons to be increased several times; shared working volume makes it possible to have practically the same efficiency for all sections; rectangular geometry of counting sections should improve the homogeneity of detection efficiency; smaller sizes of "dead zones" of the detector.

The detector is a ring, which is divided into 32 sections. Each section accommodates an electrode system consisting of a wire anode and two cathodes, which limit the sensitive area of the detector. The entrance window for neutrons will be the surface of the inner ring of the detector. Thin insulated drift electrodes are glued to the entrance window and the rear wall. At the center there is an anode plane with six thin (10-20 μm) tungsten wires wound around it, which are oriented along the chords of the detector ring. This makes it possible to obtain coordinate resolution along the beam. Anode wires are spaced ~10 mm apart. The total number of measuring channels is up to 192. The working gas mixture consists of a neutron converter (^3He) and a quenching gas (CF_4).

Electronics, computing

The requirements specifications have been approved and the development of electronic blocks for acquisition and accumulation of raw data on the EPSILON, HRFD and DN-6 diffractometers has been started. These diffractometers will employ different detector systems, but the common feature, which all of them share, is that all these systems can be considered as a set of point detectors with fixed spatial geometry. This makes it possible to design identical (from the viewpoint of hardware) electronic blocks, in which all functions and parameters are realized on the level of microprograms, which are executed in FPGA of the respective block.

A new test program has been developed and a high-speed DAQ block for 1D and 2D MWPC detectors with delay line readout has been tested. The test program is a basis for creation of a standard interface to the Sonix+ software package.

In 2009, new equipment of external communication channels for 10 Gbit/s operation was installed in the JINR local area network. This, in its turn, requires partial replacement of the existing switching equipment in the central and peripheral segments of the FLNP network. The analysis of possible changes in the network

architecture and of characteristics of the equipment available in the market has been made with due regard for prospects of further evolution of the network. In view of limited financing it has been decided to purchase one intellectual multilevel router of WS-3560 series and a limited set of communication modules. The respective contract is in the realization stage. After this equipment is tested, it will be installed in one of the IBR-2M experimental halls.

A schedule for conducting maintenance work on the IBR-2 spectrometers according to which the modernization and repair of electronic equipment and the preparation of the spectrometers to the reactor start-up will be carried out. This work is already in progress on four spectrometers.

5. SCIENTIFIC RESEARCH PLAN FOR 2010

The 2010 FLNP Scientific Research Plan contains 4 first priority themes.

Theme	Leader	Priority	Code
Investigations of Nanosystems and Novel Materials by Neutron Scattering Methods	V.L.Aksenov A.M.Balagurov D.P.Kozlenko	1	04-4-1069-2009/2011
Nuclear physics with neutrons -fundamental and applied investigations	Yu.N.Kopatch V.N.Shvetsov	1	03-4-1036-2001/2010
Upgrade of the IBR-2 complex	A.V.Belushkin A.V.Vinogradov	1	04-4-0851-1987/2010
Novel Development and Creation of Equipment for IBR-2M Spectrometers Complex	S.A.Kulikov V.I. Prikhodko	1	04-4-1075-2009/2011

In 2010 the research activity within the framework of theme **1069** will be focused on:

- Investigation of structure and properties of novel crystal materials and nanosystems by neutron diffraction;
- Investigation of magnetic colloid systems in bulk and at interfaces;
- Investigation of crystal structure of carbon nanomaterials;
- Magnetism of layered nanostructures;

- Investigation of structural and functional characteristics of biological, colloid and polymer nanodispersed materials
- Investigation of nanostructure and properties of lipid membranes and lipid complexes;
- Investigation of atomic dynamics of nanosystems and materials by inelastic neutron scattering;
- Investigation of texture, composition and properties of minerals and rocks
- Analysis of internal stresses in bulk materials and factory-made goods.

The instrument development activity will be centered on the realization of top priority projects – the construction of the DN-6 diffractometer for studying microsamples, multi-purpose reflectometer GRAINS and the modernization of the SKAT/EPSILON spectrometers. Also, particular attention will be given to the preparation of the available spectrometers to the IBR-2M reactor startup.

The following research program will be realized in the framework of theme **1036**:

- Determination of parameters of neutron beams of the IREN facility. Modernization of equipment for carrying out measurements at IREN. Creation of complex of fast electronics.
- Construction of multisectional gamma-quantum and neutron detector for measurements of capture, transmission and fission cross sections, alpha coefficient for reactor and constructional materials. Realization of experiments at IREN.
- Search for negative p-wave resonances of lead isotopes and their relation with parity violation effects in interactions of polarized neutrons with lead.
- Construction of alpha-spectrometer for measurements at IREN. Investigation of interference effects in reactions $^{35}Cl(n, p)\ ^{35}S$ and $^{14}N(n, p)\ ^{14}C$ in the resonance neutron energy range.
- Construction of sample irradiation channels with pneumatic transport at IREN. Measurement of yield of medical isotopes Mo-100 and Sn-117 at the electron bremsstrahlung beam of the IREN facility.
- Determination of the source of background at the nn-scattering measurement facility and searching for the ways to suppress this background. Experimental verification of the viability of various suppression methods.
- Obtaining of first data on the *n,e* scattering length b_{nb} at the new experimental facility. Preparation of measurements at IBR-2.
- Construction of a setup for experimental verification of the equivalence principle for the neutron.
- Investigation of interactions of UCN with matter. Investigation of "weak" UCN heating on the surface of solids; measurement of inelastic and quasi-elastic UCN scattering spectra.

- Investigations of properties of ternary and quaternary fission. Test experiment on feasibility of quaternary fission study of ^{252}Cf using pixel MEDIPIX detectors.
- Measurement of correlations of neutron escape with spin of fragments in spontaneous fission of ^{252}Cf. Probability evaluation of emission of discontinuous neutrons.
- Study of the neutron-nuclear interaction mechanism in the reactions *(n, p)* and *(n, alpha)* with fast neutrons at EG-5, FLNP JINR and at EG-4.5, Peking University.
- Development of nuclear-physical techniques for elemental analysis of solids on accelerated particle beams of the electrostatic generator EG-5.
- Continuation of mathematical and physical modeling and calibration of neutron detectors for space vehicles.
- Project REGATA. Investigation of atmospheric heavy metal depositions in a number of regions of Central Russia and in the Southern Urals, in Bulgaria, Croatia, Egypt, Greece, Macedonia, Mongolia, Poland, Romania, Serbia, South Korea, Turkey and Vietnam. Continuation of investigations using NAA in ecology, medicine, biotechnology and development of novel materials (synthesis of fine-crystalline diamonds).

In the framework of theme **1075** the following activities are planned:

- Design of a biological shield for channel 13-14 of the IBR-2M reactor.
- Calculation and optimization of neutron beams on the IBR-2 reactor channels for the YuMO and GRAINS spectrometers.
- Construction of a prototype of the technological system for the cryogenic moderator with control electronics and software.
- Design of a ring-shaped multi-section gas detector for the DN-6 diffractometer: development of design documentation and manufacturing of the detector components and units in the FLNP Experimental Workshops.
- Development of a mobile gas control desk for the IBR-2M experimental hall.
- Design and manufacturing of analog and digital electronic blocks for neutron detectors.
- Carrying out of maintenance work at the IBR-2 spectrometers, routine modernization and repair of electronic equipment (in accordance with the plan-schedule).
- Continuation of work to reconstruct neutron guides on channel 7 of IBR-2M and to modernize the EPSILON and SKAT diffractometers (in accordance with the plan-schedule of the BMBF-JINR project).
- Start-up of a cryogenic test stand for working in the temperature range of 4-300 K. Design of a gas circulation system for working in the temperature range of 1.5-4 K.
- Modernization of sample-changing system for the YuMO spectrometer.
- Completing units of equipment and testing of 1-Gbit LAN segment in the experimental halls of IBR-2M.

- Enhancement of the software package SONIX+ to automate adjusting/positioning processes of the spectrometers.
- Design of new modules and development of the old ones for the VITESS software package in cooperation with JCNS, Munich, Germany (diffraction gratings, moving masks (including at the nanoscale), polarizers and analyzers, neutron refractive lenses).
- Modernization and maintenance support of infrastructure of workplaces for engineers and programmers.

The following main tasks are to be accomplished in the year 2010 in the framework of theme **0851:**

- Completion of installation, tests, adjustment and commissioning of the IBR-2M automatic safety and control system (ASCS-12R) and of the primary and standby control panels of the reactor.
- Adjustment and trials of the experimental stand for testing transportation modes of mesitylene balls.
- Manufacturing of a cryogenic moderator for neutron beams 2-3 (CM 203). Installation of mesitylene charging pipes for the cryogenic moderator of beams 7-11 (CM 202) and for the cryogenic moderator of beams 2-3 (in case of positive results of the tests on the experimental stand).
- Preparation to the physical start-up of the reactor:
  - adjustment and complex tests of the newly-assembled technological and electrical equipment and electronics;
  - preparation of the necessary organizational and technical documentation;
  - acceptance inspection of the IBR reactor to check the preparedness to the physical startup.
- Physical startup of the IBR-2M reactor.
- Creation of the system of physical protection of IBR-2M according to the modern rules.

6. CONFERENCES AND MEETINGS

In 2009, FLNP organized the following meetings:

- II Higher Courses of CIS for young scientists, post-graduate and graduate students on advanced methods of research in nanosystems and materials "Synchrotron and Neutron Investigations of Nanosystems (SYN-nano-2009) 28.06. - 13.07.2009.
- All-Russian Scientific School for Young Scientists and Students "Modern Neutron Diffraction Studies: Interdisciplinary Research of Nanosystems and Materials" 12.10 - 20.10.2009.

In the year 2010, FLNP will organize:

- III Higher Courses of CIS for young scientists, post-graduate and graduate students on advanced methods of research in nanosystems and materials "Synchrotron and Neutron Investigations of Nanosystems (SYN-nano-2010).
- All-Russian Scientific School for Young Scientists and Students "Modern Neutron Diffraction Studies: Interdisciplinary Research of Nanosystems and Materials" (if a grant of the Russian Ministry of education and science will be available).
- Anniversary workshop "50 years from the IBR-1 reactor's start-up".