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SCIENTIFIC PROGRAMME OF THE FRANK LABORATORY OF NEUTRON PHYSICS:

Report for 2003 and Prospects for 2004

Report to the 95th Session
of the JINR Scientific Council,
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INTRODUCTION

In 2003, the FLNP scientific program was realized under five research themes of the JINR Plan for Scientific Research and International Scientific and Technical Cooperation (PSRISTC) and it was aimed at obtaining new results in condensed matter physics (theme 07-4-1031-99/2003 "Neutron.Investigations of Structure and Dynamics of Condensed Matter", headed by V.L.Aksenov and A.M.Balagurov) and neutron nuclear physics (theme 06-4-1036-2001/2004 "Nuclear Physics with Neutrons – Fundamental and Applied Investigations", 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 07-4-0851-87/2007 "Upgrade of the IBR-2 Complex", headed by V.D.Ananiev) and IREN (theme 06-4-0993-94/2004 "IREN Project", headed by W.I.Furman and I.N.Meshkov) as well as the IBR-2 spectrometry and computation complex (theme 07-4-1012-96/2003 "Development of the IBR-2 Spectrometers Complex and Information-Computation Infrastructure", headed by A.V.Belushkin and V.I.Prihodko) continued. Also, FLNP took part in two JINR themes, «ATLAS. General-Purpose pp-Experiment at CERN's Large Hadron Collider» (theme 02-0-1007-94/2005, headed by N.A.Russakovich) and «Theoretical and Experimental Investigations of the Electronuclear Method of Energy Production and Radioactive Waste Transmutation» (theme 03-0-1008-95/2005, headed by A.N.Sissakian, I.V.Puzynin , S.Taczanowsky, I.A.Shelaev).

This report contains a brief account of 2003 scientific results and outlines the 2004 year plans of the Laboratory reflected in the JINR Plan for Scientific Research (PSRISTC) submitted for approval to the present session of the JINR Scientific Council. The FLNP annual report for 2003 will give a more detail account of 2003 results.

1. SCIENTIFIC RESULTS IN 2003

1.1. Condensed Matter Physics

Diffraction. On **HRFD**, experimental investigations of the magnetic and nuclear structure of manganites with a colossal magnetic resistance were completed. In particular, there were investigated in detail samples of the type $(La_{1-y}Pr_y)_{0.7}Ca_{0.3}MnO_3$ (LPCM) with isotopic replacement of oxygen. As a key result, there should be noted the fact that the found phase diagrams of samples with the isotopes ^{16}O and ^{18}O coincide within an accuracy of a small shift towards a smaller Pr concentration for the first sample. This means that the strong isotope-effect observed in the given compounds is a result of a transition to another phase due to isotopic replacement that does not introduce any new ground states but just redistributes the energy balance.

Measurements of residual stresses in bimetallic (hardened steel/zirconium alloy) structures in view of their joint use on the RBMK beams continued. The work is being carried out together with research institutes of MINATOM, RF.

TiNi alloy-based materials were studied under external nonaxial loading at different temperatures. Dependence of the martensite transition temperature on the external loading has been detected. The formation and growth of the austenite phase with a characteristic distribution of stresses between the two phases depending on external loading has been observed. A difference between the lattice parameters of the martensite phase in freshly prepared samples and those used has been discovered.

On the diffractometer for high pressures **DN-12**, the structure of the pseudobinar system of mercury chalcogenides $HgSe_{0.7}Se_{0.3}$ 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. It is found that in MnAs in the region of high pressures and low temperatures there exists a new orthorhombic magnetic phase. Investigations of the atomic and magnetic structure of the manganites $Pr_{1-x}Sr_xMnO_3$ (x = 0.50, 0.56) were 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, that 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 $Pr_{0.5}Sr_{0.5}MnO_3$.

Polarized neutrons and neutron optics. On the reflectometer **REMUR,** there has been measured a spatial magnetization distribution at the V(650Å)/Cr bilayer interface where an effective ferromagnetic layer was discovered to exist. In addition, there were analyzed the data from reflectometric measurements of the magnetization profile in periodic Fe/V structures to determine the magnetic ordering type of vanadium atoms in the vicinity of the interface. To process the experimental data, a program for the calculation of a particular type of gaussian nonideality of the interface structure has been developed. The first calculations showing a similarity between the calculated and measured patterns of the reflected neutron distribution were performed.

Inelastic neutron scattering. With the help of neutron diffraction and elastic scattering experiments on the **NERA-PR** instrument, structural phase transitions and the dynamics of solid mesithylene were investigated. It is shown that solid mesithylene can occur in the different crystallographic modifications depending on the degree of cooling and thermal processing. The generalized phonon density function of the different mesithylene phases has been obtained and analyzed.

Small angle scattering. On the **YuMO** instrument, complex small-angle neutron scattering investigations of a number of nanosystems were carried out. In particular, experiments of the small-angle scattering of neutrons on colloid C60 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 basing on the obtained data and some complimentary methods.

Small-angle neutron scattering experiments on the solution C60/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 affects them. In the framework of 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 nucleation theory is used.

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

The basic parameters of polycarboxyl dendrimers with different molecular architectures were obtained. At the same time, it was found that the solvent penetrates into the dendrimer structure in the amount reaching up to 30% in volume. 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 increased by 2.4 angstroms. In addition, the small-angle scattering data together with those from differential scanning calorimetry allowed explaining of nonmonotonous temperature dependence of the structural parameters of polyethylenoxide/polypropelenoxide copolymers in water solutions.

Applied research. In the framework of studies in "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. On the experimental complex **SKAT-TKOS,** 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, there was first conducted a complex investigation of rocks from the different lithosphere depths at high all-round pressures and with an instrument creating triaxial stresses at temperatures up to 600°C. 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 boundarier, etc.) on the elastic anisotropy of olivine rocks has been established.

The research program 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. Among the investigated samples were dolomite and anhydrite compositions, construction marble materials, rocks from the Eastern Alps, etc.

By means of neutron diffraction on the instrument **DIN-2PI,** the structure of liquid lead/potassium alloys was investigated. An analysis of diffractograms 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 weaker 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.

Principal methodological results. Tests of the new head part of the spectrometer REMUR 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. The 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. The new magnetic system, that allows 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 obtained that with such a precessor the beam cross section 10×25 cm^2 can be used. Estimates show that such spin-precessors will allow the investigation of objects with a correlation length in the interval $10^2 \div 10^4$ Å.

The possibility of the construction and draft project development of a polarized neutron reflectometer with a vertical scattering plane on the second beam of the reflectometer **REFLEX** was investigated. The instrument is expected to have a resolution of several percent, working wavelength interval $1 \div 10$ 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 films on liquid surfacess.

On the spectrometer **REFLEX II,** a measuring technique that employs Larmor precession of neutron spin and is based on the use of current foils has been tuned. The techtnique has been developed to be used with the time-of-flight reflectometer. The tuned technique of Larmor precession combined with the time-of-flight method is a new methodological direction that increases essentially the experimental possibilities of the instrument.

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

On the instrument **EPSILON** a system of 9 radial collimators each of which can be equipped with nine detectors has been adjusted. A total of 42 new detectors are installed and thus, the number of detectors in the layout 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 in dependence on 2θ - the detector's position. All the necessary calculations (recalculations) are preformed simultaneously. 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 elastic properties of polycrystals was applied for the investigation of important technological materials, such as copper, graphite, zirconium, etc.

On the instrument **YUMO,** the two-detector system operates effectively: sample environment possibilities have become wider, the project for the creation of a facility with a magnetic field is going on successfully, a number of new experimental data procession programs, that allow higher quality corrections and modeling of the experimental data, have been written and tested. The project of a small-angle X-ray diffractometer is being developed successfully.

On the spectrometer **DIN-2PI**, works to complete the experimental base for neutron physics investigations of matter over the temperature region to 3000K were carried out. Heating of the sample and keeping its temperature on the specified level during the course of measurements are executed with the help of the thermostat TS-3000 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 PEI. The thermostat was tested in the working conditions. The new experimental possibilities of neutron physics investigations of matter at temperatures to 3000K 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 type CaF_2) in the region of the superionic transition, advanced materials for thermonuclear reactors in the temperature region to 3000K, peculiarities of the structure and dynamics of liquid-metallic systems with admixtures of carbon or carbon modifications in the region of high temperatures, etc.

1.2. Neutron Nuclear Physics

In 2003 the FLNP experimental investigation program 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 centers in Russia, Bulgaria, Poland, Czechia, Germany, Republic of Korea, France, USA, and Japan.

Early in 2003 in the course of two working 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 lead nuclei was completed. 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 but not ^{204}Pb as it was earlier obtained by an ITEP group. This bases on the discovery of a *p*-resonance in ^{207}Pb, which may explain the parity violation effect.

On 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. The objective of measurements was the ratio between neutron scattering intensities into the front and into the back hemisphere $R = I(30^0)/I(150^0)$ for the neutron energy $E = 0{,}002 \div 0{,}07$ eV. For argon, a distinct diffraction pattern was observed in good agreement with the data on the argon structural factor in the literature. The pattern, after being reduced 50 times, has lead to two important conclusions: 1) even at low pressure diffraction 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 the measurement should be conducted. Vanadium frequently used as an isotropic scatterer has first demonstrated a weak anisotropy ($R = 0{,}97 \div 1{,}06$) as predicted by J. Mayers, Nucl. Instr. Meth. **221**(1984)609. The measurements with cadmium demonstrated that cadmium has an appreciable reflectivity (~ 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, that were carried out for neutron energies characteristic of stellar conditions, was completed. 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 of direct measurements of the neutron-neutron scattering length at the reactor JAGUAR in 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. A 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 obtained data on the process of cascade gamma-decay of compound states of nuclei with a high level density by the method of coinciding pulse amplitudes summation continued. Under the program most detail and precise data on the properties of excited states of the spherical (^{118}Sn) 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 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 ^{118}Sn and in ^{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 0.5 B_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 the spirality 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. 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 the "impurity" fission width of *s*- resonances..

Applied researches. On 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. 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 over a similar energy region. The obtained data will be included in the nuclear data libraries used in the calculation of nuclear facilities.

2. NEUTRON SOURCES

2.1. 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 2 cycles with the power W=1.5 MW.

Modernization project

- 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 jacked is completed in NIKIET; test assembling of MR-3 with a jacket is under way.
- New fuel loading: manufacturing of TVELs is in the stage of completion in the industrial enterprise "Maiak"; 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 in NIKIET.
- Helium facility: development of the new Cold Helium Facility (CHF) was completed.

Development of a complex of wide spectrum neutron moderators («combi-moderators») for the IBR-2M reactor under modernization:

1. The three-year program for the investigation of radiation properties of various hydrogen-bearing materials at low temperatures (20-40K) was completed (Program leader: E.P.Shabalin). Of the new results there should be noted two phenomena nobody had observed before: spontaneous chain reaction of radicals recombination in irradiated water ice and a sharp decrease in the thermal conductivity of ice under irradiation, as well as a high radiation resistance of aromatic hydrocarbons.

2. An analysis of the effectiveness of various materials as to their use as an IBR-2M cold moderator material has been carried out (Shabalin, Kulikov, Natkaniec). The conclusion made is that mesithylene mixtures with other aromatic hydrocarbons are best for the purpose.
3. The combi-moderator for beams 7, 8, 10 and 11 of the IBR-2M reactor has been optimized.

In 2004 optimization of combi-moderators for the IBR-2M beams will be carried out and research and design works to produce a mesithylene-based cold neutron moderator (together with NIKIET) will start.

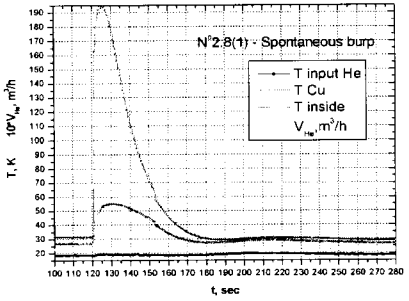

Fig.1. The burp in the ice temperature at spontaneous energy release.

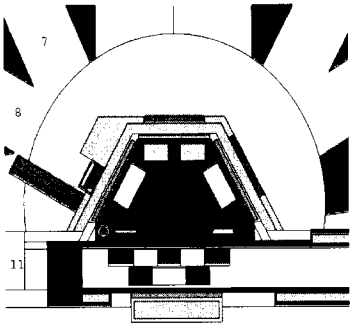

Fig.2. The combi-moderator for beam 7 (cock-like water), 8 (cold), 10 (wide-spectrum) and 11 (hole-water).

2.2. The IREN Project

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

The first one allowed fulfilling of the task in principle. But, actually, in spite of many efforts to realize the special JINR director order and the respective time-table the decommissioning of IBR-30 has not been finished in 2003. Meanwhile, most of items of this time-table 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 be able to start only next summer if dosimetric equipment is paid, delivered and installed in the first quarter of 2004 and before starting of the works the license for storage is received. The work for 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 on 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 a working out of a first part of the technological project of the facility. It was fulfilled with large delay by the Moscow design institute GSPI. We have obtained very recently the part of the general project necessary for approving in 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 of the respective payments. Very similar situation is with the technical project of the control system of the IREN source. It is completed by a special Moscow organization OKSAT NIKIET on credit but up to now JINR has not paid for it.

3. DEVELOPMENT OF THE IBR-2 SPECTROMETER COMPLEX AND 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 spectrometers complex.

1. Creation of neutron detectors

Gas detectors

Infrastructure. A large amount of work to create technological and electronic infrastructure for manufacturing and testing of the detectors has been performed:

- Preparation for the commissioning of a clean room is being completed. Some works on assembling of the detector elements have been already carried out.
- Stand for the creating of anode and cathode planes for the neutron detectors on the basis of multiwire proportional chambers (MWPC) was created and the manufacturing of electrodes for MWPC detectors with individual signal readout from each wire and with delay line data readout started.

- Electronic stand for testing two-coordinate detectors with delay line data readout was assembled. It includes an amplitude analyzer and NIM crate with a 5-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. All mentioned equipment was adjusted and first test measurements with a ^{252}Cf source on a real detector manufactured in ILL, Grenoble were performed.

Development and manufacturing of detectors

1. An original design of MSGC detector with a "virtual" cathode was developed and a prototype 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.

2. MWPC detector with a sensitive area of 20×20см^2 and a rated coordinate resolution of 2.5 mm was developed and manufactured. The determination of coordinates is realized by wire number coding. Together with the University of Magdeburg, a principal electric circuit of the block for the calculation of the center of mass of the event cluster in the detector space (64×64 wires) was developed and simulated in the FPGA environment. The accuracy of determination of the center of mass is 0.5 pixels. A simplified version of the encoding block (24×24 pixels) was developed and manufactured.

3. A similar casing will be used for the creation of a two-coordinate detector of 20×20 cm^2 with delay line data readout. The 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 will be carried out in the I-II quarters of 2004.

Scintillation detectors

Work in this direction has been successfully carried out for several years. In 2004 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 2 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 the 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 the new type (ring of 16 modules) will provide an 8-fold increase in statistics gathering rate as compared to the available ring 90°-detector on helium counters in operation on channel 12.

2. Development of sample environment systems

A microcontroller block for controlling step motors was developed to create multichannel control systems of actuating of 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*2A. Communication with PC is carried out using the RS232 protocol.

For the DSD spectrometer of the IVV-2M reactor (Sverdlovsk branch of NIKIET) a central platform of the stress-diffractometer with a linear scanner was manufactured. The central platform enables the rotation of the linear scanner as a single whole around a vertical axis and the rotation of a rotary platform with the detector around the same axis. All control systems are constructed on the basis of step motors and are 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 a closed cycle refrigerator of Leybold firm is used on the basis of the cold head CoolPower 5/100T and the compressor CoolPak 6000. The replacement of a sample does not demand 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 the 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. The refrigerator is designed as a 80 mm diameter insert submerged in a helium cryostat. It keeps the temperature of a sample at 0.31 K for 20 hours after condensation of ^{3}He at a useful heat load of 10 μW. The recondensation time is 0.5 hours.

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

3. 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 processors with OS Solaris were installed and put into operation.

Work to develop the FLNP Web-server and information system HIPNS (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 at them. The XML-version of the HIPNS system using the Apache Cocoon technology was realized. The required pages are automatically generated from the database 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 ILFA firm, Hamburg. The first version of the 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 (in HMI and in FLNP) and on the BER-II reactor in HMI. Analysis and visualization of the data were carried out using the ROOT and PV-WAVE packages. 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, operating system Windows XP and the created software. Work to adapt all control programs to Windows is in the completion stage. 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. The scheduled completion date of works is the end of the 1st quarter in 2004.

The SONIX software complex was adapted for work at the FSD spectrometer, installed, tested and put into operation. Works to install the adapted SONIX software complex at the HRFD spectrometer 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. 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.

To maintain trouble-free operation of the spectrometers during the IBR-2 cycles and preventive servicing during the reactor shutdown, required great effort.

Within the framework of the 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.

4. SCIENTIFIC RESEARCH PLAN FOR 2004

The 2004 FLNP Scientific Research Plan contains 5 first priority themes.

Theme	Leader	Priority	Code
Neutron investigations of the structure and dynamics of condensed matter	V.L.Aksenov A.M.Balagurov	1	07-4-1031-99/2008
Nuclear physics with neutrons - fundamental and applied investigations	W.I.Furman V.N.Shvetsov	1	06-4-1036-01/2004
Upgrading of the IBR-2 complex	V.D.Ananiev E.P.Shabalin	1	07-4-0851-87/2007
Construction of the IREN facility (Project IREN)	I.N.Meshkov W.I.Furman	1	06-4-0993-94/2004
Development and Creation of Elements of Neutron Spectrometers for Condensed Matter Investigations	A.V.Belushkin V.I.Prikhodko	1	07-4-1052-04/2008

In the year 2004, in the framework of theme **1031** investigations in condensed matter will be carried out in the following directions:

The plan of scientific research will base on experimental proposals selected by the experts' committee and the approved long-term projects. It will include, in the main, the research directions traditionally investigated at the IBR-2 reactor and will focus on obtaining of the new data about the microscopic properties of the investigated systems and experimental verification of theoretical predictions and models.

The plan of methodological work foresees: Creation of test pieces of optical media with specified properties for generation of laser radiation. Modernization of the REMUR polarized neutron spectrometer. Modernization of the FSD neutron Fourier-

diffractometer for analysis of internal stresses. Modernization of the neutron diffractometer complex of the IBR-2 reactor (DN-2, DN-12, HRFD. Modernization of the YuMO small-angle neutron scattering spectrometer. Modernization of the REFLEX-P neutron reflectometer. *Modernization of the neutron diffractometer complex (SKAT, EPSILON, NSVR) for studying texture and internal stresses in materials. Modernization of inelastic neutron scattering spectrometers (DIN2-PI, NERA-PR, KDSOG-M). Creation of the SEASANS spin-echo small-angle neutron scattering spectrometer. Creation of a new neutron reflectometer with a vertical plane of scattering. Creation of a new neutron diffractometer for investigations at high pressures. Creation of EXAFS - a spectrometer on the "Sibir-2" synchrotron radiation source in RSC "Kurchatov Institute" (Moscow).*

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

Continue the development of an optically polarized gaseous nuclear target at a pressure of up to 10 atm with $^{129,131}Xe$ isotopes for experiments to verify the possibility of time invariance violation in three-fold correlation. Designing and preparation of experiments at IREN (KATRIN project).

Create a channel with a gaseous deuterium target for the generation of low energy neutron beams in the neutron energy range 3.5 – 6.5 МэВ at EG-5. Modernization of the ^{7}Li- and T-based targets. Continue measurements of the total, partial and differential cross sections of the reactions (n,p) and (n, α) on ^{14}N and ^{35}Cl over the neutron energy interval from several keV to 6.5 MeV.

Completion of precision measurements of the total neutron cross section of gaseous argon as a first stage in the investigation of the (n,e)-interaction. Designing and preparation of experiments at IREN.

Complete the modernization of the instrument DRENIZ and start measurements of delay neutron yields from the thermal neutron induced fission of 245Cm nuclei.

PROJECT REGATA – investigations of heavy metal pollution in a number of regions in Russia - Moscow, Ural and Baikal, Kola Peninsula, and in Bulgaria, Poland, Moldavia, Romania, China, Egypt, Southern Korea, France. Continue investigations in occupational ecology and monitoring. Continue investigations in materials science and biotechnologies.

Continue experiments of the investigation of "weak" UCN heating at the reactor of ILL in Grenoble. Carrying out of experiments with nanopowders and sapphire traps to confirm the hypothesis of the mechanism of "weak" heating.

Perform mathematical modeling of an experimental setup for the measurement of the nn-scattering amplitude. The development and construction of the setup, preparation and carrying out of test experiments of nn-scattering at the reactor JAGUAR (Snezhinsk, Russia).

Continue measurements of the fission cross section of minor actinides at neutron energies up to 250 MeV at the source n_TOF in CERN.

The following main problems are to be solved in the year 2004 in the framework of theme **1052:**

Development and creation of a MWPC detector prototype with a sensitive area of 20×20 cm^2 with delay line readout.

Development and creation of a MWPC detector prototype with a sensitive area of 20×20 cm^2 with individual readout of coordinate information from a group of strips.

Development and creation of a MWPC detector prototype with a sensitive area of 20×20 cm^2 with data readout from individual wires.

Manufacturing of the FSD detector system (70% of total work content).

Development of the detector system project for the DN-6 diffractometer.

Development, programming and assembling of the test bench of the executive mechanism control system on the basis of a C167microcontroller.

Automation of the goniometer of the high-power magnet in the SPN spectrometer.

Replacement of the chopper control electronics on beams 6 and 10.

Development of a cryogenic insert for the ORANGE 1001 cryostat for working at temperatures down to 0.35K.

Modernization of the power supply system for electronics and computers at the IBR-2 spectrometers.

Integration of PC into the structure of the VME-based data acquisition system (development, debugging and optimization of the unified software).

Integration of PC into the data acquisition system of the MWPC detector.

Development of the new electronic blocks .

Extension of the LAN disk memory.

Routine maintenance of the IBR-2 spectrometers.

The following main tasks are to be accomplished in the year 2004 in the framework of theme **0851:**

After finalizing of the assembly and testing stand operation of MR-3, it will be assembled at a regular site near the reactor and the IBR-2 startup with MR-3 will take place in mid-2004.

New fuel loading will be shipped from "Maiak" and a working area for TVELs assembly into fuel cassettes will be organized in JINR.

Works to manufacture the new IBR-2M reactor jacket and the other basic equipment of the reactor will continue.

The IBR-2M executive mechanisms and SUZ electronist will be manufactured.

The technical proposal for the new moderators will be developed and their designing will start.

CHF will be manufactured.

In 2004, the optimization of combi-moderators for the IBR-2M beams will be carried out and research and design works to produce a mesithylene-based cold neutron moderator (together with NIKIET) will start.

5. CONFERENCES AND MEETINGS

In 2003, FLNP organized the following meetings:

1. *XI International Seminar on Interaction of Neutrons with Nuclei ISINN-11, May 28-31.*
2. *XII International Conference on Selected Problems of Modern Physics, June 8-11 (organized together with BLTP).*
3. *International Seminar Dedicated to 95-th Anniversary of I.M.Frank, October 23-24.*

In the year 2004, FLNP will organize the following meetings:

1. *XII International Seminar on Interaction of Neutrons with Nuclei ISINN-12, May 26-29.*

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