Condensed Matter Physics

Basic Facility IBR-2 and its Development

07-4-0851-87/2007

Priority of the project: 1

Status: Data taking

Modernization of the IBR-2 Reactor

Leader from JINR: V. Ananiev

Participating countries and international organizations: Austria, Czech Republic, Democratic People's Republic of Korea, Germany, Hungary, Japan, JINR, Poland, Republic of Korea, Russia, Spain, the USA.

In the development and realization of the project, the following Russian organizations take part: NIKIET, VNIINM, industrial enterprise "Maiak", NIKIMT, GSPI, INEUM, SNIIP-Sistematom, the "Geliimash".

The existing IBR-2 reactor depleted 90% of its resource on basic equipment and after the change of movable reflector MR-3 in 2003 it can only operate until 2006 inclusive. In this connection the modernization of IBR-2 is urgent.

IBR-2 modernization work is conducted in accordance with two main documents:

- "IBR-2 modernization concept for the period up to 2010" (Approved by the Director of JINR 23.12.1999);
- "Agreement between the Russian Ministry of Atomic Energy and JINR on the IBR-2 modernization" from 14.02.2002,

in which the purposes of modernization were formulated:

- improvement of basic parameters of the facility;
- improvement of accident prevention and operation safety;
- renewal of the basic equipment depleted of the resource.

On the completing of the IBR-2 modernization in 2010, it is planned to create a new modernized reactor IBR-2M with the improved accident prevention and safety (the resource of TVEL increases 1,5 times, the resource of movable reflector — 2,5 times) with the 1,5 times increased thermal neutron flux at constant mean W=2 MW. The lifetime parameters of the IBR-2M reactor will be 20–25 years.

Main design peculiarities of the IBR-2M:

- compact core (69 fuel assemblies instead of 78 as in IBR-2);
- reduced revolutions of the basic movable reflector (600 rpm instead of 1500 rpm), counter flow of MMR and AMR, application of nickel alloy for reactivity modulators;
- utilization of spigot TVELS only, which allows one to increase the degree of burn to 9%;
- vertical arrangement of the AES and the increase of its high-speed response;
- creation of easily changeable moderators, which allows one to optimize them for each beam.

An overall cost of the project is about 7200 k$, 3600 k$ of which must be paid by JINR and 3600 k$ — by the Russian Ministry of Atomic Energy. Up to 01.01.2003, 2200 k$ was invested into the project.

At present, the IBR-2 neutron pulsed reactor has the highest neutron flux in the world. After the modernization it will remain among the leading neutron sources in the world. A scientific program, which takes into consideration the tendencies of the development of natural sciences and the IBR-2M reactor parameters, is being prepared for the new IBR-2M reactor. The scientific program is aimed at solving problems of current interest in condensed matter physics, in physics and chemistry of polymers, in crystallography of biological objects and compounds, which hold promise for pharmacology, geophysics, engineering sciences and materials sciences. In this connection, besides the modernization work of the reactor itself, the work to create the moderator complex and to modernize the spectrometer complex is conducted.

Experiments and Facilities at IBR-2

07-4-1031-99/2008

Priority of the project:

Status: Data taking

Magnetism of Low-Dimensional Nanostructures

Leader from JINR: V. Aksenov

Participating countries and international organizations: Belarus, Bulgaria, France, Germany, Hungary, Romania, Russia, Switzerland.

One of the most interesting problems in the modern condensed matter physics is the study of properties of nanostructures, especially magnetic low-dimensional nanostructures — thin films, layered nanostructures, multilayered superlattices and surface of materials. The direct method of investigations of the structure and dynamics of these objects at microscopic level is the polarized neutron reflectometry.

The main directions of the research are:

- Investigations of low-dimensional magnetic nanostructures, studies of structure and dynamics of these systems at microscopic level, studies of peculiarities of formation and self-organization of structural defects and their effect on the magnetic and electronic properties;
- Development of the polarized neutron reflectometry methods and modern polarized neutron spectrometers at IBR-2 pulsed reactor.

The expected results:

- Study of coexistence of superconductivity and magnetism in layered nanostructures Fe/V, Fe/Cr;
- Study of magnetic properties of polymer thin films with different magnetic inclusions (Fe_3O_4, Fe_2O_3, Gd), parameters of magnetic clusters and roughness at the surface boundaries;
- Study of the surface dynamics. For the first time thermal neutrons will be used for investigations of energy transfer and absorption in the process of the neutron wave reflection from smooth flat surface;
- Determination of the dynamical and magnetic characteristics of investigated materials (dispersion relations and density of states for surface excitations, exchange integral) from the angle distribution of reflected neutron spectra;
- Development of neutron spin — precession techniques in the polarized neutron reflectometry and their application in scientific investigations. Study of neutron spin-precession effects. Three-dimensional analysis of the polarization in the structure using $\pi/2$ rotators. Study of magnetization of thin foils made from amorphous magnetic materials.

Importance of the results for world science:

The magnetic properties of multilayered nanostructures exhibit a reach variety of new previously unknown phenomena of low-dimensional magnetism. These systems have wide important applications in the development and manufacturing of electronic devices. Hence, the studies of those properties of multilayered nanostructures that depend on parameters characterizing the structure of the system play an important role.

The realization of this project will be performed by the staff of Neutron Optics Sector of the Department of Neutron Investigations of Condensed Matter of the Frank Laboratory of Neutron Physics JINR. During the last years important modernization of polarized neutron spectrometer REMUR and the first stage of modernization of the polarized neutron reflectometer REFLEX-P were done. Some experiments will be performed in other neutron centers — ILL (Grenoble, France), HMI (Berlin, Germany) and PSI (Villigen, Switzerland).

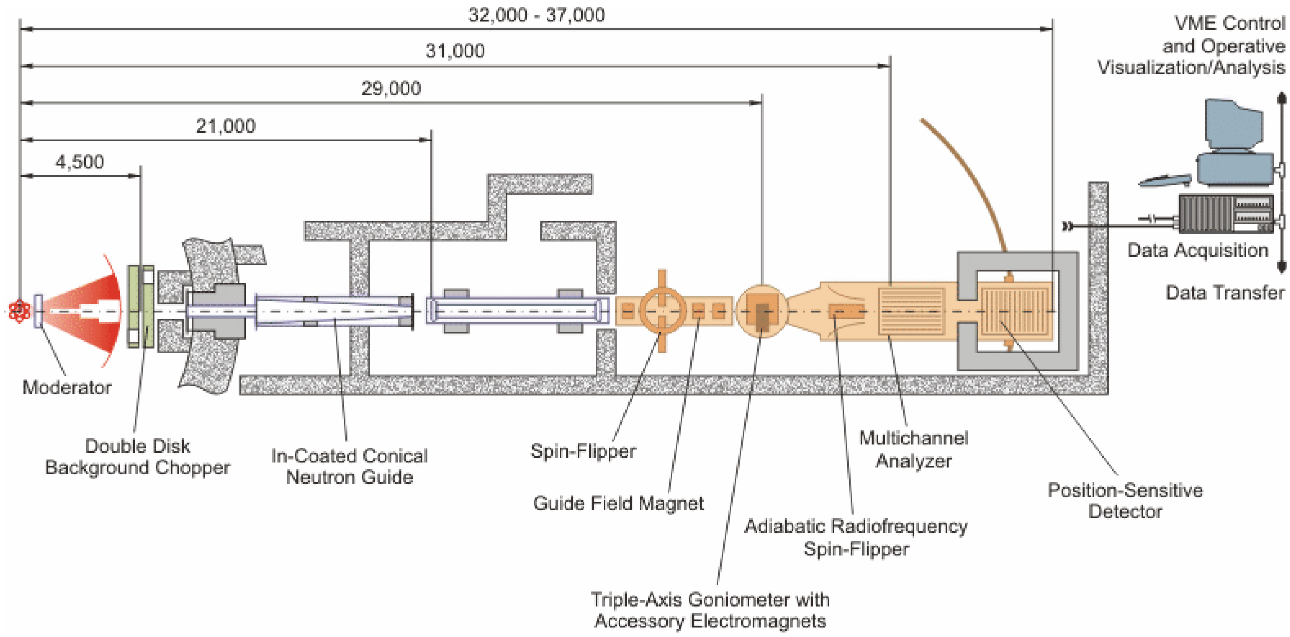


Fig.1. The design of the REMUR spectrometer installed at Beam 8 of the IBR-2 pulsed reactor.

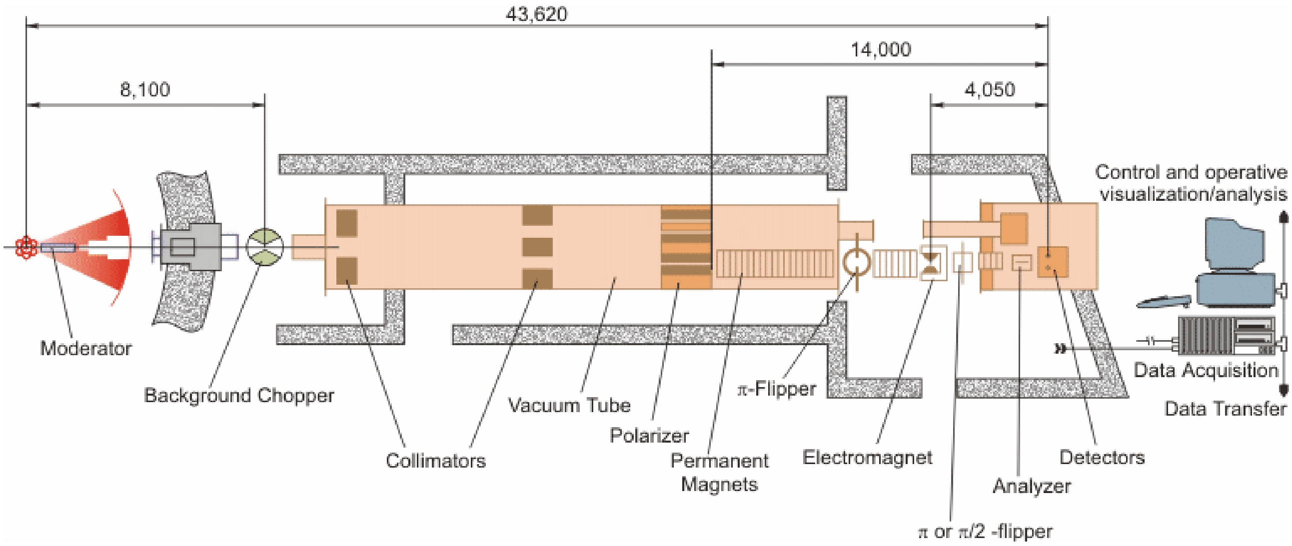


Fig.2. The design of the REFLEX-P spectrometer installed at Beam 9 of the IBR-2 pulsed reactor.

07-4-1031-99/2008

Priority of the project:

Status: Data taking

Structural Studies of New Crystalline Materials with Neutron Diffraction

Leader from JINR: A. Balagurov

Participating countries and international organizations: Belarus, Bulgaria, Czech Republic, France, Germany, Japan, Poland, Russia, Switzerland, Ukraine, the United Kingdom.

The project is devoted to the investigations of the structure and properties of novel crystalline materials by means of neutron diffraction. In FLNP, large experience in diffraction investigations has been gained during last years. Powerful experimental basis, data acquisition and processing systems are available. Laboratory has close contacts with a lot of research institutions, both in Russia and abroad, the user policy to choose among experimental proposals is established.

Main directions of the research and expected results:

The clarifying of the correspondence between the structure and properties of crystal is one of the fundamental problems of crystallography and condensed matter physics. It is important for understanding such phenomena as superconductivity, superionic conductivity, phase separation in crystals, colossal magnetoresistence effect, etc. General problems which can be investigated with the help of neutron diffraction may be formulated as following:

- atomic and magnetic structure of crystals;
- structural changes under application of high pressure and low or high temperature;
- transition phenomena in crystals;
- internal stresses in bulk industrial materials and components.

At the IBR-2 pulsed reactor there are several instruments intended for variety of structural studies. They include three specialized diffractometers (HRFD, FSD and DN-12), a multipurpose diffractometer (DN-2) and the instrument for performing test and methodical diffraction experiments (TEST). The HRFD diffractometer is designed for high resolution powder studies when $\Delta d/d \approx 0.001$ is required. The DN-12 diffractometer is designed for experiments with powder samples for investigations of atomic and magnetic crystal structure under high pressure. At the DN-2 diffractometer both single crystals and powder samples can be investigated. FSD a high resolution ($\Delta d/d \approx 0.004$) instrument for stress studies in bulk samples and elastic properties of materials at various external conditions, for instance, at high temperature. In contrast to HRFD, FSD is optimized just for such kind of experiments and is equipped with necessary units.

Importance of the results for world science:

All the diffractometers operating at the IBR-2 reactor are intended for a rich variety of structural studies of crystalline materials with interesting physical properties which are of the main interest in the modern condensed matter physics — superconductivity, colossal magnetoresistance effect, superionic conductivity, materials having important properties for industrial and technological applications and investigations of internal stresses in bulk industrial materials at the top world level. Experiments with HRFD, DN-12, FSD and DN-2 diffractometers are performed in the framework of the user policy. It includes collection of the proposals for experiments from FLNP, Russia and abroad. All the proposals are considered by an international expert committee to allocate the available beam-time. Each year, about several dozens of experiments are performed with diffractometers of the IBR-2 pulsed reactor, mainly in collaboration with leading condensed matter Institutes from Russia and other countries.

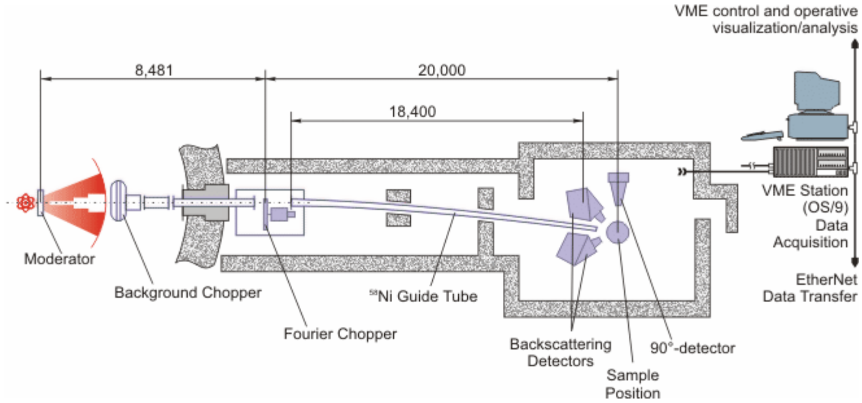


Fig.1. High Resolution Fourier Diffractometer (HRFD) at the beam 5 of the IBR-2 Pulsed Reactor.

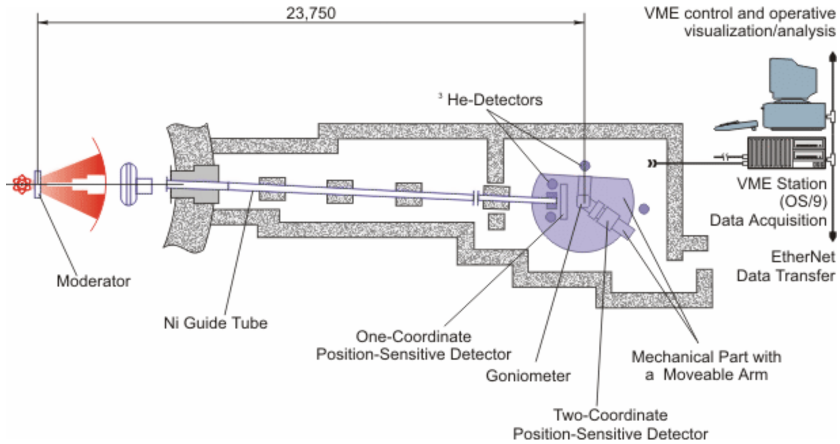


Fig.2. Multipurpose Diffractometer (DN-2) at the beam 2 of the IBR-2 Pulsed Reactor.

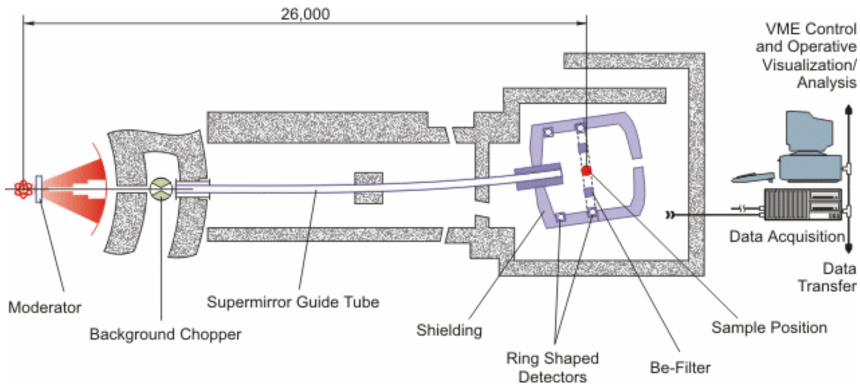


Fig.3. High Pressure Diffractometer (DN-12) at the beam 12 of the IBR-2 Pulsed Reactor.

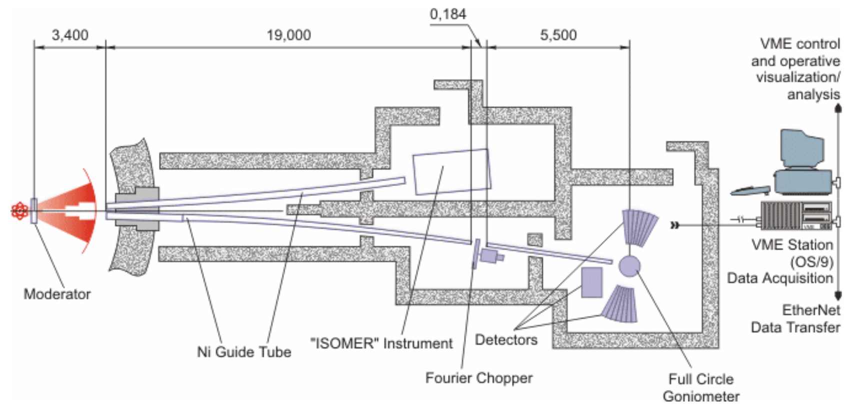


Fig.4. High Resolution Fourier Stress Diffractometer (FSD) at the beam 12 of IBR-2 Pulsed Reactor.

07-4-1031-99/2008

Priority of the project:

Status: Data taking

Investigation of Non-Crystalline Materials and Liquids by Small Angle Neutron Scattering

Leader from JINR: A. Kuklin

Participating countries and international organizations: Czech Republic, France, Germany, Holland, Hungary, Poland, Romania, Russia, Slovak Republic, Ukraine.

Small angle neutron scattering is the effective method of solving fundamental and major technological problems, and this method is widely applied in the investigation of mesostructures. It is used by condensed matter physics, physics-chemistry of colloidal systems and surfactants, biophysics and molecular biology, for research of polymers, in metallurgy and other departments of science and engineering. The work on the project will be carried out in the following general directions:

Direction of biophysics and molecular biology:

Investigation of biological structures and macromolecules (biological membranes, protein-lipid and DNA-lipid complexes, enzymes).

- Interaction of lipid — DNA complexes;
- Structure of biological membranes over active molecules;
- Structure of biological membranes over high pressure;
- Interaction polymer (pluronic) /membranes;
- Membrane protein/lipid membrane behaviour in the course of protein crystallization;
- Micellar change of phospholipid/ bile acids system:
- structure DNA-lipid complexes utilized by genetic therapy;
- influence of active agents used by medicine on biological membranes and their components.

Direction of physical chemistry of surfactants and:

- Determination of structural parameters of micelles;
- Investigation of correlation of micellar mixed state structure with its catalytic properties;
- Behaviour and structure of monoglyceride/water system;
- Structure and properties of surfactant changed polymer gels;
- Ferroliquid structure.

Self-assembly of rigid-rod poly (sodium p-phenylenesulfonate) in aqueous solution:

- Hydrophobic gels structure;
- Highly branched polymers (dendrimers) structure;
- Structure of polymers in membranes;
- Research of polymer structure in supercritical CO_2 ($SCCO_2$).

Science of materials direction:

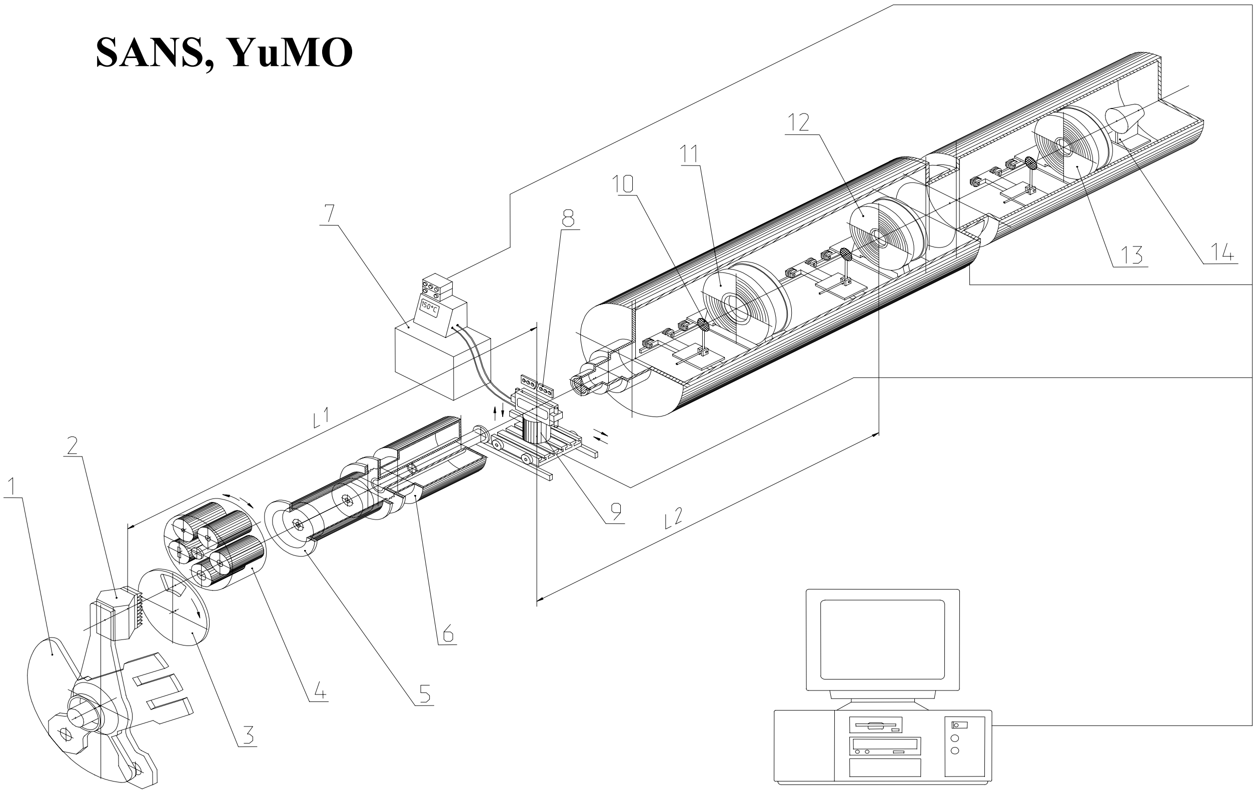
- Technical and biological consistent ferrofluid structure: magnetic particles concentration effect;
- Investigation of powders having various nature;
- Alloys (objects of metallurgy industry);
- Investigation of structure and dynamics of intelligent materials, including ferrofluids and nanocomposites;
- Small angle neutron investigation of polymeric pellicle used for selective filtration of substances.

Methodical development:

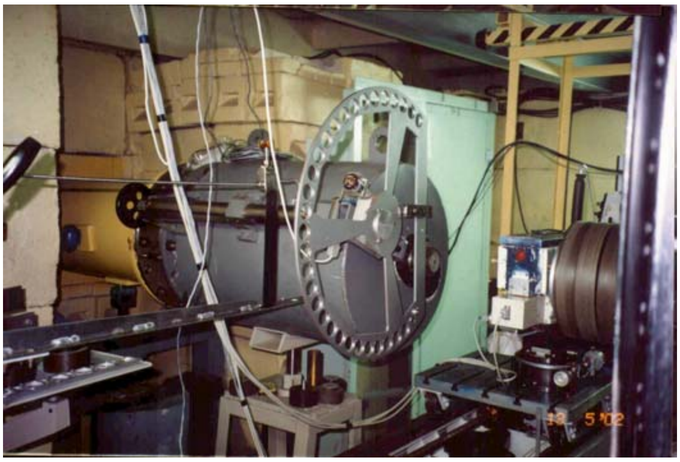
Application of mathematical methods to the treatment of SANS data, software, development and modernization of the YUMO spectrometer.

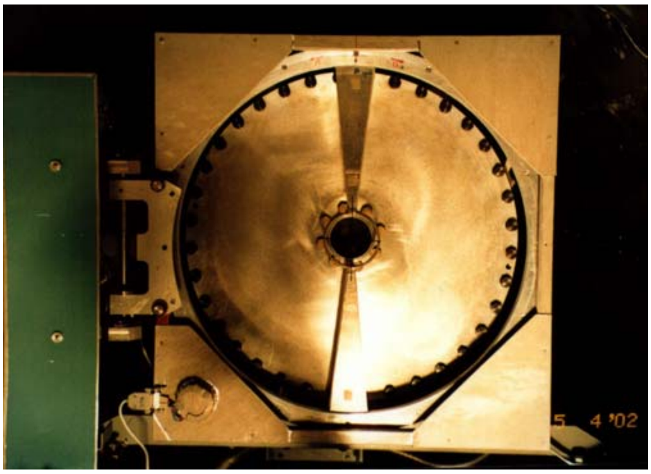
Experiment realizing is proposed at the small-angle neutron YUMO spectrometer, the 4th beam of IBR-2. Besides, it is intended to create a new spectrometer MURN-C at high-flux beam. Sample preparation, current status estimation, testing, realizing of additional measurements will be carried out on two x-ray spectrometers (difractometer DRON-4 successfully in operation, Kratky chamber — is in the modernization process) and in the biochemical laboratory, where the additional devices are located: cool refrigerators, siccative and vacuum ovens, centrifuge, high purify water system, ultrasound instruments, a microscope, pH-meters, balances, a spectrophotometer, a densimeter.

SANS, YuMO



1 — two reflectors, 2 — zone of reactor with water moderator, 3 — chopper, 4 — first collimator, 5 — neutron tube, 6 — second collimator, 7 — thermostat, 8 — table for sample, 10 — Vn-standard, 11, 12 — scattering detectors, 14 — direct beam detector.





07-4-1031-99/2008

Priority of the project:

Status: Data taking

Structural Organization of Molecular and Biological Systems

Leader from JINR: M. Avdeev

Participating countries and international organizations: France, Germany, Hungary, Romania, Russia, Switzerland, Ukraine.

The aim of the project is to investigate structural features and formation of a number of molecular complexes in different systems including biological objects. Main directions of the project are the following:

- Cluster state of fullerene in solutions;
- Cluster formation in colloidal solutions;
- Cluster formation and growth in molecular materials for moderating neutrons;
- Molecular complexes for drag delivery;
- Biological macromolecular systems.

Molecular complexes and clusters in the scale of 1–100 nm are of current interest in different fields of physics, chemistry, biology, materials science, geology and others. The corresponding directions of the project mentioned above are developed at FLNP, JINR, at the biophysical group organized to centralize such kind of research at the division of neutron investigations of condensed matter. Members of the group carry out experiments on neutron scattering at a number of instruments around the IBR-2 pulsed reactor (mainly, small-angle diffractometer YuMO). Also, complementary techniques, such as electron microscopy, spectroscopy, X-ray scattering, dynamic light scattering and others are actively used, which makes it possible to perform complex investigations of molecular complexes and nanosystems in comparatively short periods of time. Among expected results of the project are:

- Determination of conditions and theoretical description of the cluster state of fullerenes in molecular solutions;
- Explanation of the stabilization mechanism in aqueous dispersions of fullerenes;
- Construction of the phase diagram of the cluster state of fullerenes in binary solutions;
- Determination of the structure of biocompatible magnetic fluids; description of the aggregation processes under magnetic field in such fluids;
- Determination of aggregation growth mechanisms in molecular materials with high content of hydrogen under neutron irradiation;
- Determination of the structure of a number of lipid complexes for drag delivery (liposomes);
- Determination of the structure under different functional stages for a number of proteins with unfixed ternary structure.

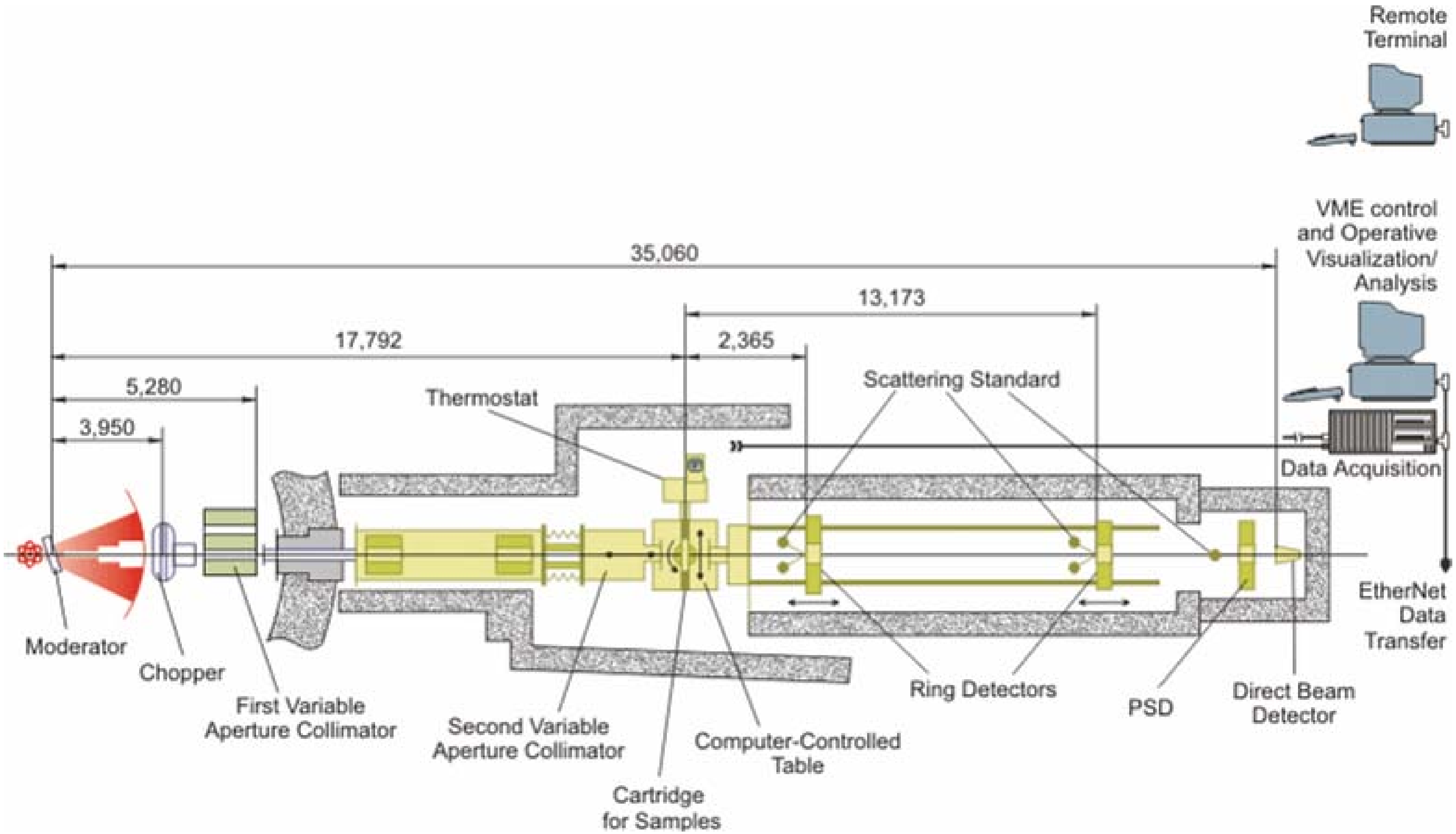


Fig.1. The YuMO small-angle diffractometer at beam 4 of the IBR-2 pulsed reactor.

07-4-1031-99/2008

Priority of the project:

Status: Data taking

Investigation of Texture and Properties of Rock Materials and Minerals by Means of Neutron Diffraction in the Wide Temperature and Pressure Range

Leader from JINR: A. Nikitin

Participating countries and international organizations: Czech Republic, Germany, Russia.

Preferred orientation of crystallites of minerals forming rock materials is one of the key factors controlling the anisotropy of rock materials. The knowledge of texture of rock materials and minerals is important for reconstruction of paleotectonic strained states of earth core blocks located at different depth. A study of relationship between the crystallographic texture formation and physical mechanisms of geological magmatic, deformation and metamorphic processes is important for reconstruction of the stages of geological evolution of the Earth. Due to the high penetrating abilities of neutrons, neutron diffraction is one of the best methods to study the texture of rock materials. IBR-2 pulsed reactor is equipped with three diffractometers specially designed for studies of the crystallographic textures and strains in rock materials and minerals — SKAT, NSVR and EPSILON.

Main directions of research and expected results:

- Study of relationship between crystallographic texture and shape texture with physical properties (elastic, thermal, magnetic, etc.) of rock materials at different thermodynamic parameters;
- Study of metamorphic, geodynamics and evolution processes in lithosphere, using the information on texture of rock materials located deep and near the surface of the Earth core;
- Investigation of texture, structure and properties of meteorite substance;
- Study of evolution, contents, structure and properties of rock materials forming lithosphere at different thermodynamical parameters;
- Development of the theory and methods of reconstruction of paleotectonic deformations and strains using the information on crystallographic texture of rock materials along with the data about seismical anisotropy and computer modeling of lithosphere blocks;
- Application of neutron diffraction studies of local, residual and lattice strains at normal and high temperatures and pressures for modeling earthquake hearth physics.

Importance of the results for world science:

The obtained results give a possibility to understand the relationship between the crystallographic texture and properties of rock materials and minerals. The information about crystallographic texture and strains of rock materials obtained from different depth of the Earth core, along with the data obtained with other methods, will allow us to model different tectonic processes in the Earth lithosphere and behaviour of lithosphere blocks in the earthquake hearth.

The realization of the project will be performed by the staff of the Department of Neutron Investigations of Condensed Matter (Frank Laboratory of Neutron Physics, JINR) in collaboration with other scientific centers in Russia, Germany and the Czech Republic. The experiments will be performed mainly at SKAT, NSVR and EPSILON diffractometers at the IBR-2 pulsed reactor.

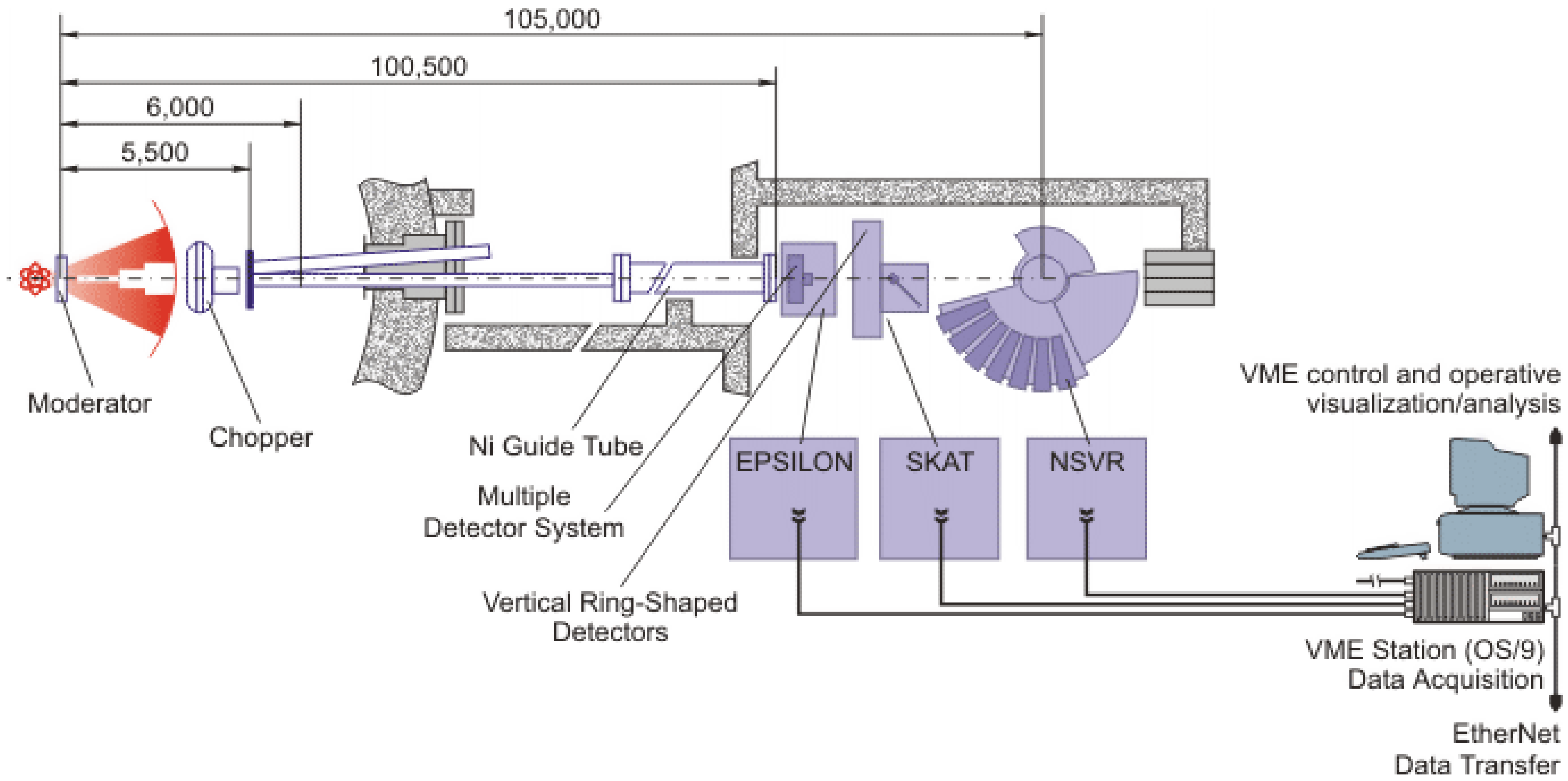


Fig.1. Diffractometers EPSILON, SKAT and NSVR at beam 7a of the IBR-2 reactor.

07-4-1031-99/2008

Priority of the project:

Status: Data taking

Texture and Strain/Stress Properties Investigation at SKAT and EPSILON-MDS

Leader from JINR: Ch. Scheffzuek

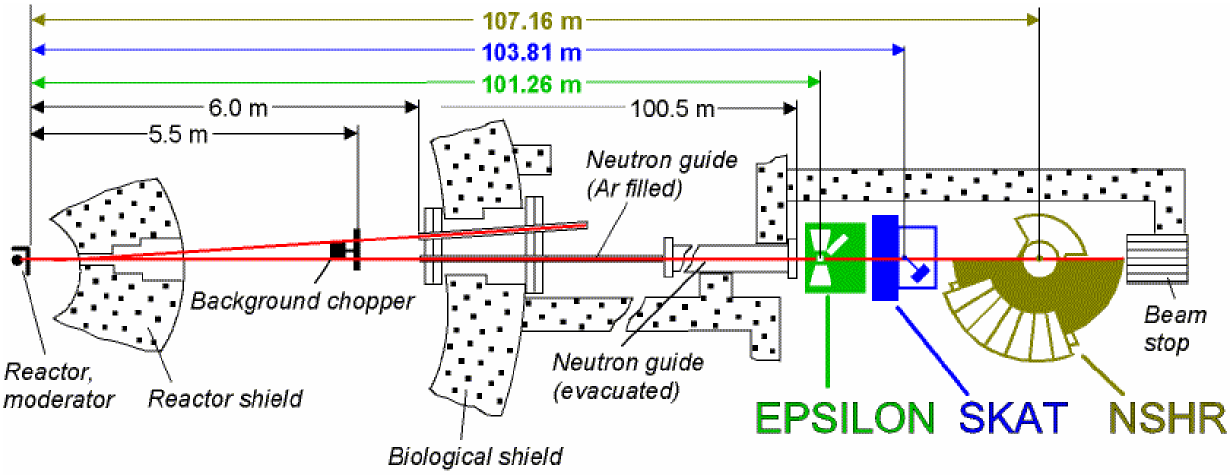
Participating countries and international organizations: Germany, Russia.

The project focuses on the operation and development of the experimental complex SKAT and EPSILON-MDS, and investigation of geological and industrial materials. The instruments are especially designed for the investigation of crystallographic preferred orientation (texture) and applied and internal stresses in multiphase materials with mainly lower crystallographic symmetry. Due to the long neutron flight path of more than 100 m, a quite good resolution is achieved to investigate multiphase materials and to analyse the mineral components separately.

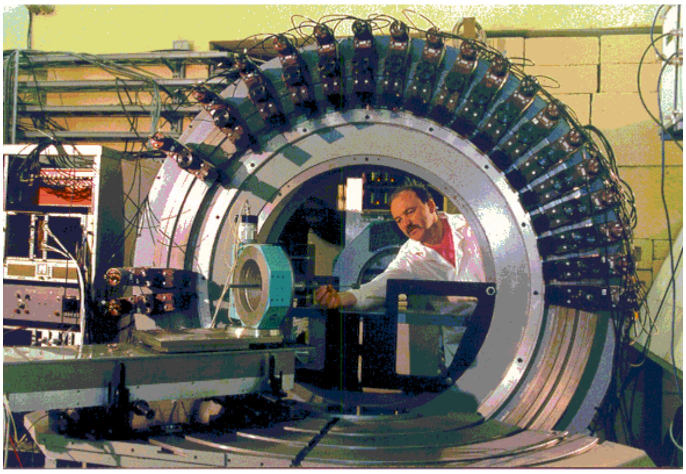
The SKAT texture diffractometer is equipped with a multi-detector-system of 19 detectors to measure pole figures for characterizing texture of materials. Using this detector system, a very fast texture measurement is possible, because only a sample rotation about one axis is required. Scientific investigations focus on the characterization of tectonic processes in the Alps and other tectonically structures like folds. It also allows one to draw conclusions about historical evolution of geological structures.

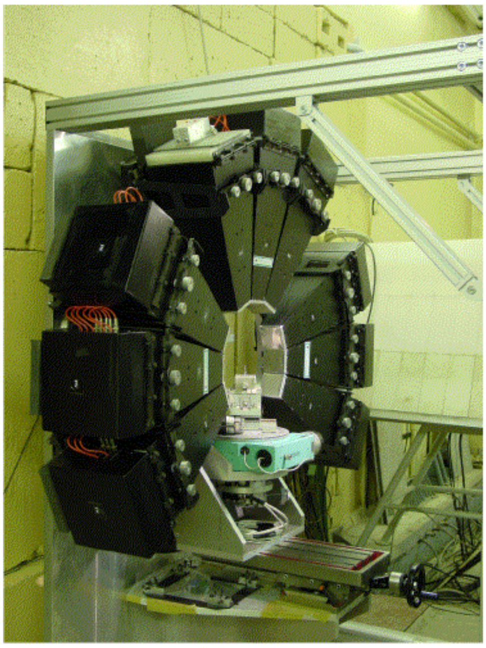
The EPSILON-MDS diffractometer is equipped with a 4-axis goniometer, nine radial collimators to operate a multi-detector-system. Furthermore, a pressure device is installed for in situ-deformation up to 100 kN. The following diffractometer allows a high resolution measurement of the applied and residual strain/stress behaviour in nine directions simultaneously. This is important for understanding of the origin, redistribution and release of natural strain/stresses wheu they occur by tectonic zones.

Texture and strain/stress properties investigation at SKAT and EPSILON-MDS



General layout of the instruments at beam line 7A.





The SKAT (left) and the EPSILON-MDS diffractometer (right) for texture (crystallographic preferred orientation) and strain/stress measurements at beam line 7A at IBR-2.

07-4-1031-99/2008

Priority of the project:

Status: Data taking

Investigations of Atomic Dynamics of Condensed Matter by Means of Inelastic Neutron Scattering Method

Leader from JINR: I. Natkaniec

Participating countries and international organizations: Bulgaria, France, Germany, Poland, Romania, Russia.

The project is directed to the study of the dynamical properties of amorphous materials, liquids and crystalline materials which play an important role in the atomic energy industry, and are of considerable interest for biological and pharmacological applications.

Main directions of research include:

- Study of low frequency excitations in crystalline and amorphous materials by means of the inelastic neutron scattering method;
- Study of dispersion relations and vibrational spectra of materials with perspective properties for the utilization as heat carriers and moderators for modern nuclear reactors, cold moderators for modern pulsed neutron sources, including the IBR-2 pulsed reactor;
- Investigations of new electrolyte materials and materials with superionic conductivity;
- Investigations of dynamics of molecular complexes and biologically active materials by means of the inelastic neutron scattering.

Expected results:

- Study of Bose-condensation and superfluidity in the thin films of liquid He;
- Study of structure and dynamics of alloys Pb-K, Pb-Na, effects of disordering in oxides of fuel reactor materials — UO_2, ThO_2 and PuO_2 at temperatures close to melting;
- Investigations of superionic conductors — CaF_2, PbF_2, Cu_2Se;
- Investigations of carbon (C) and its modifications (fullerene, graphite, etc) at high temperatures;
- Investigations of simple metals in the vicinity of melting point.

Importance of the results for the world science:

The materials chosen for the study in this project are used in atomic energy, industry, modern technology or have properties perspective for possible industrial applications. The knowledge of dynamical characteristics of these materials is important for understanding of their properties in relation to the extending possible range of applications in industry and search for other materials with properties important for possible use in industry.

The realization of the project will be performed by the staff of the Department of Neutron Investigations of Condensed Matter (Frank Laboratory of Neutron Physics, JINR), in collaboration with other scientific centers in Russia, Poland, Bulgaria, Germany, Romania, France. The experiments will be performed mainly at inelastic neutron scattering spectrometers NERA-PR, DIN-2PI and KDSOG-M of the IBR-2 pulsed reactor. Some experiments will be performed at HMI (Berlin, Germany) and ILL (Grenoble, France).

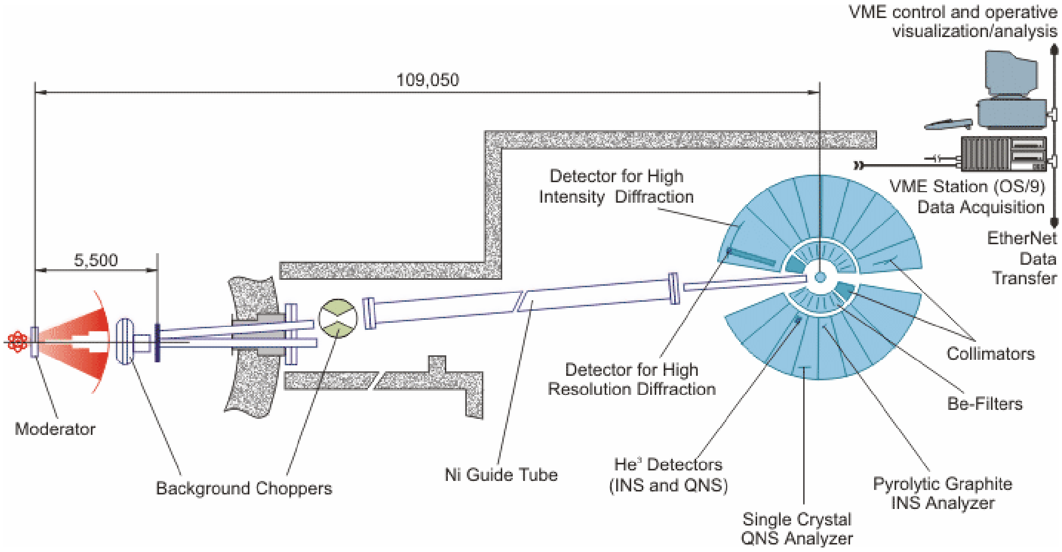


Fig. 1. The design of NERA-PR inelastic neutron scattering spectrometer installed at beam 7b of the IBR-2 reactor.

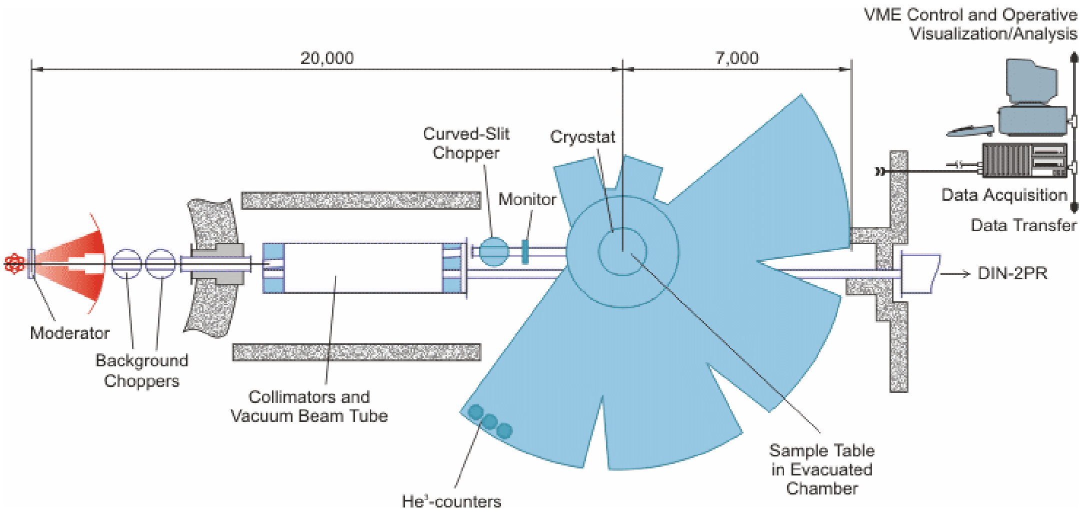


Fig.2. The design of DIN-2PI inelastic neutron scattering spectrometer installed at beam 2 of the IBR-2 reactor.

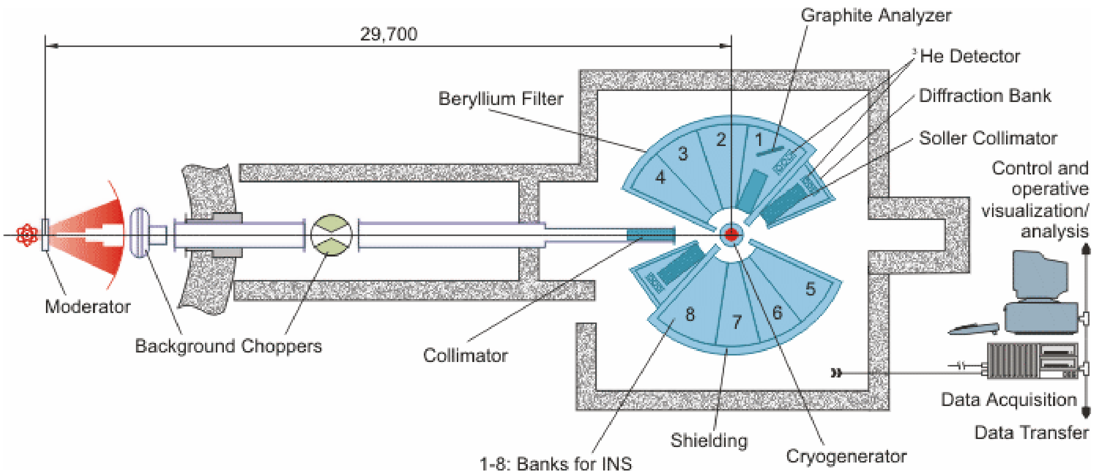


Fig.3. The design of KDSOG-M inelastic neutron scattering spectrometer installed at beam 10 of the IBR-2 reactor.

07-4-1031-99/2008

Priority of the project:

Status: Data taking

Spectrometer REMUR Development

Leader from JINR: A. Petrenko

Participating countries and international organizations: France, Germany, Hungary, Russia.

In the last few years fast development of neutron spectrometers which measure neutron reflection under grazing angles (neutron reflectometers) and small-angle neutron scattering (small-angle neutron scattering spectrometer scan be observed). Lately, in connection with interface phenomena physics development, it has become necessary to carry out investigations of layered structures with atomic spatial resolution. All mentioned measuring possibilities exist in the spectrometer of polarized neutrons REMUR.

Spectrometer REMUR has two measuring modes. The first mode (grazing angles reflection) allows one to carry out investigations of neutron reflection from layered structures under glancing angles 3–10 mrad, has spatial resolution about 10–100 nm and measures spatial nuclear and magnetic profile on the depth up to 1 μm. The second mode (reflection under large angles, small-angle scattering in the bulk samples) allows one to carry out investigation at glancing angles 5–20 degrees and has spatial resolution 0.2–1 nm. Experience of work on the spectrometer shows that in the first mode it is necessary to decrease the background to investigate small size samples. And in the second mode it is necessary to increase the spectrometer luminosity because of low reflection power of the samples.

In connection with that, the project of the spectrometer REMUR development deals with increasing of the spectrometer efficiency, namely decreasing its background and increasing luminosity.

REMUR staff has experience in the spectrometer SPN development, investigation and creation of new experimental techniques. These are the gradient radio-frequency neutron spin-flipper, the position-sensitive detector, the neutron supermirror polarizers, the focused analyzer of neutron beam polarization.

It is expected that due to installation of a regulated collimator and placing of the first mode polarizer in a new position, the background in the spectrometer in the first mode will be decreased 10 times. It is expected that due to creation of a new collimator before the second mode polarizer, the spectrometer luminosity will be increased thrice.

The time schedule of the project execution is 2004–2005.

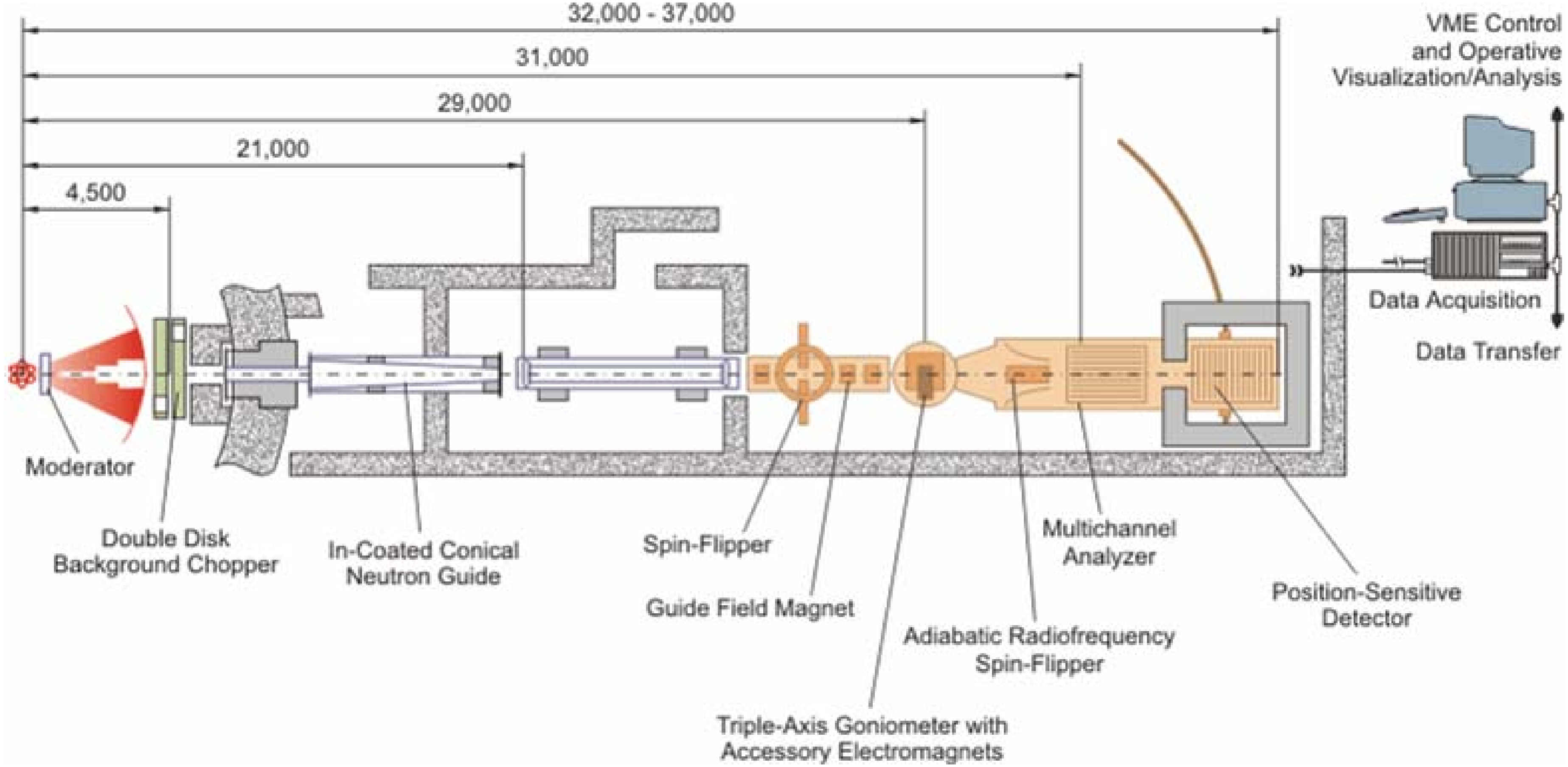


Fig.1. The design of the REMUR spectrometer installed at Beam 8 of the IBR-2 pulsed reactor.

07-4-1031-99/2008

Priority of the project:

Status: Data taking

Spin-Echo Small-Angle Neutron Scattering Spectrometer (SESANS)

Leader from JINR: Yu. Nikitenko

Participating countries and international organizations: France, Germany, the Netherlands, Russia.

At present small-angle neutron scattering is used widely in investigations of subatomic structure and low frequency dynamics of polymers and biomaterials. The linear size and the oscillation frequency of molecules in polymers and biomaterials are equal r=1 nm÷100 mkm and f=1 kHz÷1 THz, respectively. For the measurements of r in the interval 1÷100 nm a small-angle neutron scattering spectrometer (SANS) is used. For the measurements of r in the interval 1 nm÷100 mkm and f in the interval 1 MHz÷1 THz a spin-echo small-angle neutron scattering spectrometer (SESANS) has been proposed in which the momentum transfer is encoded in the precession phase of neutron spin.

In the spin-echo spectrometer SESANS tight relation between momentum transfer resolution and luminosity of the spectrometer is absent. As a result, high luminosity and high resolution are realized simultaneously in the spectrometer. 1000 times changing interval of momentum transfer is accessible in the spectrometer due to a large interval of the neutron wavelength and possible 10 times changing interval of the spin-precessor sensibility. At present spin-echo spectrometers are being created in ILL (Grenoble, France), FZJ (Juelich, Germany), ANL (Argonne, USA), HMI (Berlin, Germany) and other neutron centres. To fulfil the project, five scientists of the neutron optics sector, DD (designing department) and the workshop of FLNP, external organisations will be involved. The participants of the project have experience in neutron polarization techniques designing and creation of new spectrometers.

It is supposed that on the channel No.8, equipped by a cold moderator, two neutron beams will be created. On the first beam the existing polarized neutron spectrometer REMUR will be placed and on the second one the new spectrometer SESANS. On the spectrometer it will be possible to carry out structural investigations of bulk inhomogeneous magnetics with the correlation length in the interval 1–100 nm, structural investigations of polymers and biomaterials with correlation length in interval 1 nm–100 μm and low frequency dynamics of polymers and biomaterials in the frequency interval 10 kHz–1 THz.

Plan of the works

The project will be fulfilled during 2004–2010:

- 2004 — design of channel head part and SESANS;
- 2005 — continuation of design and test measurements;
- 2006–2007 — manufacturing of channel head part and spectrometer;
- 2008 — placing of head part and spectrometer;
- 2009 — testing of motors and equipment, software and programs of treatment;
- 2010 — spectrometer testing on the neutron beam.

It will be possible to carry out investigations on the spectrometer in a momentum transfer interval, inaccessible before on any neutron and other spectrometers. This will allow one to carry out simultaneously structural and dynamic systematic investigations of such soft materials as polymers, biomaterials, gels and other.

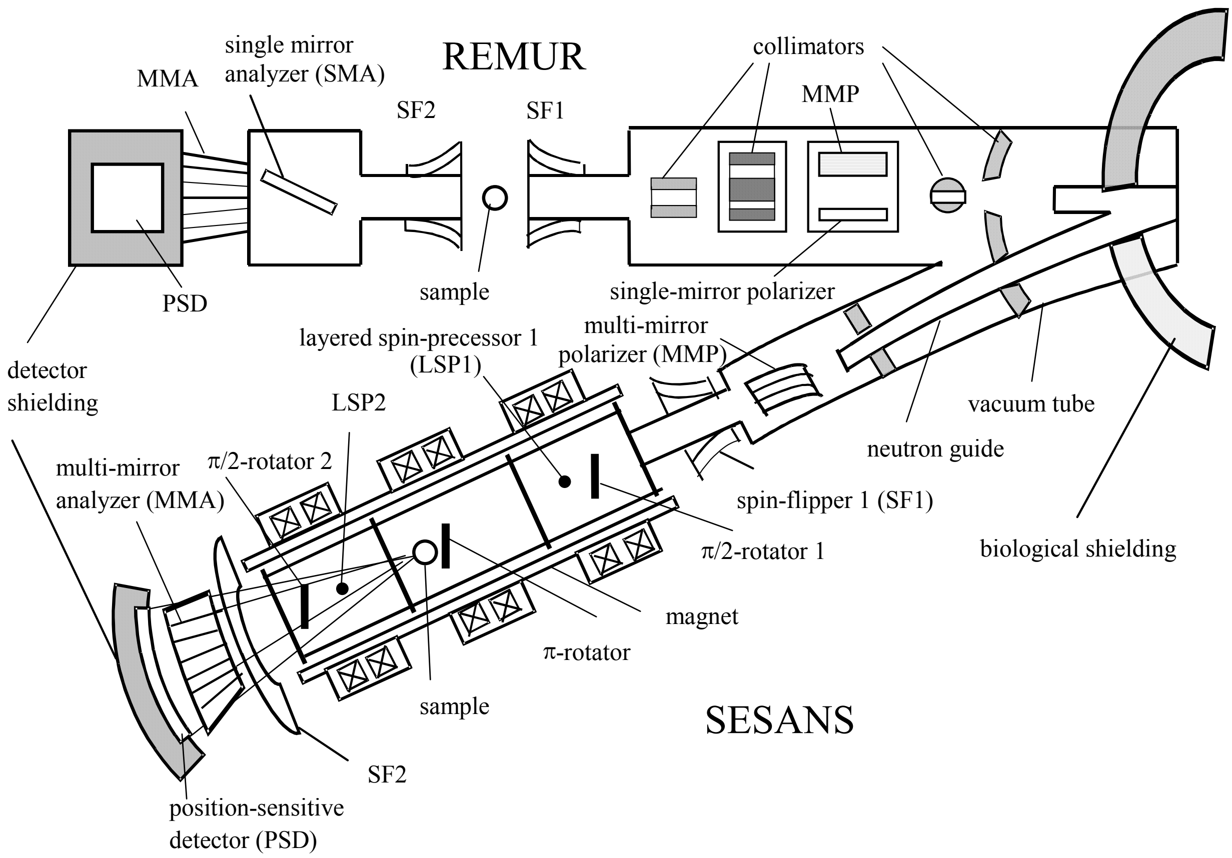


Fig.1. The schematic layout of the SESANS instrument at the beam No.8 of IBR-2.

07-4-1031-99/2008

Priority of the project:

Status: Data taking

Modernization of the Polarized Neutron Reflectometer REFLEX-P

Leader from JINR: V. Bodnarchuk

Participating countries and international organizations: Germany, Russia.

Polarized neutron reflectometer REFLEX-P began to work in the end of the 1990s. The project of this spectrometer took into account all the experience of the exploitation of the SPN spectrometer and similar spectrometers in other neutron centers. So, the parameters of the REFLEX-P are comparable with the analogous parameters of the spectrometers of other neutron centers. But in the last years very dynamic development in reflectometry demanded the maximum of efficiency in using of beam time and in obtaining of the sample information. These objectives and new methodical ideas demand corrections in the reflectometer scheme.

The main tasks of the modernization

Spin-flipper

It is proposed to remove the Korneev's spin flipper for the radiofrequency adiabatic spin-flipper. Moreover, it is proposed to place one more spin-flipper in the scattering beam for realization of the experimental scheme of the full polarization analysis.

Polarization analyzer

The reflectometer needs a new analyzer of polarization.

Detectors

Now, the spectrometer detector system consists of only a monodetector ^{3}He. To increase the efficiency of experiments it is necessary to use the two-dimensional position sensitive detector.

Electronics and software

The electronics of data acquisition bases on the CAMAC standard. All software using at the spectrometer was written in the end of the 1980s. It is clear that exchanging of the old electronics and software is very necessary.

Engineering

It is necessary to modernize the collimator systems, to create few adjusting tables and a permanent magnet holder.

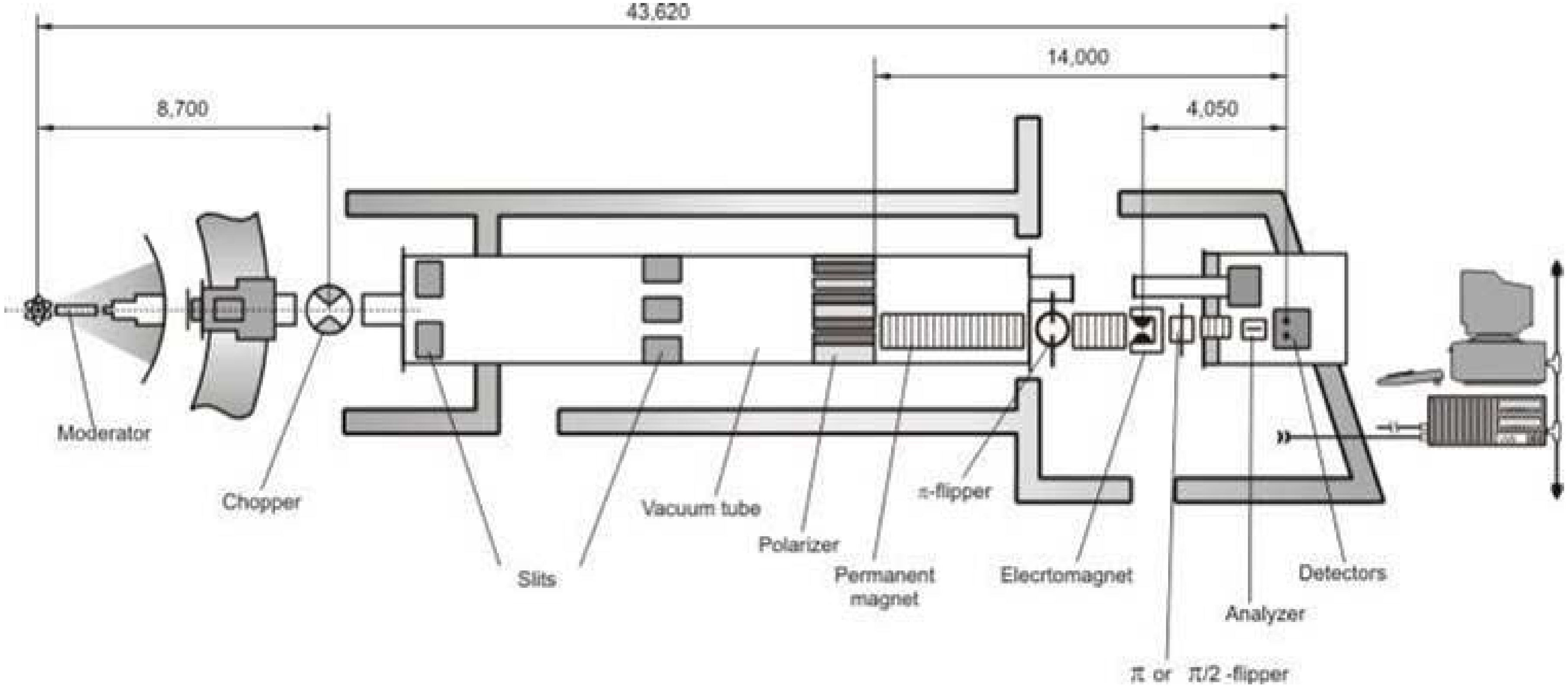


Fig.1. The scheme of the polarized neutron reflectometer REFLEX-P at beam 9 of the IBR-2 pulsed reactor.

07-4-1031-99/2008		Priority of the project:
		Status: Data taking

New Polarized Neutron Reflectometer with Horizontal Sample Placement on the 9-th Channel of the IBR-2 Reactor

Leader from JINR: V. Bodnarchuk

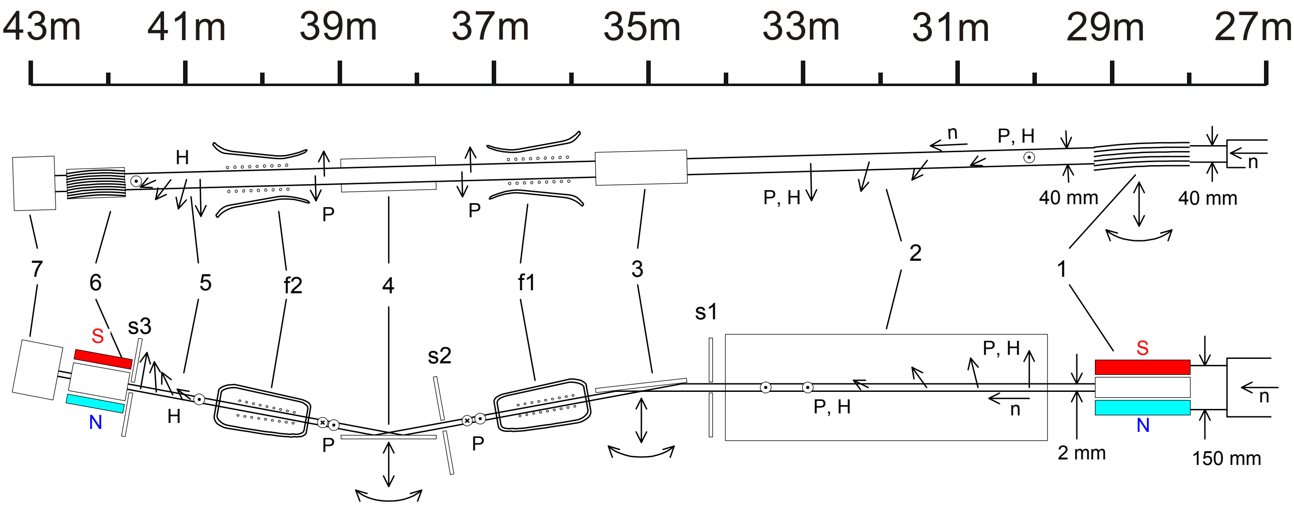
Participating countries and international organizations: Germany, Russia.

The field of the neutron reflectometry is the studies of the surfaces and media boundaries. For these experiments, it is necessary to make special thin film samples and multilayers. The specific group of these samples is liquids. To study the liquid surface it is necessary to have a spectrometer with a vertical scattering plate. In the present time there is no similar spectrometer in Russia However, many experiments using the liquid interfaces can be done. This project proposes the creation of a polarized neutron reflectometer with a vertical scattering plate to study the liquid surfaces. The position of the future spectrometer is the 9^{th} channel of the IBR-2 reactor. The sizes of the shiber hole of the 9^{th} channel and the length of flight path allowed one to split a beam into two beams. One of these beams uses the reflectometer REFLEX-P, and the other is free now.

The main necessary work for creation of a new polarized neutron reflectometer with a vertical scattering plate is the following:

- Modernization and optimization of the collimator system of the 9^{th} channel to operate simultaneously with two spectrometers: REFLEX-P (vertical sample placement) and the new reflectometer with horizontal sample placement;
- Optics:
  - a polarizer. It is proposed to use the supermirror FeCoV/TiZr bender;
  - a deflecting mirror. It is necessary to organize an incident beam on the horizontal surface;
  - a polarization analyzer. The types of the analyzer are defined by the detector. In the case of using PSD (proposed by this project), the best analyzer is the multychannel supermirror analyzer;
- A sample holder. It is necessary to design and create the adjusting table and a sample holder for the liquid samples;
- Spin-flippers. For the scheme of the experiment with the full polarization analysis it is necessary to have two RF spin-flippers in incident and scattering beams;
- A detector. The two-dimensional position sensitive detector with the size of working area 200·200 mm;
- Electronics and software;
- Designing and creation of equipment of sample environment.

Top view



Side view

Fig.1. Scheme of the new polarized neutron reflectometer with horizontal sample placement.

1 — Bender-polarizer of neutron beam; 2 — Region of adiabatic magnetic guide field H rotation and polarization of neutron beam P; 3 — Deflecting mirror; 4 — Sample; 5 — Region of adiabatic magnetic guide field H rotation and polarization of neutron beam P; 6 — Multychannel supermirror analyzer; 7 — Position sensitive detector; s1, s2, s3–Slits; f1, f2–Radiofrequency spin flippers.

07-4-1031-99/2008

Priority of the project:

Status: Data taking

DN-6 Time-of-Flight High-Pressure Neutron Spectrometer for Investigation of Microsamples

Leader from JINR: B. Savenko

Participating countries and international organizations: Czech Republic, Germany, Russia.

Neutron scattering is a powerful method which allows one to obtain information on both structure and dynamics of condensed matter. A whole set of important issues, such as magnetic transitions, structural phase transitions in systems containing atoms with small or similar atomic numbers and investigations of dynamics of condensed matter can be solved only by the neutron scattering method. One of the main thermodynamical parameters which may change significantly the structural, magnetic and electronic properties of the materials is the high external pressure. For example, a simultaneous effect of high pressure and high temperature on the structure of carbon C, which at ambient conditions exists in graphite structural modification, leads to formation of diamond modification.

Since neutrons interact comparatively weakly with matter, neutron scattering experiments under high external pressure require rather large amount of sample and for a long time it was possible to perform such experiments only in a few ranges of pressures up to 2–3 GPa. Only a few years ago, new methods were developed which make it possible to extend the pressure range in neutron scattering experiments up to 10 GPa and even higher.

In the project, it is proposed to construct a special high pressure spectrometer DN-6 dedicated for neutron scattering investigations of condensed matter at high pressures up to 20–30 GPa on the basis of diamond and sapphire anvil high pressure cell technique.

The design of the DN-6 spectrometer is shown in page 1. It is placed at the beamline N 6b of the IBR-2 reactor and consists of the following main systems: neutron beam chopper phased with the power pulse of the reactor, the beam collimating system, the detector system (two circular detectors), a cooled beryllium filter, information management, registration and processing system. With sapphire and diamond anvils high pressure cells it will be possible to perform elastic and inelastic incoherent neutron scattering experiments with DN-6 at pressures up to 15 GPa. The sample volume required for the experiment will be about 0.1–2 mm^3, the typical exposition time will be about 10–30 h for neutron diffraction and 20–50 h for inelastic neutron scattering experiments. For simultaneous experiments at high pressure and low (high) temperature in the range 10–1000 K it is planned to equip, spectrometer DN-6 with a cryostat on the basis of the closed cycle helium refrigerator and the furnace.

Now, most of the spectrometers for neutron scattering investigations of condensed matter existing in the world allow one to perform high pressure experiments in the range about 0–10 GPa. A new DN-6 spectrometer will give a possibility to perform experiments in considerably higher pressure range up to 20–30 GPa.

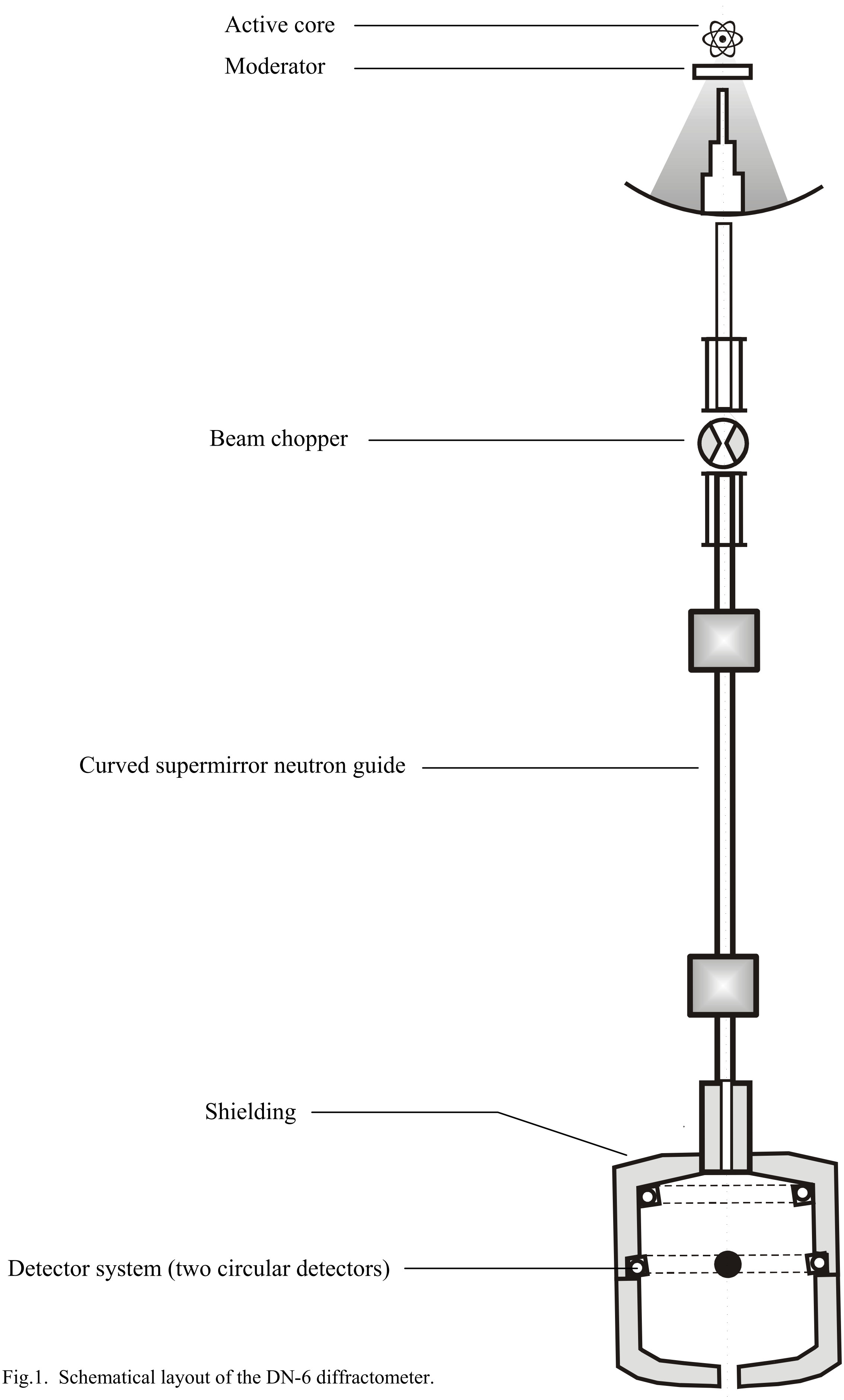


Fig.1. Schematical layout of the DN-6 diffractometer.

07-4-1031-99/2008

Priority of the project:

Status: Data taking

Creation of Modern Small Angle Neutron Scattering Spectrometer (MURN-C) on High Flux Pulsed Reactor IBR-2

Leader from JINR: A. Kuklin

Participating countries and international organizations: Czech Republic, France, Germany, Poland, Romania, Russia, Slovak Republic.

In the project it is offered to create a modern small angle neutron scattering (SANS) spectrometer with the curved neutron guide on one of the beam-lines with a cold moderator and with the flux on a sample from 10^7 up to $4{\cdot}10^7$ n/(s cm^{-2}) and with a range of the momentum transfer from $1{\cdot}10^{-3}$ up to 0.5 and, accordingly, a range of size scales of objects from 10 up to 6000 Å. The necessity for creation of the spectrometer is caused by a great demand on use of the SANS method, that is in turn caused by the wide range of solved problems (from materials technology up to modern problems of biology). In the project main ways of application both of the method, and the suggested installation are presented.

The risk at the realization of this project is eliminated, as we refer to both world and Russian experience in creation of similar spectrometers and separate units. The potential circle of scientists, who will use the instrument is extremely wide. In the project the reference to the modernizing YuMO project is made, and it is shown that the concept of development of the old instrument and the creation of the new one allows us to achieve not only the minimal expenditures on modernizing YuMO, but also to reduce essentially the expenditures on creation of the new installation MURN-C at the expense of unification of some units, software, sample environment of both installations.

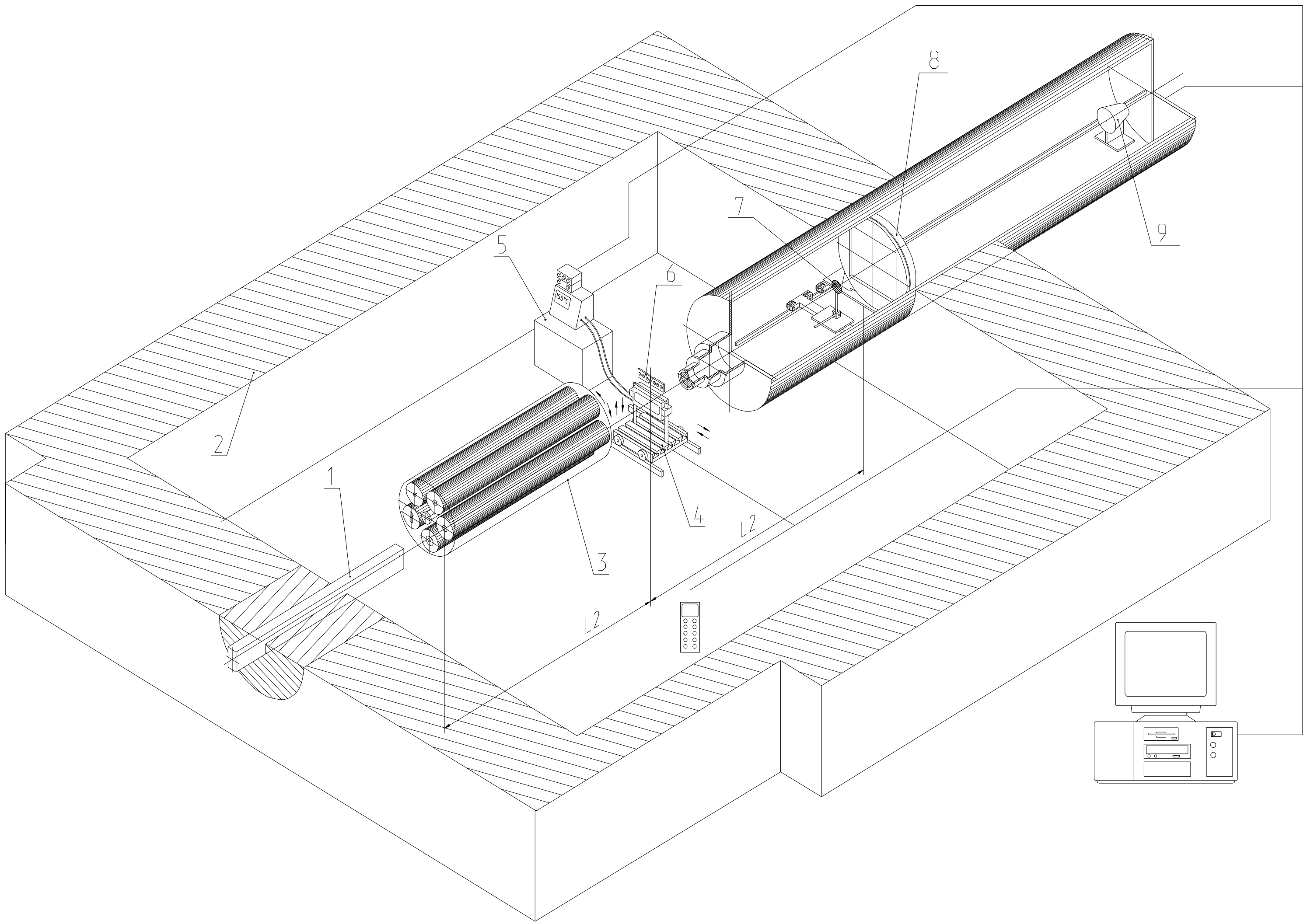
The planned schedule and the estimation of the basic expenditures on the realization of the given project is presented in view of the YuMO project modernizing and development and creation of the new installation MURN-C.

According to the arrangement with ILL, ILL transmits free-of-charge position sensitive detector used earlier on the ILL 16-th channel. The commercial price of the similar detector is about 300.000 $. In case of successful tests it will be necessary to adapt electronics for the time-of-flight technique used on IBR-2.

The time of the measurement necessary for a set of sufficient statistics in the required range of momentum transfer will much depend on the neutrons, falling on a sample. Therefore, it is offered to install the spectrometer MURN-C on the highest flux beam of IBR-2 using a cold moderator. The major parameters: sensitivity (the minimal possible concentration of a sample), disposable in measurement, minimally accessible magnitude of the momentum transfer in a combination with high-rate of accumulation of experimental data will depend on the place of the installation of the MURN-C spectrometer.

It is supposed, that the realization of the given project will allow to have in Russia a SANS spectrometer, with the parameters considered the best in the world, and will give the opportunity to some scientists to perform small angle neutron investigations of structure and properties with characteristic sizes 10÷6000 Å in many actual areas of science and engineering: from solid state physics up to molecular biology and biophysics.

In the appendix lists of the project the design of the spectrometer MURN-C (the first stage of the design), the design of the spectrometer MURN-C (the second stage of the design), the clamping of the installation MURN-C to 6б to the channel of the spectrometer, the list of publications and references and the list of contracts are attached.



The MURN-C spectrometer scheme (stage 1).

07-4-1052-2004/2008		Priority of the project:
		Status: New

Gas Detectors

Leader from JINR: A. Belushkin

Participating countries and international organizations: Russia, Belarus, Germany, France.

Within the next few years along with the radical modernization of the IBR-2 reactor, the creation of new instruments and modernization of the available spectrometers are planned. In this connection in FLNP the project "Gas detectors" has been started, aiming at equipping the IBR-2 spectrometers with up-to-date neutron position-sensitive detectors. Expected parameters of neutron detectorare:

- Coordinate resolution is at a level of from several hundred micrometers to several millimeters for different types of detectors;
- Time resolution is less than 1 μs;
- Counting rate is at a level of $10^6/(cm^2 \cdot s)$;
- Counting efficiency of thermal neutrons is 50–80 %;
- Low sensitivity to gamma-radiation background.

Fig.1. Neutron monitor with a display unit.

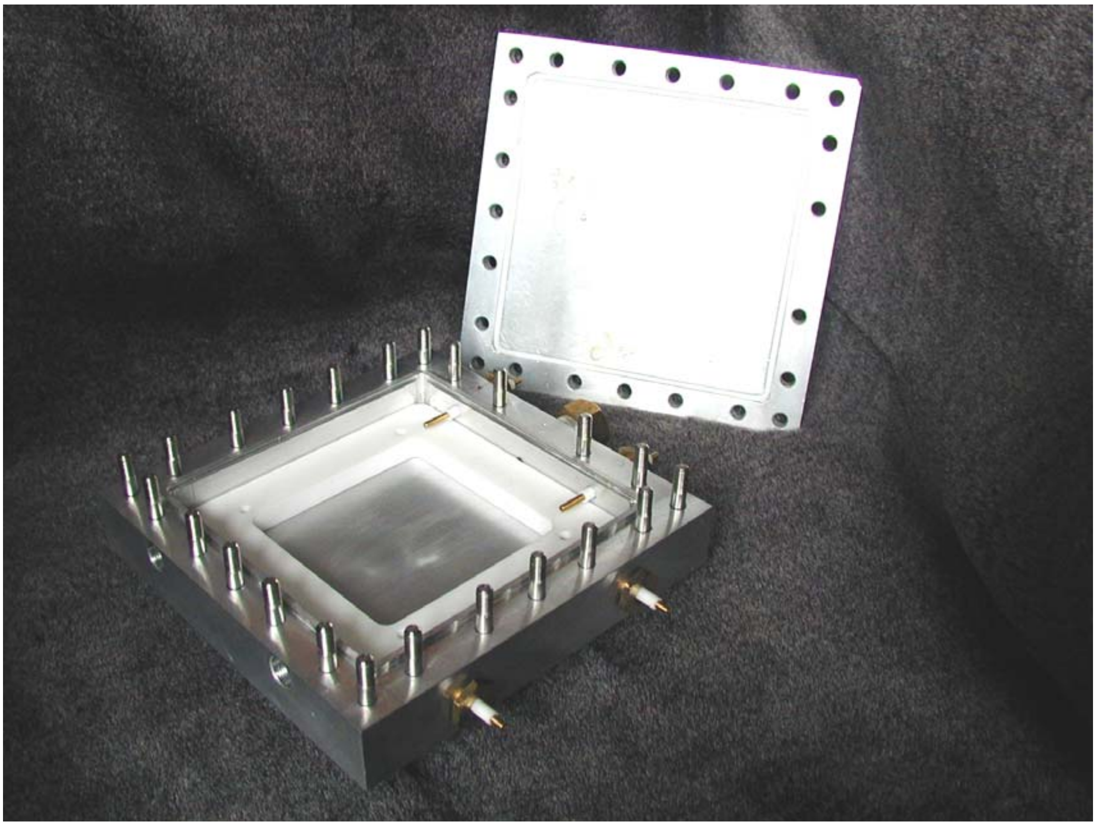


Fig.2. Case of the prototype of MSGC detector on the basis of Schott S8900 glass before the installation of a substrate with evaporated strips.

07-4-1052-2004/2008

Priority of the project:

Status: New

Development of Wide-Aperture Low-Background Detectors for High and Medium Resolution Neutron Diffractometry

Leader from JINR: E. Kuzmin

Participating countries and international organizations: Russia, Belarus, Germany.

At the IBR-2 reactor in FLNP, JINR a specialized instrument is under construction — Fourier-stress diffractometer (FSD) for measurement of internal stresses in engineering components and structures by neutron high-resolution diffraction. One of the main components of the diffractometer is a new-type detector with combined electronic-geometrical focusing uniting a large solid angle with small geometry contribution to the instrumental resolution. The first two modules of the detector, based on scintillation screen ZnS (Ag)/6LiF with wavelength shifting fiber readout have been developed and tested on the beam of the IBR-2 reactor.

To modernize the detector system of the DN-12 spectrometer, intended for condensed matter investigations at high pressures, the method of “rough” time focusing is suggested, making it possible to create economical small-area detectors with large solid angle for classical time-of-flight spectrometers with large flight path, thus ensuring high resolution of the spectrometer.

Combination of such spectrometer parameters as high resolution and high counting rate will allow the FSD and DN-6 instruments to take the leading position in the world among scientific instruments intended for internal stress studies and condensed matter investigations at high pressures.

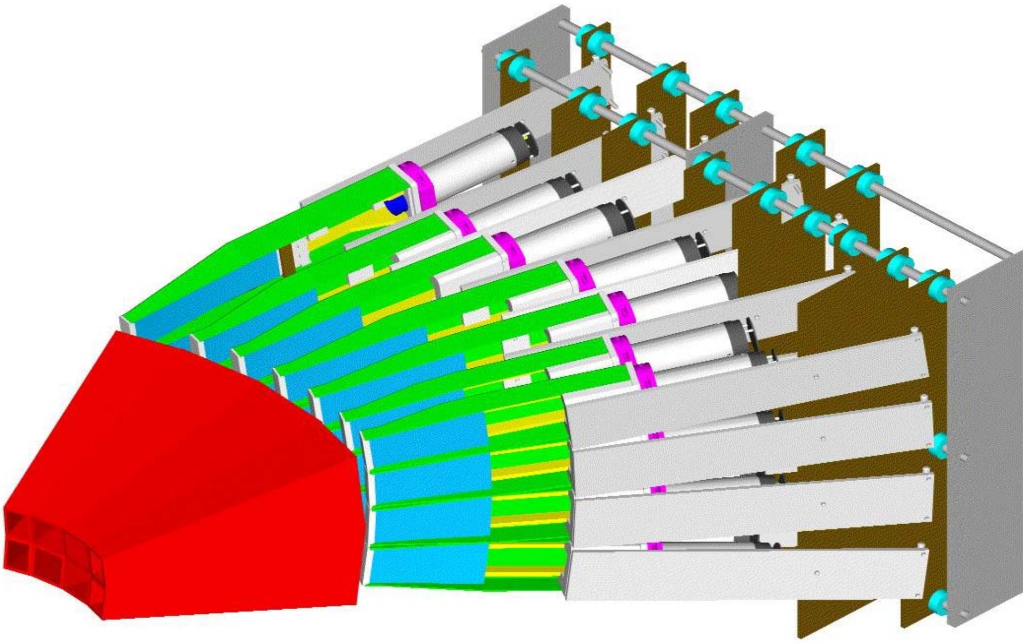


Fig.1. Three-dimensional model of one of the banks of the detector system of the FSD diffractometer.

Fig.2. Photo of the first section of the detector system commissioned in October, 2002.

07-4-1052-2004/2008

Priority of the project:
Status: New

Development of Control Systems of Spectrometer Equipment and Sample Environment Systems

Leader from JINR: A. Sirotin

Participating countries and international organizations: Germany, Romania, Russia.

Each experiment requires equipment for creating certain conditions at a sample (for example, temperature, pressure, magnetic or electric field, etc.) and for moving and spatial orientation of a sample. In recent years considerable progress has been made in equipping spectrometers with such equipment and in its standardization, as well as in unification of control systems.

Within the framework of the given project work on realization of the concept of the user mode of operation of control systems will be continued:

- Modernization and creation of new executing mechanisms (goniometers, scanners, devices for changing samples, collimators, etc.), and equipment for creating conditions at a sample (furnaces, refrigerators, cryostats), as well as control electronics in the form of autonomous subsystems, which can be used on different spectrometers;
- Equipping new spectrometers with neutron microcontroller-based choppers, modernization of power drives of choppers;
- Lowering of temperatures down to 0.35 K by equipping ORANGE cryostats with special inserts;
- Increase of temperatures up to 3000 K (in cooperation with the Institute of Physics and Nuclear Technology, Romania);
- Development and introduction (in cooperation with IHPP RAS, Troitsk) of gas and toroidal high-pressure chambers (up to 1GPa, 50–290 K and up to 10 GPa, 290 K, respectively);
- Modernization of control subsystems of the equipment of spectrometers within the framework of unified architecture of data acquisition and experiment automation systems.

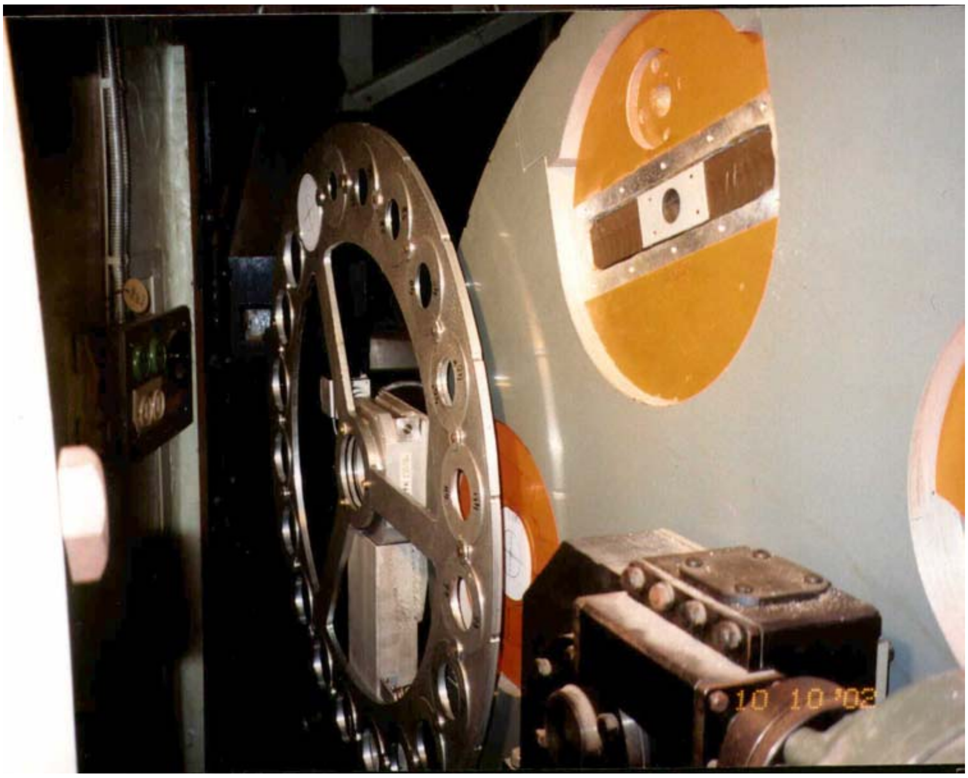


Fig.1. Two ring replaceable collimators at the YuMO spectrometer.

Fig.2. Closed cycle cryostat KGU801 on the basis of two-stage cryogenerator RGD1245.

Fig.3. Thermostatic system TS-3000 to study samples at the DIN-2PI spectrometer at temperatures up to 3000 K.

07-4-1052-2004/2008

Priority of the project:

Status: New

Development of Data Acquisition Systems for the IBR-2 Spectrometer Complex and the FLNP Information and Computing Infrastructure

Leader from JINR: V. Prikhodko

Participating countries and international organizations: Russia, France, Germany, Slovak Republic.

Within the next few years along with the radical modernization of the IBR-2 reactor, the creation of new instruments and modernization of the available spectrometers are planned. In this connection in FLNP the 7–year program of the development of data acquisition (DAQ) systems of the IBR-2 spectrometer complex and the FLNP computing infrastructure has been worked out. The given project is an integral part of this program. The aim of the project is to create electronics and software of data acquisition, accumulation and processing systems adequate to the world level of FLNP spectrometers, andit calls for application of advanced hardware, software and information technologies and requires a unified (for all spectrometers) approach to the design of these systems. The investigations and developments planned in the given project are aimed at achieving this goal.

The development of data acquisition and computing infrastructure systems is of key importance for successful realization of the program of condensed matter investigations at the IBR-2 reactor. The improvement of experimental techniques, increase in the number of controlled parameters and in the number of detectors used in the experiment and their sophistication, heightened requirements for accuracy and speed of data acquisition equipment, necessity to provide remote (from any point of LAN) control over spectrometer subsystems and the experiment as a whole impose new requirements on experiment automation systems, which cannot be satisfied in full measure within the framework of the available hardware-software environment and computing infrastructure. The user mode of operation of IBR-2 spectrometers places additional demands on data acquisition systems, which should be easy to master and easy to work, should have convenient graphic interface and provide access to results of measurements via the Internet, etc.

The main directions of development of DAQ-systems of the IBR-2 spectrometer complex for the planned period (including for experiments on the modernized IBR-2 reactor) are:

- Integration of PCs into the structure of VME DAQ systems to provide friendly user interface in habitual Windows environment and to use efficiently PC software designed in FLNP and other neutron centers for primary processing and analysis of data;
- Integration of modular PCs into separate measuring and control subsystems and creation of PC mini-farms for controlling spectrometers and data processing;
- Development of new, specific for neutron experiments, electronic blocks with the improved characteristics with due regard to natural progress in designing and manufacturing of electronic components;
- Development of new software.

The problems with the network of FLNP and JINR as a whole (low data transfer rate, large broadcasting traffic, poor protection and controllability of the network, etc.), as well as rapid advancement of network and computer technologies demand permanent modernization and development of LAN and computer park of the Laboratory. The designing of the FLNP network of the next generation is aimed at eliminating the specified problems, part of which was solved in 2003.

The main objective of further LAN development is to design a fully redundant high-speed core by installing a second router. The availability of two routing switches and duplicated trunk communication channels will permit a gradual changeover to the Gigabit Ethernet technology. In addition, there will be a possibility of automatic load distribution over the communication channels on the basis of traffic classification. In case of failure of the network core components, the data transfer will be resumed in a few seconds. The failure-resistance in this network structure will be provided:

- on the physical level — by the availability of no less than two connections with each node;
- on the logical level — by using protocols, which make it possible to re-direct data flows in case of failures.

In the coming years the development of the FLNP computing infrastructure and keeping it at the up-to-date level will require replacement of worked-out central and specialized servers, peripheral devices and disk subsystems, as well as permanent modernization of the park of personal computers.

As a result of the implementation of the project, a new generation of unified DAQ systems with the characteristics corresponding to the world level will be created for the IBR-2 spectrometer complex. These systems will possess flexibility for fast adaptation to any changes in the experimental conditions and equipment composition. The chosen architecture of DAQ-systems fits well into the network infrastructure and will provide simplicity and low cost of their permanent modernization according to the progress in computer and communication technologies.

The second (vital for the Laboratory) task of development of computing infrastructure and keeping it on the up-to-date level will be fulfilled as well.

JINR's Participation in Experiments at External Facilities

07-4-1031-99/2008

Priority of the project:

Status:

Energy Dispersive EXAFS-Spectrometer on Synchrotron Radiation Beams on "Siberia-2"

Leader from JINR: S. Tiutiunnikov

Participating countries and international organizations: Belarus, Latvia, Russia.

The development of a dedicated radiation synchrotron radiation (SR) source of high brightness ensures considerable advance in usage of methods of absorption spectroscopy of uptake for definition of local atomic and electronic structure of absorption centers in materials technology, physics, chemistry, biology.

In the review, the basic theoretical principles of EXAFS-spectroscopy are given, as one of principal directions of the absorption spectroscopy permitting with high accuracy to gain parameters of the short-range order in multicomponent amorphous and quasicristal media. The methods of the analysis EXAFS of spectra with allowance for effects of multiple scattering are featured. For the investigation of the phase transition and external effects the energy-dispersive EXAFS-spectrometer is creating at the National center of the RRS "Kurchatov institute", that can measure the EXAFS spectrum with a time resolution.

The main parameters of the spectrometers are $E\gamma$=5÷30 keV — energy range, ΔE=2÷5 eV — energy resolution. The dimension of the sample 0,2·0,2 mm in polyxromatic focus, the time of measuring EXAFS spectrum is 2÷3 ms.

The manufacturing of mains units of spectrometers is being finished.

The SR beam from the beam line has requisite parameters (intensity, dimension).

For complex research of objects by methods of the EXAFS-spectroscopy complimentary a set of the equipment has been created (Raman confocal microscope, x-ray diffractometer, Fourier spectrometer).

Now, the program of scientific research on EXAFS a spectrometer of effects of structural reorganization in ferroelectrics under action of pulse electron beams is formed. Results of structural phase reorganization in the studied samples are presented.

№№	The list of phases	Terms of performance	Responsible persons
1.	Manufacturing mobile units of supporting the detector, a sample, control systems of monochromator	Up to 01.04.2004	V. Shaliapin M. Kovalenko
2.	Complex starting of a EXAFS spectrometer on a SR beam	Up to 01.07.2004	S. Tiutiunnikov V. Shaliapin V. Kopachevsky
3.	Working off of operating modes of the EXAFS spectrometer on a SR beam. (pre-production operation)	01.09.2004 31.12.2004	S. Tiutiunnikov V. Shaliapin V. Kopachevsky V. Efimov

It is planned to receive the following results:

- Nanostructure systems:
- − parameters of the near order in semi-conductor and metal clusters depending on the size and conditions of the synthesis;
- Structural phase transitions in ferroelectric structures depending on the temperature, and also at modifying these structures under action of corpuscular beams of radiation;

- Photo induced processes in high temperature superconductors and ferroelectrics;
- Structural phase transformations of semiconductors as a result of ionic implantation.

Energy dispersive EXAFS-spectrometer on synchrotron radiation beams on "Siberia-2"

Crystal	Energy range, keV	Resolution δE/E
Si (111)	5–15	$\cong 10^{-4}$
Si (311)	7–30	$\cong 10^{-4}$
Asymmetric Si (311), *a* = – 12	7–30	$<10^{-4}$

The main parameters of spectrometer

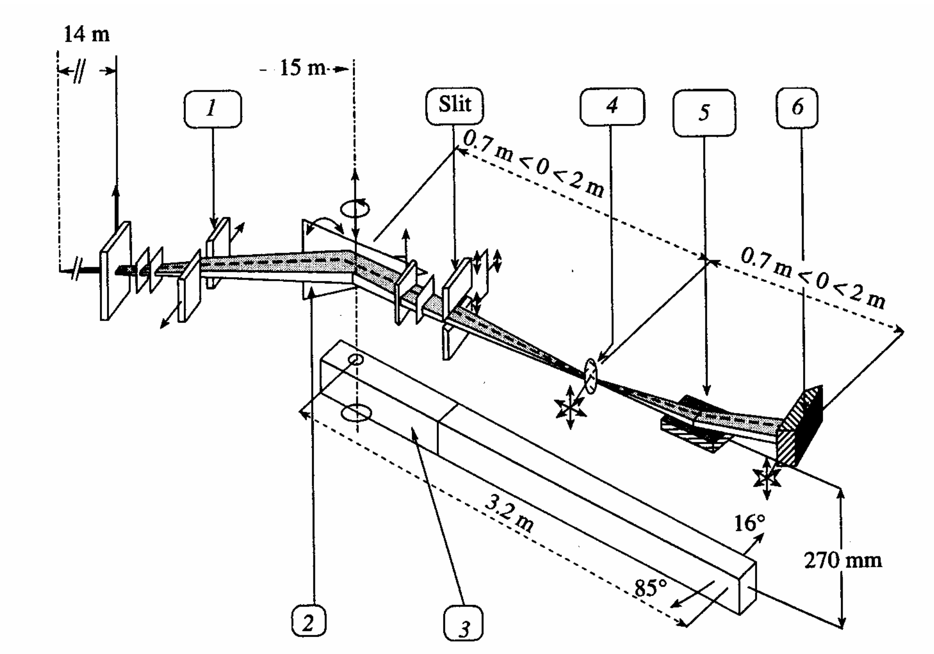


Fig. Block diagram of the energy-dispersive EXAFS spectrometer: (1) input forming optics, (2) monochromator with triangular Si crystal and bending device, (3) optical bench on aerostatic supports, (4) cryostat and high-pressure chamber, (5) mirror unit, (6) cryogenic two-dimensional position-sensitive detector.

General view of an optical bench made of marble in the room of energy-dispersive EXAFS-spectrometer.

Applied Research

| 07-5-1013-96/2008 |

| Priority of the project: |

Status:

Implantation Cyclotron “IC-100”

Leader from JINR: S. Dmitriev

Participating countries and international organizations: Bulgaria, Czech Republic, Egypt, Hungary, Germany, JINR, Kazakhstan, Poland, Russia, Slovak Republic, the United Kingdom.

IC-100 cyclotron is a very compact accelerator — cyclical implantator with poles diameter of 100 cm, designed for performing complex research of the structure and surface modification of semiconductors, monocrystals and dielectric materials irradiated with heavy ions for microengineering technology, microelectronics, optoelectronics etc.

General view of IC-100

07-4-1031-99/2008

Priority of the project:

Status: New

Optical Spectroscopy

Leader from JINR: S. Tiutiunnikov

Participating countries and international organizations: Belarus, Latvia, Russia.

The investigated problem and the purpose of research

In modern physics of condensed matter the big place is occupied by the research of physical properties of nanostructure systems of different composition: semi-conductor, metal. In particular, at transition to scales of dozens nanometers, there is a reorganization of phonon spectrum, electronic properties in comparison with the bulk structure. Also represents the big interest of research complex of nonstructural systems consisting of semi-conductors and metal clusters which can form a basis for creation of highly effective radiating environments, materials for cathodes of photoelectronic and semi-conductor devices. It represents also the big interest research of nonstructural system's behavior in fields of corpuscular radiation of different kind.

Actuality of the problem

Heightened interest to nonstructural systems, on the one hand, is connected to a direction of synthesis of new materials with set properties from elements of nonstructural system clusters with the set distribution in a matrix. And on the other hand, — with fundamental changes of properties of materials at transition by the sizes of clusters, to components some lengths of an elementary cell.

The modern condition of research is concentrated:

- Finding-out phonon structures of nonstructural systems;
- There is a change of phonon spectra, depending on the cluster size;
- Change of optical spectra of luminescence;
- Influence of cluster surface in various structures on their structural — phase conditions.

Actual direction of research is related to optical properties of heterogeneous structures with semi-conductor and metal clusters,together with in which effects of the compelled coherent radiation can be caused, and also medium with the set optical properties ε (ω) (dielectric permeability in the given spectral range) are created.

Expected results

In 2004–2008 it is planned to receive the following results:

- Phonon spectra in nanostructure of different composition: semi-conductors and metals, depending on frequencies and cluster sizes;
- Dependence of intensity of Raman mode of semi-conductor structures on affinity of metal clusters;
- Spectra of luminescence semiconductors from the cluster size;
- Spectral research of the heterogeneous structures consisting of photon points, search for effects of coherent radiation;
- Influence of corpuscular radiation on optical properties of semi-conductor and metal clusters;
- Dynamics of structural reorganization of nanoclusters in fields of corpuscular radiation.

Value of results for a global science

Optical properties of nanostructure systems involve enhanced attention as in them new fundamental laws low dimension systems with new properties are shown, on the one hand, and with another — opening prospect of creation artificial matters with the set optical properties.

On the basis of similar matters can be created lasers with possible reorganization on frequency and capacity and high efficiency. On a basis metal clusters can be created unique environments for acceleration of chemical reactions, etc.

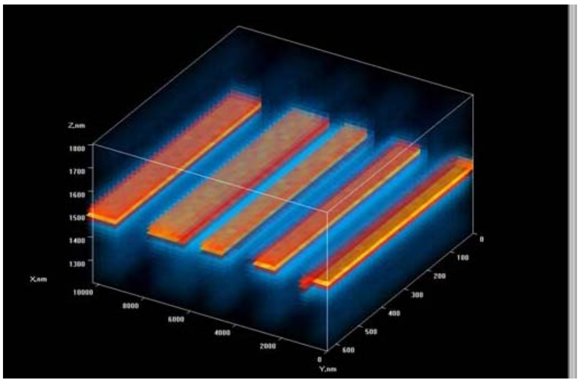
In this connection extremely important problem is creation and research of optical properties both isolated cluster, and taking place in structure of difficult complexes.

Scanning Confocal Microscope

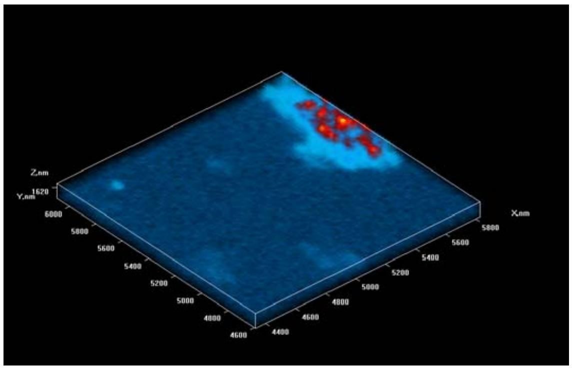
3-D tomography by confocal laser microscope based on cross-section spectroscopy at 0.2 µm spot.

Raman, fluorescence and lifetime analysis of compounds, contaminants; defects and stress in semiconductor;

films, liquid crystal, biological saline…



Semiconductors



Nanocrystals

Image of different structures from Scanning Confocal Microscope

X-Ray difractometer with digital CCD camera

07-7-1046-2002/2004

Priority of the project: 2
Status: Technical proposal

Synchrotron Radiation Complex DELSY
(Phase-1, FEL)

Leader from JINR: I. Meshkov, G. Shirkov

Participating countries and international organizations: Germany, JINR, Japan, Netherlands

Over the last decades synchrotron radiation (SR) has turned into a most powerful research tool applied in many different fields of science: in physics, radiation chemistry and photochemistry, molecular biology, in material sciences, medical diagnostics and other fields of science. This rapid progress was driven by the development of new, brilliant synchrotron radiation sources installed at electron storage rings. In parallel, recent advances in the development of linear accelerators and successful operation of very precise undulators open an exciting new possibility to build Free Electron Lasers (FEL). A free electron laser generates tuneable, coherent, high power radiation, currently spanning wavelengths from millimeter to visible and potentially ultraviolet to X-ray.

The project DELSY (Dubna ELectron SYnchrotron) is being under development at the Joint Institute for Nuclear Research. It is based on an accelerator facility presented to JINR by the Institute for Nuclear and High Energy Physics (NIKHEF, Amsterdam): linear accelerator MEA (Medium Energy Accelerator) and electron storage ring AmPS (the Amsterdam Pulse Stretcher).

Analysis of the accelerator equipment transferred from Amsterdam to Dubna has shown that it has a significant operating resource and can be used for many years in the future at an appropriate change of auxiliary equipment. Analysis has shown also that it would be possible to build in Dubna a universal light source with unique characteristics consisting of the following components:

- a complex of free electron lasers covering continuously the wavelength range from far-infrared (150 μm) down to UV (150 nm) and far-infrared coherent radiation source capable of generating high-power radiation (up to 100 MW peak and up to 50 W average) in the wavelength range from 150 μm up to 1 mm;
- the DELSY storage ring;
- a VUV/soft X-ray free electron laser with minimal wavelength down to 5 nm (SASE FEL — Self Amplified Spontaneous Emission Free Electron Laser).

After complete commissioning of the DELSY facility we will have a unique light source covering continuously the wavelength range from 1 mm down to a fraction of Angstrom. It is important that a significant fraction of the spectrum (from 1 mm down to 5 nm) will be covered by free electron lasers providing extremely high brilliance of the output radiation.

In line with concept, the construction of the DELSY facility will proceed in three phases (Fig.1).

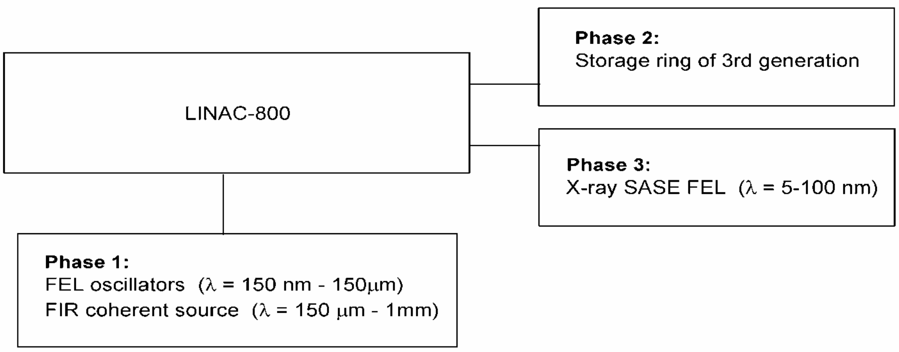


Fig.1. Structure of the DELSY project.

Phase-1 will be accomplished with the construction of a complex of free electron lasers (oscillators) covering continuously the spectrum from far infrared down to ultraviolet (of about 150 nm). The far-infrared coherent source will cover continuously the submillimeter wavelength range. Realization of this phase will not require a significant modification of the JINR infrastructure, and all the accelerator equipment and user facility can be mounted inside existing buildings. It is relevant to mention that even the first stage of the project will result in a unique user facility in the world. The present facilities is able to produce in one place such a wide spectrum of coherent radiation. In Table 1 a summary of the radiation properties from coherent radiation sources being planned to build in Phase-1 is presented. Notations G1-G4 refer to the FEL oscillators, and FIR stands for the far-infrared coherent source.

Table 1. Summary of radiation properties from coherent radiation sources in Phase-1.

	FIR	**G1**	**G2**	**G3**	**G4**
Radiation wavelength [μm]	150-1000	20-150	5-30	1-6	0.15-1.2
Peak output power [MW]	10-100	1-5	1-5	3-15	10-20
Micropulse energy [μJ]	500	50-200	25-100	25-100	50-100
Micropulse duration (FWHM) [ps]	5-10	10-30	10	10	3-5
Spectrum bandwidth (FWHM) [%]		0.2-0.4	0.6	0.6	0.6
Micropulse repetition rate [MHz]			19.8/39.7/59.5		
Macropulse duration [μs]			5-10		
Repetition rate [Hz]			1-100		
Average output power (max.) [W]	10-50		0.2-1		

The generators of coherent radiation will be driven by the electron beam produced by the linear accelerator. The requirements for the driving beam for the FEL are follows: the value of the peak current in the bunch should be as large as possible, while the micropulse separation can be much larger than rf oscillation period (0.3 ns). The upper limit on the micropulse separation is given by the round-trip time of the optical pulse in the FEL optical cavity (50 ns in the case of DELSY parameters). The problem of producing the beam with required peak current and time structure is solved in a simple way by means of replacing the MEA injector by a subharmonic rf buncher. As a result, the accelerator will produce bunches with the following parameters: 1 nC bunch charge, 50 A peak current, 10 ps pulse duration, 20 π mm-mrad normalized emittance. These parameters of the beam are sufficient for driving the FEL oscillators of infrared and optical wavelength range. An important feature of the DELSY project is that it is intended to produce radiation with much shorter wavelength (down to 100–150 nm) with respect to the present world record (270 nm) for linac-driven FELs.

Successful commissioning of the Coherent Radiation Facility will allow to perform a wide range of scientific experiments in different fields of physics, chemistry, biology and medicine, etc.