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The Joint Institute for Nuclear Research (JINR) is an international intergovernmental research organization established based on a Convention signed by eleven founder states on 16 March 1956 and registered by the UN on 1 February 1957.

V.A. MATVEEV,
Member of the Russian Academy of Sciences, Director of the JINR

JINR headquarters

The Institute was formed for the purpose of consolidating the efforts and the scientific and material capabilities of the 18 member states in studying the fundamental properties of matter. The Russian Minister for Education and Science is the plenipotentiary representative of the Russian Federation Government at the JINR.

The JINR's major fields of theoretical and experimental research are physics of elementary particles, nuclear physics and condensed matter physics.

The JINR includes 7 laboratories, each of the scale of research comparable to that of a large research institute. The JINR has a staff of about 5000 persons, including over 1200 scientists and about 2000 engineers and technicians.

The JINR possesses a unique fleet of experimental physical facilities: Nuclotron, a superconductive accelerator of nuclei and heavy ions, the only one in Europe and Asia; the U-400 and U-400M heavy-ion cyclotrons with record-breaking beam parameters used for experiments in synthesis of heavy and exotic nuclei; the IBR-2, a unique pulsed neutron reactor upgraded to be used for research in neutron physics and condensed-matter physics; and a synchrocyclotron – a proton accelerator used for beam therapy.

Late 2008 saw the successful launch of a new base facility, IREN, designed for research in the field of nuclear physics using a time-of-flight technique in the neutron energy range up to hundreds keV.

The JINR has been successfully implementing the Nuclotron-M project, which is expected to form the basis for the new superconducting collider NICA, as well as a project to build the DRIBs-II heavy-ion complex.

The JINR possesses a fleet of high-power high-capacity computers networked, via high-rate communication channels, to international computer systems. The Dubna-Moscow communication channel of the initial throughput 20 Gbit/s was put into operation in 2009.

An important aspect of the JINR's activities is extensive international cooperation in science and technology: the Institute collaborates with nearly 700 scientific centers and universities in 64 countries of the world. In Russia alone, which is its major partner, the JINR cooperates with 150 research centers, universities, industrial enterprises and firms in 43 Russian cities.

Annually, the JINR sends over 1500 papers and reports compiled by about 3000 authors to many journals and organizing committees of conferences. The JINR's publications are circulated to more than 50 countries of the world.

The JINR accounts for a half of the discoveries (numbering about 40) registered in the field of nuclear physics in the ex-USSR. The recognition of the outstanding contributions made by the JINR's scientific staff to modern physical and chemical science has been the decision by the International Union of Pure and Applied Chemistry (IUPAC) to give the name dubnium to chemical element 105 of the Mendeleev periodic table.

Dubna's scientists have been the first in the world to synthesize new, long-lived super-heavy elements 113, 114, 115, 116, 117 and 118. These important discoveries have crowned the 35-year international efforts in searching for the 'stability island' of super-heavy nuclei.

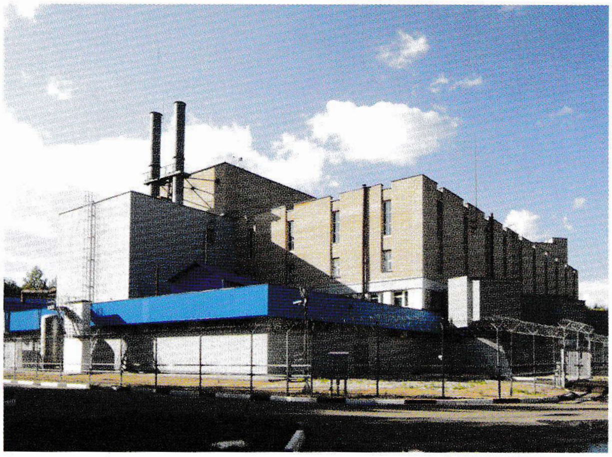
It has been for 15 years now that the JINR is involved in the program to form the so-called innovation belt of Dubna. 2005 saw a Russian government resolution signed to establish a special technology innovation economic zone in Dubna. The zone's major focus is on research in nuclear physics and information technology, which is the specialization of the JINR. For the implementation in the special economic zone, the JINR has prepared over 50 innovation projects, with the Dubna special economic zone's 9 resident companies having their origin in the JINR.

The Joint Institute for Nuclear Research is a major multi-profile international scientific center, which integrates fundamental nuclear physical research, development and application of advanced technologies, and university-level education in the respective fields of knowledge.

IBR-2M FAST PULSED REACTOR

The IBR-2M research reactor is an upgrade of the IBR-2 reactor.

The upgraded IBR-2 pulsed research reactor is the base facility of the I.M. Frank Laboratory of Neutron Physics (LNP). The laboratory was set up in 1957 on the initiative of the JINR's first director D.I. Blokhintsev, a corresponding member of the USSR Academy of Sciences. Until his death in 1979, D.I. Blokhintsev was the scientific supervisor for the IBR-2M reactor. Academician I.M. Frank, a Noble Prize winner, and V.L. Aksenov, a corresponding member of the Russian Academy of Sciences, held the post of the scientific supervisor for the reactor respectively in 1979-1990 and in 1990-2006. The latter headed the Laboratory in 1998-2000.



IBR-2 reactor building

The upgraded IBR-2M reactor is the world's only fast pulsed reactor with periodic operation. Its major difference from other reactors is that it uses mechanical reactivity modulation with the aid of a movable nickel-steel reflector (MR). The movable reflector is a complex mechanical system, which supports reliable operation of the two components, reactivity modulation relies on: a main movable reflector (MMR) and an auxiliary movable reflector (AMR). The MMR and AMR rotors rotate in opposite directions at different speeds with a power pulse generated near the reactor core at the instant the both reflectors align. The reflectors are rotated by an asynchronous motor and are enclosed in a thin-wall sealed helium-filled case.

Top view of IBR-2 reactor building

This design makes it possible to use time-of-flight spectrometry methods for studies in condensed-matter physics.

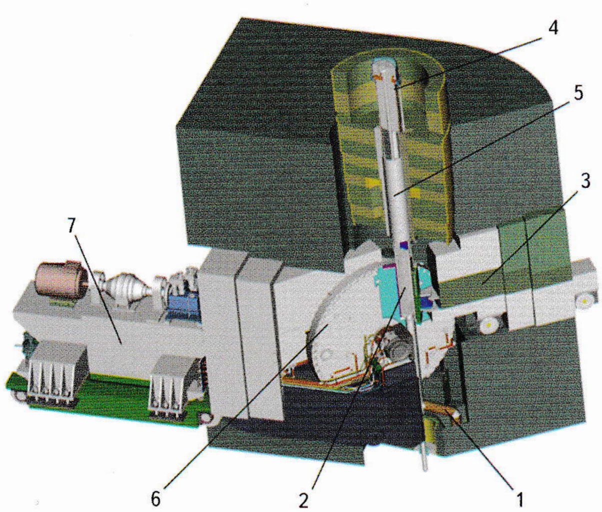
The IBR-2 reactor was developed by NIKIET. It was built at the JINR in 1969-1980 and commissioned on 10 February 1984. The IBR-2 reactor achieved first criticality on 15.12.1978 and saw its energy startup on 10.02.1984.

Over the period of operation from the commissioning time to 2007, the IBR-2 reactor had operated, in total, for about 50 000 hours, providing physical scientists, while having a relatively small average thermal power of ~2 MW, with one of the world's most intensive thermal-neutron flux (the peak value 10^{16} $cm^{-2} \cdot s^{-1}$, from the moderator surface). The fifty-year operating history of the IBR, IBR-30 and IBR-2 reactors gave the LNP an experience that has enabled it to develop, collaboratively with NIKIET, VNIINM and others, a project for upgrading the IRB-2 reactor to have the estimated post-retrofit life of at least 30 years.

The upgraded IBR-2M reactor, including the set of spectrometers, is now a part of the 20-year European strategic program for neutron scatter research.

The IBR-2M reactor uses a fuel based on plutonium-239 dioxide.

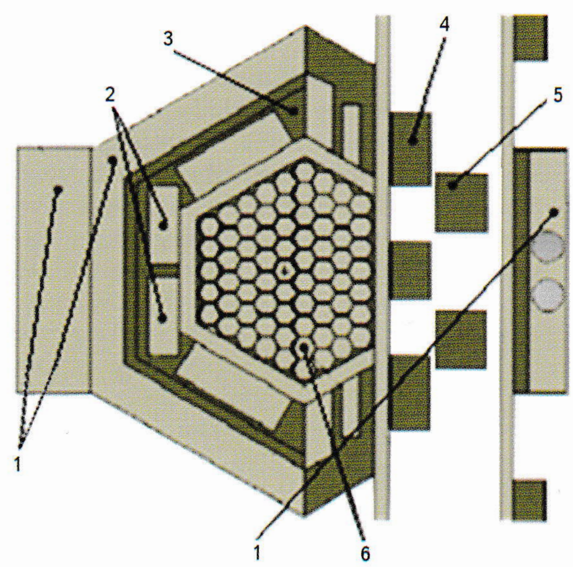
The IBR-2M reactor has a three-circuit cooling system, which comprises two loops for safety reasons. The coolant in circuits 1 and 2 is liquid sodium, and the coolant in circuit 3 is air.



A sectional view of the upgraded IBR-2M reactor facility:
1 – pressure header; 2 – core; 3 – retractable shielding; 4 – upper part of the reactor vessel; 5 – reactor vessel; 6 – movable reflector

Main performance of the upgraded IBR-2M reactor

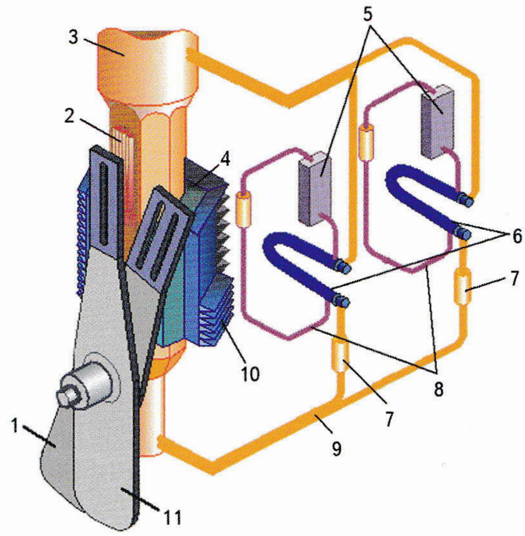
Average power	2 MW
Fuel	PuO_2
Number of fuel assemblies	69
Maximum burnup	9%
Pulse frequency	5 Hz; 10 Hz
Pulse half-width	~200 ms
Movable reflector rotation speed:	
main reflector	600 rpm
auxiliary reflector	300 rpm
Reflector material	Nickel, steel
Fast neutron flux, maximum	10^{17} $cm^{-2} \cdot s^{-1}$
Moderator	Water + mesitylene
Fast neutron flux from the moderator surface:	
time-averaged	10^{13} $cm^{-2} \cdot s^{-1}$
pulse-maximum	10^{16} $cm^{-2} \cdot s^{-1}$



IBR-2M reactor core arrangement:
1 – water moderators; 2 – emergency protection; 3 – fixed reflector; 4 – main movable reflector; 5 – auxiliary moveable reflector; 6 – fuel assembly

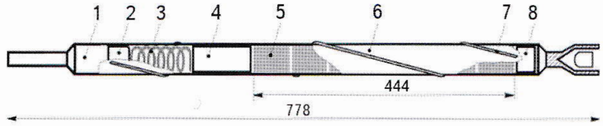
Electromagnetic pumps are used to circulate sodium in circuits 1 and 2.

When in the loops of circuit 1, the sodium conveys its heat to the secondary (intermediate) circuit coolant via the intermediate sodium-to-sodium heat exchangers. The secondary circuit heat is removed in the air heat exchangers thanks to chimney effect in the air heat exchangers and in the tubes above these.

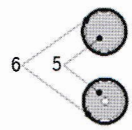


A schematic of the IBR-2M reactor:
1 – main movable reflector; 2 – core; 3 – reactor vessel; 4 – fixed reflector; 5 – sodium-air heat exchangers; 6 – intermediate heat exchangers; 7 – sodium pumps; 8 – cooling circuit 1; 9 – cooling circuit 2; 10 – moderator; 11 – auxiliary movable reflector

IBR-2M control room

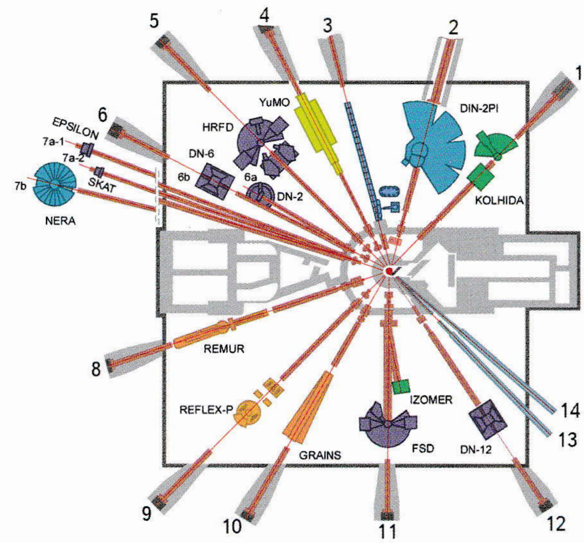


IBR-2M fuel element:
1 – upper plug; 2 – spring support; 3 – resting spring; 4 – tungsten insert; 5 – fuel pellet; 6 – fuel element cladding, Ø8.6×0.45 mm; 7 – spacer wire; 8 – lower plug



Cross-section of a fuel element with a solid pellet

Cross-section of a fuel element with a pellet having a central channel of Ø1.5 mm



Experimental facilities of the upgraded IBR-2M reactor

Experimental capabilities of the upgraded IBR-2M reactor

The reactor is fitted with 14 horizontal and 3 inclined experimental channels. Besides, there are two horizontal rabbit tubes for the activation analysis installed on the retractable shields behind the fixed reflector.

There are 13 spectrometers mounted above the horizontal channels for condensed-matter investigations and two facilities for research in neutron nuclear physics. The condensed-matter spectrometers are used within the frameworks of LNP's user policy program. The spectrometer set consists of seven diffractometers (HRFD, DN-2, DN-12, DN-6, SKAT, EPSILON, FSD), three reflectometers (REMUR, REFLEX, GRAINS), one small-angle-scatter spectrometer (YuMO) and two inelastic-scatter spectrometers (DIN-2PI, NERA).

Main areas of studies

The reactor can be used for studies in:

– the structure and properties of new crystalline materials and nanosystems by neutron diffraction method;

– magnetic colloidal systems in bulk and at interfaces;

– the structure of carbonic nanomaterials;

– the magnetism of layered nanostructures;

– the supermolecular structure and functional characteristics of biological, colloidal and polymeric nanodispersion materials;

– the nanostructure and properties of lipid membranes and lipid complexes;

– the atomic dynamics of nanosystems and materials by neutron inelastic scatter method;

– the texture and properties of minerals and rock;

– analyzing inner stresses in bulk materials and products;

– nuclear pseudomagnetism based on a facility with polarized neutrons and polarized nuclei;

– measuring yields of delayed neutrons during actinide fission.

International cooperation

The JINR carries out international cooperation in the field of condensed matter, in upgrading the spectrometer set and in creation of new spectrometers. This cooperation in this field involves over 150 universities and research institutes in nearly 40 countries of the world.

All users are given permits to conduct experiments based on an application assessed by an international selection panel, with the experiment time allocated given the application's scientific value.

Main activities

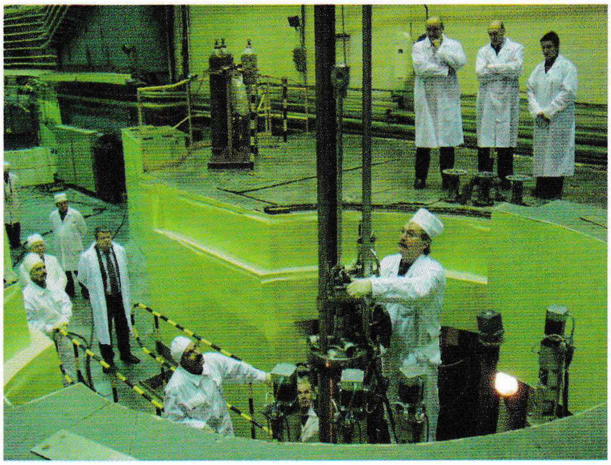
The IBR-2 reactor had its service life expired in late 2006. The IBR-2 enhancement concept was developed jointly by the JINR's LNP and NIKIET to evolve and improve the reactor, with 2010 set as the upgrade completion year. To implement the concept, a program was developed for the IBR-2 upgrading in an outage conditions.

These documents envisaged the creation of the upgraded IBR-2 reactor with the following improved parameters:

– a higher flux of thermal neutrons from the moderator surface (1.5 times as high as in the IBR-2 reactor) thanks to a compact reactor core;

– reduced speeds (600 rpm instead of 1500 rpm) of the main movable reflector (MMR), combined with the use of a nickel alloy, make it possible to preserve the existing length of the neutron pulse and give the machine a 2.5 times as long life (55 000 h);

– use of only sleeve-type fuel elements as the fuel to bring the burnup up to 9 %, which is 1.5 times as high as in the IBR-2 reactor;



First FA being loaded into the upgraded IBR-2M reactor

– use of two emergency protection blocks, combined with a drive using a step motor, to enable fast and slow scram functions. This gives a much simpler design to the fixed reflector and improves the reliability of the scram mechanism;

– presence of retractable moderators enabling rapid moderator replacement, which makes it unnecessary to dismantle the fixed reflectors and the CPS rods;

– presence of a set of thermal and cold neutron moderators: this is for the first in international experience that it is suggested to use solid mesitylene as the working material for cryogenic moderators at T = 20…30 K. This leads to a 25 times as high cold-neutron flux with a wavelength of over 0.4 nm, which is critical for research in the field of nanotechnologies.

Use of novel components meeting current international safety and reliability requirements (reactor vessel, fixed reflectors, electronic equipment, CPS actuators and others) will extend the reactor life to another 30 years.

The components newly designed based on modern regulations and rules include the fuel load, the reactor vessel, in-vessel and near-vessel components, the movable reflector of an improved performance, electronic hardware for the reactor control and protection system with new actuators, the reliable power supply system, the process parameter monitoring equipment and the reactor state monitoring system. The components with the expired life were dismantled. Most of the disassembly and assembly operations on the reactor components were performed by in a hard environment, including high induced activity and limited space in some of the reactor rooms. A great deal of repair and construction work was done inside and outside the reactor building. Work is continued to build a modern physical protection system for the reactor.

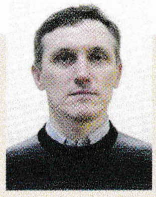
17 December 2010 saw the launch of the fuel loading operations on the IBR-2M facility at the Frank Laboratory as part of the first criticality program for the upgraded IBR-2 reactor.

First criticality was achieved at the upgraded reactor with a new core on 4 February 2011. At 12:35 pm the reactor reached criticality in terms of delayed neutrons and the power of 10 W.

At 2:34 pm 12 October 2011, the IBR-2 reactor reached the rated power of 2 MW. Following its energy startup program completion, the reactor operates at 2 MW for physical benchmark experiments on the neutron beams extracted.

In 2011 many of the reactor characteristics were studied, its safe operating limits and conditions were determined and confirmed in different operation modes, and experiments were conducted on the extracted neutron beams. Unique cryogenic moderators have been installed in the reactor.

Contact person



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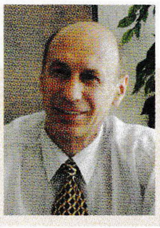

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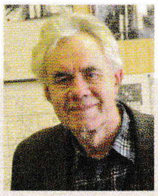

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