MEGASCIENCE: THE OECD FORUM

UNIQUE RESEARCH FACILITIES IN RUSSIA

For technical reasons, OCDE/GD(95)81 has been split into 9 parts. This is the Part 5.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Paris 1995
CHAPTER 4. CONDENSED MATTER PHYSICS
The complex IBR-30 + LUE-40 is a source of resonant neutrons, based on the subcritical reactor core IBR-30, driven by the LUE-40 linac.

Date of commissioning: June 1969.

Field of science
Physics (nuclear physics, experimental elementary-particle physics).

Fields of research
• Fundamental properties of neutrons (polarisability, mean-square charge radius, n–e interaction amplitude, and life-time).
• Fundamental symmetry violation (parity and time invariance).
• Highly excited states of nuclei.
• Neutron-induced nuclear fission.

Main characteristics
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron energy, MeV</td>
<td>40</td>
</tr>
<tr>
<td>Electron-beam pulse current, mA</td>
<td>400</td>
</tr>
<tr>
<td>Electron-pulse duration, µs</td>
<td>1.6</td>
</tr>
<tr>
<td>Frequency, Hz</td>
<td>100</td>
</tr>
<tr>
<td>Average power, kW</td>
<td>10</td>
</tr>
<tr>
<td>Pulse power, kW</td>
<td>25000</td>
</tr>
<tr>
<td>Neutron-multiplication coefficient</td>
<td>200</td>
</tr>
<tr>
<td>Neutron fluency, n/s</td>
<td>~ 10^{15}</td>
</tr>
<tr>
<td>Neutron-pulse duration, µs</td>
<td>4.0</td>
</tr>
<tr>
<td>Power consumption, kW</td>
<td>~ 200</td>
</tr>
</tbody>
</table>

Major advantages
The peculiarity of the neutron spectrometric complex LUE-40 + IBR-30 is its combination of an electron injector (middle-class linac) with a subcritical plutonium reactor core which multiplies the number of primary photo-neutrons by 200 times. It is a low-cost source of resonant neutrons, the best in Europe and comparable with the most powerful neutron source based on a proton accelerator in Los-Alamos (United States).

In addition, the IBR-30 is equipped with a wide net of neutron guides and experimental halls with a set of outstanding experimental set-ups for detecting virtually all the channels of neutron–nuclei interaction. For example, the POLYANA complex is designed for studying interaction of
polarised neutrons with polarised nuclei. There are also spectrometers of \( \gamma \)-cascades, \( \alpha \)-particles, protons, fission fragments, \( \gamma \)-quanta multiplicity, etc.

The experimental data are processed at a specialised computing centre equipped with the SparcStation 5, SparcStation 10, and SparcStation 20 workstations. Users also can access to all international computing resources available on the Internet.

**Current research**

- Measuring the total cross sections for \(^{208}\text{Pb}\) with filtered and quasi-monochromatic beams to determine the neutron polarisability.
- Investigations with polarised resonant neutrons and polarised nuclei to measure \( P \)-odd effects in neutron resonances.
- Measuring the \( P \)-even and \( P \)-odd angular correlations in neutron reactions emitting charged particles and the radiation capture of neutrons \((n,\alpha)\), \((n,p)\), and \((n,\gamma)\) by light nuclei with the aim of refining the parameters of weak nucleon–nucleon interaction.
- Measuring the radiation strength functions of primary \( \gamma \)-transitions at energies higher than 0.5 MeV in even–odd and even–even nuclei and the non-statistical effects in decays of excited states.
- Studying new proton and \( \alpha \)-particle resonances in stable and radioactive nuclei over the neutron-resonance energy range.
- Measuring neutron cross-sections, resonance parameters, and \( \gamma \)-quanta multiplicity distribution after resonance neutron capture and neutron-induced fission.
- Resonant neutron-induced nuclear fission.
- Spectrometry of the prompt \( \gamma \)-quanta fission fragments of \(^{233}\text{U},^{235}\text{U}\) and \(^{239}\text{Pu}\).
- Measuring angular anisotropy of fission fragments by using a cryogenic target with aligned \(^{235}\text{U}\) nuclei.
- Correlation study of a ternary \(^{235}\text{U}\) fission.

**Possible research**

Fundamental symmetry violation:

- Developing a procedure for measuring time-invariance violation in reactions induced by resonant neutrons.

Applied research:

- Measuring nuclear constants for nuclear-power industry of a new generation.
- Investigations in the transmutation (burn-out) of nuclear waste consisting of long-lived radioactive fission products in nuclear facilities.
- Modelling an electron-linac-based electro-nuclear installation at the complex.
- Investigations of a \( \gamma \)- and neutron-radiation impact on electronics and detectors used in high-energy physics.

**Main scientific results**

- Parity-violation enhancement was discovered in neutron resonances.
- Magnetic dipole moments of highly excited nuclear states were measured for the first time.
- \( \alpha \)-decay of neutron resonances was discovered and studied.
The predicted properties, i.e. total reflection and storing in traps, were discovered in ultra-cold neutrons.

- For the first time the spin dependence of neutron strength function was measured with high accuracy in a wide energy range.
- For the first time significant dependence of the relative probability of electric and magnetic dipole \(\gamma\)-transitions on properties of the nuclear state was discovered.

**Basic papers**


**Current financial support and co-operative projects**

Grants of the Russian Foundation for Basic Research:

- Correlation \(\gamma\)-spectroscopy of the fission fragments from isolated highly excited nuclear states (94-02-05121).
- Determination of the \(n,e\) amplitude on energy dependence of the slow-neutron scattering cross section in noble gases (94-02-03118).
- Measuring the angular distributions of neutron-nuclei scattering in the energy region from eV to several hundred keV (electric polarisability of a neutron) (93-02-17384).
Experimental investigation of nuclear fission at the FLNP JINR pulse reactors (95-02-03740).
Investigations of \( P \)-odd and \( P \)-even correlations in resonant-neutron-induced reactions with charged-particle emission (95-02-05212).
Studying of highly excited nuclear states in the neutron-binding energy region (95-02-03848).

International Scientific Foundation Grants:
- Investigation of Parity Violation in Neutron Resonances (NK1000).
- Research in Electric Polarisability of the Neutron and its Mean-Square Charge Radius (RFS000).
- Proton and Alpha Decay of Compound States Research Program (RFI000).

Collaborative projects with the following foreign centres:
- United States: LANL (Los-Alamos), ORNL (Oak-Ridge), Triangle Univ. Lab.
- Germany: TU (Munich), TU (Darmstadt), TU (Tübingen), Reactor Station (Garching), FZ (Rossendorf), Nuclear Research Centre (Karlsruhe).
- France: ILL (Grenoble), CEN (Cadarache).
- Japan: KEK (Tsukuba), Kyoto University.
- Latvia: IP (Riga), Riga University.
- Ukraine: INR (Kiev).

**Scientific and technical personnel**
27 researchers and 28 technicians.

**Possibilities for international exchange**
Number of foreign scientists working at the installation: 15 man-year.
Possibilities for additional accommodation of the foreign scientists for work on the installation: no less than 10 researchers.
Vacancies for accommodation of foreign specialists: 10 man-year.

**General information**
The Institute is located 130 km north-west of Moscow.

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Phone: (09621) 6-2623
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Director of the Institute: Victor L. Aksenov
Responsible person: Walter I. Furman
RESEARCH NUCLEAR REACTOR IVV-2M
Neutron Materials Science Centre at the Institute for Metal Physics

The reactor was built in 1969 and upgraded in 1988.

Field of science
Physics (solid-state physics, physics of strength and plasticity, crystal structure and growth, high-pressure solid-state physics, magnetic phenomena, radiation-damage physics, and low-temperature condensed-matter physics).

Fields of research
Physics of strength and plasticity of new structural materials, developing methods of producing structural materials with specified properties, atomic structure and properties of crystals, development of new methods for treatment of materials under high static and dynamic pressures, investigations of ferro-, antiferro- and ferrimagnetic phenomena, radiation damage physics of metals and alloys, superconductivity, and low-temperature magnetism.

Main characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat power, MW</td>
<td>15</td>
</tr>
<tr>
<td>Thermal neutrons flux, cm⁻².s⁻¹</td>
<td>up to 4.10¹⁴</td>
</tr>
<tr>
<td>Fast neutrons flux, cm⁻².s⁻¹</td>
<td>up to 1.10¹⁴</td>
</tr>
</tbody>
</table>

The reactor has eight horizontal channels for neutron beam outputs and seven cavities in the core, where irradiated facilities may be situated. Also, there is a channel cryostat installed in the core for irradiation of materials below 80 K by fast neutron flux up to 5.6.10¹³ cm⁻².s⁻¹. There are also opportunities for irradiating samples in various gas media in the temperature range of 300–1 500 °C under varying external pressure. In the horizontal channels are four neutron diffractometers, a triple-axis neutron spectrometer and a small-angle scattering diffractometer. Thermal-neutron scattering experiments are carried out (with irradiated and non-irradiated materials) in the temperature range of 2–1 500 K, under pressure up to 10 kbar and magnetic field up to 1.5 T.

Besides diffraction data, the following characteristics of materials are under investigation:
- Magnetisation in magnetic fields up to 2 T in the temperature range of 4.2–600 K.
- Electrical resistivity in the temperature range of 0.3–400 K in magnetic field up to 15 T; magnetic susceptibility and the Hall effect in the temperature range of 0.3–400 K.
- Heat capacity in the temperature range of 2.5–350 K.
- Mechanical properties in the range of 80–300 K.
Current research

• With both irradiated and non-irradiated samples we investigate.
• Crystal and magnetic structure of alloys and compounds.
• Lattice and magnetic dynamics of superconductors.
• Impact of neutron irradiation on the properties of structural, magnetic and superconducting materials.
• Tritium interaction with materials proposed for fusion reactors.
• Development of radiation-resistant weakly activated structural materials for nuclear power engineering.

Main scientific results

• New physical approaches have been found to achieve high density of sinks for point defects to increase radiation resistance for metals and alloys.
• New structure steels stable against radiation swelling have been developed.
• Anomaly fine grains in commercial Ti–V alloys were found under saturation with hydrogen; this is important for explanation of their superplasticity.
• Some mutual rules were found for variation in the conduction-band electron spectrum in high-temperature superconductors when introducing atomic-scale defects.
• Density of states at the Fermi level decreases as disorder increases and localised magnetic moments appear simultaneously at copper ions.
• Magnetic structures were experimentally determined for band antiferromagnets with Laves-phase crystal structure and also for strongly correlated electron systems with monoxide- and chalkogenide-type structures (transitional metals).

Basic papers


**Current financial support and co-operative projects**

Grants of the Russian Foundation for Basic Research: 95-02-03539a, 93-02-2808.

HTSC Project: 93-001.

INTAS Grant: 93-0135 (Switzerland, ETH; Great Britain, Rutherford Appleton Lab.; Germany, Univ. Erlangen-Nurnberg).

ISTC Project: 94-019.

IPP Project (United States, Argonne National Lab.), 942492402

ISF Grants: RG8000, RG6000.

**Possibilities for international exchange**

For work at the reactor, two foreign scientists a year can be received.

**General information**

Neutron Materials Science Centre at the Institute for Metal Physics.

Ural Division of the Russian Academy of Sciences

18 S. Kovalevskaya St., 620219 Ekaterinburg GSP-170

Phone: (3432) 44-4494

Fax: (3432) 44-2603

E-mail: RDNR@neutron.e-burg.su

Director of the Institute: Vitalii Shcherbinin

Responsible person: Boris Goshchitskii
The reactor is in the process of construction.

Field of science

Fields of research
Nuclear and atomic physics, condensed-state physics, applied investigations.

Main characteristics
Heat power, MW  100
Thermal-neutron flux in the reflector, cm$^{-2}$s$^{-1}$  1.2$\cdot$10$^{15}$
Flux in the central vertical channel, cm$^{-2}$s$^{-1}$  5$\cdot$10$^{15}$
Number of horizontal channels  10
Number of inclined channels  6
Number of vertical channels for irradiation  6
Number of sites for arranging experimental set-ups  50
Completion of the PIK complex, %  75

Major advantages
Full-power experimental opportunities at the PIK reactor will be the same or better than those at the ILL reactor in Grenoble, which is the best at present time.

Possible research
• Investigation on reactor safety, development of cold- and hot-neutron sources.
• Development of separation of hydrogen isotopes (cleaning heavy water from tritium).
• Development of installations for investigations in nuclear physics and condensed-state physics.

Scientific and technical personnel
210 researchers and 200 technicians.

General information
Institute is placed near Gatchina, 45 km south of Saint-Petersburg.

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E-mail: vnazar@lnpi.spb.su, npi@lnpi.spb.su
Director of the Institute: Vladimir A. Nazarenko
Responsible person: Victor V. Sarantsev
OR-M INSTALLATION
Russian Research Centre “Kurchatov Institute”
Institute of Nuclear Reactors

Date of commissioning: 1954, date of reconstruction: 1989.

Field of science
Physics (physics and technology problems of power).

Fields of research
Study of neutron and photon transport with continuous reactor spectrum in various materials and compositions; bench-mark macroscopic experiments in one-, two-, and three-dimensional geometry; shielding mock-up tests for various nuclear power systems as well as for externally irradiated facilities.

Main technical units of the facility
- VVER-type nuclear reactor with an easily varied and monitored thermal power from 0.01 to 300 kW is used as a neutron and gamma-radiation source; the core's linear dimension is about 0.5 m.
- Cavity (2 m long, 1.6–2.4 m² stepwise square cross section) in a biological shield, adjacent to the core and intended for accommodation of the shield systems tested, as well as for extraction of a wide (up to 2 m across) reactor beam of the neutron and gamma-radiation into a test tunnel connected with the cavity.
- 2.1 × 2.1 m² test tunnel with the walls at least 1 m thick, intended for forming a wide and practically mono-directional (divergence of a few degrees) reactor-radiation beam with a diameter up to 1.5 m.
• System of diaphragms, spaced along the beam's path length, movable along an irradiation space (cavity-tunnel) on rails, and having the collimation-slit diameter from 0.05 to 1.0 m at the total diaphragm thickness of several meters; the adopted method of collimation allows the background radiation in the beam to be reduced to a few percentage points at the location of the shield system tested.

• Set of filters along the beam's path length, to vary the component and energy composition of the radiation beam.

• 150 m$^2 \times 3$ m laboratory hall adjacent to the tunnel, load-lifting mechanisms for 5 and 20 tons nominal load, two 40 m$^3$ storage chambers.

**Current research**

• Macroscopic two-dimensional bench-marks of neutron and gamma transport in LiH and Pb assemblies, using a wide uni-directed radiation beam from the reactor.

• Macroscopic one-dimensional bench-marks of primary photon transport in heavy materials to compare the results with data calculated using several codes and libraries.

**Possible research**

• Study on shielding properties of new materials, shielding mock-up tests for various nuclear power systems as well as for externally irradiated facilities.

• Irradiation bioexperiments.

**Main scientific results**

A global methodology of shielding experiments in one-, two-, and three-dimensional geometry was developed, including a bench-mark approach to neutron and gamma transport in shields for practical applications. A great number of materials and compositions were studied. Several recommendations were developed for optimum use of transport codes and nuclear-data libraries as well as for practical tasks in radiation shielding and safety.

**Basic papers**


**Scientific and technical personnel**
15 researchers and 25 technicians.

**Possibilities for international exchange**
Up to 5 foreign scientists a year could be accepted for co-operative work at the OR-M set-up.

**General information**
Russian Research Centre “Kurchatov Institute”

Institute of Nuclear Reactors
1 Kurchatov Sq., Moscow 123182
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Fax: (095) 196-8971, (095) 531-2403 (BOX 3847, via Relcom Fax gate)
E-mail: ank@atis.kiae.su
President of RRC “Kurchatov Institute”: Ye.P. Velikhov
Director of the Institute: N.Ye. Kukharkin
Responsible persons: Nikolai N. Ponomarev-Stepnoi and Viktor G. Madeev
COMPLEX OF NEUTRON-PHYSICS INSTRUMENTS
FOR SOLID-STATE PHYSICS RESEARCH AT THE IR-8 REACTOR
Russian Research Centre “Kurchatov Institute”
Institute for Superconductivity and Solid-State Physics

The complex was completed by mid-1980s.

Field of science
Physics (structure, phase transitions, and phonon spectra of solids).

Fields of research
Structure and phonon spectra of superconductors, influence of electron–phonon interaction on the phonon spectra of metals, neutron studies of solids under high pressures, neutron optics and acoustics.

Main characteristics
A light-water swimming-pool-type reactor IR-8 operates in the Kurchatov Institute (8 MW power, neutron flux $1.5 \times 10^{14} \text{ cm}^{-2} \cdot \text{s}^{-1}$ in the middle of core). Five channels are used for solid-state physics instruments, three for nuclear-physics instruments, two for neutron-activation analysis and one for neutron radiography. Neutron flux at the exit of a channel is $(0.3–1.0) \times 10^{10} \text{ cm}^{-2} \cdot \text{s}^{-1}$.
A unique complex of instruments was created at the IR-8 reactor for solid-state physics research using neutron scattering (general view of a reactor hall is shown in the figure):

- Single-crystal diffractometer MOND with a five-circle goniometer and a wavelength range of 0.07–0.55 nm.
- Triple-axis crystal spectrometer ATOS of the wavelength range 0.11–0.19 nm.
- Powder multi-detector annular diffractometer DISC with a minimum sample volume of about $10^{-3}$ mm$^3$.
- Triple-axis spectrometer STOIK with ideal crystals at the wavelength range of 0.08–0.25 nm and angular resolution of about 1 s of arc.
- Time-of-flight neutron spectrometer with a beryllium filter, propane cold-neutrons source, and resolution of 0.9–0.5 meV at initial energy of about 5 meV.

**Major advantages**

The complex installed at the medium-flux reactor makes it possible to carry out investigations which cannot be performed even at high-flux reactors. This set of facilities is unique among the world’s reactor centres.

**Current research**

Investigation in:
- Neutron acoustics of weak ferromagnets and superconductors.
- Dynamics of the atomic and magnetic lattices of superconductors.
- Structure of solids at high pressures (using sapphire and diamond anvil cells).
- Volume domain structure of ferromagnets.

**Possible research**

- Study of micro-samples of strongly absorbing and radioactive substances.
- Investigation in the structure of fullerenes and cluster compounds.
- Study of elementary excitations in solids at high pressures.
- Research in phonon spectra of amorphous alloys and alloys amorphised under saturation with hydrogen.
- Exploration of interaction of radiation with perfect crystals of ferromagnets and superconductors.

**Main scientific results**

- Work on structure and phase transitions of hydrogen in the lattice of metals and inter-metallides and, and on excitation spectra of disordered alloys with light and heavy impurities; determination of features of electron–phonon interaction in the crystals of metals and alloys and of the shape of Fermi surface by anomalous phonon dispersion; neutron optics and acoustics; development of the methods of new neutron experiments.
- Research in the structure of substances under pressure up to 370 kbar, which is several times the greatest pressures at high-flux reactors, has been carried out in the past years at the neutron
diffractometer DISC; the structure and the equation of state of solid hydrogen and of several hydrides and oxides have been studied.

- Great attention is paid to high-$T_c$ superconductors; methods of phonon dispersion have been developed single crystals with a volume of 10–100 mm$^3$, which is maximally achieved for complex conducting oxides, as well as these methods of partial excitation spectra using in isotopic contrast; experimental data revealed the nature of interatomic interactions in the complex lattices of high-$T_c$ superconductors.

- Possible observation of dynamic nuclear and magnetic scattering is demonstrated in the perfect crystals of weak ferromagnets and superconductors; also possible imaging of the domain wall layout in the bulk of large ferromagnetic crystals is shown with the use of the method of neutron radiography with refraction contrast; full domain structure of iron crystals was reconstructed on the basis of these images; new methods of neutron radiography have been developed; new trends have also been developed in neutron-diffraction acoustics, non-linear magneto-acoustic effects caused by coupled atomic and magnetic excitations have been studied in detail.

**Basic papers**


V.V. Kvardakov, V.A. Somenkov, V. Paulus, G. Heger, and S. Piniol (1994), Observation of anomalous transmission in x-ray scattering in the superconducting crystals Nd$_{0.85}$Ce$_{0.15}$CuO$_{4-b}$. *Pisma v ZhETF*, No. 10.

**Current financial support and co-operative projects**

Grants of the Russian Foundation for Basic Research:

- Neutron optics of high resolution (95-02-04691).
- Amorphisation of intermetallide-hydrogen systems (94-02-05988).
- Study of non-equilibrium effects in the non-linear system of magneto-elastic waves in antiferromagnets (95-02-03960).
Experimental study of partial spectra of atomic vibrations in metallic glasses (95-02-04690). Magnetic phase transitions at high pressures (95-02-04693).

Fullerenes and Atomic Clusters Programme Grant, Neutron Project No. 32.
HTSC Programme Grants: Nos. 93161 and 93192.
ISF Grants: MNU000 and MNU300.
Agreement on collaboration with the Laue–Langevin Institute (Grenoble, France).
Agreement on collaboration with the Leon Brillouin Laboratory (Saclay, France).
Project on neutron diffractometry of perfect crystals, RRC KI–Forschungzentrum Rossendorf (Germany).

*Scientific and technical personnel*
15–20 researchers and 10–12 technicians.

*Possibilities for international exchange*
Vacancies for accommodation of foreign scientists: 5 man-years. Before the reactor shutdown there was a broad scientific co-operation with western and eastern European countries on the basis of short-term exchange (1-2 weeks) and long-term visits (1-2 months) for carrying out joint experimental and methodological research. The main partners are: the Institute Laue–Langevin (Grenoble, France), Leon Brillouin Laboratory (Saclay, France), Forschungzentrum Rossendorf (Germany), KFKI (Budapest, Hungary). Total extent of collaboration was 1 man-year. This naturally ceased when the reactor was out of operation, but has started again since the reactor was restarted in 1995.

Six-seven short-term visits are expected in 1995; this collaboration can be then extended to 1-2 man-years.

Total extent of international collaboration with Asian countries can reach 4-5 man-year. There are 5 places for accommodation.

*General information*
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E-mail: head@lnitt.kiae.su
Director of the Institute: Alexander Y. Rumiantsev
Responsible person: Victor A. Somenkov
ELECTRON ACCELERATOR SINUS-7
High-Current Electronics Institute

Date of commissioning: 1992.

**Field of science**
Physics (radio-physics and electronics, high-frequency relativistic electronics).

**Fields of research**
- Investigation of pulsed microwave-power limitations and the RF breakdown when generating electromagnetic pulses in the frequency range from 3 to 10 GHz with power over 1 GW.
- Search for the ways to decrease the magnetic field energy in efficient Cherenkov microwave generators.
- Study of various devices for stimulated electromagnetic emission of relativistic electron beams, in particular, highly efficient free-electron lasers in the frequency range up to 100 GHz.

**Main characteristics**
- Electron-beam pulse duration, ns 40
- Electron energy, MeV 2.0 1.5
- Beam current, kA 20 15
- Pulse-repetition rate, s⁻¹ 10 100
  (limited by the load)

**Major advantages**
- The cathode for the accelerator SINUS-7 has an extended emission area and a lifespan of over $10^8$ pulses.
- The power-supply system of the accelerator has been improved, so that energy efficiency from the mains to the electron beam exceeds 50% in a pulsed regime.

**Current research**
Presently, the accelerator SINUS-7 is used for generation of powerful pulses of electromagnetic radiation.
Possible research

- Applications of electron beams for structural modification of properties of materials and surfaces, for sterilisation of large surfaces in medicine and food production, for hardening of polymeric lacquers in the air, etc.
- The use of the electron accelerator as a source of hard x-rays. Contrary to traditional isotopic sources, there is no radioactive waste or induced radioactivity, and the power of x-bremsstrahlung can reach several kilowatts.
- New applications are possible in related fields, such as super-long-distance radio-location, energy transmission and conversion, and plasma heating.

Main scientific results

- The microwave-pulse power of 1.5 GW is reached in the 10 GHz frequency band.
- The conditions are set in order to increase the efficiency of the relativistic backward-wave oscillator up to 40%. Care is taken to prevent RF break-down inside microwave guiding systems.
- A free-electron laser is designed for operation at the wavelength of 4 mm.

Basic papers


Scientific and technical personnel

- 2 researchers and 3 technicians.

Possibilities for international exchange and co-operation projects

The institute has international co-operation projects with several research institutions of the United States, France, United Kingdom, and China, and it is ready to undertake research with any interested organisations.

The working and living terms for foreign specialists can be specified in a concrete co-operation agreement.

General information

High-Current Electronics Institute, Siberian Division of the Russian Academy of Sciences
4 Akademichesky Av., 634055 Tomsk
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E-mail: bugaev@hq.hcei.tomsk.su
Director of the Institute: Sergei P. Bugaev
The complex will be put into operation in 1996.

**Fields of science**

Microelectronics, micromechanics, physics, physical metallurgy, chemistry, biology, pharmacology, medicine, and metrology.

**Fields of research**

- Microelectronics: investigation and development of technological processes, production of integrated circuits and devices with submicron and nanometer dimensions.
- Micromechanics: investigation and development of technological processes for a wide range of micro-devices and micro-mechanisms, based on a “deep” x-ray lithography application.
- Physics: experimental investigations in solid-state physics, crystallophysics, and physics of semiconductors and dielectrics.
- Chemistry: experimental investigations of high-molecular organic structures and photochemistry processes.
- Materials science: investigation and production of new materials with specified properties and of structures based on these materials.
- Biology: investigation of structure and properties of biological membranes and surfaces; protein crystallography.
- Pharmacology: investigation of molecular structure of synthetic medicines.

**Main characteristics**

The complex consists of two buildings: the R&D building of 16 400 m² to house an electron-storage ring and the power building of 3 600 m². The synchrotron radiation (SR) source is an accelerator-storage complex and it consists of the following parts:

- Injector (electron linac with 80-100 MeV energy).
- A booster (small electron-storage ring with 0.4 GeV energy).
- Large electron-storage ring with energy up to 2 GeV.
Parameters of the Zelenograd SR source:

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating electron energy, GeV</td>
<td>1.2–1.6</td>
</tr>
<tr>
<td>Maximum electron energy, GeV</td>
<td>up to 2</td>
</tr>
<tr>
<td>Maximum stored current</td>
<td></td>
</tr>
<tr>
<td>Single-bunch mode, mA</td>
<td>100</td>
</tr>
<tr>
<td>Multi-bunch mode, mA</td>
<td>300</td>
</tr>
<tr>
<td>Critical wavelength of Bending magnets, nm</td>
<td>0.6–1.5</td>
</tr>
<tr>
<td>Lithography wigglers, nm</td>
<td>0.5–4</td>
</tr>
<tr>
<td>Superconducting wigglers, nm</td>
<td>0.1–0.2</td>
</tr>
<tr>
<td>Undulators, nm</td>
<td>5–50</td>
</tr>
<tr>
<td>SR pulse duration, ns</td>
<td>13</td>
</tr>
<tr>
<td>SR pulse interval, ns</td>
<td>5.5–386</td>
</tr>
<tr>
<td>Number of insertion devices</td>
<td></td>
</tr>
<tr>
<td>Lithography wigglers</td>
<td>5</td>
</tr>
<tr>
<td>Superconducting wigglers</td>
<td>2</td>
</tr>
<tr>
<td>Undulators</td>
<td>2</td>
</tr>
<tr>
<td>Number of SR beam-lines from</td>
<td></td>
</tr>
<tr>
<td>Bending magnets</td>
<td>20</td>
</tr>
<tr>
<td>Lithography wigglers</td>
<td>5</td>
</tr>
<tr>
<td>Superconducting wigglers</td>
<td>10</td>
</tr>
<tr>
<td>Undulators</td>
<td>2</td>
</tr>
<tr>
<td>Perimeter, m</td>
<td>5.73</td>
</tr>
<tr>
<td>Electron-beam life-time, h</td>
<td>5</td>
</tr>
</tbody>
</table>

The large storage ring includes six mirror-symmetric superperiods and includes 12 rectilinear sections each 3 m long. The beam-injection system, the HF resonator and also the inserted SR devices—superconductive and lithographic wigglers and undulators—are installed on rectilinear sections.

**Major advantages**

The parameters of the source make it possible to carry out simultaneously fundamental and applied investigations, resulting in development of new modern high-technology processes primarily for the electronics industry, micromechanics, etc. In accordance with the special programme, a complex of unique equipment for investigations using SR has been developed. This complex includes stations for x-ray analysis of crystals, plane-wave topography, express topography, investigation of atom-clean surfaces by the standing x-ray waves method, EXAFS spectroscopy, etc. Lithography wigglers allow one to work with SR beams $10 \times 10$ cm$^2$, which is
very important for technology. Undulators provide for investigation and development of low-temperature radiation-stimulated technological processes.

**Main scientific results**

- Technology for production of x-ray masks has been developed as well as of high-sensitivity positive and negative x-ray resists with high resolution.
- New physical models have been constructed, and new methods of investigation and computer programmes for modelling x-ray lithography processes, including the standing x-ray waves method, the methods for determination of permittivity tensor components and magnetic structure of surface and multi-layer coatings, the magnetic EXAFS-spectroscopy technique, etc.

**Scientific and technical personnel**

80 researchers and 100 technicians

**Possibilities for international exchange**

Vacancies for accommodation of foreign scientists: 10 man-years.

**General information**

The complex is situated 20 km north-west of Moscow.

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Director of the Institute: Nikolay S. Samsonov
Responsible person: Sergey N. Mazurenko
EXPERIMENTAL TEST BENCH ON THE BASE
OF A CHAMBER 13Ya-3
High Energy-Density Research Centre

Date of commissioning: 1993.

Fields of science
Physics, mechanics (thermal physics, low-temperature plasma physics, condensed-matter physics, gas dynamics, strength and failure, electro-physics, direct energy conversion, and databases).

Fields of research
Experimental methods for generation of high densities of energy; diagnostics of high-energy states; influence of powerful shock and detonation waves on materials and constructions; equations of state; transport and optical properties of materials at extreme pressures and temperatures; mechanical properties (rheology, spallation, fragmentation) of materials under shock loading; kinetic and thermo-physical properties of chemically active media under the action of intense shock waves, thermal and corpuscular loads; phase transformations under the action of shock and detonation waves; development of physical and mathematical models, data banks, and application programmes for the influence of shock and thermal waves on construction and geological materials; physical and mathematical modelling of intense pulsed impacts; tests of materials, chemically active media, and constructions under intense power actions.
**Main characteristics**

The test bench consists of a spherical metallic explosive chamber 13Ya-3 with an experimental building of test beds, control and diagnostic facilities.

The explosive chamber 13Ya-3 is 12 m in diameter, its mass is 500 tons, and it may be used for blasting charges with mass of to 100–500 kg. The experimental building provides control and diagnostics and includes 10 test beds: explosive chamber VBK-2 is for high-explosive mass up to 20 kg; capacity battery of 10 MJ (5 kV) and 1 MJ (50 kV); explosive magnet generators with peak voltage up to 500 kV; 10-mm calibre electrodynamic launch (railguns) with muzzle velocity 5-7 km/s; generators of powerful electron beams with power up to 1 MeV (Luch and Impulse test beds); microwave-pulse generator with power 100–300 MW; electro-thermal gun for launching thin foils with speeds up to 15–20 km/s.

**Major advantages**

The explosive chamber 13Ya-3 only exists in two copies and makes it possible to perform experiments with unique energetic parameters under laboratory conditions using a stationary complex of diagnostics, which is difficult or impossible at a test site.

**Current research**

Experiments are conducted along all the lines mentioned for various kinds of directed energy (electron-beam, microwave, kinetic) with power providing pressure up to 10 Mbar; there is, in particular, a large programme on transition from the combustion of large volumes of hydrogen-air mixtures to an explosion, which may occur in serious accidents in nuclear power stations; promising fundamental research concerns experiments on phase changes in the carbon system under the influence of high temperatures and pressures; this is important for designing materials with unique thermal and electro-physical properties needed for electronics and nuclear power engineering.

**Possible research**

- Debugging of new technologies for pulsed processing materials (explosive welding and hardening, powder compaction).
- Modelling of pulsed cut-off emergency valves for power-intensive productions, action of optical and microwave radiation on biological objects, etc.

**Main scientific results**

- The equations of state of engineering materials were designed for a wide area of phase diagrams.
- Study of the dynamic strength of protective shells.
- Investigation of impact initiation of chemically active materials under the action of neutron and electron beams and high-speed macrobodies.
- Mathematical models of physical processes of intense pulsed impacts in agreement with experimental data.
Basic papers


Current financial support and co-operative projects

Nine grants of the Russian Foundation for Basic Research, 7 grants of the International Science Foundation, and 7 contracts with foreign companies.

Scientific and technical personnel

92 researchers and 52 technicians.

Possibilities for international exchange

Possibilities for accommodation of foreign scientists for working at the facility: 7 persons per year.

General information

High Energy-Density Research Centre, Russian Academy of Sciences

13/19 Ishorskaya St., Moscow 127412, Russia
Phone: (095) 485-7988
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Director of the Centre: Vladimir Ye. Fortov
Responsible person: Vyacheslav A. Petukhov

EXPERIMENTAL INSTALLATION HELIUM
The most unusual part of the installation -- a nuclear demagnetisation cryostat -- was constructed in 1982.

**Fields of science**
Physics (condensed matter physics, magnetic phenomena, low temperatures and superconductivity).

**Fields of research**
Fundamental research at superlow temperatures; study of quantum liquids, quantum crystals, and solids at superlow temperatures.

**Main characteristics**
The set-up consists of a nuclear demagnetisation cryostat, two optical cryostats, and three dilution refrigerators $^3$He--$^4$He.

**Nuclear demagnetisation cryostat:**
- Minimum temperature of the $^3$H sample, $\mu$K: 120
- Minimum (calculated) temperature of electrons at the nuclear demagnetisation stage, $\mu$K: 50
- Time of warming up to 1 mK after demagnetisation, days: 2–3
- Heat leak to the demagnetisation stage, nW: 1
- Magnetic field of the demagnetisation solenoid, T: 8.9

**Optical cryostats:**
- Minimum temperature in the single mode, mK: 300
- Minimum temperature in the continuous mode, mK: 400
- Heat leak through optical windows, $\mu$W: 2
- Pressure range in the experimental cell, bar: 0–150
- Diameter of optical windows, mm: 30

**Dilution refrigerators:**
- Temperature in the continuous mode, mK: 10–20

**Major advantages**
The set-up allows one to carry out investigation of quantum liquids and crystals (normal and superfluid $^3$He, normal and superfluid $^4$He, $^3$He and $^4$He solutions, solid $^3$He and $^4$He) simultaneously under various conditions and by using various methods.

The nuclear demagnetisation cryostat is the most complex installation of the set-up. It is the only cryostat in Russia which can cool experimental samples below 1 mK. In particular, the minimum temperature of a liquid $^3$He sample, obtained using this cryostat, is about 120 $\mu$K. This result is close to the best in the world. It was achieved due to the number of original technical
features. In order to isolate the cryostat from electromagnetic radiation, the room in which it is installed is shielded by a copper screen. To decrease vibrations the low temperature part of the cryostat is mounted on a 1 000 kg concrete base suspended by long elastic ropes. The unique feature of the optical cryostats is a system for growing oriented helium monocrystals. This system, allowing one to change the orientation during experiment, is constructed on the basis of an electrical engine operating at temperature 1 K.

The dilution refrigerators allows testing experimental methods before using them in the nuclear demagnetisation cryostat.

**Current research**

- The nuclear demagnetisation cryostat is used in investigations of the non-dissipative Fermi-liquid spin currents in normal and superfluid $^3$He and in $^3$He–$^4$He solutions at temperatures about 1 mK.
- The optical cryostats are employed to study anisotropy of charge mobility in helium crystals.
- The dilution refrigerators are used for investigations of the phonons passing through a liquid helium–crystal (dielectric or semiconductor) interface.

**Possible research**

- The nuclear demagnetisation cryostat may be used in a variety of NMR experiments in quantum liquids and solids at temperatures below 1 mK.
- The optical cryostats can be employed for investigations of anisotropic surface properties of helium crystals (thermodynamics, surface phase transitions, growth kinetics).
- With the use of dilution cryostats one can investigate solids at temperatures about 10 mK using NMR and ultrasound technique.

**Main scientific results**

Investigations of superfluid $^3$He phases in the nuclear demagnetisation cryostat result in a number of discoveries. The most important is the discovery of magnetic superfluidity, i.e. non-dissipative transfer of magnetic moment while the mass current is absent (State Prize for Science, 1993). In these experiments magnetic analogues of such effects have been observed (typically for superfluid systems), such as phase slips, Josephson effect, quantum vortices, fourth sound, etc. As a result of these experiments a new field of research has appeared: spin (magnetic) superfluidity. The experiments stimulated a theory, and now it is
clear that magnetic superfluidity can be observed not only in $^3$He but in other magnetically ordered systems. New NMR methods have been developed with the use of the phenomenon of magnetic superfluidity.

The most important result obtained in optical cryostats is the discovery of new macroscopic quantum phenomena: quantum crystallisation and crystallisation waves, i.e. non-dissipative melting-crystallisation waves on the liquid helium–crystal surface (Lenin Prize for Science, 1986).

During recent years there has been a systematic investigation of phonons passing through the liquid helium–metal interface at superlow temperatures using dilution refrigerators.

**Basic papers**


Yu.M. Bunkov et al. (1989), Catastrophic Relaxation in $^3$He–B at 0.4TC. *Europhys. Lett.* Vol. 8, p. 645.


V.V. Dmitriev et al. (1995), Coherently precessing spin state in normal $^3$He in pulsed NMR. *Pisma v ZhETF*, Vol. 61, p. 309.

**Current financial support and co-operative projects**


Grants of International Science Foundation: M1C000, M5C000, and N8G000.

Joint projects (Grants of INTAS):1010-CT93-0045 (in collaboration with the Leiden University, Holland), and 1010-CT93-0051 (in collaboration with the National Center for Scientific Research, Grenoble, France)

**Scientific and technical personnel**

17 researchers and 7 technicians.

**Possibilities for international exchange**

For work at the facility under international exchange, the Institute can receive 5 persons per year.
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Fax: (095) 938-2030
E-mail: andreev@magnit.msk.su
Director of the Institute: Alexander F. Andreev
Responsible person: Alla V. Buklina
Date of commissioning: 1967.

Field of science
Physics (experimental solid-state physics).

Field of research
Study of transport phenomena, magneto-optical phenomena and magnetic properties of solids in strong magnetic fields, including continuous ones.

The main parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of magnetic fields, kOe</td>
<td>up to 200</td>
</tr>
<tr>
<td>Power supply, MW</td>
<td>9</td>
</tr>
<tr>
<td>Bore diameter of the warm-field magnet, mm</td>
<td></td>
</tr>
<tr>
<td>($H&lt;200$ kOe)</td>
<td>30</td>
</tr>
<tr>
<td>($H&lt;150$ kOe)</td>
<td>55</td>
</tr>
<tr>
<td>($H&lt;100$ kOe)</td>
<td>110</td>
</tr>
</tbody>
</table>

An automated system of control and data acquisition includes four simultaneously recording DC channels with 0.1 $\mu$V resolution and magnetic-field sweep control.

Cryogenic systems and high-temperature devices operate in the temperature interval of 0.35–600 K.

Major advantages
The solenoid installation is a complicated assemblage consisting of a Bitter-type water-cooled magnet, the high-power and high-current supply based on motor generators and two water cooling circuits. The installation is the one of 10 similar installations in the world and takes the third place in terms of power supply [after the National Magnetic Field Laboratory (United States) and the Grenoble Centre (France), of about 10 MW]. The advantage of the solenoid is the fast swept magnetic field, which is not accessible in superconducting or hybrid-type magnetic systems and provides a highly efficient data acquisition system. An original magnet design allows maintenance to be carried out after over 1 000 h.
A set of special spectroscopic, cryogenic and high-temperature equipment provides for experiments in all fields of modern solid-state physics, including experiments in high magnetic fields with microwave radiation of millimeter wavelengths.

**Current research**

- Study of superconducting magnetic properties and critical behaviour of novel amorphous materials and metastable solid solutions synthesised under high pressure.
- Investigation of galvano-magnetic and thermo-electrical properties of heavy-fermion systems.
- Observation of cyclotron resonance in quasi-two-dimensional organic conductors.
- Study of hopping conductivity in amorphous semiconductors.

**Possible research**

- Study of galvano-magnetic and magneto-optical properties of hetero-structures and super-lattices.

**Main scientific results**

- Discovery of the magnetic breakdown phenomenon, when studying the Fermi surface of tellurium.
- Discovery of magnetic resonances in various antiferromagnets and ferromagnets.
- Discovery of amorphisation-induced superconductivity in amorphous semiconductors prepared by high-pressure quenching.
- Establishment of a microscopic mechanism for enhancing superconductivity in metastable aluminium–silicon solid solutions, increasing critical temperature 7–10 times.
- Determination of the structure of resonant magneto-absorption and discovery of cyclotron resonance in quasi-two-dimensional organic metals.

**Basic papers**


**Current financial support and co-operative projects**

Grant of the Russian Foundation for Basic Research:

The medium-range order, localisation of electronic states, dynamic and static hopping conductivity in amorphous semiconductors obtained by quenching under high pressure (95-02-03815a).

Grants of INTAS:

Quantum and quasi-classical magneto-oscillations of electron systems in low-dimensional organic metals and superconductors, studied by means of galvano-magnetic, thermal, and magneto-optical measurements (93-2400).
Experimental and theoretical studies of effective-mass renormalisation in organic molecular metals (94-1788).

International research project of the Ministry of Science and Technological Policy of Russian Federation:

The new materials.

Joint project of the Royal Society between the General Physics Institute and the Clarendon Laboratory, University of Oxford;
Study of magneto-transport and magneto-optical phenomena in organic molecular metals, semiconductors, and superconductors.

**General information**

General Physics Institute, Russian Academy of Sciences

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E-mail: demis@magopt.gpi.msk.su
Director of the Institute: Alexander M. Prokhorov
Responsible person: S.V. Demishev
SUBMILLIMETER BWO-SPECTROMETER EPSILON
General Physics Institute

Date of commissioning: 1982.

Field of science
Physics (radio-physics, condensed matter physics).

Field of research
Far-infrared and microwave spectroscopy, characterisation of microwave and infrared devices, materials science, lattice dynamics, mechanisms of conductivity and relaxation, ionic transport, superconductivity.

Main characteristics
Composition
set of millimeter–submillimeter generators (BWOs);
high-voltage stabilised supply system (6.5 kV);
high-precision recording system;
quasi-optical measuring equipment.

Measurable spectra
transmissivity  $T(\nu) = t(\nu)e^{i\phi(\nu)}$
reflectivity  $R(\nu) = r(\nu)e^{i\phi(\nu)}$
refractive coefficient  $N(\nu) = n(\nu)+ik(\nu)$
dielectric function  $\varepsilon(\nu) = \varepsilon'(\nu)+i\varepsilon''(\nu)$
dynamic conductivity  $\Sigma(\nu) = \Sigma'(\nu)+i\Sigma''(\nu)$
magnetic permeability  $\mu(\nu) = \mu'(\nu)+i\mu''(\nu)$
loss tangent  $\tan \delta$
absorption coefficient  $\alpha(\nu)$
birefringence  $\Delta n(\nu)$

Operating frequency range
basic  $\nu = 100–1000$ GHz
optional  $\nu = 60–1200$ GHz

Frequency resolution
$\nu/\nu \sim 10^{-4}–10^{-5}$
on average  0.001 cm$^{-1}$

Dynamic range
40–45 dB
optional  45–60 dB
signal/noise ratio  $10^3–10^6$

Polarisation degree of operating radiation  99.99%
Temperature range of measurements  2–1000 K

Major advantages
The submillimeter BWO-spectrometer Epsilon is a unique device with no analogues in the world. It was designed to fill up a methodological gap in radio-spectroscopy between microwave and far-infrared techniques. It is a multi-purpose instrument for basic research and characterisation of materials and devices in the millimeter–submillimeter range ($\lambda = 5–0.2$ mm). The unique feature of Epsilon is the use of special radiation sources—the short-wave backward-wave oscillators (BWO)—adopted for research from the defence industry and available exclusively in Russia. BWOs generate an intensive monochromatic instrumental line with electronically tuneable
frequency, providing a perfect tool for spectroscopic measurements. The measurement methods installed in the Epsilon combine the advantages of both microwave and infrared techniques—high-quality working radiation and wide range quasi-optical measuring schemes. As a result, information of the highest quality is recorded in real time, yielding the spectra of absolute values of real and imaginary parts of electrodynamic response or dielectric function. At present the Epsilon is unrivalled for fast and precise submillimeter measurements.

**Current research**

The frequency-temperature behaviour of dielectric response function in substances of different classes—simple dielectrics, ferroelectrics, ionic conductors, dipole glasses, incommensurate crystals, semiconductors, superconductors, low-dimensional conductors and antiferromagnets—has been studied. Thousands of samples—single crystals and ceramics, glasses and polymers, powders, composites, liquids, films and fibres, as well as various radio-physical devices such as cut-off and band-pass filters, beam splitters, resonators, frequency meters, substrates, attenuators, polarisers, lenses, etc. -- have been investigated in the frequency range of $10^{11} - 10^{12}$ Hz which is difficult to access. New reference data on dielectric submillimeter properties of microwave and optical materials have been accumulated.

**Main scientific results**

- Detailed data were found on the soft modes and central peaks in classical and new ferroelectrics.
- Brillouin zone folding was discovered in some ferroelectric, super-ionic and semiconducting layered crystals.
- Ferroelectricity and the incommensurate state were discovered in the family of triple semiconducting crystals of the TlGaSe$_2$ type.
- Unknown phase transitions were discovered in some ferroelectric and super-ionic crystals.
- Eigen-excitation of the incommensurate crystalline phase were detected.
- General features of ionic conductivity were revealed in super-ionic conductors.
- A coherent peak was detected in a conventional superconducting compound NbN.
- Unpinned Frohlich mode and charge-density-wave fluctuation effects were observed in a number of low-dimensional conducting crystals.
- Magnon behaviour in antiferromagnets was comprehensively explained.

**Possible research**

- BWO data are pertinent in the fields of microwave and infrared spectroscopies, laser physics, plasma diagnostics, and astronomy.
- BWO techniques can be used for the measurement of liquids in medicine and biology.
- BWOs are promising for the development of all-wavelength dielectric spectroscopy.
Use of higher-speed detectors, control elements, and new software opens the possibility of investigating fast processes in substances.

Quasi-optical BWO techniques are very well suited to demonstrations and this makes them unique educational equipment for students in the field of radio-physics.

**Basic papers**


**Current financial support and co-operative projects**

Grants of the Russian Foundation for Basic Research: 93-02-16110, 93-02-15910, 93-02-17123.
Grants of the International Science Foundation: MCX000, MH100, SE6000.
United States NSF Grant (collaboration with the University of California): NDMR 9216500.
Grant of the Russian Ministry of Science and Technological Policy.

**Scientific and technical personnel**

10 researchers and 3 technicians.

**Possibilities for international exchange**

The institute can receive 4 foreign scientists per year for work at the Epsilon.
Vacancies for accommodation of foreign specialists: 4 persons per year.
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Director of the Institute: Alexander M. Prokhorov
Responsible person: Alexander A. Volkov