International Seminar on

ADVANCED PULSED NEUTRON SOURCES

PANS-II

June 14 – 16, 1994, Dubna, Russia

ABSTRACT

Dubna, 1994

Frank Laboratory of Neutron Physics
Joint Institute for Nuclear Research
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International Seminar on

ADVANCED PULSED NEUTRON SOURCES :
Physics of/at Advanced Pulsed Neutron Sources
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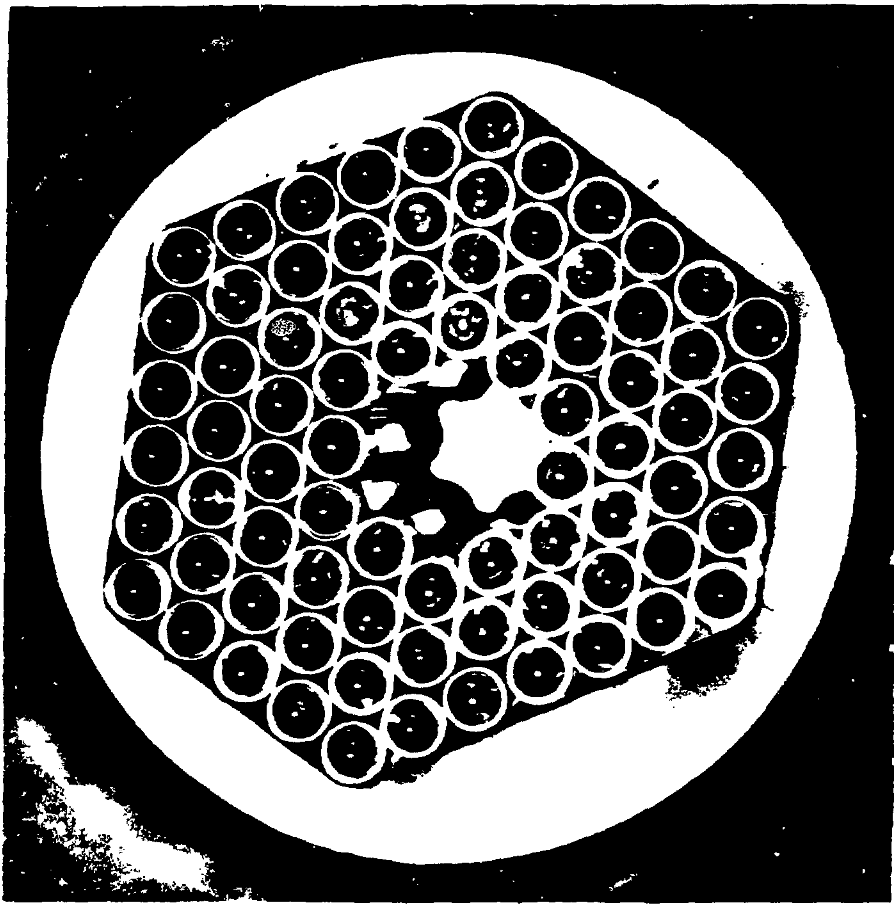

INVITED TALKS

COMPUTER SIMULATIONS OF HOMOGENEOUS WATER SOLUTION PULSE REACTORS

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Several new computer models for simulating the behavior of homogeneous water solution pulse reactors have been proposed and tested in recent years. These models have attempted to predict transient pressures and kinetic energy as well as peak fission rates and energy yields. Both single-region models and multy-region models have been developed, and various methods for representing the production of radiolytic gas have been tried.

The most recent model for radiolytic gas recognizes that inertial pressure in solutions has two components. The lag in thermal expansion during a rapid nuclear excurtion could produce inertial pressure in any fuel-bearing material. In a water solution, the rapid formation of radiolytic gas bubbles may produce additional pressure by causing a transient compression of the surrounding liquid.

The amount of gas in the form of bubbles depends on the fission rate, the dissolved gas concentration, and the pressure. A power excurtion is visualized as having three stages, each with its own mechanism for gas void formation.

The first stage extends from the start of the excursion to the point of threshold, or saturation, concentration. During this stage, short-lived microscoping bubbles are formed by each fission fragment. these bubbles are very sall, but they contribute enough void volume to produce an increase in isothermal compressibility.

The second stage is from the point of threshold concentration to the moment of peak pressure. A fraction of the bubbles produced by fission tracks are thought to grow very rapidly ba the diffusion of the dissolved gas. We believe that bubbles formed during this stage may utilize only about ten percent of the dissolved gas available.

The final stage occurs immediately after peak pressure. The sudden relief of pressure forces the remaining excess gas rapidly out of solution in a process similar to violent cavitation. The result is a violent disassembly with rapidly decreasing fission rate and a highly assymetric pulse shape.

Computed results have been compared to experiental data from pulse reactors and simulated criticality accidents in the United States and in France. This paper is a review and comparison of some of the models, together with some historical observations and some applications of the models to criticality accident simulation.

PULSED NEUTRON SOURCES FOR PHYSICAL RESEARCH

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A conceptual discussion on creating intense pulsed neutron sources based on medium-energy high-current proton accelerators and multiplying targets with limited multiplication is presented. The features and limitations of these schemes are considered.

Possibilities of creating Super-intense neutron sources for physical research with an effective proton beam power (relative to pure spallation sources) of about 10 MW on the basis of "old" technologies are discussed.

DEVELOPMENT OF HIGH-EFFICIENCY MODERATORS FOR PULSED NEUTRON SOURCES

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The present paper summerizes the recent progress in high-efficiency moderator developments in Japan in connection with the KENS-II program (pulsed spallation neutron source program in Japan). Various moderators such as coupled liquid hydrogen moderators for cold neutron experiments, composit moderators for narrow pulses of thermal neutrons, extended moderators, overlaped moderators, back-scattering moderators, etc. were studied experimentally in order to realize a higher moderator-efficiency. Various premoderators, target-moderator coupling configurations were also studied. We

discuss about the pulse tailoring and the flux peaking in the spatial distribution for small-angle and critical scattering experiments.

NEUTRONICS OF COUPLED SOLID METHANE MODERATOR WITH PREMODERATOR

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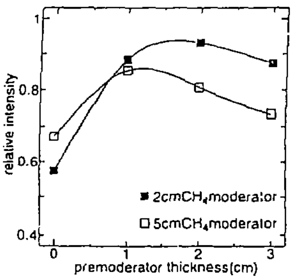
The effect of the premoderator of neutronic performance was studied for a coupled solid methane moderator system in a pulsed neutron source. Figure 1 shows relative intensities of cold neutrons (4.3~5.7A) as a function of polyethylene premoderator thickness for solid methane moderators of two different thicknesses (2cm and 5cm). The maximum values of premoderator gain factors (relative intensity with premoderator to without) are about 1.3 and 1.7 at premoderator thicknesses of 1 cm and 2 cm, respectively. Although the gain factors are not so large as those in a coupled liquid hydrogen system, there exists a fine gain for thin solid methane (2~5 cm). However, the optimal premoderator thickness is smaller than in the case of the coupled liquid hydrogen system.

The pulse characteristics are also measured at the optimal premoderator thicknesses and compared with those for a coupled liquid hydrogen moderator system. Figure 2 shows full widths at half maximum (FWHM) of a pulse. The FWHM values for the 5 cm thick solid methane moderator are the smallest over the wavelength range studied. This is due to the superior energy exchange mechanism of solid methane. The FWHM's of the 2 cm solid methane are narrower than those of the 5 cm thick coupled liquid hydrogen moderator.

As a conclusion, the neutronic performance of a thin solid methane moderator is almost the same as that of the reference moderator (the 5 cm thick coupled liquid hydrogen moderator with a 2 cm thick premoderator) as far as the premoderator is thin (1~2 cm). Beyond this thickness a premoderator acts as an attenuator.



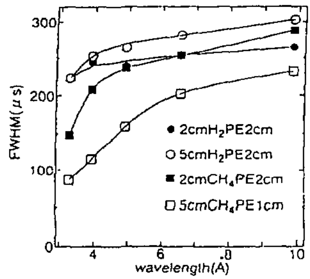


Fig.1: Intensity gain by premoderator **Fig.2** Full width at half maximum of the pulse

THE IPNS UPGRADE: FEASIBILITY STUDY OF A 1-MW PULSED SPALLATION NEUTRON SOURCE.

J.M.Carpenter

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RAPIDLY PULSED TRIGA REACTOR: AN INTENSE SOURCE FOR NEUTRON SCATTERING EXPERIMENTS

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The need for ever increasing intensities of thermal neutron beams for neutron scattering experiments has stimulated the development of increase study state research reactors such as the 53-MW ILL reactor at Grenoble. The source flux at the reactor end of the beam ports is typically $10^{15}n/cm^2s$ for its thermal neutron beams. To achieve still higher source fluxes of neutrons, the family of pulsing IBR was developed. In this type of facility the pulse repetition rate is low (~5/sec) typically but the instantaneous peak fluxes are high, ranging up to 5 x $10^{15}n/cm^2 \cdot s$ at the surface of the moderator[1]. Another type of intense neutron source is that exemplified by the proton synchrotron accelerators with their spallation targets. The first of these has been the IPNS at Argonne National Laboratory. This neutron source produces 30 pulses per second with an individual peak thermal neutron intensity of 4 x $10^{14}n/cm^2 \cdot s$ from the moderator[1].

An equivalent, alternative intense neutron source can be based on a rapidly pulsed TRIGA reactor. With a pulsed thermal neutron intensity of more than $10^{15}n/cm^2 \cdot s$ occurring 50 times per second at the source end of beam ports, the rapidly pulsed TRIGA reactor combines some of the best features of the pulsed fast reactors such as IBR-2 and the spallation neutron sources but with the safety of a thermal neutron reactor with a large, prompt, negative temperature coefficient of reactivity. The initial concept of the rapidly pulsed TRIGA reactor was developed and initially reported in 1966[2]. Subsequently, the standart fuel format for U-ZrH_x fuel has been developed to include a small diameter fuel particularly well suited for the rapidly pulsed application. This fuel is LEU, satisfying all the requirements for non proliferation, and has a very long core life time. In the proposed application, the peak fuel temperature does not vary more than 1° C from the average peak fuel temmperatures during each pulse. Hence long term metallurgical stability is thus assured. With a core lifetime that can be designed for up to 10,000 MWD, operation at an average power of 10MW (with peak pulsed powers of 50 MW) with an equilibrium core can be conducted for 1000 full power days.

A possibly significant advantage of the rapidly pulsed TRIGA reactor for cold neutron production is that the cold source moderator can be as large as required to optimize the production of cold neutrons. A neutron beam chopper near the reactor will be needed to provide the necessary narrow pulses for time-of-flight studies. By contrast, the cold source moderator for the pulsed spallation targets uses a relatively small cold source moderator to produce a relatively short pulse width of the moderated cold neutrons. This design usually eliminates the need for a chopper near the moderator but does sacrifice some of the cold neutron intensity, especially if a "*poisoned*" moderator is used.

The safety of TRIGA reactor, based as it is on the U-ZrH_x fuel matrix, is well recognized internationally and applies as well to the rapidly pulsed TRIGA reactor. The large prompt negative temperature coefficient of reactivity assures that the pulsing operations can be conducted in safety. Should the rotating wheel used to pulse TRIGA reactor repetitevly fail introducing a large uncompensated reactivity, the fuel whould be undanged. The reason is that TRIGA fuel has been pulsed routinely to produce up to 23000 MW peak pulsed power without fuel damage in the ACPR TRIGA reactor at the JAERI NSRR laboratory[3]. The safety is also augmemted by the large retention of fission products within the fuel matrix even if the clad is accidentally breached at high, operating fuel temperatures. As a consequence of this fact, a confinement, not containment, building can be used to house the reactor. The present day 16.5-MW Romanian TRIGA is housed in a confinement building during its successful operation which started in 1979 and continues to the present.

The multiply pulsed TRIGA reactor has already been used for several applications requiring pulses every few seconds. An example was reported in 1973[4] in which frequent large pulses were planned for reactor induced laser emission. A more recent application has been proposed for producing a long series of neutron radiographs of a large, moving object. A pulsed repetition rate of a 100 MW pulse every 6 seconds was proposed to provide an essentially continuous radiograph of the long object.

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SOLID METHANE MODERATOR ACTIVITIES AT IPNS

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THE ISIS LIQUID METHANE MODERATOR

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Rutherford Appleton Laboratory, UK

A liquid methane moderator has been used on ISIS since the start of operation in 1985. The cryogenic system is described. Radiation damage to the methane has proved to be a serious operational problem and to date four moderators have been used. The experience at ISIS is described and the development programme to increase the lifetime of the moderator is outlined.

A FEASIBILITY STUDY FOR A ONE-MEGAWATT PULSED SPALLATION SOURCE AT LOS ALAMOS NATIONAL LABORATORY

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A team at Los Alamos National Laboratory has undertaken a feasibility study for a 1 MW pulsed spallation source (PSS) based on the use of the existing 800 MeV linac at the Los Alamos Meson Physics Facility (LAMPF). The proposed facility will use an accumulator ring to compress the proton beam pulses to about $0.5\mu sec$. Sixty proton pulses per second will be shared between two target stations, one operating at 20 Hz and the other at 40 Hz. Vertical injection of the proton beam into tungsten targets will ensure the maximum possible access for experimenters, and about 20 flight paths will be serviced by each target station. Two methods of cooling the targets have been examined, one involving the use of a rod bundle and the other based on the technology of micro-channel plates. Either method appears feasible. Ambient temperature and cooled moderators are planned at each target station, and the Los Alamos team is working tc optimize the performance of these by exploring combinations of flux-trap geometries, forward and back-scattering, and coposite moderators. Progress on this feasibility study was recently reviewed by a large group of accelerator and target experts who identified a number of issues, such as remote handling, that require further study. The present status of this one-going study will be the subject of the talk.

ORAL CONTRIBUTIONS

THE IBR–2 PULSED RESEARCH REACTOR: STATUS REPORT

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The IBR–2 pulsed reactor of periodical operation occupies an intermediate position between reactors of conventional type, single pulse reactors, and spallation neutron sources. It has an advantage of both rather high time–averaged neutron flux and peak neutron flux, which is required for studying both static and dynamic properties of condensed matter with time–of–flight neutron scattering methods.

The IBR-2 reactor was put into permanent operation in April 1984. Its main characteristics are:

- pulse duration 216 mcsec;
- pulse frequency 5 pps;
- peak power 1500 MW;
- mean power 2 MW;
- peak thermal neutron flux (near the core) 1E16 $n/cm^2/s$.

The reactor had been operated for 10 years without accidents. It works 110 days per year; liquid sodium coolant loops are working permanently. There were two shut–downs for changing MR about one year each.

The IBR-2 reactor is well suited for condensed matter researches, especially with cold neutrons. It has all capabilities of being the most powerful intense source of cold neutrons. To reach this goal, a solid methane moderator was designed, constructed and tested at a data–sheet power of 2 MW. Due to its rather high mean power, the IBR–2 reactor is successfully used for applied research, including neutron activation analysis, neutron doping of silicon crystals, radioisotope production, and coloring gems.

THE EUROPEAN SPALLATION NEUTRON SOURCE PROJECT ESS

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The status of the European Spallation Source (ESS) project is presented. The basic parameters agreed on are a 5 MW proton accelerator delivering short bursts of tp$\leq 1\mu$s at a repetition rate of 50 Hz. The accelerator concept comprises a normal or superconducting linac and an adequate number of pulse compressors (storage rings or one or the other type of synchrotrons). Two target stations are envisaged, a high power target taking 4 MW (four out of five accelerator pulses) and a low power target at 1 MW and 10 Hz. A two year feasibility study supported by the European Union has just started. It is meant to identify the problems of the different accelerator options, select from a series of possible target solutions including stationary, moving or liquid metal targets and provide a cost estimate of the entire facility.

THE HIGH-LUMINOSITY LEAD SLOWING-DOWN NEUTRON SPECTROMETER DRIVEN BY THE PROTON LINAC OF THE MOSCOW MESON FACTORY

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Construction of the high-luminosity lead slowing-down neutron spectrometer driven by the proton linac of the Moscow Meson Factory is nearing completion at INR RAS. The spectrometer is the cube of lead of especial purity (99,99 %) weighing 10 tons and embracing the section of the linac proton pipe with the lead target. It is planned to be used for the measurements at the proton energies 100eV<E<50 Kev. In this region the spectrometer would have record luminosity (and the neutron intensity of $\sim 7 \cdot 10^{13}$ n/s.)

The programme for experimental investigations is outlined in this report. Feasibility of generating the Maxwellian spectrum neutron fluxes at temperatures up to 30-50 KeV for measuring the reaction cross sections necessary for nucleosynthesis calculations by using a special attachment to the spectrometer (a lead block of special configuration containing neutron absorbers and moderators) is also discussed.

THE PULSED NEUTRON SOURCE FOR THE MOSCOW MESON FACTORY ON THE BASIS OF URANIUM TARGETS

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I.T.Tretiakov, V.I.Trushkin
Research and Development Institute for Energotechnics A.D.Rogov
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The paper presents a concept of uranium targets for the Moscow meson factory, introduces the basis for choosing the geometry and the material (U_3Si) of the target, and gives the details of the fuel elements. The results of neutronics computations, the data on the corrosion rates of chosen materials and the measures for providing their compatibility are presented. The advantages of the chosen fuel composition over other compositions, the design details and a possible alternative version are discussed.

THE INTENSE PULSED NEUTRON SOURCE FOR THE IN-06 MOSCOW MESON FACTORY

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The pulsed neutron source with the peak thermal neutron fux density of $\simeq 5 \cdot 10^{15} n/cm^2 s$ and the beam-stop facility with the neutron flux density inside the radiation channel of $\sim 5 \cdot 10^{14} n/cm^2 s$ is described. The main design features and the physical characteristics of the shielding, the targets and the auxiliary equipment are presented.

ADVANCED NEUTRON SOURCE FOR PHYSICAL RESEARCH

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The possibility of creating a super-intense pulsed neutron source for solid state research on the basis of the 10 GeV fast-cycling proton synchrotron and the liquid-metal Pb-Bi and PuO_2 -Na multiplying targets is discussed. The thermal neutron peak flux as high as $\simeq 10^{18} n/cm^2 s$ is expected to be achieved using this scheme.

THE PULSED NEUTRON SOURCE FOR THE MOSCOW MESON FACTORY. SECOND GENERATION

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The possibility of creating an intense pulsed neutron source of the next generation based on a modernized linear accelerator, a storage ring and a uranium multiplying target with a liquid-metal coolant to operate in existing experimental buildings is considered. It is expected to have the peak flux of thermal neutrons on the surface of the water moderator as high as $2*10^{17} n/cm^2 s$ and the pulse duration of about 30 μs. The main aspects of the accelerator, storage ring and target design are discussed.

ON SOME USUAL AND UNUSUAL APPLICATIONS OF THE NEUTRON

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Russian Research Centre "Kurchatov Institute"

This report deals with the problems of using pulsed neutron sources for experiments on neutron scattering on microsamples, in particular for the experiments conducted at high pressure and with highly irradiated samples. Some possibilities of using pulsed sources for investigations in the Earth's atmosphere and space are discussed.

EXPANDING THE FRONTIERS OF NEUTRON SCATTERING

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Accelerator based pulsed neutron sources have in recent years significantly expanded the frontiers of neutron scattering as a microscopic probe of the condensed states of matter. This talk discusses why such sources have been developed, and what their advantages are over conventional steady state reactors. Particular preference is made to the most advanced of the present generation of pulsed neutron sources, the UK pulsed spallation source ISIS. Scientifis advantages are illustrated using recent examples of structural and dynamical studies from the science programme at ISIS. The development potential of pulsed sources, both in terms of new instrumentation and new sources, is also discussed, with particular reference to the proposed European Spallation Source.

NEUTRON-AIDED INVESTIGATIONS OF CONDENSED MATTER AT PULSED SOURCES

I.P.Sadikov
Russian Research Centre "Kurchatov Institute"

Results of a number of investigations of the condensed state of matter carried out at the pulsed neutron sources : "Fakel" (Kurchatov Institute), ISIS (RAL) and IBR-2 (JINR), are presented.

1. Structure and dynamics of quantum systems (isotopes of molecular hydrogen) under high pressure (phase diagrams, equation of state, zero vibrations and phonon spectra, short-range peculiarities in the liquid state, etc.).

2. Short-range structure of amorphous binar alloys (on a level of partial functions of a radial distribution) with different kind bonds: metal-metal and

metal-metalloid (influence of the dimensional effect, atom concentrations, etc.).

3. Magnetic and phonon excitations in strongly correlated intermetallides on the basis of light rare-earth metals (inter-valence and heavy-fermion states: relaxation spectra, ... effects, partial densities of phonon states, inter-multiplet transitions).

PLUTONIUM BOOSTER IREN: STATUS OF THE PROJECT, DESIGN TOPICS

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and

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The plutonium concept of the 150 MeV linac–based booster IREN is presented as the final version of the new pulsed neutron source for nuclear physics in Frank Laboratory, JINR. The compact core containing 17.6 kg of plutonium and nonfissile electron target of the 150–MeV, 10– kWt 300–ns linac permits to get the time averaged intensity of the source over 10^{15} neutr/s at a fast neutron pulse duration of no more than 0.5 μs. The gain factor for the neutron flux density at the surface of the moderator is equal to 2 in comparison with the previous (uranium) version of the core.

The results of the Monte Carlo calculation of the core as well as electron–photon showers simulation in the target media are presented. The targets based on natural convection and the so called 'water-lift' cooling mechanisms are discussed in comparison with the traditional helium cooled convertor. The advantages of the beryllium beam scatterer, proposed for decreasing the energy deposition density in the heavy metal of the convertor, are also discussed.

NEUTRON SPECTROSCOPY AT THE IBR-2 PULSED REACTOR

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Instruments for inelastic neutron scattering (INS) at IBR-2 have two different modifications: "direct geometry" – based on the monochromatization of incident and time–of–flight (TOF) analysis of scattered neutrons, and "inverted geometry" – using the TOF analysis of incident and monochromatization of scattered neutrons. Two direct geometry spectrometers, DIN–2PI and DIN–PR [1,2], act in parallel on one neutron beam–line at distances of 20 m and 95 m from the reactor core. Both spectrometers are equipped with a set of curved-slit and background choppers, which offer a wide range of incident energies: 1–50 meV and 2–500 meV, with a resolution of 4-10 % and 2.5–13 %, respectively. Multi–detector systems with a wide range of scattering angles: 5–135 and 3–163 degrees, are placed at sample–detector distances of 7 m and 10 m, respectively. These parameters offer a wide range of energy and momentum transfers, as well as resolutions for atomic dynamics investigations in liquids and solids. The main application of these spectrometers is the investigation of: atomic dynamics in quantum and classical liquids, liquid metals, lattice dynamics of metals and alloys, local vibrations of interstitials in alloys, etc. Two inverted geometry spectrometers, KDSOG–M [3] and NERA–PR [4], which offer different luminosity and resolution, are located at distances of 29 m and 109 m from the reactor core, respectively. Energy analyses of scattered neutrons is performed with the help of pyrolitic graphite plates installed behind berylium filters. The higher luminosity KDSOG-M spectrometer is mainly intended for studies of crystal–field transitions in rare–earth alloys and vibrational spectroscopy of materials with a low concentration of hydrogen atoms. The multicrystal energy analyzing system of the NERA–PR high resolution spectrometer allows one to investigate the INS spectra (within a resolution of 2–5 % up to an energy transfer ca. 500 meV), and quasielastic neutron scattering (QNS) with an energy resolution of 0.03 - 0.05 meV. Simultanously, the neutron diffraction spectra of a sample under investigations can be recorded, within a resolution better than 1 % over a wide range (0.1 - 0.7 nm) of neutron wavelengths. Thus, it allows one to simultaneously investigate the dynamics and the structure of substances exhibiting phase polymorphism. It is especially suited to studies of liquid and plastic crystals in which phase transitions are accompanied by changes in structure, lattice dynamics and stochastic motions of molecules or molecular groups. Most representative investigations will be shortly reviewed.

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HIGH-INTENSITY NEUTRON SOURCE ON THE BASIS OF POWERFUL PULSED ELECTRON ACCELERATOR LIU-30 AND PULSED NUCLEAR REACTOR BR-1

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The results of experimental investigations aimed at development of a high-intensity neutron source on the basis of the powerful pulsed machines: the LIU-30 accelerator and the BR-1 reactor, are presented. The results have been obtained in joint operation of the accelerator with a composite tungsten target and the reactor in different states above delayed criticality, including supeprompt-criticality states. Steady synchronous operation of the complicated nuclear physics machines to generate a powerful neutron pulse with the neutron yieldt of up to 10^{14} neutrons from the accelerator target (for the intensity of up to $5 \cdot 10^{21}$ neutrons/sec) with simultaneous emission of up to $5 \cdot 10^{17}$ neutrons from the reactor core has been confirmed for the accelerator target - reactor core distance of about 0.9 m.

ON INVESTIGATION OF THE POSSIBILITY OF CREATING A PULSED NEUTRON SOURCE BASED ON A POWERFUL ELECTRON ACCELERATOR AND A PULSED NUCLEAR REACTOR

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The results of an experimental investigation (1986) for realization of joint operation of a powerful electron accelerator and a pulsed nuclear reactor aimed at creating a powerful neutron source are presented. Synchronized operation of the LIU–10 accelerator (13 MeV, 40 kA, $15 \cdot 10^{-9}$ sec, 10^{12} neutrons/pulse) and the GIR reactor ($7 \cdot 10^{16}$ fissions, $3 \cdot 10^{-4}$ sec) has been realized to generate a fission pulse. Composite photoneutron tantalum – lead and tantalum – beryllium targets were used. For the first time experiments on direct irradiation of a reactor core with a powerful electron beam in the moment when the reactor achieves a super-criticality state for prompt neutrons have been performed. The obtained results were used for designing the high–intensity neutron source based on the LIU–30 accelerator and the BR–1 reactor.

A COLD MODERATOR AT IBR-2 AS THE BASIS OF THE NEW POSSIBILITIES IN NEUTRON SCATTERING STUDIES

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The experience of operating IBR–2 with solid methane moderator (T ¡ 30 K) demonstrated the power of such combination on the DN–2 diffractometer in the backscattering time–resolved mode ($\Delta d/d \simeq 5 \cdot 10^{-3}$). Due to enhanced flux of neutrons with the wavelength $\lambda > 6$ Å (by $\approx$ 20–30 times as compared to water moderator), it turned out to be possible to distinguish immediately (without any procedure of deconvolution) all different phases in the mixture of $YBa_2Cu_3O_{7-\delta}$ compound and its derivatives ($Y_2Cu_2O_5$, Y_2O_3, Y_2BaCuO_5). In order to have the similar effect in the λ–interval < 6 Å the resolution $\Delta d/d \approx 5 \cdot 10^{-4}$ is required. Taking into account that a minute exposition is enough to have appropriate statistics, it is clear that quite new possibilities are offered in studying transient phenomena and chemical reactions.

ULTRACOLD NEUTRON (UCN) GENERATOR AT THE BIGR REACTOR (ARZAMAS-16)

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The experimental feasibility of the UCN setup depends on the UCN density. Now, the maximal value of UCN density is 50 $n \cdot cm^{-3}$ and it is obviously the highest density, that can be achieved at stationary reactors using the traditional methods of UCN producing. The long-term prospects of UCN physics in our view are associated with using pulsed reactors for UCN producing. It will allow the UCN generation to have densities corresponding to the peak flux densities of thermal neutrons at pulsed reactors. The pulse value of thermal neutron flux density inside the moderator (polyethylene) located near the core of the BIGR reactor is $5 \cdot 10^{17}$ cm^{-2} s^{-1} that is more than two orders of magnitude higher than at the best stationary reactors. The dynamic converters method [1] (extraction of UCN from the entire volume of the converter) also gives much than an order of magnitude increase in UCN density. We are planning to do away with the traditional method of UCN extraction - neutron guides, but to make use UCN transportation from the reactor hall in to an evacuated trap. Such a method will permit one to keep the initial UCN density. The modeling experiments at the BIGR reactor show that the induced beta-gamma activity of a steel trap does not influence the operation of neutron counters The final test of the setup in Dubna is planned to be in July 1994 and the first measurements in Arzamas-16 in December 1994. The number of UCN, produced per one pulse of the BIGR reactor is expected to be about 10^9 in 2 liters trap. It gives the possibility to carry out neutron lifetime measurements (first planned experiment with the pulsed UCN generator) with an accuracy of about 1% per one pulse.

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NEUTRON OPTICS FACILITIES AT IBR-2 HIGH FLUX PULSED REACTOR

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The property of the neutron to be reflected from interfaces of media has found broad application in experimental neutron physics. For a long time this property has been employed to form neutron beams using mirrors and neutrons for research reactors. It has been about ten years since this property was first applied to the investigation of physical properties of surfaces and thin films. Now, the method of neutron reflectometry is widely used in the physics of surfaces (see, for example, the proceedings of recent conferences dedicated to the investigation of surfaces with X-rays and neutrons). Since 1989, a neutron reflectometer (SPN) has been successfully operating in Dubna, and now,the construction of a two-reflectometer complex, with unpolarized (REFLEX-1) and polarized (REFLEX-2) neutrons, is nearing completion. This talk is dedicated to the Polarised Neutron Spectrometer(SPN-1) and new reflectometer REFLEX being built at the high flux pulsed reactor IBR-2. In designing the REFLEX we based on the experience of the world leading laboratories in the field and the five-year experience gained by the FLNP neutron polarization team in the operation of the polarized neutron spectrometer SPN-1 at the IBR-2. The general principles lying in the basis of the design outlined, a schematical description of the instrument and brief on the details of the experimental procedure are given. The high efficiency of the REFLEX is ensured by double splitting of a neutron beam, that allows one to actually have two double beam reflectometers REFLEX-1 and REFLEX-2 on one beam, the latter being a polarized neutron reflectometer.

THE UNIVERSITY OF TEXAS COLD NEUTRON SOURCE

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A cold neutron source has been designed, constructed, and tested by the Nuclear Engineering Teaching Laboratory(NETL) at the University of Texas at Austin. The Texas Cold Neutron Source(TCNS) is located in one of the beam ports of the NETL 1-MW Triga Mark II reactor. The TCNS consists of a cold source system and a neutron guide system. Some aspects of the design features of the TCNS facility will be given and the performance and possible applications of the TCNS will be discussed. The TCNS cold source system includes a cooled moderator, a heat pipe, a cryogenic refrigerator, a vacuum jacket, and connecting lines.The cold source system was designed to maintain 80 mL of mesitylene moderator at about 30 K in a chamber within the reactor graphite reflector. Mesitylene, 1,3,5-trimethylbenzene, was selected for the cold moderator because it has been shown to be an effective and safe cold moderator. Using mesitylene as a moderator simplified the cold neutron source design because mesitylene is a liquid at room temperature and is less flammable than hydrogen and methane. The neon heat pipe (properly called thermosiphon) is a 3-m long aluminum tube which is used for the cooling down of the moderator chamber. The heat pipe is filled with neon gas and is connected to a reservoir. The measured stable temperatures for the moderator chamber and the cold head wihout heating are 29 K and 26 K, respectively. The cold neutrons obtained from the TCNS will be transported by a curved neutron guide. This 300 m radius guide is 6-m long with a 50 x 15 mm cross-section, Ni-58 coated, and separated into 3 channels. The TCNS system will provide a low-background subthermal neutron beam for neutron reaction and scattering research. After the installation of the external curved neutron guide and completion of the shielding structure, neutron focusing and a Prompt Gamma Activation Analysis facility will be installed at the TCNS.

HIGH RESOLUTION AND HIGH INTENSITY NEUTRON DIFFRACTION AT THE IBR-2 PULSED REACTOR.

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Several time-of-flight diffractometers for studies of both single crystals and powders have been constructed at the IBR–2 pulsed reactor and a lot of various investigations have been performed with them. In the past two years redesign of some of these has been accomplished and the new quality in diffraction experiments has been achieved. In 1992 the high resolution Fourier diffractometer has been realized and the idea has received confirmation that the Fourier technique in combination with a pulsed neutron source, such as the IBR-2 reactor, gives the diffraction pattern of very good quality. Recently the method of real time neutron powder diffraction was developed at IBR-2. Now it is possible to measure the complete diffraction pattern in several minutes or sometimes seconds and the wide range of d-spacing is available for diffraction together with small angle scattering. In this paper the characteristics of new diffractometers are given and the recent results of diffraction studies presented.

THE EUROPEAN SPALLATION SOURCE: NEW SCIENTIFIC OPPORTUNITIES

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Neutron scattering is an intensity limited technique. Although advances in sources and instrumentation over recent years have led to significant progress in both structural and dynamical studies using neutrons, we are still limited by the neutron fluxes available from existing sources. There is however significant potential for further development, especially of pulsed spallation sources, and initial studies have suggested that power enhancements of a factor of 30 or so above the most powerful existing such source ISIS are possible.

Such an increase in neutron intensity would open up much science that is presently not accessible to neutrons, and some of these scientific opportunities are discussed.

EXPERIMENTAL STUDY OF NEUTRONIC PERFORMANCE OF THE IBR-2 REACTOR SOLID METHANE MODERATOR

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The results of the experimental research of neutron yield from the solid methane moderator obtained during its test operation at the IBR-2 reactor are presented. The main purpose of the work was to study the spectra of thermal neutrons emitted from the surface of the moderator within the range of the wavelengths of [illegible] to 25 Å depending on various factors which determine the condition of the moderator operation. The neutron yield data depending on the moderator temperature, reactor power, neutron fluence in the moderator, netron spectrum changes after annealing heavy hidrocarbon and hydrogen release from the moderator, have been gathered. With the help of highly efficient methods of the thermal neutron spectra registration the dynamic of the spectrum changes in the course of spontaneous moderator temperature rise, as well as various processes of the moderator temperature changes have been investigated. The comparative data of the neutron yield from different water moderators are given.

SOLID METHANE MODERATOR AT THE IBR-2 : TEST OPERATION AT 2 MW

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A cold moderator facility, comprising a light water premoderator and a solid methane camera cooled by helium at 10–15 K, has been installed near the reactor core of IBR-2 at the routine site. Three–week operation of solid methane at the data–sheet power of the reactor was performed in 1994. Radiation dose rate in solid methane was in the range of 0.1–0.2 W/g; heat deposition in the camera, including walls, was about 350 W. Solid methane temperature did not exceed 26K.
The longest run with a fresh charge of methane lasted 3 days. The facility behaved predictably and acceptably, resisting burps and periodic releases of radiolytic hydrogen. Unfortunately, a leak of helium into a methane camera had appeared shortly before testing was completed, so we had to terminate the operation. Very likely, it was a consequence of a defect in welding.
The gain factor in cold neutron intensity, as compared to that of the light water grooved type moderator was confirmed to be as much as 20–25, like it was observed in earlier testing in 1992. After the cause of a crack is determined, a reserve solid methane moderator will be commissioned and put into permanent operation.

SMALL ANGLE NEUTRON RESEARCHES AT IBR-2: SOME RESULTS AND PERSPECTIVES

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The small angle neutron scattering spectrometer at IBR–2 pulsed neutron reactor (JINR,Dubna) is a unique physical device with no analogy in the world judging by its great potentialities. The high level luminosity of the source in combination with relatively low background and good space resolution allows to investigate macromolecules in the wide range od their molecular weights and sizes in the area of transmitted impulses from 0.008 to 0.25 $\AA^{-1}$. Comparative investigation of real possibilities of two small angle spectrometers (MURN and D11 (HFR, Grenoble)) carried out with three models which differ in sizes and chemical compositions (ribosomes, protein and tetramethylurea) has shown that both the spectrometer MURN at the pulsed neutron reactor IBR–2 with a medium power of 2 MW and a thermal moderator and the spectrometer D11 at the stationary reactor HFR with a medium power of 57 MW and a cold moderator have comparable results in a number of parameters of small angle scattering.

The scientific programme of investigations being carried out at present circles an ample spectrum of natural and synthetic objects from ribosomes and diaphragms to alloys and concretes. However the present infrastructure at the spectrometer MURN (preparation and the cheking of models, accumulation and treatment of experimental data) impedes in a great deal to advance large scientific pragrammes especially in the field of structural biology.

Therefore the top important tasks to develop MURN are as follows:

1. a moderate–sized but well–equipped biochemical laboratory;
2. a new position–sensitive detector is to be put into operation;
3. an installation of a cold moderator.

Solving these problems will stimulate the development of a great number nev :ientific trends and make it possible to create in Dubna a small angle res :h center not far different from world scientific centers.

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