JP0150507

JAERI-Conf 2001-002

ICANS-XV
15th Meeting of the International Collaboration on Advanced Neutron Sources
November 6-9, 2000
Tsukuba, Japan

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Neutron Beam Facilities at the Australian Replacement Research Reactor

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Abstract

Australia is building a research reactor to replace the HIFAR reactor at Lucas Heights by the end of 2005. Like HIFAR, the Replacement Research Reactor will be multipurpose with capabilities for both neutron beam research and radioisotope production. It will be a pool-type reactor with thermal neutron flux (unperturbed) of 4 x 10^{14} n/cm^2/sec and a liquid D_2 cold neutron source. Cold and thermal neutron beams for neutron beam research will be provided at the reactor face and in a large neutron guide hall. Supermirror neutron guides will transport cold and thermal neutrons to the guide hall. The reactor and the associated infrastructure, with the exception of the neutron beam instruments, is to be built by INVAP S.E. under contract. The neutron beam instruments will be developed by ANSTO, in consultation with the Australian user community. This status report includes a review the planned scientific capabilities, a description of the facility and a summary of progress to date.

Introduction

Neutron beam science began in Australia with the commissioning of the HIFAR research reactor at the Lucas Heights Research Laboratories in 1958. Over its lifetime HIFAR has operated with HEU fuel generating 10MW thermal power and a thermal neutron flux of 1×10^{14} n/cm^2/s and providing neutrons for science, radioisotope production and NTD silicon. ANSTO is now working to replace the HIFAR research reactor by the end of 2005. The new reactor is to be a multipurpose reactor operating with LEU fuel at 20MW thermal power and a thermal neutron flux (unperturbed) of 4 x 10^{14} n/cm^2/s. It will have improved capabilities for neutron beam research and for the production of radioisotopes for pharmaceutical, scientific and industrial use. The neutron beam facility is intended to cater for Australian scientific, industrial and medical needs well into the 21st century.

The Scientific Capabilities

The scientific capabilities of the neutron beams at the replacement reactor were planned in consultation with representatives from academia, industry and government research laboratories to address the scientific priorities of the Australian research community. The aim is to provide a facility for condensed matter research, not only in the traditional disciplines of physics, chemistry and materials science, but also for the expanding areas of life sciences, engineering and earth sciences. Cold and thermal neutron sources are to be installed from the beginning, with provision for a hot neutron source in the future. Neutron guides will be used to position most of the neutron beam instruments in a neutron guide hall outside the reactor confinement building. Eight instruments are planned for 2005, with a further three to be developed by 2010. The initial suite of instruments will build on the traditional strengths of the Australian neutron scattering community in the areas of crystallography, materials science and polarised neutron techniques, and will expand into cold neutron techniques such as small angle neutron scattering and reflectometry and instruments with an industrial focus, such as residual stress. Subject to support from special interest groups in Australia and overseas, other neutron beam instruments may also be developed.

Description of the facility

The reactor and the associated infrastructure, with the exception of the neutron beam instruments, is to be built to ANSTO's specifications by an accredited reactor builder INVAP, SE and their subcontractors in a *turnkey* contract. Subcontractors involved in the construction of the neutron beam facility include St. Petersburg Nuclear Physics Institute for the cold neutron source and Mirrotron for neutron guide systems. The budget for construction of the facility is AU$278M, including cold neutron source and neutron guides. There is a separate budget for construction of the neutron beam instruments. The cold neutron source will be a vertical liquid deuterium thermosyphon. It will be ~20 litres in volume, re-entrant in the direction of the cold neutron guides and placed near the peak thermal neutron flux.

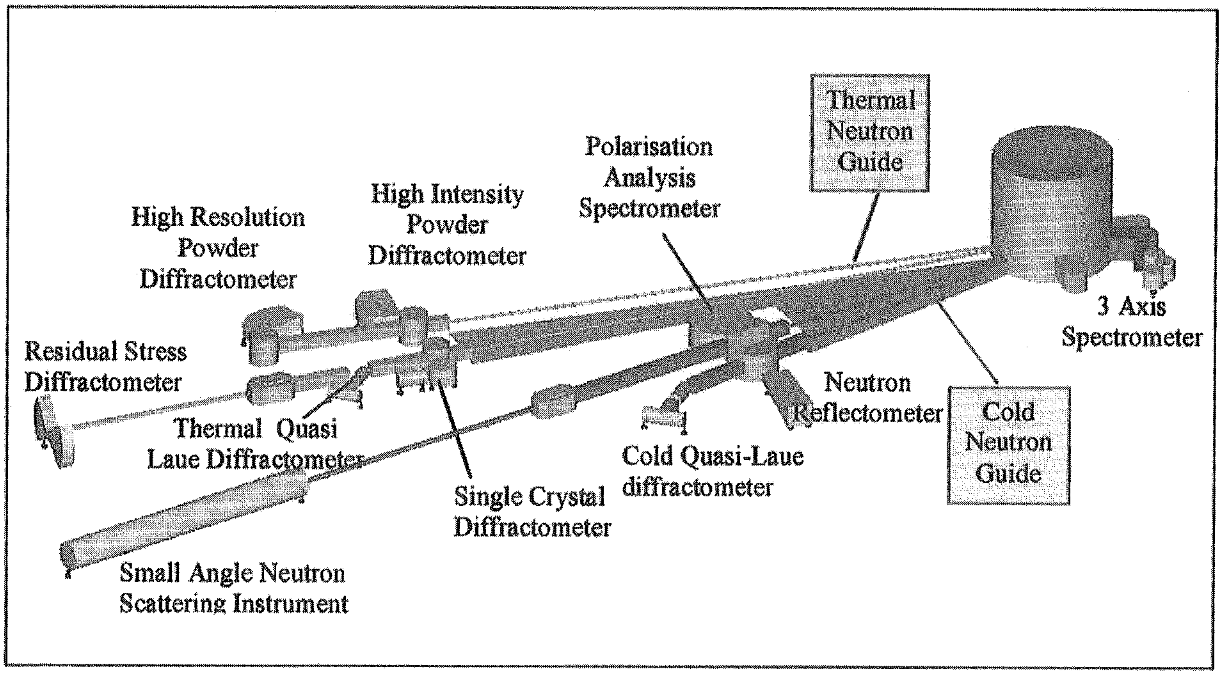

Fig. 1 The neutron beam facility at the Australian Replacement Research Reactor

The layout of the neutron beam facility is illustrated in the fig. 1. Five neutron beam assemblies will be installed with neutron beam tubes placed tangential to the core to reduce background radiation due to fast neutrons and γ-rays. One beam assembly will feed the two thermal neutron guides (TG1 & TG3) and another will feed the two cold neutron guides (CG1 & CG3) that lead to the neutron guide hall. Each pair of guides will be spaced 6 degrees apart to provide sufficient separation at the instrument locations, and in each case an extra beam will be installed between the guided beams but will terminate at the reactor face. The guides will be curved beyond line-of-sight of the moderator to further reduce background radiation. The neutron guides will start ~1.5 m from source end of the beam tubes. The neutron guide hall will have initial capacity for 8 to 12 neutron beam instruments, depending on specific instrument requirements. The capacity is limited not by the guide hall dimensions (~65m x 35m)but by the neutron guide capacity. Placement of the bulk of the neutron beam facility in a neutron guide hall removes the space restrictions that tend to limit the development of reactor face instruments and offers the benefit of substantial reduction in background radiation levels. Separation of the neutron beam facility from the reactor operations and from the irradiation facilities will also reduce congestion and access restrictions that hamper scientific activities at the HIFAR reactor. As the facility is expected to provide a basis for high quality neutron beam research for the first half of the twenty first century, the design includes considerable flexibility to cater for potential changes in utilization. Capacity beyond the initial suite of instruments will be achieved by building neutron guides on the extra cold and thermal beam lines (CG2 & TG2) that terminate at the reactor face between the pairs of thermal and cold neutron guides.

The neutron beam assemblies opposite those feeding the neutron guide hall will provide one thermal beam (TG4) and one cold beam (CG4) at the reactor face. Provision has been made in the design to modify these beams to allow for a more substantial expansion of the facility. This could be achieved by replacing the single guides in each assembly with three neutron guides to transport beams to a second guide hall in a space that has been left free outside the reactor containment. In this way a doubling of the neutron beam capacity would be attained. Provision has also been made for installation of a hot neutron source that would feed two independent neutron beams at the reactor face (HB1 & HB2), spaced 5 degrees apart. Initially these beams will provide two thermal beams at the reactor face. In the event that hot neutron science does not develop at the reactor, enhancement of the thermal beam flux or conversion to cold neutron beams may be desirable. To allow for this provision will also be made for later insertion of neutron guides into these beam tubes.

The Neutron Transport System and Beam Instruments

Efficient transportation of thermal and cold neutrons to the guide hall requires the use of modern *supermirror* reflecting guides. By installing m=2 to m=3 *supermirror* guides we expect to deliver beam fluxes to the instruments in the neutron guide hall that are comparable, and in some cases exceed, those currently enjoyed at the world's leading neutron beam facilities. To further enhance the capability of the reactor face instruments beam assemblies TG4, CG4, HB1 and HB2 will be widened at the source end. This increase in source width will facilitate more efficient use of double-focussing monochromators but will not compromise use of these beams for other applications. The basic neutron guide characteristics were determined in a detailed simulation study at ANSTO as part of the development of specifications for the reactor. Neutron source flux estimates were based on Monte Carlo source modelling and transport simulations used ray- tracing programs developed at ANSTO for this project. Further refinement of guide characteristics has been effected through consultation between ANSTO and Mirrotron. This refinement process is expected to continue into 2001.

The characteristics of the neutron beam lines, ANSTO's estimates of neutron flux and the location of the planned neutron beam instruments are summarised in table 1. The eight instruments that are to be ready at reactor startup have a solid bullet and those that are under review have an open bullet. The supermirror coatings listed in the table are the reference design, but consideration is being given to tailoring the coating on the cold guides (CG1 & CG3) to enhance the shorter wavelength neutrons without reducing lond wavelength neutron flux by increasing critical angle of the outer curved surface (garland side). The guide characteristics after the first break are not yet determined and are being considered in conjunction with conceptual design of the downstream instruments.

The neutron beam instruments will be developed by ANSTO and other contracted organizations in consultation with the user community and interested over-seas scientists. The priority listing of instruments was initially developed in consultation with representative from the Australian user community, and is currently being reviewed in a series of scientific workshops. Conceptual design and recruitment of scientists for the instrument development has begun and will proceed throughout 2001. Further information on the neutron beam instrument development program can be found at the website http://www.ansto.gov.au

Table 1 Summary of the neutron beam lines planned for the replacement reactor

Beam line	Planned Neutron Beam Instruments	Guide characteristics (at first guide break)	Calculated neutron flux (n/cm^2/sec)	Wavelength Peak (Å)
TG1	• High Intensity Powder Diffractometer • High Resolution Powder Diffractometer ○ Neutron Radiography	• 300mm x 50 mm • m=3 supermirrors top and bottom • m=2.5 to 3 supermirrors on sides • radius of curvature 4.5km	~1.5 x 10^9	1.3
TG2	(stop at reactor face)	• 150mm x 50 mm • m=3 supermirrors • radius of curvature 4.5km		
TG3	• Residual Stress Diffractometer • Four Circle Diffractometer ○ thermal neutron Quasi-Laue diffractometer			
TG4	• thermal neutron Triple Axis Spectrometer	• 200mm x 50 mm • m=3 supermirrors	~2.6 x 10^{10}	1.1
CG1	• Polarisation Analysis Spectrometer • Small Angle Neutron Scattering instrument	• 200mm x 50 mm • m=3 supermirrors top and bottom • m=2 to 2.5 supermirrors on sides • radius of curvature 1.3km	~4 x 10^9	3.9
CG2	(stop at reactor face)			
CG3	• neutron reflectometer ○ cold neutron Quasi-Laue diffractometer			
CG4	○ cold neutron Triple Axis Spectrometer		~1.3 x 10^{10}	3.3
HB1 & HB2	Not decided	• 200mm x 50 mm • collimators only (no reflecting coatings)	~3 x 10^{10}	1.1