

Thermal Triple-axis Spectrometer at OPAL Reactor

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Inelastic neutron scattering is widely used to study the excitations such as phonon and magnon in condensed matter. A triple-axis spectrometer (TAS) is one of main instruments used in neutron scattering studies. TAS TAIPAN will be the first inelastic instrument at the Australian research reactor OPAL. It will be placed at a reactor face position and will use double focusing monochromators and analyser. In addition to the double-focusing regime, TAIPAN will have a standard mode of operation with Soller collimators providing high resolution. The instrument will use supermirror benders for polarization analysis.

1. Introduction

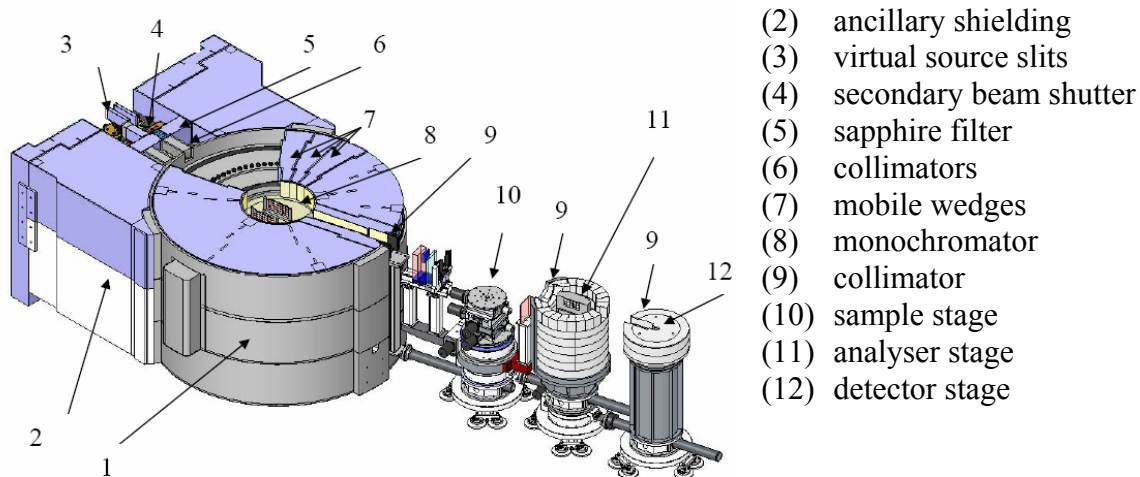
Triple axis spectrometry is one of the most commonly used and powerful techniques for investigations of inelastic scattering at steady-state neutron sources. In TAS single crystals are used to define the energy of incident and scattered neutrons making possible to measure the energy of excitations in the sample. Typically these instruments are very flexible and permit the measurement of the scattered intensity against energy or momentum transfer, performing scans through the Brillouin zone in any desired direction.

TAS TAIPAN will be the only inelastic instrument among the first suite of seven instruments to be built at Australian research reactor OPAL. Installed at the thermal beam, the instrument will be located close to reactor shielding face in the OPAL reactor beam hall. It will use double focusing monochromators and analyser; however a high resolution mode of operation with Soller collimators is also provided. The new TAS will have a standard secondary spectrometer with a single detector. Polarisation analysis will be provided by supermirrors..

2. Spectrometer design

TAS TAIPAN will be located on the TG4 tangential beam tube at OPAL. The neutron guide is built through the reactor face to the edge of the core. The first element of the in-pile beam guide is the horizontally expanded beam tube. The second part is coated with $m=3$ supermirror continued through the shutter. This guide converges horizontally and expands vertically so that beam exit window at reactor shielding face is of $50 \times 175 \text{ mm}^2$ in size. The guide with total length about 4.3 m is filled with helium heat exchange gas, which enhance transmission of neutrons. With 20 MW thermal power OPAL is designed to deliver an unperturbed thermal flux of order $4 \times 10^{14} \text{ n} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$ [1]. The estimated flux of thermal neutrons at the TG4 beam exit is $1.8 \times 10^{10} \text{ n} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$.

A 3-D design model of the spectrometer is shown in Fig. 1. The primary spectrometer mounted in the monochromator shielding (Pos. 1, Fig.1) defines the monochromatic beam of incident neutrons. Energy analysis of neutrons scattered by sample (Pos. 10) is performed by the analyser crystal (Pos. 11). Neutrons selected by the analyser are collected by the detector (Pos. 12). For polarisation analysis a compact supermirror benders similar to developed for LONGPOL spectrometer will be used [2]. They are based upon bent thin single crystal Si wafers coated on one side with Si-FeCo polarising multilayer.



(1) monochromator shielding

Fig. 1 Sectional view of TAS TAIPAN at the beam height, upper part is not shown.

2.2 Primary spectrometer

TAIPAN will have two double focusing monochromators: HOPG(002) and Cu(200). The horizontal and vertical curvatures can be varied independently. The monochromator stack (Pos.8, Fig.2) is mounted inside the monochromator shielding assembly and consists of tilting, rotation and linear translation stages to allow position control of the monochromators. Between the reactor beam exit and the monochromator (Pos. 8), close to the reactor wall is located the input optic assembly. It consists of mobile horizontal slits (Pos. 3), the secondary beam shutter (Pos. 4), a sapphire filter (Pos. 5) and collimators (Pos. 6). The aim of virtual source slits is to provide optimal conditions for monochromatic horizontal focusing and for adjustment of the width of the beam. The collimator changer (Pos. 6) allows choosing between double focusing mode of operation (no collimator) and a standard set-up with Soller collimators and flat or vertically focused monochromator. Other collimators at the monochromator beam exit and in front of analyser and detector (Pos. 9) can be changed or removed manually.

2.3 Monochromator shielding

In order to maximize the flux at the sample position a large emphasis has been placed on designing a compact shielding drum around the monochromators to minimize the monochromator to sample distance. This work has relied heavily on the use of the MCNP-B simulation program to evaluate, and optimise, the effectiveness of the shielding. As a result a monochromator shielding assembly with outer diameter 2140 mm and a 600 mm diameter inner space for monochromators has been designed and presently is in fabrication. The shielding is constructed from non-magnetic materials and consists of the shielding mix pour (60% volume 316 stainless steel shot and 40% volume borated paraffin wax) encased in stainless steel fabrications. The variable monochromator take-off angle $2\Theta_M$ can be changed from 15° to 85°

2.4 Sample, analyser and detector stages

The sample assembly (Pos. 10) consists of χ and ϕ tilt stages on top of horizontal translation table and a sample rotation stage (ω). These components allow the accurate positioning and alignment of sample in respect to the neutron beam. The sample assembly

also includes a stage to slew the analyser module (Pos. 11). Sample, analyser and detector stages are mounted on air pads moving on polished granite floor.

TAIPAN has a conventional secondary spectrometer with heavy polyethylene shielding installed around the analyser and detector elements. The design is similar to the IN8B instrument at ILL [3]. The double-focusing analyser is of pyrolytic graphite, HOPG(002).

3. Parameters of the instrument

The main parameters of spectrometer are given in Table 1. Resolution of the instrument depends on collimation, initial and final energies, and focusing conditions. In case of elastic scattering (vanadium sample) it is expected to be 1.5-5% in the energy range of 5-60 meV for collimations $C_1-C_2-C_3-C_4 = 15'-20'-20' 20'$.

The energy range of the instrument is from -50 meV for neutron energy gain to about 100 – 120 meV for energy loss.

The TAIPAN triple axis spectrometer at OPAL will be a state of the art instrument for the measurement of excitations (phonons and spin waves) in single crystal specimens. It is anticipated that it will begin commissioning in July 2006 and will be available to the scientific community for scheduled experiments in the beginning of 2007.

Table 1. TAS TAIPAN main characteristics.

Size of beam at reactor face	$50 \times 175 \text{ mm}^2$ (W×H)
Horizontal virtual source aperture	$(0-65) \times 200 \text{ mm}^2$
Monochromators	HOPG(002) 24', Cu(200) 20', double-focussing 9 rows \times 7 columns, $200 \times 200 \text{ mm}^2$
Monochromator take-off angle	$15^\circ \leq 2\theta_M \leq 85^\circ$
Incident energy range	$5 < E_i < 120 \text{ meV}$
Sample table	On air-pads, maximum central load 5 kN,
Sample scattering angle	$-145^\circ \leq 2\theta_S \leq 115^\circ$
Analyser	PG(002) 24', double-focussing mechanism, 7 rows \times 5 columns, $160 \times 140 \text{ mm}^2$
Analyser scattering angle	$-110^\circ \leq 2\theta_A \leq 110^\circ$
Typical range of energy transfer	$\hbar\omega < 120 \text{ meV}$
Distance Source – Monochromator	6500 mm
Distance Reactor Face – Monochromator	2000 mm
Distance Virtual Source – Monochromator	1710 mm
Distance Monochromator – Sample	1750 - 2000 mm
Distance Sample – Analyser	810 - 1125 mm
Distance Analyser – Detector	810 - 1125 mm
Pre-monochromator collimators, (C_1)	15', 30', Open, $90 \times 185 \text{ mm}^2$ (W×H)
Post-monochromator (C_2), pre-analyser (C_3), and pre-detector (C_4), collimators	20', 40', Open, $50 \times 130 \text{ mm}^2$ (W×H)

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References

- [1] R.A. Robinson and S.J. Kennedy, *Physica* **B311**, 44 (2002).
- [2] T. Ersez, S.J. Kennedy, T.J. Hicks, Y. Fei, Th. Krist and P.A. Miles, *Physica* **B335**, 183 (2003).
- [3] A. Hiess, R. Currat, J. Saroun, and F.J. Bermejo, *Physica* **B276-278**, 91 (2000).