

## Irradiations, X-ray Instruments, Reactor Operations, and External Facilities

### X-ray instruments

- 2650 The Small Angle X-ray Scattering Instrument (SAXS)  
2900 The X-Ray Reflectometer

### The National Deuteration Facility

- 2810 Biodeuteration  
2811A Biodeuteration - purified deuterated protein - partially deuterated  
2811B Biodeuteration - purified deuterated protein - perdeuterated  
2812A Biodeuteration - deuterated biomass - target partially deuterated  
2812B Biodeuteration - deuterated biomass - target perdeuterated  
2813 Biodeuteration - deuterated DNA  
2814 Biodeuteration - deuterated biopolymers  
2815 Biodeuteration -  $^2\text{H}$  /  $^{13}\text{C}$  /  $^{15}\text{N}$  double or triple labelled recombinant protein  
2820 Chemical deuteration  
2821 Chemical deuteration of carboxylic acids or functionalised derivatives  
2822 Chemical deuteration - surfactants  
2823 Chemical deuteration - lipids  
2824 Chemical deuteration - phospholipids  
2825 Chemical deuteration - substituted aromatics and heterocyclics  
2826 Chemical deuteration - sugars

### Irradiations

- 3700 Neutron Irradiations  
3711a Low Thermal Flux Irradiation ( $3\text{E}12$  up to  $1\text{E}13$   $\text{ncm}^{-2}\text{s}^{-1}$ )  
3711b Low Thermal Flux Irradiation per 24 hours thereafter  
3712a Medium Thermal Flux Irradiation ( $1\text{E}13$  up to  $6\text{E}13$   $\text{ncm}^{-2}\text{s}^{-1}$ )  
3712b Medium Thermal Flux Irradiation per 24 hours thereafter  
3713a High Thermal Flux Irradiation ( $6\text{E}13$  up to  $1.4\text{E}14$   $\text{ncm}^{-2}\text{s}^{-1}$ )  
3713b High Thermal Flux Irradiation per 24 hours thereafter  
3714a Fast Flux Rigs Irradiation (approx  $1\text{E}13$   $\text{ncm}^{-2}\text{s}^{-1}$ , at greater than 1MeV)  
3714b Fast Flux Rigs Irradiation per 24 hours thereafter  
3730 Gamma Irradiation Facility – GC220  
3740 Gamma Irradiation Facility – GATRI

### Irradiation Services

- 6000 Hot Spot Irradiators  
6100 Gamma Sources – Physical Science  
6200 Deep Level Transient Spectrometer  
7400 Gamma Spectrometer

### Reactor Operations Facilities – General

- 8200 Computer Evaluation of Reactor Operation and Safety, Neutronics and Shielding Calculations  
8300 Water Tunnel Flow Facility

... cont.

### Other Facilities

- 9010 Cemented Waste Facilities
- 9020 Health and Safety - Gamma irradiation facility (GIS) – irradiation only
- 9021 Health and Safety - Gamma irradiation facility (GIS) – irradiation & biology rooms
- 9030 Health and Safety – in vivo gamma spectrometry (IVGS)
- 9200 Heavy Water
- 9210 Heavy Water Dispensing Fee
- 9800 AINSE Facilities

### External Facilities

- 1700 SIMS - Secondary Ion Mass Spectrometry - Cameca IMS 5fE7 – University of Western Sydney
- 9910 Linear Accelerator / Pulse Radiolysis Facility – the University of Auckland
- 9930 National Plasma Fusion Research Facility (H-1NF) – the Australian National University
- 9940 The Australian Positron Beamline Facility – the Research School of Physical Sciences and Engineering, ANU

## 2650 The Small Angle X-ray Scattering Instrument

### Description

The SAXS instrument is a Bruker NanoSTAR II equipped with a rotating anode source and three-pinhole collimation. SAXS is complimentary to Small Angle Neutron Scattering (SANS) which is available on the new QUOKKA instrument at the OPAL research reactor. A variety of sample environments are available for solids and liquids, including two temperature control units one covering temperature range  $-30^{\circ}\text{C}$  to  $120^{\circ}\text{C}$  and a second unit for ambient to  $300^{\circ}\text{C}$ . The instrument is capable of being run in two separate configurations either high resolution or high flux; the Q-range accessible is  $0.005 \text{ \AA}^{-1}$  to  $3.1 \text{ \AA}^{-1}$  in high resolution mode and  $0.01 \text{ \AA}^{-1}$  to  $3.1 \text{ \AA}^{-1}$  in high flux mode.



### Applications

SAXS is used to study any materials with structure of the length scale 1-100nm. The performance of many advanced materials is crucially dependent on nanostructure, and SAXS can be used to obtain valuable data. It can be used for study of density variations, colloidal sizes, particles sizes, porosity, domain sizes, orientation, phase identification, the list is extensive. With research being directed more towards nano-sized science, SAXS is becoming a widely used tool.

### Instrument Specifications

Rotating Anode Cu Ka source ( $1.541 \text{ \AA}$ )
Montel optics
3 pinhole collimation
Large multifunctional sample chamber
Sample temperature control from $-30^{\circ}\text{C}$ to $150^{\circ}\text{C}$ or ambient to $300^{\circ}\text{C}$
Capillaries: 2mm ID disposable or reusable
Vantec 2D detector with $100\mu\text{m}$ resolution
Capability of two configurations: high resolution or high intensity.
$Q_{\min} = 0.005 \text{ \AA}^{-1}$
$Q_{\max} = 3.1 \text{ \AA}^{-1}$

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## 2900 X-ray reflectometer for investigation of interfacial thin films

### Description

The X-ray reflectometer is a Panalytical X'Pert Pro instrument. The instrument is capable of measuring reflectivity at air-solid or air-liquid interfaces. The X-ray reflectometry method provides information complementary to that from neutron reflectometry which is available at OPAL. The X-ray reflectometer is used for research on thin-films and surfaces by the Australian scientific and industrial communities. The sample geometry is horizontal with (specular reflectivity) taking place in the vertical plane. It is suitable for the study of air-solid and air-liquid interfaces (i.e. horizontal surfaces).

The X-ray reflectometer is equipped with a Cu tube source with parallel beam optics, motorised beam defining slits, an automatic beam attenuator, a "De Wolf" beam knife and a Xe scintillator detector (capable of >106cps). Solid samples will be mounted on a motorised XYZ, Phi sample stage while a motorised Huber stage will be employed for liquid studies.

### Applications

X-ray reflectometry is used to probe the structure of surfaces, thin-films or buried interfaces as well as processes occurring at surfaces and interfaces such as adsorption, adhesion and interdiffusion. In particular, recent years have seen an explosion of interest in the biosciences as well as the emerging field of nanotechnology. Applications cover photosensitive films, electrochemical and catalytic interfaces, surfactant layers, polymer coatings and biological membranes. The increasing importance of hybrid materials, the properties of which are determined by their interfaces and the rapid development in the field of thin film technology provides a strong demand for x-ray reflectometry.

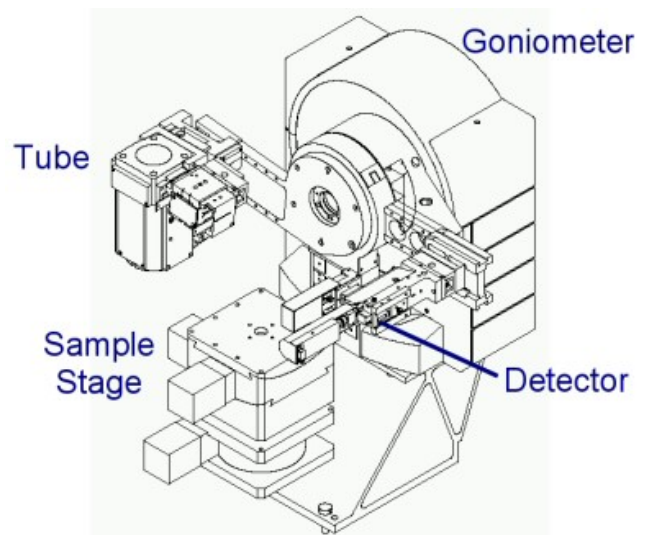


Figure 1. Schematic of the X-ray Reflectometer

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## 2800 The National Deuteration Facility

### Description

The National Deuteration Facility (NDF) offers the facilities, staff and expertise to produce molecules where all or part of the molecular hydrogen is in the form of the stable (non-radioactive) isotope deuterium ( $^2\text{H}$ ). This is of benefit as it enables scientists to use neutron scattering, Nuclear Magnetic Resonance (NMR) or InfraRed (IR) spectroscopy more effectively in the investigation of the relationship between molecular structure and function.

The Facility offers molecular deuteration using either *in vivo* biodeuteration or chemical deuteration techniques. Biodeuteration involves the use of microbial expression systems. Typically, *Escherichia coli* is grown in heavy water ( $\text{D}_2\text{O}$ ) on either a hydrogenated ( $^1\text{H}$ ) or deuterated ( $^2\text{H}$ ) carbon compound to obtain partly or totally deuterated proteins, nucleic acids or other biopolymers including cellulose, polyhydroxyalkanoates and chitosan. The biomass is harvested and the desired molecule purified and characterised to ensure it is structurally analogous to the native molecule of interest. Such purification may be undertaken by the NDF, or by the applicant in their own laboratory after provision of deuterated biomass. Chemical deuteration involves deuterating the precursors for the desired molecule by exposing them to  $\text{D}_2\text{O}$  at high temperature and pressure in the presence of a catalyst and followed by organic synthesis of the target molecule in its deuterated form e.g. surfactants, functionalised alkyl hydrocarbons, lipids, phospholipids, substituted aromatics, heterocyclics and sugars. NMR and MS are used to characterise the percentage deuteration and the disposition of  $^2\text{H}$  in the product.

### Applications

Current applications focus strongly on organic materials rich in hydrogen. When molecules are placed in front of a neutron beam, hydrogen and deuterium scatter neutrons quite differently (ie they have a different scattering length density). Molecular deuteration of subunits of a molecule, or a complex, enables the creation of contrast between these components and those containing  $^1\text{H}$  in a system that would otherwise offer far less information. Thus, it is possible to observe the arrangement of subunits of a protein or protein complex, or changes in shape when molecules interact or become active/inactive, using molecular deuteration and small angle neutron scattering. This can be done with partially deuterated molecules in solution under relevant real life conditions using the small angle neutron scattering instrument Quokka at the OPAL reactor.

Another type of application involves the use of neutron reflectivity (Platypus at the OPAL Reactor) and selective deuteration to investigate thin films, assembled multilayer systems including nanotech devices, and model membrane bilayer systems and their interaction with proteins, peptides and other molecules. The disposition, thickness and molecular orientation of layers can be determined in order to investigate the behaviour of components during events such as molecular binding, thermal change, disruption by toxins or enzymes, as well as the position and shape of membrane bound proteins.

Perdeuterated proteins can be produced for neutron crystallography where deuteration leads to less "noise" in the data and enables use of a smaller crystal. This facilitates resolution of key hydrogens in a molecule, for example in the region responsible for catalysis by an enzyme. Thus neutron crystallography of deuterated proteins may augment information obtained from X-ray crystal structures that have ambiguity in the position of hydrogens in the molecule (due to the poor ability of X-rays to resolve the position of hydrogen).

The NDF also produces labelled proteins for structural analysis using NMR, including multi-labelling with  $^2\text{H}$  /  $^{13}\text{C}$  /  $^{15}\text{N}$ .

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Biodeuteration

- 2811 Purified deuterated protein**
  - A – partially deuterated
  - B - perdeuterated
- 2812 Deuterated biomass containing the target molecule which is:-**
  - A – partially deuterated
  - B - perdeuterated
- 2813 Deuterated DNA**
- 2814 Deuterated biopolymers e.g. poly-hydroxyalkanoates (PHAs), cellulose, chitosan**
- 2815  $^2\text{H} / ^{13}\text{C} / ^{15}\text{N}$  double or triple labelled recombinant protein**

Chemical Deuteration

- 2821 Deuteration of carboxylic acids (C4-C12) or functionalised derivatives (e.g. alcohol aldehyde, ketone, chloride, amide, amine)**
- 2822 Surfactants e.g, SDS, CTAB**
- 2823 Lipids e.g. oleic acid, glycerol monoleate**
- 2824 Phospholipids**
- 2825 Substituted aromatics and heterocyclics**
- 2826 Sugars e.g. trehalose, sucrose**



## 3700 Neutron Irradiations

### Applications

There is a wide range of potential applications for neutron irradiations. They vary from irradiating minerals to determining yields to irradiating tracer substances for various research, environmental, and industrial processes and applications. A total of 55 irradiation facilities are available at 7 levels of thermal neutron flux to perform a wide range of irradiations.

### Support services and facilities

Facilities are available for canning of samples for irradiation, post irradiation handling and quick return of the irradiated sample in a suitable shielded container. Technical advice on the usage and methods to minimise radiation levels are also available.

### Availability

The availability of this service is dependent on reactor scheduling. Prior contact with ANSTO is required to ensure correct scheduling is achieved

- 3711a Low Thermal Flux Irradiation ( $3E12$  up to  $1E13$   $ncm^{-2}s^{-1}$ )**
- 3711b Low Thermal Flux Irradiation per 24 hours thereafter**
- 3712a Medium Thermal Flux Irradiation ( $1E13$  up to  $6E13$   $ncm^{-2}s^{-1}$ )**
- 3712b Medium Thermal Flux Irradiation per 24 hours thereafter**
- 3713a High Thermal Flux Irradiation ( $6E13$  up to  $1.4E14$   $ncm^{-2}s^{-1}$ )**
- 3713b High Thermal Flux Irradiation per 24 hours thereafter**
- 3714a Fast Flux Rigs Irradiation (approx  $1E13$   $ncm^{-2}s^{-1}$ , at greater than 1MeV)**
- 3714b Fast Flux Rigs Irradiation per 24 hours thereafter**

### Technical Enquiries

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## 3730 & 3740 Gamma Irradiation Facilities

### Description

ANSTO Radiation Technology operates two cobalt-60 gamma irradiators; a dry storage Gammacell (GC220) and a wet storage batch irradiator (GATRI). These units are suitable for research & development projects and small scale precision irradiations. ANSTO's high dose irradiation and dosimetry service supports Australian research applications in areas such as polymerisation, medical and health care, horticulture, agriculture.

### Irradiation Service Capabilities

Dose rates	Up to 4 kGy.h <sup>-1</sup>
Doses	1 to 10 <sup>6</sup> Gy
Temperature	-78 °C (under dry ice) up to room temperature
Product size	Up to 1 m <sup>3</sup>

### Dosimetry Service Capabilities

ANSTO is the only Australian provider of the following dosimetry systems (with measurement traceability to the Australian standard for absorbed dose)

Dosimeter	Dose Range	Uncertainty (95% confidence)
Fricke	50 – 350 Gy	2.0 %
Ceric Cerous (Low Dose)	1 – 12 kGy	3.0 %
Ceric Cerous (High Dose)	10 – 35 kGy	3.5 %

### Applications

Controlled dose rates and temperatures enable users to test ideas, develop applications and perform irradiations under non-standard conditions.

Applications include -

- Low dose (e.g. radical chemistry 1 Gy, seed mutation studies 10Gy, sterile insect technique studies 60 to 150 Gy)
- Temperature controlled irradiation (chilled or frozen)
- Precision irradiation not achievable in industrial gamma irradiation facilities
- Long irradiations for materials (e.g. polymers, diodes etc) and degradation studies
- Product qualification studies (e.g. for medical products ISO 11137)

### Availability and Cost

The facilities are available to AINSE members throughout the working year. Advance bookings are essential and depend on scheduling. The charges are determined on a case-by-case basis and can be provided on request.

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## **Irradiation services**

### **Radiation (Biology, Chemistry and Physics)**

#### **6000 Hot Spot Irradiators**

#### **6100 Gamma Sources – Physical Science**

##### **Description**

One small shielded gamma facility with dose rate of approx. 0.2 kGy/h is available. A series of lead shields provide a range of lower dose rates. Access to samples under irradiation is possible through access holes in the upper shielding plug. The unit is equipped with an automatic meniscus sensing and tracking mechanism controlled by a dedicated computer to enable the acquisition of dilatometric data. Temperature control of irradiations is possible.

##### **Applications**

Radiolytic product studies, dosimetry, radiation damage, crosslinking, grafting and polymerisation work. Kinetic investigations.

#### **6200 Deep Level Transient Spectrometer - Semiconductor Science**

##### **Description**

A deep level transient spectrometer, usually operating in the capacitance mode. Based on the Miller exponential correlator method. Used to characterise deep level centres in semiconductors. The spectrometer is run by the Ionising Radiation Physics Group.

##### **Support Services and Facilities**

Optical DLTS which is particularly suited for the trap of high resistivity material such as CdTe and semi insulating GaAs. C(V) and N(X) profiler with associated computer based facilities for data manipulation. Resistivity measurements using 4 point probe and associated standards. Vacuum system for the evaporation of metallic (Au, Al and Pd) contacts.

##### **Applications**

Electronic characterisation of high purity semiconducting materials such as Ge, Si and GaAs, used to fabricate nuclear radiation detectors. The characterisation and possible identification of centres introduced into such materials during crystal growth furnace annealing, or other high temperature cycle. The study of damage to the crystal lattice caused by prolonged exposure to radiation.

#### **7400 Gamma Spectrometer – Physical Science**

#### **Beta Spectrometer – Physical Science**

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## **8200 Computer Evaluation of Reactor Operation and Safety, Neutronics and Shielding Calculations**

### **Description**

Nuclear Operations develops and maintains computer software and associated data libraries with which neutron and/or gamma ray fluxes can be calculated for proposed experimental assemblies. These assemblies may be free standing or form part of rigs for insertion in OPAL. In the latter case the effect on OPAL can be calculated, if necessary, to determine the implications of the rig insertion on the safety of the reactor.

For assemblies containing fissile materials criticality certificates would need to be issued before the experiments begin. The results of the appropriate calculations can be provided to users.

Where the assemblies produce radiation fields of consequence to users and others, assessment of the necessary shielding can be provided.

### **Support Services and Facilities**

For projects that involve computer simulation of neutron and/or gamma ray populations in target materials or assemblies, advice and assistance are available in using the bank of software and data maintained on ANSTO computers. These include multigroup SN and neutron diffusion codes, codes to prepare multigroup data from a master library of 200 neutron and 37 photon groups, the ENDF/B-VI cross section file and Monte Carlo based neutron and gamma transport codes.

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## 8300 Water Tunnel Flow Facility

### Description

The Reactor Operations Water Tunnel is a closed loop flow rig of 3000L capacity, used for velocity measurements, pressure loss measurements and flow visualisation in flow fields surrounding immersed bodies, or within hydraulic components. Water is circulated by a double suction pump driven by a 75 kW AC motor and variable speed controller, to achieve flow control up to 230 Ls<sup>-1</sup>. The pipes range from 230mm to 690mm in diameter.

Models of the flow components, usually manufactured from highly polished acrylic, are positioned in the test section of the loop. Reflective particulate additives are used as flow tracers which are illuminated by a double pulsed Nd-YAG laser or a continuous wave Argon laser system. The resulting images of the flow patterns are captured digitally and processed to provide flow velocity and direction information.

The WTFF has also undertaken performance tests on hydraulic fittings, eg. valves, to Australian Standards. These tests include flow/pressure characteristic tests and endurance testing.

### Support Services and Facilities

- Laser PIV and LDV systems
- Workshop machinery available for model manufacture and development
- Computing facilities

### Applications

Flow analysis in hydraulic systems using PIV and LDV measurement techniques and flow visualisation.

Hydraulic testing of fittings to Australian Standards, determining flow loss and endurance characteristics.

### Availability

The Water Tunnel is available on an advance booking basis and subject to ANSTO needs.

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## 9010 Cemented Waste Facilities

### Description

Cement Waste Forms Laboratory is for

- the characterisation of cement and cemented waste forms eg. shrinkage at different relative humidities
- sample preparation for SEM, XRD
- preparing hydrated cement compounds eg milling, shear mixing and glove boxes
- examining conditioned cemented wastes (eg leach testing)

### Applications

For characterisation of cement and cemented waste forms.

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**9020 Health and Safety – Gamma Irradiation Suite (GIS) – irradiation only**

**9021 Health and Safety – Gamma Irradiation Suite (GIS) – irradiation and biology rooms**

The gamma irradiation suite (GIS) is utilised in radiobiology research. It consists of two main sections: the irradiation room and the animal/biology rooms.

The irradiation room is equipped with a Cobalt-60 collimated beam (Theratron). Different gamma dose rates can be obtained by changing the Source to Sample Distance, however, the field size is a function of the SSD. A number of beam attenuators are also available. They can be used to reduce the dose rates with little change to the field size however, the scattered radiation is proportional to the attenuator thickness. The Irradiation period can run from seconds to days.

The suite has a dedicated room to hold small animals e.g. mice over days to a few weeks. It has also an adjacent room to perform animal dissection and CO<sub>2</sub> euthanasia if required. The biology lab is classified as PC1. Biological supporting staff may be available to limited tasks.

The temperature, humidity and light of the suite are controlled.

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**9030 Health and Safety – in vivo gamma spectrometry (IVGS)**

Generally not applicable to AINSE users but grants have been awarded for whole body monitoring.

**Description**

The Internal Radiation Dosimetry (IRD) provides a qualitative and quantitative measurement of radioactivity in living samples eg. the human body. The investigated radionuclide must be a photon emitter of energy greater than 14KeV ie. gamma radiation or x-ray. The measurements are usually performed in a graded shielded room to provide a low radiation background environment. The detection system utilises NaI, HPGe or Phoswich large crystals as a detector.

**Applications**

- whole body gamma spectrometry
- thyroid gamma spectrometry
- lungs gamma spectrometry
- K-40 body content
- gamma spectroscopy on bulk samples in a low radiation background environment

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## 9200 Heavy Water

### Description

Specifications of the heavy water available is normally as follows

- isotopic purity - nominally 99.92% by mass
- conductivity - less than 1 mS/m
- turbidity - less than 2 NTU
- $\text{KMnO}_4$  demand - Less than 10 mg/kg
- tritium content - less than 5  $\mu\text{Ci/kg}$
- oxygen-18 content - approximately 0.22 atom per cent

### Support services and facilities

The heavy water is normally supplied in 500g or 1000g quantities in stainless steel transport containers dispensed under dry nitrogen. On receipt the heavy water should be transferred to the consignee's own container and the transport container returned to ANSTO at the expense of the consignee. On occasions larger quantities may be supplied in similar, larger, returnable transport containers, when available.

## 9210 Heavy Water Dispensing Fee

Please note that a prerequisite of supply of heavy water is the receipt by ANSTO of information on proposed end use and regulatory approval.

### Availability

Limited quantities of heavy water may be made available to academic organisations. Although the heavy water is subject to the Nuclear Non-Proliferation (Safeguards) Act 1987, no Permits are required for small quantities used for research purposes, however, supply is contingent upon regulatory (ASNO) approval for the transfer.

### ANSTO Contact:

Nuclear Safeguards Officer – Campus Services

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## 9800 AINSE Facilities

### Description

Lecture Theatre

- 120 seat capacity
- Equipped with audio-visual equipment.

Conference / Seminar Room complete with audio-visual equipment; to seat up to 40 people.

In general, there is no charge to AINSE member universities or ANSTO. A hiring fee may be applicable in all other cases.

### Costs

Theatre	\$500 per day
Council Room	\$300 per day
Foyer Area	\$200 per day

The rooms are only hired out to corporate groups.

### AINSE Conferences - Contribution to Travel and Accommodation

Depending upon circumstances, AINSE may provide a contribution towards travel costs for nominated participants from member universities. The extent of any such travel contribution will be determined by AINSE when all nominations have been received and the circumstances are known. Preference is given to students presenting papers and posters. Where appropriate, group leaders will be advised of the amount which can be made available for travel costs for the group, and the basis for payment. AINSE may meet bed and breakfast charges for participants from member organisations during the conference.

### AINSE Awards - Travel and Accommodation

Researchers planning to use the Lucas Heights facilities are expected to take advantage of the discounted airfares. The airfares are normally calculated on the basis of advance purchase airfares plus travel to and from Sydney airport.

### Car travel

AINSE interstate award holders who wish to use cars for travelling to Lucas Heights may be eligible to receive reimbursement. A tax invoice must be received from the University claiming an agreed amount and not exceeding the AINSE award.

### Bookings and further information

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**1700 SIMS - Secondary Ion Mass Spectrometry - Cameca IMS 5fE7, located at the University of Western Sydney's Hawkesbury Campus, Richmond NSW.**

The Cameca IMS 5fE7 magnetic sector SIMS instrument is used for surface isotopic analysis and depth profiling of a wide variety of materials. It has both Cesium and Oxygen primary ion sources and can be operated in either microprobe or microscope mode enabling a unique combination of in-situ analysis, depth profiling and imaging. Analyses and images of masses between 1 – 500amu can be made in areas up to the size of 500 $\mu$ m x 500 $\mu$ m. Concentrations in the ppm/ppb range can be detected under favourable conditions. Depth profiling can be performed to depths of around 10 $\mu$ m.

The instrument is routinely used for isotopic analysis, studies of surface contaminants, imaging of materials and the analysis of trace and rare earth elements in samples. Samples are to be supplied suitable for mounting. Specimens should be less than 2.5cm in diameter and less than 1cm deep. Where possible the upper surface should be as flat as possible.

**Support services and facilities**

Sample preparation is a critical step in SIMS analysis and all samples must be suitably prepared prior to arriving at UWS. It is strongly recommended that the SIMS Operator is consulted for advice in this matter. The SIMS Operator is available for consultation on matters relating to data interpretation following SIMS analysis.

**Availability**

The SIMS instrument has periods of down time while routine maintenance is performed. To maximise operational efficiency the instrument is operated in a single mode for scheduled periods. Accordingly, successful grant applicants will be allocated scheduled instrument time. The projects and instrument time required must be agreed with the SIMS Operator prior to the submission of an application.

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## 9910 Linear Accelerator / Pulse Radiolysis Facility – the University of Auckland

### Description

A Dynaray 4 linear accelerator converted to deliver electrons in single pulses of up to 180 mA current. Pulse lengths available are 200 ns, 750 ns, 1.5  $\mu$ s and 3  $\mu$ s. Beam energy can be varied between 0.5 and 5 MeV but normal operation is at 4 MeV. Radiation dose per pulse can be set between 1 and 100 Gy. A range of optical cell pathlengths between 0.5 cm and 3.0 cm as well as combined optical and AC conductivity detection cells of 1.0 cm and 2.0 cm are available for pulse radiolysis studies. Transient spectrophotometric detection is over 210 nm – 2000 nm using photomultipliers and photodiode detectors. Conductivity measurements are made using a 250 kHz AC system capable of handling up to 0.01  $\Omega^{-1}$ . Optical and conductivity detection cells, combined with temperature control (4-90  $^{\circ}$ C), are also available, as well as a pre-pulse rapid-mix facility (under development). Both xenon (for uv-vis detection) and tungsten lamps (for long observation times, seconds) are available.

### Support Services and Facilities

The modern, PC-driven, optical and conductivity radical detection system is operated in a LabWindows environment. Data is harvested/displayed by a 300 MHz digitizer/scope and full kinetic, spectral and conductance analysis is carried out using dedicated modern software. Data analysis can also be carried out off-line using stand-alone software as well as data sent to home institutions via the internet. Gas mixing lines are installed for saturating samples prior to pulse radiolysis and samples changed remotely between electron pulses.

The dedicated facility is located in the Department of Chemistry, the University of Auckland. The full range of research facilities on site includes a  $^{60}\text{Co}$  gamma source providing a dose rate of up to 7 Gy  $\text{min}^{-1}$  for complementary steady-state radiolysis studies. A fully equipped laboratory is available for sample preparation and analysis. Experienced radiation chemists are on the staff and can assist with experimental design and supervision of student research projects.

### Applications

Pulse radiolysis experiments are used to identify radical intermediates and to study reaction mechanisms in solution by measuring time-resolved spectra and conductance changes. Electron transfer reactions between donors and acceptors are studied in real time. Conductivity measurements can be used to identify and study charged species that do not have accessible absorption spectra and to confirm the protonation state of species. Studies on complex organic and inorganic molecules as well as biological systems can be carried out. Temperature-dependent kinetic studies are used to obtain thermodynamic parameters for the studied reactions. Thermodynamic redox potentials of compounds and their radical intermediates are determined from radical equilibrium measurements with reference compounds.

Cumulative electron pulses for material science and sterilization studies are also available.

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### 9930 National Plasma Fusion Research Facility (H-1NF) - Australian National University.

The H-1 National Plasma Fusion Research Facility (H-1NF) is designed to perform research into the basic properties of magnetically confined, high-temperature plasma as part of an international program, whose ultimate aim is environmentally sustainable power generation by the controlled fusion of hydrogen isotopes. This facility is built around the existing H-1 Heliac experimental confinement device at the Australian National University, established under the Commonwealth Major National Research Facilities program. The research aims to build upon Australia's internationally recognised position of excellence in basic plasma physics and applications such as plasma diagnostics and plasma processing, and to enable Australian scientists, engineers and industry to tackle the "grand challenge" problems presented by fusion research; this provides excellent postgraduate training and generates spin-offs with commercial potential.

The H-1 Facility is integral to the strategy for Australian fusion science and engineering, developed by the Australian ITER Forum, an association of over 100 scientists, engineers, students and others interested in the development of plasma fusion energy. A significant allocation for facility upgrades in the 2009 Budget will enable the facility to support the key elements of this strategy such as building Australia's capability, and developing advanced instrumentation for fusion reactor prototypes, and ultimately ITER.

#### Research Fields

Physics and technology of magnetically confined plasma, including its generation, heating, confinement, stability, remote measurement systems and numerical modelling.

#### Research Outcomes

- A detailed understanding of the behaviour of hot plasma which is magnetically confined in the helical axis stellarator configuration. (This forms part of an international program under the IEA Implementing Agreement on Stellarators, to which Australia is a party).
- The development of advanced measurement systems ("diagnostics"), integrating optical and microwave detectors, real-time processing and multi-dimensional visualisation of data on large scale computer networks, and theoretical modelling.
- Fundamental studies of turbulence and transport of particles and energy in confined plasmas.
- Significant contributions to the global fusion research effort and an increased Australian presence in the field of plasma fusion power.
- Improvements in knowledge of basic plasma physics and related technologies for applications such as plasma processing of semiconductors.
- Improvements in skills of Australian industry in the areas of materials, modern power engineering, and communications and control.

#### Description

H-1NF is a three-field period flexible heliac, a type of stellarator in which the minor axis of the plasma twists three times as it goes around the torus the long way. Figure 1 illustrates the magnetic configuration of H-1. The external toroidal field coils are displaced helically around a central coil assembly comprising a circular ring coil and helical coil. By adjusting the relative currents in the circular, helical, and other coils, the H-1NF configuration can be made to vary its shape and confinement properties; hence it is called a flexible heliac.

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The plasma in H-1NF is heated by 50-250 kW of rf power at 4-26 MHz and a 200 kW, 28 GHz gyrotron microwave source from Kyoto University and the National Institute of Fusion Science in Japan. A large number (>100) of ports provide access for diagnostics, and several gate valves of various sizes allow convenient connection of user's instruments.

A number of internationally unique diagnostic systems are being developed as part of the MNRD development project. These include:

- mm-wave tomographic interferometry for electron density imaging;
- Individual and arrays of electrical probes to measure particle energies and fluxes, and a dual 20 coil magnetic probe array for investigation of MHD/Alfvén instabilities;
- 8-mm microwave scattering for turbulence studies;
- Coherence spectroscopy systems for imaging plasma temperatures, flows, and fluctuations;
- Supersonic helium beams for local spectroscopic measurement of electron temperature and density.

### Applications

The H-1NF Facility upgrade builds on a major investment by the ANU, allowing Australia to capitalise on the current resurgence of interest in magnetic fusion configurations of the stellarator type. The flexibility of H-1NF provides access to a wide range of configurations, including some with the promising "reversed shear" characteristic of advanced tokamaks, but without the drawback of multi-megampere plasma currents and associated instabilities. This allows H-1 to be used for basic studies or as a test-bed for divertor and edge diagnostics for ultimate application to the international fusion experiment, ITER.

H-1NF is Australia's main experimental contact with the international fusion community and is the largest plasma facility in the Southern Hemisphere, and the only alternative concept device in the South East Asian region. The H-1NF Facility offers many diplomatically important opportunities for academic and technological exchange. Significant collaborative activities with Japan, Korea, Europe and the US are already under way, with exchanges of personnel and scientific equipment.

### Availability

The Facility is available to all Australian physicists and engineers and is affiliated with AINSE. Scientists outside of the ANU are involved in all aspects of experimental program of the H-1NF, and to this end, much of the data acquisition and analysis is readily conducted over the AARNET computer network, enabling data mining, remote access via metadata portals and grid computing.

Time allocation is overseen by the appropriate AINSE Specialist Committee. Proposals may be made at any time by contacting the Director, and scheduling of experimental time will be arranged between the applicant and the Management Committee of the H-1NF. Typical projects include development of new diagnostics, or use of the many existing diagnostics for studying wave, turbulence or confinement physics, or materials interaction, possibly leading to further experimentation on international devices.

### Contact Scientist

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## 9940 The Australian Positron Beamline Facility at the Research School of Physical Sciences and Engineering, ANU

### Description

The Australian Positron Beamline Facility (*APBF*) provides a unique national facility for scientists to study fundamental interactions of positrons with matter and to use positrons as a diagnostic tool for materials and bioscience activities. It was initially supported by the ARC through LIEF and Centre of Excellence grants. Participants include the ANU, Flinders, Griffith, Murdoch, Curtin, Adelaide, UWA, James Cook and Charles Darwin Universities, ANSTO, and the CSIRO. The *APBF* provides the only variable energy, positron beam lines in Australia. Positrons emitted from a 50 mCi  $^{22}\text{Na}$  source are moderated using solid neon and then loaded into a Penning-Malmberg trap, where they are accumulated and cooled, using gas-collision techniques, to form a positron cloud at room temperature ( $\sim 30$  meV). By modulating the well depth of the trap, pulses of positrons several usec wide are produced, with a 100-4000 Hz repetition rate, and these are then used in two experimental beamlines.

### Applications

The two positron beamlines are available for both high and low energy studies:

(i) The low energy (0.1-200 eV), high-energy-resolution ( $\sim 30$  meV) beamline is being used to investigate positron interactions with atoms and molecules, including measurements of ionization, annihilation and positronium formation. Important bio-molecules, and the fundamental interactions with them that underpin medical imaging processes such as Positron Emission Tomography (PET), will be studied.

(ii) The second, high energy (0.1-20 keV) beamline is dedicated to materials science and bioscience studies. The pulsed beam will be further bunched to form a sub-nanosecond, positron pulse that can be injected at high energies into the surface of the material under study. The positrons quickly thermalise and many of them combine with an electron in the material to form positronium – a mutually orbiting electron-positron pair. When this exotic 'atom' decays, it produces gamma rays that are detected in time coincidence, allowing the lifetime of the positronium to be determined. The lifetime depends critically on the free space in the material, and it is thus an excellent probe of voids and defects in materials, on the nano-scale, and at depths up to several microns. The *APBF* will enable, for the first time in Australia, the study using a variable energy positron beam, of new and exotic materials that are designed to have certain characteristics such as porosity or conductivity, or the controlled release of embedded agents such as drugs.

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