The Utilisation of Australia’s Research Reactor, OPAL

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Introducing ANSTO

- Centre of Australian nuclear expertise
- Home of Australia’s only nuclear reactor
- Australian government science and technology organisation
- Around 1000 employees
- Addressing issues such as health care, environment protection, assistance to industry and regional interactions
OPAL Research Reactor and applications

Nuclear-based science benefiting all Australians
Research reactor operation

- HIFAR operating since 1958 (Shutdown in 2007)
- National facilities → Centre of Excellence
  - Neutron beams for science
  - Radio-isotopes for medicine and industry
  - Commercial & research irradiations
OPAL Reactor

- Multi-purpose facility – neutron beams, radiopharmaceuticals, irradiation of materials
- 20 MW thermal power
- Compact core (~300 kW/L)
- Plate type Low Enriched Uranium fuel
- D$_2$O reflector
- Upward coolant flow (light water)
- 2 independent & diverse shutdown systems
12th August 2006
Howard opens Australia’s new nuclear reactor

SYDNEY: Prime Minister John Howard has officially opened Australia’s new $400 million nuclear research reactor in Sydney.

The OPAL reactor at Lucas Heights replaces Australia’s first nuclear research facility, which was shut down in January after 48 years of operation.

Mr Howard toured the new reactor yesterday morning amid tight security, before officially opening the facility before an audience of about 200 scientists, politicians and a delegation from Argentina, the source of the fuel which feeds the reactor. He said the work by scientists at the reactor deserved to be celebrated just as much as the achievements of Australia’s sportsmen and women.

“This facility will relieve human suffering, it will be of direct life-saving benefit to countless thousands of our fellow country men and women,” Mr Howard said.

“It will also be a remarkable demonstration to the world of the expertise and the cutting-edge capacity of the Australian nation.”

The OPAL reactor sits in a 13-metre deep container of water, whereas its predecessor was contained in steel. Its main purpose is to generate neutrons for nine neutron-beam instruments.
Existing Capabilities

- Education & Training:
  - Public Tours and Visits
  - Training on Reactor Operation
  - Training on Radiation Protection
- Irradiations for Neutron Activation Analysis
- Delayed Neutron Activation Analysis
- Production of Radioisotopes
  - Medical radioisotopes for needs of Australia and other countries
  - Range of isotopes for industrial and research purposes
Existing Capabilities

– Irradiations for Geochronology
  • Argon Geochronology
  • Fission Track Geochronology

– Transmutation Effects
  • Neutron Transmutation Doping of Silicon up to 8 inch diameter
  • Materials Irradiation

– Neutron Beam Research
  • SANS, neutron diffraction, residual stress measurement
Existing Capabilities

- Nuclear Analysis capabilities in neutronics, criticality, thermal-hydraulics and shielding
- Water Tunnel for hydraulic testing and flow studies
- Cold Neutron Source for beam research over cold neutron energy range
Potential Capabilities

– Education & Training:
  • Teaching programs for physical/ biological science and nuclear engineering
– Prompt Gamma Neutron Activation Analysis
– Positron Source
– Testing
  • Instrument Testing and Calibration
  • Loops for Testing Nuclear Fuel
Potential Capabilities

- Neutron Radiography
  - Static Radiography
  - Motion Radiography
  - Tomography
- Hot Neutron Source for beam research using fast neutrons.
Reflector facilities

- CNS
- Si rigs
- Core
- Pneumatic transfer system tubes
- PCS suction line
- Bulk irradiation facilities
Radioisotopes for Nuclear Medicine/ Research Isotopes

• Total of 17 Bulk Irradiation Facilities arranged in three different classes, principally for the production of Molybdenum-99 and Iodine-131

• Total of 55 Long Residence Time Facilities available for the production of a range of isotopes for medical and research purposes.
Bulk irradiation facilities

- Low Flux Facilities
  - Mo-99
- Medium Flux Facilities
  - I-131
- High Flux Facilities
Irradiations Currently Performed

- Medical Isotopes – Mo99, Iodine 131, Samarium 153, Chromium 51, Yttrium 90, Lutetium 177
- Long and Short Residence Time NAA
- Material Irradiations for research and to determine neutron damage
- Delayed NAA for Uranium Analysis
- Neutron Transmutation Doping of Silicon
Planned Irradiations

- Bulk production of Lutetium 177
- Geochronology samples – Fission Track and Argon Dating
- Radioactive Tracers – Scandium 46
- Gold 198 Grains
- Brachetherapy Sources – Iodine 125 seeds
Rigs and cans

- Lifting Lug
- Top Dummy
- Silicon Ingot
- Bottom Silicon Dummy

TARGETS 
NOZZLE 
Silicon Ingot 
Bottom Silicon 
Dummy 

Inner Can 
Outer Can 
8.960 
70
Results - BIF

Compare calculations and measurements
The Production Process

LEU in reactor for irradiation & Mo-99 from fission process

Mo-99 separated

Tc-99m Generator to Customer
Silicon irradiation

- 6 facilities for silicon irradiation at OPAL suitable for 4”, 5”, 6” and 8” diameter silicon crystals
- Facilities are located in the reactor D\textsubscript{2}O reflector vessel exposed to a neutron flux with Cd ratio > 1000 (approx)
- Silicon crystals are irradiated in aluminum cans in rotating rigs and water cooled
- Neutron flux range from 2.5E12 to 1.6E13
- Customer base – Japan & Europe electronics suppliers
Applications of NAA and DNAA

- environment
- geoscience and mineralogy
- forensics and counter-terrorism
- archaeology
- agriculture and food science
- materials science
- medical science
- metrology
NAA - short residence time facility – ‘self-service’

< 3E13 cm\(^{-2}\) s\(^{-1}\)
< 15 minutes
Long residence time facility
< 20 hours  ~ 9E12 cm⁻² s⁻¹
Short and long irradiation NAA cans
NAA results
- reference material irradiated in SRT and LRT facilities

Element

Concentration - Measured / Certified

June 2009 - Short IF
Aug 2009 - Long IF

Yb  Ce  Pr  Zn  Th  As  Au  Br  Sb  Mo

Nuclear-based science benefiting all Australians
DNAA facility

\[ \sim 6 \times 10^{12} \, \text{cm}^{-2} \, \text{s}^{-1} \]
DNAA can loading device
NAA and DNAA at ANSTO

- **Australian universities**
  - archaeology: pottery, ochre, bone, ...
  - environment: mining, estuarine, ...
  - geology and mineralogy

- **ANSTO**
  - mineral processing, U
  - climate change
  - forensics

- **Industry**

- **Government research agencies**
  - metrology
  - geoscience

- **INAA method development**

- **International networks**
Utilisation of Irradiation Facilities

![Graph showing the utilisation of irradiation facilities across operating cycles.](image)

- The x-axis represents the Operating Cycle, ranging from 1 to 22.
- The y-axis represents the Number of Irradiations, ranging from 0 to 1600.
- The graph displays a trend where the number of irradiations increases significantly from cycle 13 onwards, peaking at cycle 21.
Beams for neutron scattering science
Beam facilities

Assembly #1
Thermal Beam

Assembly #2
Cold Beam

Assembly #3
Cold Beam (Future)

Assembly #4
Thermal Beam

Assembly #5
Hot Beam
Reactor face, guide bunker & neutron guides

Thermal neutron guides run ~ 40m in bunker

Beams vary from 50 - 100 mm wide and from 150 - 300 mm high at exit window
Thermal Neutron Fluxes & Spectra

**TG1 Au foil measurement**
- $\Phi = 1.24 \times 10^{10} \text{ n/cm}^2/\text{s}$
  (2nd break after Reactor Face)
  - Estimate $\Phi_{RF} \leq 5.0 \times 10^{10} \text{ n/cm}^2/\text{s}$
- $\Phi = 3.3 \times 10^9 \text{ n/cm}^2/\text{s}$
  (Wombat 45m from Reactor Face)
  - c.f. predicted value of $2.4 \times 10^9 \text{ n/cm}^2/\text{s}$

**Wombat**
- $\Phi = 2.9 \times 10^9 \text{ n/cm}^2/\text{s}$
- 2% contours
- variation: 10% (h) x 2% (v)
Cold Neutron Source

- Long wavelength neutrons are produced in a moderator of liquid D₂ (~20 K) next to the core of the reactor.
Cold Neutron Fluxes & Spectra

- **Peak in cold neutron spectrum at reactor face:** \( \lambda \sim 3 \text{ Å} \)

\[
\Phi = 3.6 \times 10^9 \text{ n/cm}^2/\text{s}
\]

10 % contours

**CG4**

- **OPAL:CG4@19MW** (235U) + **OPAL:TG4@300kW**, calibration \( z = 0, w = 1.00 \mu \text{s} \)

![Graph showing neutron counts vs. wavelength for CG4 and TG4](image)
Operational Neutron Beam Instruments at OPAL

- **Platypus** (Reflectometer)
- **Wombat** (Hi-Intensity Powder)
- **Kowari** (Residual Stress)
- **Echidna** (Hi-Resolution Powder)
- **Koala** (Single Crystal)
- **Quokka** (SANS)
- **Taipan** (Thermal TAS)
The Next Generation (under construction)

Kookaburra (USANS)

Sika (Cold TAS)

Pelican (Polarised Spectrometer)

Bilby (SANS)

Dingo (Radiography)

Emu (Backscattering)
ANSTO’s neutron-beam instruments are used to solve complex research and industrial problems in many important fields.
Battery Materials on Wombat

- Ion-mobility
- Structure-property relationships
- Cell construction (cathode/electrolyte interfaces, microstructure)

Image: http://www.gaston-lithium.com
• *In-situ* charging/discharging cycling on Wombat
Welded Pipelines on Kowari

- Integrity assessment of a welded branch connection for high-pressure gas pipeline on KOWARI - found to be fit for service.
Papers so far from OPAL

- **37 papers from 6 instruments (+13 submitted)**
Interface with Customers

• Regular contact is maintained with all internal customers to ensure that their requirements are met in the delivery of Medical Isotopes and Commercial Irradiations. In addition:

  – Monthly meetings are held with major internal customers at management level for intermediate and long term planning
  – Weekly meetings held with all internal customers to review irradiation schedules and to receive feedback on client satisfaction
  – Continuous feedback provided to customers when disruptions occur to reactor operations and irradiation schedules
Future Utilisation

• There has been a significant increase in the utilisation of reactor facilities in the past 4 years
• Significant achievements have been gained in the areas of NAA and DNAA and also in utilising the neutron beam instruments for research over a wide range of applications
• A strategic plan is in place to further improve the use of OPAL towards achieving optimum utilisation of irradiation and beam facilities
Thank you