Neutron Scattering at OPAL Research Reactor

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10 Years of Neutron Beams

100 Operating Cycles of OPAL

1000 Scientific Research Papers
Outline

1 Introduction to ANSTO
2 OPAL Reactor & Neutron Beam Facilities
3 Australian Centre for Neutron Scattering
4 Why Neutrons?
5 User Access
6 Closing Remarks
Australian Nuclear Science & Technology Organisation

Camperdown
Cyclotron
NSW

Main site
Lucas Heights
NSW

Clayton
Australian Synchrotron
VIC
Public research organisation with a variety of roles for the nation.
ANSTO operates Australia’s research nuclear reactor - OPAL

<table>
<thead>
<tr>
<th>Formed in 1953</th>
<th>HIFAR critical 1958</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;$1 billion assets under management</td>
<td>Annual turnover &gt; $350 million</td>
</tr>
<tr>
<td>Circa 1200 employees; 300 Ph.D.'s</td>
<td>OPAL Reactor Critical 2006</td>
</tr>
</tbody>
</table>
ANSTO Research Infrastructure for Users and Industry

**Landmark**
- OPAL Multipurpose Reactor
- Australian Centre for Neutron Scattering
- Australian Synchrotron

**National**
- National Deuteration Facility
- Centre for Accelerator Science
- Medical Research Cyclotron

**Institutional**
- Local with national impact
  - Isotope Tracing and Dating
  - Nuclear Forensics
  - Activity Standards
  - Neutron Activation and Irradiations
  - Radiotracers and Bioimaging
  - Materials Characterisation
ANSTO businesses

- ANSTO Health
- ANM: ANSTO Nuclear Medicine
- ANSTO Minerals
- ANSTO Silicon
- ANSTO Synroc
- ANSTO Radiation Services
ANSTO Lucas Heights Campus & OPAL Reactor

- 20 MW
- Open pool
- Compact core

Sydney CBD

- D$_2$O reflector
- Plate type Low Enriched Uranium fuel
- Commenced operation 2006

Melbourne AS 800 km
OPAL’s Neutron Beam Facilities

Primary Shutter TG123 In-pile & shutter components to be replaced during 2019 long shutdown
Reactor Face, Neutron Guides & Bunker

Thermal neutron guides run ~ 40m in bunker

300 x 50 mm  150 x 50 mm

TG1    TG3

Supermirror neutron guides transmit up to ~80 m from the core
Cold Neutron Source Mk2

- Licence application – CNS life 10 years (2018)
  - Conservative due to limited data on AlMg5
  - Life extension now to 15 years (2024)
- 2 x CNS currently being fabricated by HNFT
  - Increased height and volume

<table>
<thead>
<tr>
<th>Case 1 (current)</th>
<th>Case 2 (no cavity)</th>
<th>Case 3 (increased height)</th>
<th>Case 4 (no cavity and increased height)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Case 1" /></td>
<td><img src="image2" alt="Case 2" /></td>
<td><img src="image3" alt="Case 3" /></td>
<td><img src="image4" alt="Case 4" /></td>
</tr>
</tbody>
</table>

![Graph showing Gain/Loss of Cases 2, 3 & 4 normalised to Current Cold Source](image5)

![Cold Neutron Source Mk2 image](image6)
Australian Centre for Neutron Scattering

- 80 staff support 300 reactor days
  - 225 days to user service
- 14 (+1) neutron beam instruments
- 4,300 registered users
- 450 user experiments per year
- 500 individual users visit per year
  - 1,400 user visits per year
- 1061 journal publications with neutron data from users & staff (2007-2018)
  - 184 in 2017
  - 127 in 2018
### Diffractometers:

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECHIDNA</td>
<td>High-resolution powder diffractometer</td>
</tr>
<tr>
<td>WOMBAT</td>
<td>High-intensity diffractometer</td>
</tr>
<tr>
<td>KOALA</td>
<td>Single-crystal Laue diffractometer</td>
</tr>
<tr>
<td>KOWARI</td>
<td>Strain scanner</td>
</tr>
<tr>
<td>JOEY</td>
<td>Crystal-alignment Laue diffractometer</td>
</tr>
</tbody>
</table>

### Small-angle Spectrometers:

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUOKKA</td>
<td>Monochromatic SANS</td>
</tr>
<tr>
<td>BILBY</td>
<td>Time-of-flight SANS</td>
</tr>
<tr>
<td>KOOKABURRA</td>
<td>Ultra-SANS</td>
</tr>
</tbody>
</table>

### Imaging & Reflectometry:

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DINGO</td>
<td>Radiography/tomography/imaging station</td>
</tr>
<tr>
<td>PLATYPUS</td>
<td>Reflectometer</td>
</tr>
<tr>
<td>SPATZ</td>
<td>Reflectometer (under construction)</td>
</tr>
</tbody>
</table>

### Inelastic Spectrometers:

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAIPAN</td>
<td>Thermal-neutron three-axis spectrometer, with Be-filter option</td>
</tr>
<tr>
<td>SIKA</td>
<td>Cold-neutron three-axis spectrometer</td>
</tr>
<tr>
<td>PELICAN</td>
<td>Cold-neutron time-of-flight spectrometer</td>
</tr>
<tr>
<td>EMU</td>
<td>High-resolution back-scattering spectrometer</td>
</tr>
</tbody>
</table>
ACNS Operations Teams

Scientific Operations (Scott Olsen 9): Mechanical workshops, neutron delivery systems, chopper systems, vacuum systems and shielding

Sample Environment (Rachel White 8): Sample environments and laboratories support; key interface with users and support for specific experiments

Computing & Electronics (Nick Hauser 12): Software and electronic engineering, data-acquisition and data-analysis software and hardware, detectors and technical support for ACNS user portal

Electrical Engineering (Frank Darmann 8): Motion controls, encoding, safety interlocks, pneumatics, control systems, power distribution and signal earthing
SE Equipment and Instrumentation

- More than 60 individual pieces of Sample Environment equipment, including:
  - 14 cryostats or cryofurnaces + dilution insert + 3He one-shot
  - 4 magnets
  - 8 multi-sample changers
  - 3 Robots one (6 axis) dedicated to texture measurements
  - 5 furnaces
  - + pressure cells, Eulerian cradles, gas/vapour delivery, electric field, differential scanning calorimeter, rapid viscosity analyser, rheometer, solid-liquid and stopped-flow cells + more!
Lab and Main SE Work Area
ACNS Partnerships

- **Strategic Partnerships**
  - National Synchrotron Radiation Research Center (NSRRC)
  - Helmholtz-Zentrum Berlin
  - University of Tokyo
  - National Collaborative Research Infrastructure Strategy

- **Joint Research**
  - Universities & Industry
  - Students, Post-docs
  - Australian Research Council Discovery, Linkage, LIEF, Centres of Excellence, Industrial Transformation Training Centres

- **Facilities & Associations**
  - J-PARC, PSI, CIAE, BATAN, KAERI

- **Joint Appointments**
  - Adjunct Positions with Universities

- **Strategic Partnerships**
  - National Synchrotron Radiation Research Center (NSRRC)
  - Helmholtz-Zentrum Berlin
  - University of Tokyo
  - National Collaborative Research Infrastructure Strategy
Where do the users come from?

2008 – 2018

ANSTO
Users Visiting ACNS (June 2018)

4,300 registered users
Demand from 2019-1

- **Last Round 281 Proposals**
  - Australia 53%
  - Asia/Oceania 37%
  - Europe/USA 10%
Papers from ACNS Neutron Beam Instruments (July 2018)

- JIF > 6
- 3 < JIF < 6
- JIF < 3
- No JIF
Papers from ACNS NBI (October 2018)
ACNS Industrial Liaison Office

- Dedicated industry portal for access to ACNS:
  - Provide industrial access to neutron and X-ray instruments
  - Develop software and high-tech instrumentation
  - Collaborate or partner with industry in research and development projects
  - Provide specialised training for academic and industry users.
Neutrons as a Probe of Atomic and Nanoscale Structures

1. Have the right (tunable) wavelength

- Human hair: ~100,000 nm
- Red blood cells: ~7,000 nm
- Deposited nanostructures: ~500 nm
- Influenza virus: ~100 nm
- DNA: ~2 nm
- Silicon atoms: ~0.2 nm
Neutrons as a Probe of Atomic and Nanoscale Structures

2. Scatter from the nucleus
   - See light atoms next to heavy ones
   - Distinguish neighbouring atoms in periodic table
3. Scatter from the nucleus: isotopic sensitivity
   - isotopic sensitivity - contrast between H and D

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>X-ray</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>-0.374</td>
<td>0.28</td>
</tr>
<tr>
<td>D</td>
<td>0.667</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Biological and Chemical Deuteration

- ANSTO’s National Deuteration Facility
  - User Provide access to specialised laboratory space, equipment, and expertise for deuteration
  - Merit access via proposal

**Chemical synthesis in D₂O**

**Growing bacteria in D₂O**

**Deuterated product**

**Neutrons**

**Infra Red (IR)**

**Nuclear Magnetic Resonance (NMR)**

**Kinetic Effect**
Probe of Atomic and Nanoscale Structures

4. Energy comparable to atomic and molecular motion and dynamics
Probe of Atomic and Nanoscale Structures

5. Penetrate deeply
6. Neutrons have a magnetic moment
7. Neutrons are Fermions with spin $\frac{1}{2}$

Study of magnetism at atomic level

What is the relative size?

- Proton
- Neutron
- Electron

- 1 amu
- 1 amu
- $\sim 1/1836$ amu

- AMU = atomic mass unit = 1/12 CARBON ATOM
- (standard)

2000 electrons
1 proton
Probe of Atomic and Nanoscale Structures
$^3$He Neutron Polarisation on 7 Instruments

- **PLATYPUS**
- **QUOKKA**
- **WOMBAT**
- **TAIPAN**
- **ECHIDNA**
- **SIKA**

Helium-3 Polarising Station
Wombat Detector
• 12 years reliable service & low maintenance cost

Quokka Detector
• High performance SANS detector
• 7k counts/second/pixel (upgradeable to 25k)
• 250m counts/second/detector
SPATZ Neutron Reflectometer

- BioRef Reflectometer transferred from HZB (BER-II reactor) to ANSTO in 2017
  - First neutrons in late 2018 & first users in early 2019
## Access to ANSTO

<table>
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<tr>
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<tbody>
<tr>
<td>Normal &amp; Program (3 years) proposal rounds - 15&lt;sup&gt;th&lt;/sup&gt; March &amp; 15&lt;sup&gt;th&lt;/sup&gt; September.</td>
<td>Sample preparation, experiment, analysis and reporting conducted by a team of specialist scientists</td>
<td>High impact science, Measurements critical to students thesis or to complete a publication</td>
</tr>
<tr>
<td>Mail-in for Powder Diffraction measurements on ECHIDNA</td>
<td>Timely access, minimal waiting period</td>
<td>Continuously open round</td>
</tr>
<tr>
<td>No charge but expectation to publish</td>
<td>IP conditions that support commercial use</td>
<td>No charge but expectation to publish</td>
</tr>
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</table>
Proposal Process

- Preparation
- Submission (Proposal Deadlines: 15 Sep, 15 Mar)
- Review – online through Web portal
  - Scientific – national & international experts
  - Technical & Safety Review – instrument scientists, sample environment manager, laboratory manager
  - Program Advisory Committee (PAC)
Proposal Process

- Approval
  - ACNS Director approves PAC recommendation & makes adjustments if required (may balance for institutional commitments)

- Scheduling
  - user office & instrument scientists

- Completion
  - customer feedback requested

- Reporting
  - brief scientific report
  - publications
Access Policy

- Principal Investigator agrees to principles of non-proprietary research and takes responsibility for their team
  - Non-proprietary research (no IP)
  - Publish in open literature
  - Acknowledgment of ANSTO on publication:
    - Service – standard assistance with experiment up to and including data reduction
    - Collaboration – special sample environment/experiment, assistance with data analysis, writing papers
Access Policy

- Data policy
- Each Researcher completes a Guest Researcher agreement upon arrival
  - Safety
  - Security
  - Confidentiality
  - Has Medical Insurance/Cover (international users)
Integrated User Portal & Infrastructure

Dynamic Web Pages

User Portal

Sample management

Facility Status Monitor

Publications

Instrument Schedules
Scholarships & Awards

- **AINSE Honours Scholarships**
  - Students are eligible if they are either undertaking work at ANSTO or processing prior data
  - Students receive a $5,000 stipend

- **AINSE Post Graduate Research Awards**
  - Students must have an Australian Postgraduate award or equivalent
  - Students receive:
    - $7,500 stipend per year
    - 2 return flights and up to four weeks accommodation at ANSTO

- [https://grants.ainse.edu.au/](https://grants.ainse.edu.au/)
Thank you.