The Cold Neutron Source at OPAL Reactor

Weijian Lu, Reactor Operations
The OPAL Reactor

- Located in Sydney, it’s Australia’s only nuclear installation
- 20 MW multi-purpose research reactor
- Compact core (MTR-type fuel)
- Light water cooled and moderated, heavy water reflected
- Radiopharmaceutical and NTD silicon Production
- Neutron beam research
- NAA and DNAA
- 300 days of operation per year; average reactor cycle 32 days, typical maintenance shutdown 5 days, occasional major shutdowns (weeks or months)
- 77 reactor cycles as of May 2016 since Nov 2006 commissioning
The OPAL Reactor

Cerenkov Glow
OPAL Reactor and its CNS

CRYO-PIPE

PCS PIPE

CNS

CORE
CNS in the World Today (Operational)

- Reactor based
  - OPAL (Australia)
  - ILL, ORPHEE (France)
  - NIST, HFIR (USA)
  - FRM II (Germany)
  - JINR (Russia)
  - HANARO (South Korea)
  - BNC (Hungary)
  - CMRR (China)

- Spallation source based
  - SNS, LANSCE (USA)
  - J-PARC (Japan)
  - ISIS (UK)
  - PSI (Switzerland)
Important CNS Considerations

• Purpose (science, politics and finance)
  – reactor or accelerator, continuous or pulsed

• Specifications (physics and engineering)
  – cold neutron flux, locations (in-pile or in-beam, vertical or horizontal), moderator (H₂, D₂, CH₄, mesitylene C₉H₁₂, triphenylmethane C₁₉H₁₆, etc), boiling or single phase, cooling power, interaction with reactor

• Fundamental question
  – is there a viable neutron science program?
ANSTO Neutron Guide Hall – International Open User Program
ANSTO Cold Neutron Instruments

- **PLATYPUS** Neutron Reflectometer
- **QUOKKA** Small Angle Neutron Scattering
- **PELICAN** Time-of-Flight Spectrometer
- **SIKA** Cold Neutron 3-Axis Spectrometer
- **KOOKABURRA** Ultra Small-Angle Neutron Scattering
- **BILBY** 2nd Small-Angle Neutron Scattering
- **EMU** High-Resolution Backscattering Spectrometer
The OPAL CNS

• 20 L of sub-cooled liquid deuterium at average 25 K
• Vertical thermosiphon in heavy water reflector
• Located 50 cm centre-to-centre from reactor core
• 5 kW heat – cooled by 500 kW helium refrigerator
• Two tangential beams followed by 5 neutron guides serving 7 instruments
• Gain of 20 at 5 Å and 45 at 8 Å
• Separation from nuclear safety case
• Early outages due to process system faults, but near perfect reliability since 2013
Part of Reactor Structure

CNS
Vacuum
Containment

Support Tube

Beam Tube

Reactor Face
OPAL CNS In-Pile

Liquid D₂ Circuit + Helium Circuit + D₂O Circuit + CNS In-pile Assembly = Vacuum Containment
OPAL CNS Moderator Chamber with Cavity
OPAL CNS Gain

Maxwell-Boltzmann Distribution

- cold neutrons

- f(T1) - 300 K
- f(T2) - 25 K
- Ratio

NO/SO gain

- QUOKKA(CG1)
- BILBY(CG2)
- PLATYPUS(CG3)
- KOOKABURRA(CG3)
- ptrac

Maxwell-Boltzmann Distribution

- f(T1) - 300 K
- f(T2) - 25 K
- Ratio

Wavelength (Å)

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15

Gain

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45

Velocity (m/s)

- 0
- 500
- 1000
- 1500
- 2000
- 2500
- 3000
- 3500

Maxwell-Boltzmann Distribution

- f(T1) - 300 K
- f(T2) - 25 K
- Ratio

Wavelength (Å)
Monte Carlo Modelling

CNS

CG1-3

CG4

Tally surface

Tally surface
Experimental and Computational Characterisation

- Neutron flux (TOF, Au foil, MCNP)
- Nuclear heat (thermal balance, MCNP)
- Thermosiphon (prototype, thermal balance, CFD)
- Material (PIE)
Cavity Parametric Study
OPAL CNS MK II Options (2019)

<table>
<thead>
<tr>
<th>Case 1 – As Is</th>
<th>Case 2 – no cavity</th>
<th>Case 3 – moderator chamber height increased by 7 cm (i.e. cases 2 and 3 combined)</th>
<th>Case 4 - no cavity and moderator chamber height increased by 7 cm</th>
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</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image 1" /></td>
<td><img src="image2.png" alt="Image 2" /></td>
<td><img src="image3.png" alt="Image 3" /></td>
<td><img src="image4.png" alt="Image 4" /></td>
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</tbody>
</table>

A) ![Diagram A](DiagramA.png)  
B) ![Diagram B](DiagramB.png)  
C) ![Diagram C](DiagramC.png)  
D) ![Diagram D](DiagramD.png)  

[Checkmark]
CNS in the Future – Upgrades, In Development or Proposed

• Reactor based
  – CARR (China)
  – JINR (Russia)
  – RA-10 (Argentina)
  – BNC (Hungary)
  – PIK (Russia)
  – TU Delft (Netherlands)
  – Brazil
  – India

• Spallation source based
  – ESS (Sweden)
  – SNS (USA)
  – ISIS (UK)
  – CSNS (China)
The End. Thank You.