Development of Instruments, Techniques, and Components for Neutron Scattering Applications

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July 7, 2011
Some Major Areas for Long-Term Development

- Instrument Concepts for new source types
  - ESS and Second Target Station at the SNS – long-pulsed source instruments
    - 1 – 2 msec pulses, 10-20 Hz
    - Emphasis on cold neutrons
    - How to make best use of this combination of characteristics?
      - Polarized neutrons – Larmor precession techniques?
    - What scientific prospects are going to inspire the neutron user community?
      - Beam lines will be very expensive ($10M to $20M at SNS), will we build innovative instruments?

- Neutron Optics
  - Possible long instruments (150 – 300 m) at new sources -> need for cheaper neutron transport schemes
  - Neutron focusing – K-B mirrors can get <100 \( \mu \text{m} \) – objective should be 1 \( \mu \text{m} \) spot size
  - Better matching of neutrons into beam line optics (next 3 slides)
    - SNS BL2 – 10% more flux on sample for every 1 m guide entrance was closer to moderator
    - Brighter sources (includes moderator development)
Aside: Where do all the neutrons go?

<table>
<thead>
<tr>
<th>Systems</th>
<th>Production (n/p)</th>
<th>Capture (n/p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Module</td>
<td>21.7 (85%)</td>
<td>5.1 (20%)</td>
</tr>
<tr>
<td>Moderator System</td>
<td>0.1</td>
<td>2</td>
</tr>
<tr>
<td>Inner Reflector Plug</td>
<td>2.4 (9%)</td>
<td>8.8 (34%)</td>
</tr>
<tr>
<td>Outer Reflector Plug</td>
<td>1</td>
<td>5.9 (23%)</td>
</tr>
<tr>
<td>Proton Beam Window</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>25.6</strong></td>
<td><strong>22.2</strong></td>
</tr>
</tbody>
</table>

2.1 n/p are deposited into the shielding
1.3 n/p (5%) exit the outer reflector (1m radius) towards the instruments
How many neutrons does SNS make in a year?

- 26 neutrons/1 GeV proton
- SNS at 1 MWatt
  - 1 GeV protons @ 1 mA (time averaged) (approx. $1.04 \times 10^{14}$ protons/pulse, 60 Hz)
- Neutrons/sec = $26 \times 6.24 \times 10^{15} = 1.6 \times 10^{17}$ n/sec
- Neutrons/year (5000 hours) = $2.9 \times 10^{24} = 4.8$ moles/year
How many neutrons do we count?

- Guide transmits about $2\cdot10^7$ n/sec to sample
- 10% scattering sample into $4\pi = 2\cdot10^6$ n/sec
- Analyzer is 1.2 sr, 10% scattered neutrons reach analyzer = $2\cdot10^5$ n/sec
- Analyzer accepts about 0.004, reflecting back to detectors = 800 n/sec
- There is some loss in radial collimator 80% transmission so count about 600 n/sec
- SNS produces about $1.6\cdot10^{17}$ n/sec
- Beamline counts $4\cdot10^{-15}$ of neutrons produced
  - Other instruments have higher fluxes and there are essentially 24 instrument stations, but CAN WE DO BETTER?
The Case for Collaborations

- Development activities at major facilities are expensive.
  - Beam lines at spallation sources are costly to build – $12M - $20M at the SNS (shielding/optics/detectors/people)
  - Beam lines are a limited resource – building a development beam line is in competition with new instruments to support the user program
  - Activation of components can limit hands-on approach

- SNS/HFIR Science Goals
  - Deliver a strong user program – robust/relentless
  - Mature the current instrument suite – invest in operating instruments/upgrades – distinctive capabilities
  - Produce signature, high-impact science
  - Our near-term development efforts will be focused on contributing to these three objectives
    - Developments that will improve capacity of the beam lines – e.g. detector improvements/gains
    - Developments that will improve instrument efficiency – e.g. automatic sample changers
    - Developments that will provide distinctive capabilities – e.g. pump-probe techniques/apparatus that capitalizes on high peak power and “event-mode” data acquisition
ORNL Neutron Scattering Near-Term Development Activities

• Neutron Detectors
  – Finer pixelation, Higher efficiency, Higher Count Rates
  – Replacement for $^3\text{He}$
  – Multi-year efforts – competition with deployment

• Polarized Neutron Components/Apparatus
  – $^3\text{He}$ spin filters – routinely deploy on beam lines
  – Flippers …
  – Adapting polarized devices/concepts to time-of-flight pulsed neutron sources
    • R. Pynn – Indiana Univ. – leads this collaboration, sought and found the funding

• Sample Environment Equipment
  – Humidity cells
  – Electrochemical cells
  – Pressure cells
  – Automatic sample changers
  – Furnaces

• Techniques
  – Pump-probe/event-mode data collection – light, magnetic field, stop-flow cells, voltage (batteries)
Characteristics of a “CANS” that can foster development activities

• Modest cost beam lines
• Limited shielding – open beam line designs allow for rapid prototyping/reconfiguration
• Operating/Funding models that may provide easier, more rapid access to neutrons
• Location-Location-Location: University-based sources bring a different context than a national user facility
  – Direct access to a talent pool of students
  – Innovation driven by diverse scientific needs (broad pool of researchers from many scientific disciplines)
Summary

• Innovation in neutron scattering techniques, instruments, and components is needed to meet more demanding and diverse science missions
  – Cost drivers promote conservatism (low-risk beam lines) – more/faster but not innovation

• National user facilities balance resources with primary objectives to provide reliable access to suite of operating instruments for the user community

• Compact Accelerator-Driven Neutron Sources possess many characteristics that foster development activities and there is a clear role and strong need for this