The Low Energy Neutron Source at IUCF

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- Many more!

OUTLINE
- Why use neutrons and how do you do it?
- What is LENS?
- Early results and plans for the future
- Conclusions

Why Neutrons?
- Weak non-destructive probe of condensed matter with easily interpretable results.
- Random n-nucleus cross section across the elements --> “sees” light elements amongst heavy.
- n-H is very different from n-D --> useful for probing polymers, biomaterials, etc. to really see what the hydrogen is doing!
- Also sensitive to magnetic moments!
- Versatile probe of the weak interaction

From J Root: http://www.orau.org/council/02presentations/root.pdf

Water in Fuel Cells

Neutron Radiography from NIST
**H on nanotubes**

From Paul Sokol

**Artificial membranes**

Neutron Reflectometry from NIST CNBT team 2005

**Protein Interactions (in solution!)**


Calmodulin and myosin L C Kinase

**Scattering:** \[ \lambda + \theta \rightarrow Q \]

**Neutron Facilities (traditional)**

- Reactor (\( \delta \lambda/\lambda \))
- Crystal (\(< 1\%\))
- Vel. Selector (1-40\%)
- Spallation (Time-of-flight (\(< 1\%\))

**A Comparison of Reactors & Spallation Sources**

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<td>Neutron spectrum is &quot;slowing down&quot; spectrum – preserves short pulses (\langle Q \rangle )</td>
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<td>Constant, small (Q), at large neutron energy (E) (\rightarrow) excellent resolution especially at large (Q) and (E)</td>
<td>Resolution can be more easily tailored to experimental requirements, except for (\delta) neutrons where monochromator crystals and choppers are less effective</td>
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<td>Large flux of cold neutrons (\rightarrow) very good for measuring large objects and slow dynamics</td>
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<td>Low background between pulses (\rightarrow) good signal to noise</td>
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Brightness over the years

From http://www.sns.gov/aboutsns/benefits.htm

The Spallation Neutron Source (SNS)

What is LENS?

- **Low Energy Neutron Source**: based on low-energy $(p,nx)$ reactions ($E_p<13\text{MeV}$) in Be.
- Applications to Materials Research and Single Event Effects in electronics (SREEP).
- The source is tightly coupled to a cold moderator (e.g. solid CH$_4$ at $4\text{K}<T<25\text{K}$).
- LENS will have a **variable pulse width** (from $<5\ \mu\text{s}$ to more than $1.0\ \text{ms}$).
- In long-pulse mode, LENS will have a time-averaged cold neutron intensity suitable for materials research with SANS, reflectometry and other techniques.
- Budget: $13\text{M+}$ (not including surplus etc.).

Missions

- Training and Education
- Source and Instrument Development
- User Program

IUCF
Distinct Features of LENS

- **Its low proton energy** makes LENS ideal for studies of new moderator materials and designs.
- No high-energy \((E>11\text{MeV})\) neutrons and few \(\gamma\)'s allows reduced costs, lower moderator temperature, close-in choppers, etc.
- **Its variable pulse width** (<5\(\mu\)s to 1ms) makes LENS suitable for instrumentation development.
- **Its low cost** (both capital and operating) should make such sources accessible to industry and/or smaller nations.

Major Applications

- Neutron moderator development.
- SANS studies of materials (glassy, magnetic, biological, composite, polymer, etc.).
- Develop precession instrumentation: SESAME, high-resolution diffraction, and reflectometry studies of materials.
- Neutron Radiography
- Education, particularly in the areas of Chemistry, Biology, and industrial applications.
- LPSS instrumentation development.
- Some fundamental physics (weak interaction).

The Facility Timeline

- Official NSF project funding started in Sept. 2003
- **Phase I** (Now: 7MeV, 7mA, 0.3% DF; 10^{11} n/s)
  - Moderator studies: Benchmarking LENS performance, lower T, different materials, ...
  - Simple diffraction experiments with SANS instrument
  - Initial instrumentation commissioning: Radiography, SANS
- **Phase Ia** (Early 2006: 7MeV, 20mA, 2% DF; 10^{12} n/s)
- **Phase II** (Fall 2006: 7MeV, 50mA, 5% DF; 10^{13} n/s)
  - SANS studies of complex fluids, nano-materials, clays, ...
  - Development of Precession instrument, RF spin flippers etc.
  - Neutron Radiation effects (SFE) studies in electronics
  - Eventual power (13MeV, 50mA, 5% DF; 10^{14} n/s)

\[ p + ^{7}\text{Be} \rightarrow \text{Neutron Yield (n/mC)} \]

- **p + ^{7}\text{Be} Reaction**
  - Yield ~ 0.007 n/p@ 13 MeV
  - ~0.015 n/p@ 7MeV

\[ E \text{ (MeV)} \]

- **p + ^{7}\text{Be Reaction**
  - Neutron Yield (n/mC)

\[ 0 \ 10 \ 20 \ 30 \ 40 \ 50 \ 60 \]

\[ 10^{11} \ 10^{12} \ 10^{13} \ 10^{14} \ 10^{15} \]

- Neutron Yield (n/mC)
LENS Floor Plan-2007

Target Moderator Reflector (TMR)

MCNP model of TMR

Neutron Flux within the TMR 32kW beam power
Cryostat insertion

Water

CH4

Al

Polyethylene

PT-410

50 cm

first methane cooldown - 06Apr05

88 90 92 94 96 98 100 102

T [K]

P [torr]

vapor pressure curve

normalized T3 data

8He detector here

Activation Foil here

Cold Neutrons: 15 Apr. 2005

First Neutron Spectra

First Cold Spectrum (T=3.6K)
Spectral Analysis: MCNP

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<thead>
<tr>
<th>P(W)</th>
<th>T4 (K)</th>
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<tbody>
<tr>
<td>0.0</td>
<td>4.9</td>
<td>3.8</td>
</tr>
<tr>
<td>1.0</td>
<td>7.3</td>
<td>5.9</td>
</tr>
<tr>
<td>2.0*</td>
<td>8.9</td>
<td>7.2</td>
</tr>
<tr>
<td>3.0</td>
<td>10.2</td>
<td>8.3</td>
</tr>
<tr>
<td>4.0</td>
<td>11.3</td>
<td>9.1</td>
</tr>
<tr>
<td>5.0</td>
<td>12.3</td>
<td>10.0</td>
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* Estimated thermal load at 32kW

Moderator Cryogenic Tests

Dec. 2004

Spin Echo SANS

Conclusions

- LENS has produced its first cold neutrons and is starting its work on science, education, and technology.
- The next few years will see a steady increase in the source power, instrument commissioning, etc.
- The facility provides a unique opportunity for developing cold-mediator technology, novel instrumentation, materials research, and neutron radiation effects.