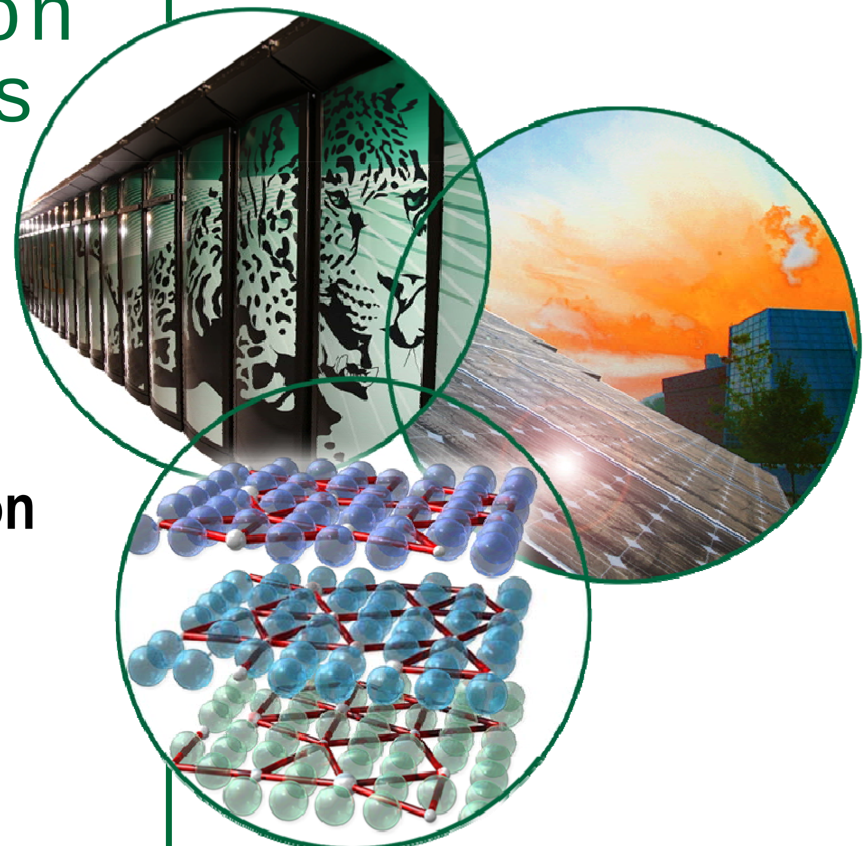
Development of Instruments, Techniques, and Components for Neutron Scattering Applications



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July 7, 2011

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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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 μm – objective should be 1 μm 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?

Systems	Production (n/p)	Capture (n/p)
Target Module	21.7 (85%)	5.1 (20%)
Moderator System	0.1	2
Inner Reflector Plug	2.4 (9%)	8.8 (34%)
Outer Reflector Plug	1	5.9 (23%)
Proton Beam Window	0.4	0.4
Total	***25.6***	22.2

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. $1.04 \cdot 10^{14}$ protons/pulse, 60 Hz)**
- **Neutrons/sec = 26 x $6.24 \cdot 10^{15}$ = $1.6 \cdot 10^{17}$ n/sec**
- **Neutrons/year (5000 hours) = $2.9 \cdot 10^{24}$ = 4.8 moles/year**

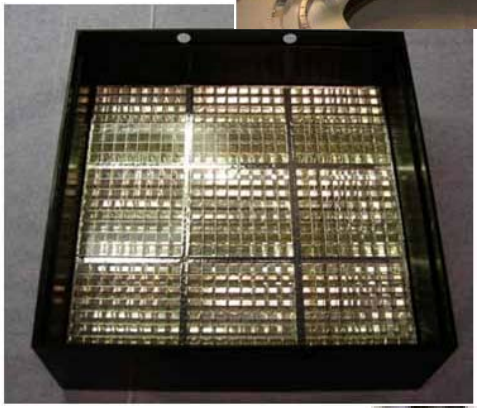
How many neutrons do we count?

- **Guide transmits about 2•10^7 n/sec to sample**
- **10% scattering sample into 4π = 2•10^6 n/sec**
- **Analyzer is 1.2 sr, 10% scattered neutrons reach analyzer = 2•10^5 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•10^{17} n/sec**
- **Beamline counts 4•10^{-15} of neutrons produced**
  - **Other instruments have higher fluxes and there are essentially 24 instrument stations, but CAN WE DO BETTER?**

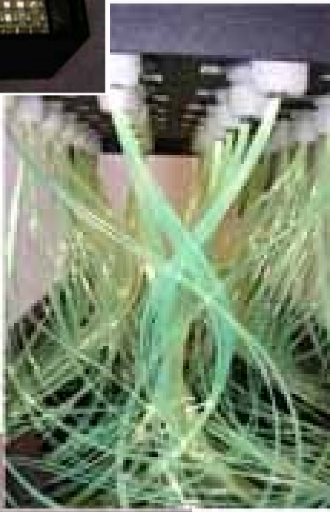
The Case for Collaborations

- **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

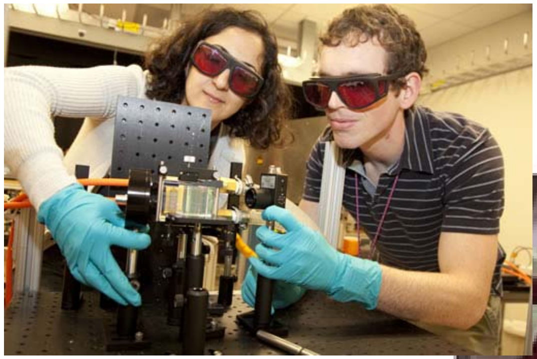
ORNL Neutron Scattering Near-Term Development Activities

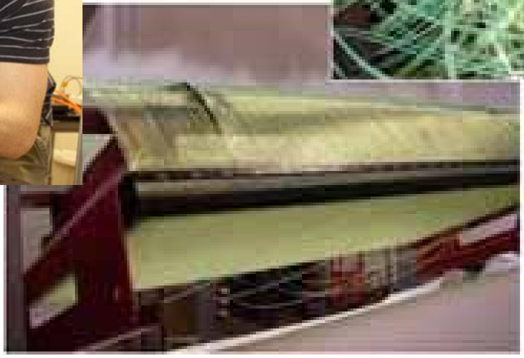


- **Neutron Detectors**
  - Finer pixelation, Higher efficiency, Higher Count Rates
  - Replacement for ^{3}He
  - Multi-year efforts – competition with deployment
- **Polarized Neutron Components/Apparatus**
  - ^{3}He spin filters – routinely deploy on beam lines
  - Flippers …
  - Adapting polarized 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**