Neutron Methods for Nanotechnology

Many neutron and x-ray scattering methods are ideally suited characterize the structure and dynamics of materials on the nanoscale

… however there is great room for improvement

- sophisticated sample environments
- instrumentation built around dedicated sample environments
- better devices for manipulating neutron beams

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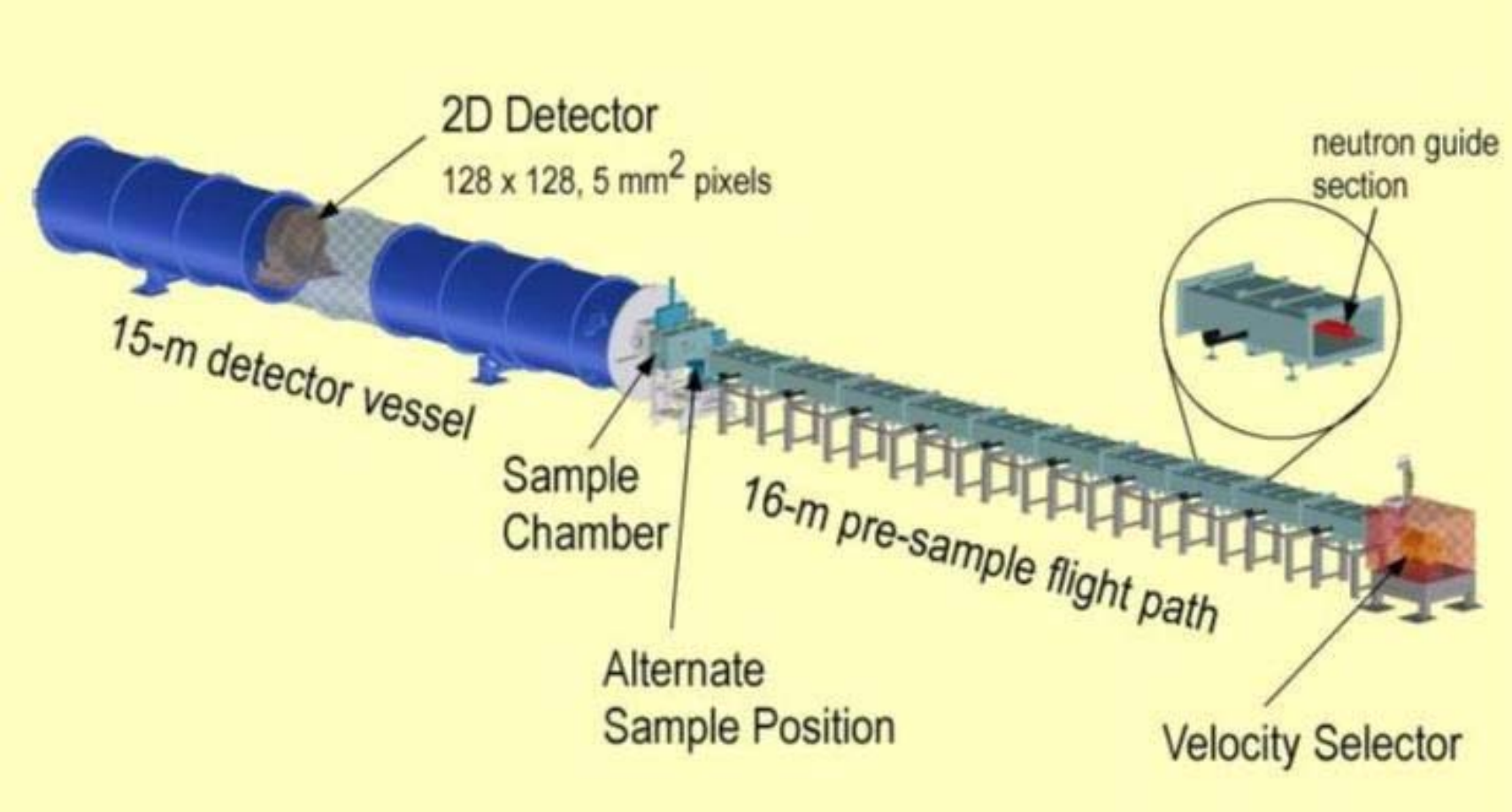
SANS



Q-range : 0.008 nm^{-1} to 7.0 nm^{-1}
Length Scale : 1 nm to over 500 nm

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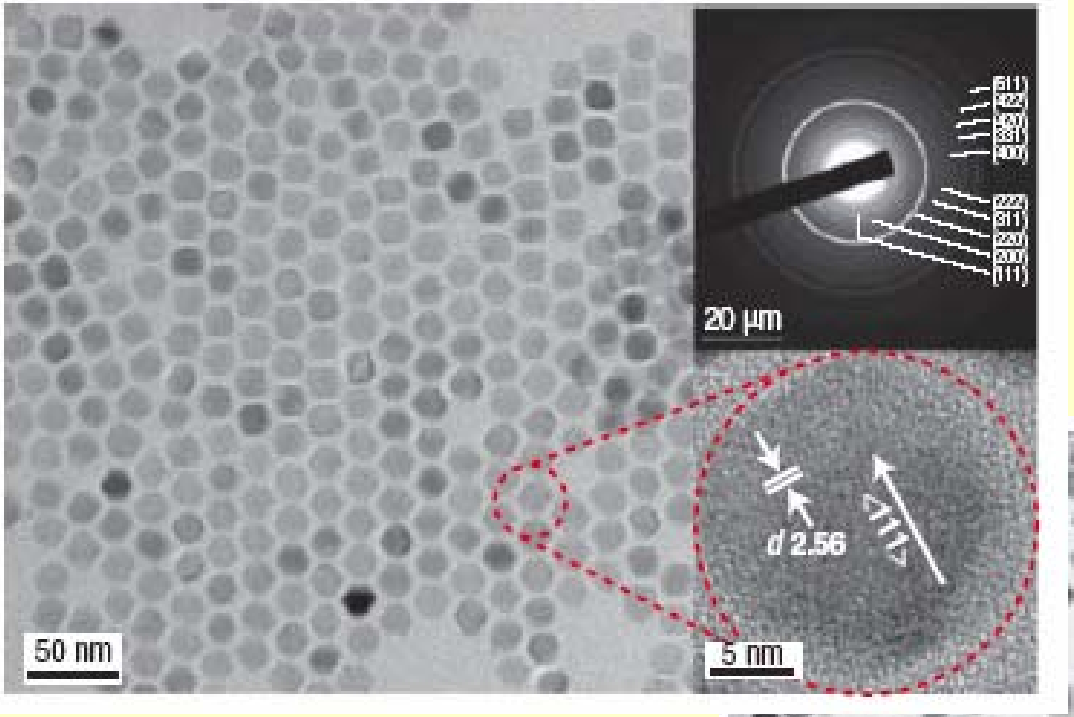
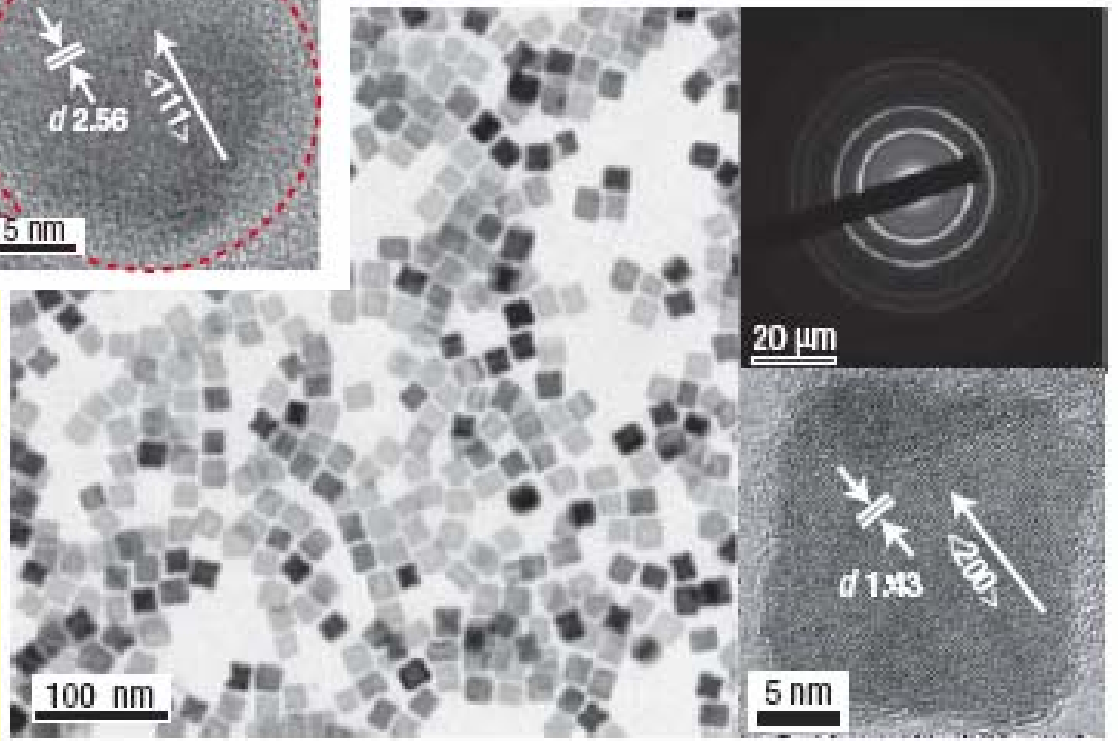
Nanostructured Magnetic Materials



MnO

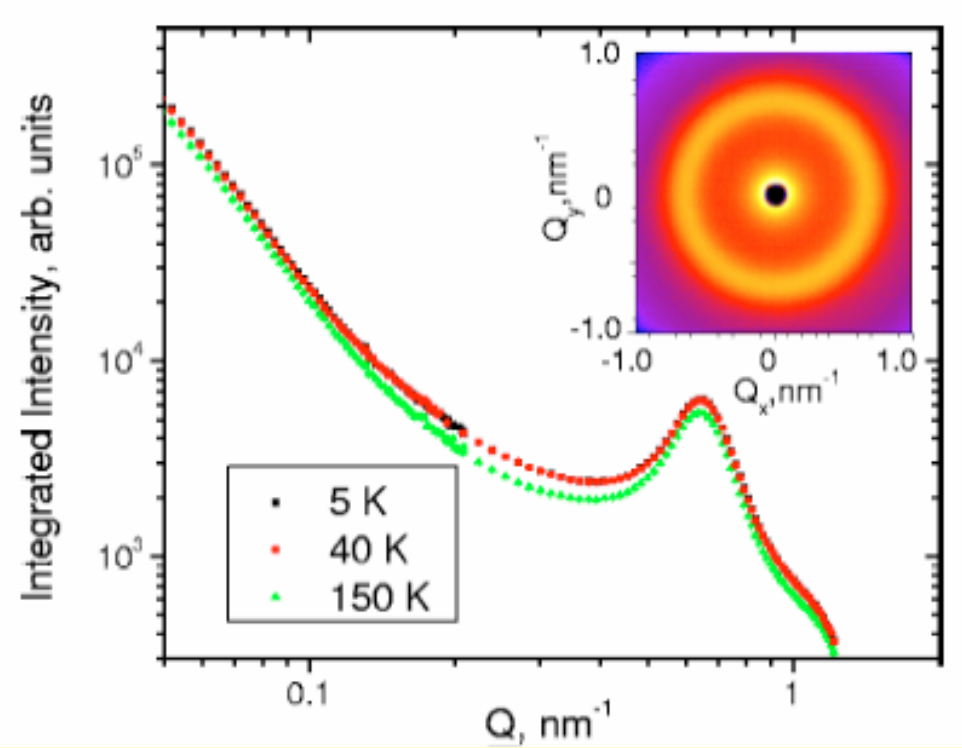
Fe

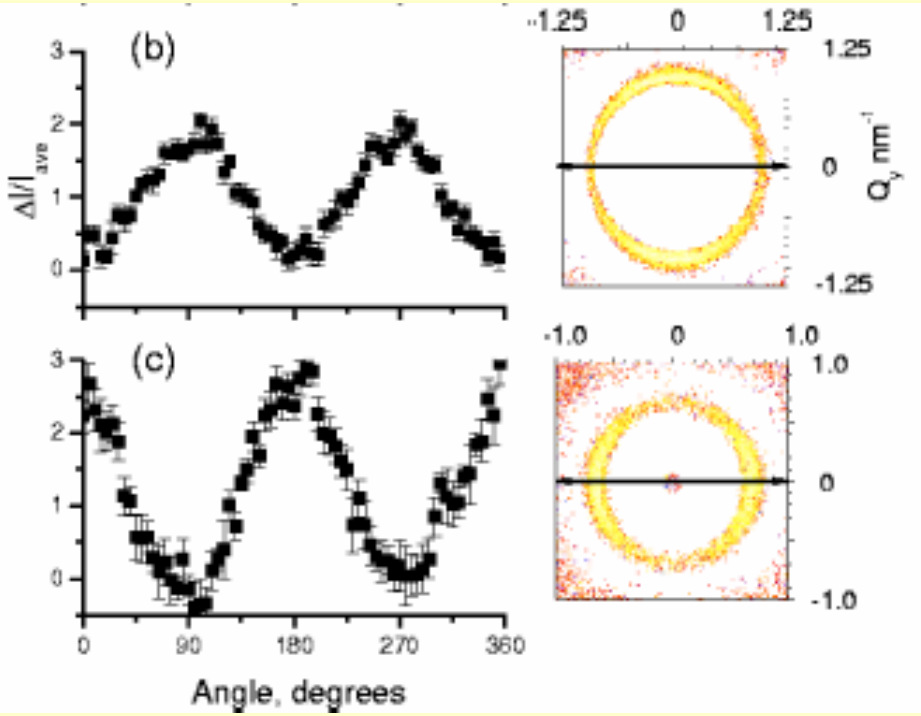


Monodispersed nanocrystals

J. Park *et al*., Nature Matls. **3**, 891 (2004).

Nanostructured Magnetic Materials





Fe nanopartcles

Length scale of interactions below “blocking T”

Oxidized nanoparticles show “spin-flop coupling” between the metallic core and the oxidized surface

Y. Ijiri *et al*., APL (in press).

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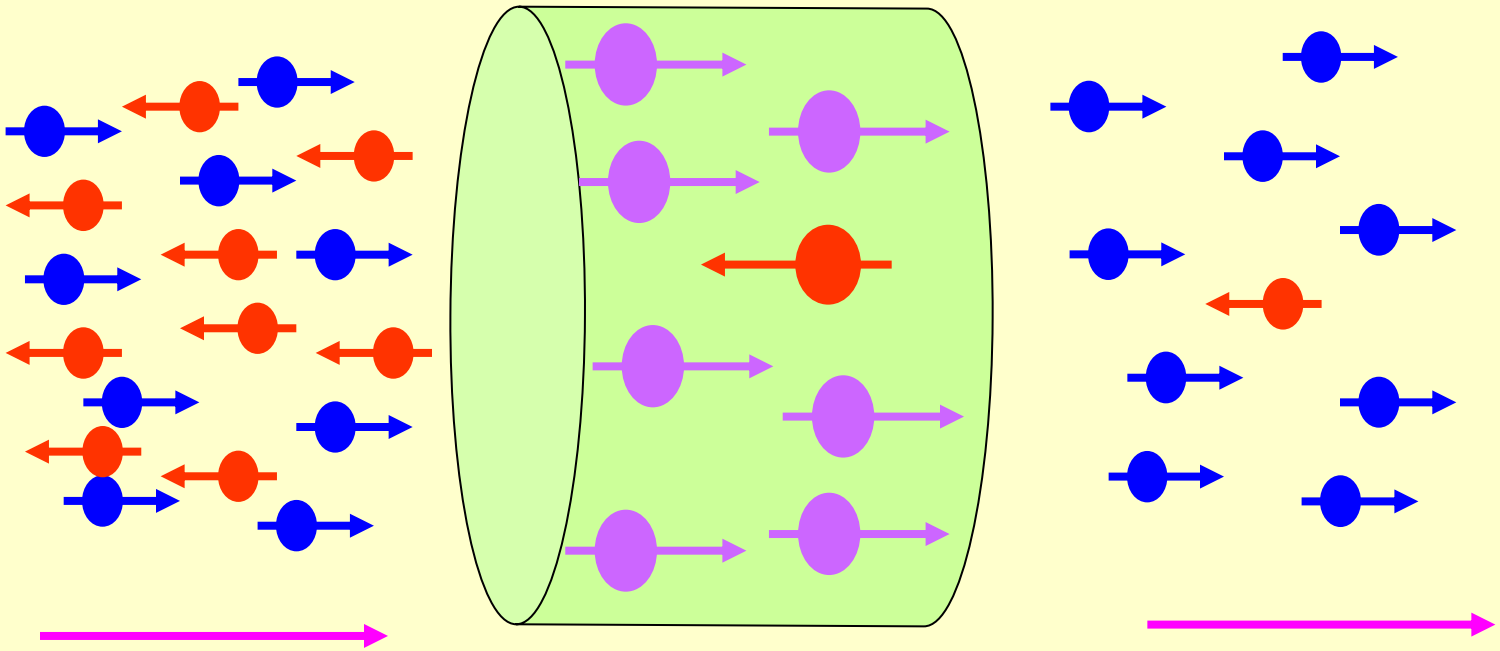
Polarized Beams



polarized ^{3}He

unpolarized incoming neutrons

polarized outgoing neutrons

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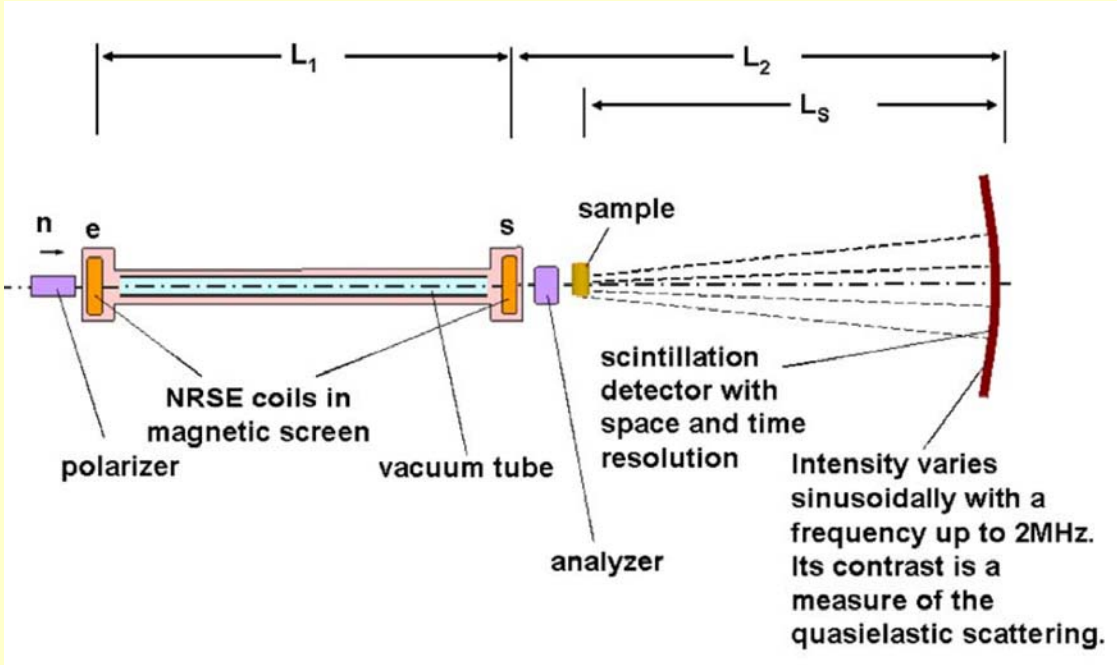
Polarized Beams

More readily available broad-band polarization techniques are crucial not only for magnetic systems, but for instruments which manipulate neutron spin (GISANS, SESANS, MISANS…)

Magnetic lenses

Create contrast via nuclear polarization



Q-range : 0.001 $Å^{-1}$ to 0.02 $Å^{-1}$

Max t : 500 ns

M. Bleuel *et al.*, Physica B **356**, 215 (2005).

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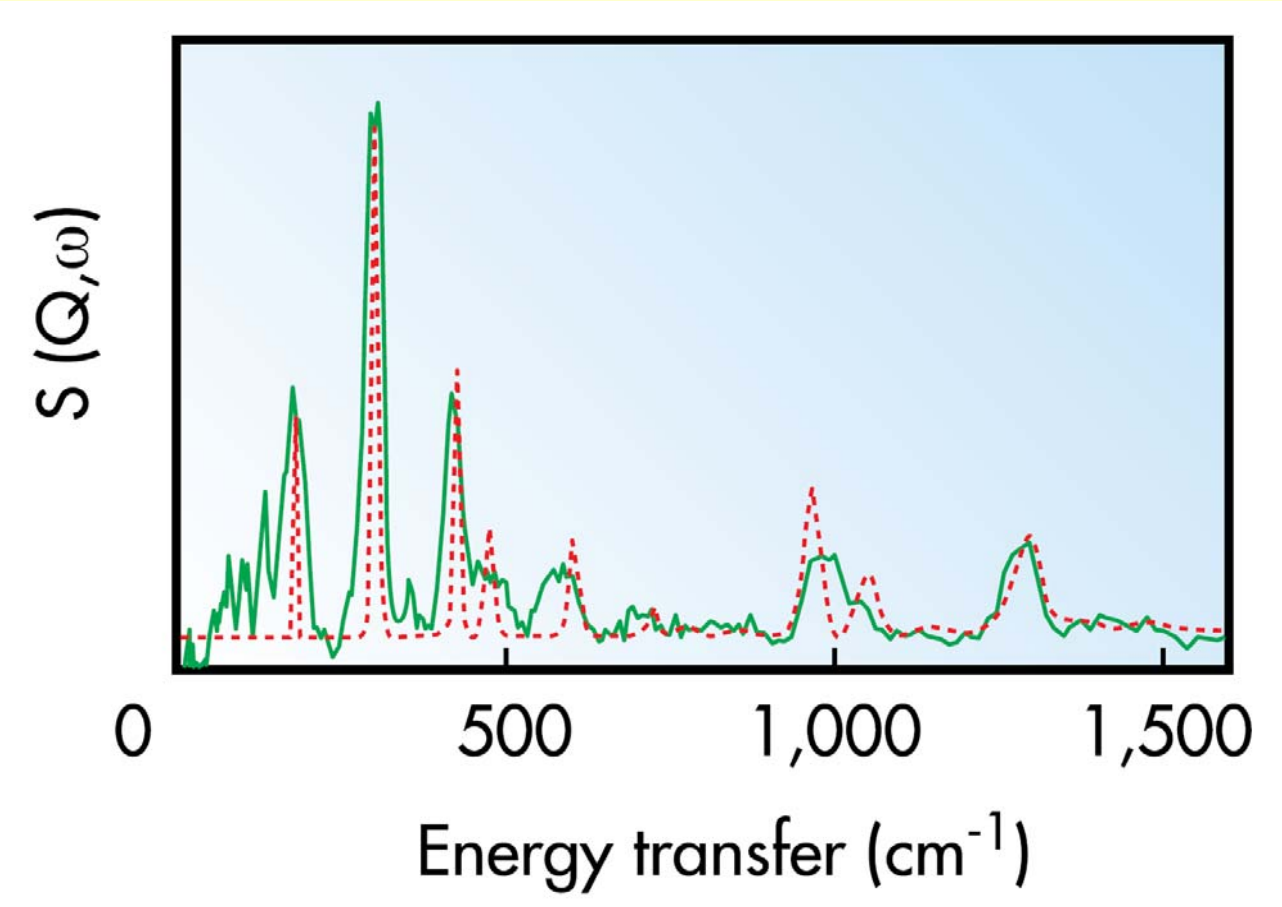
Neutrons and Catalysis

Pd Catalysts



Inelastic neutron scattering has shown that this Pd catalyst became deactivated by surface methyl groups.

This catalyst had been used for a process involving the hydrogenation of C=O groups to C-OH groups of functionalized aromatic and polyaromatic systems.

P. Albers *et al.,* Chem. Comm. Int. Ed. **17**, 1619 (1999).

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“Sample Environments”

Create “Sample Environments” that allow a one to manipulate the sample and make multiple measurements simultaneously

=> shear cell for SANS and Rheometry

Design sample environments for in-situ materials synthesis

=> MBE

Design instruments around sample environments

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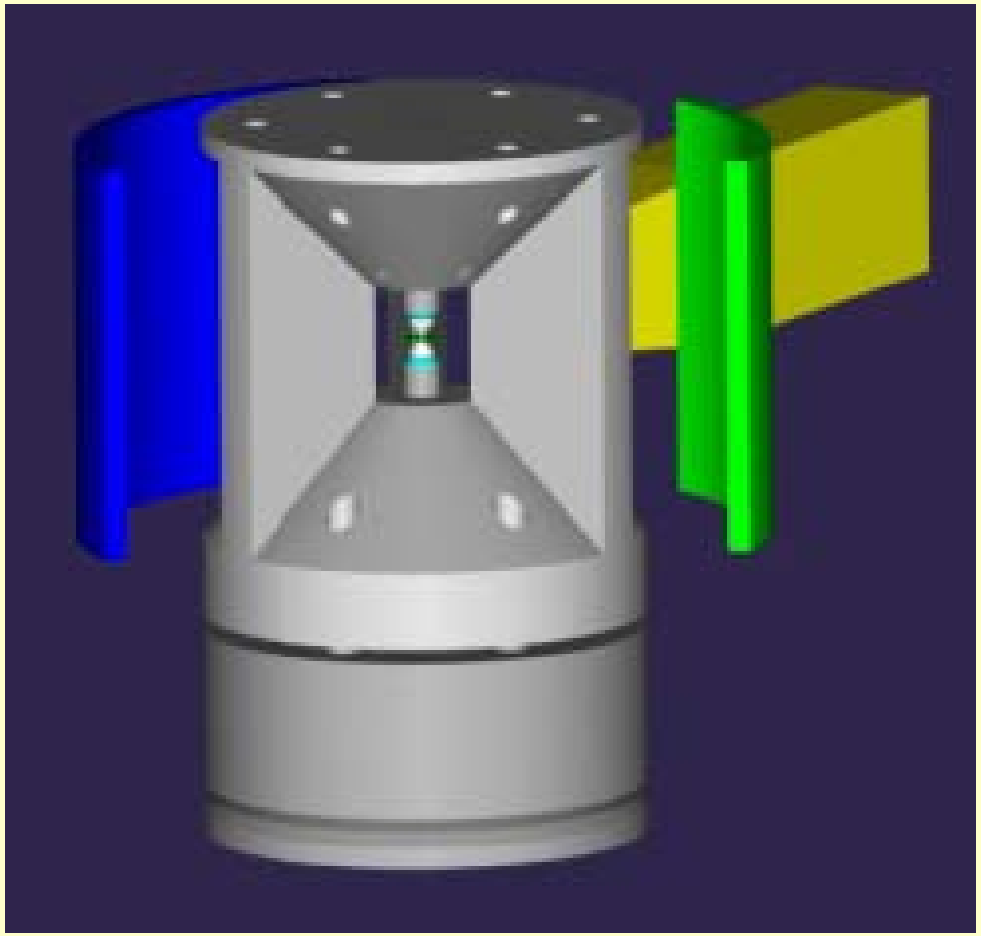
Dedicated Instruments

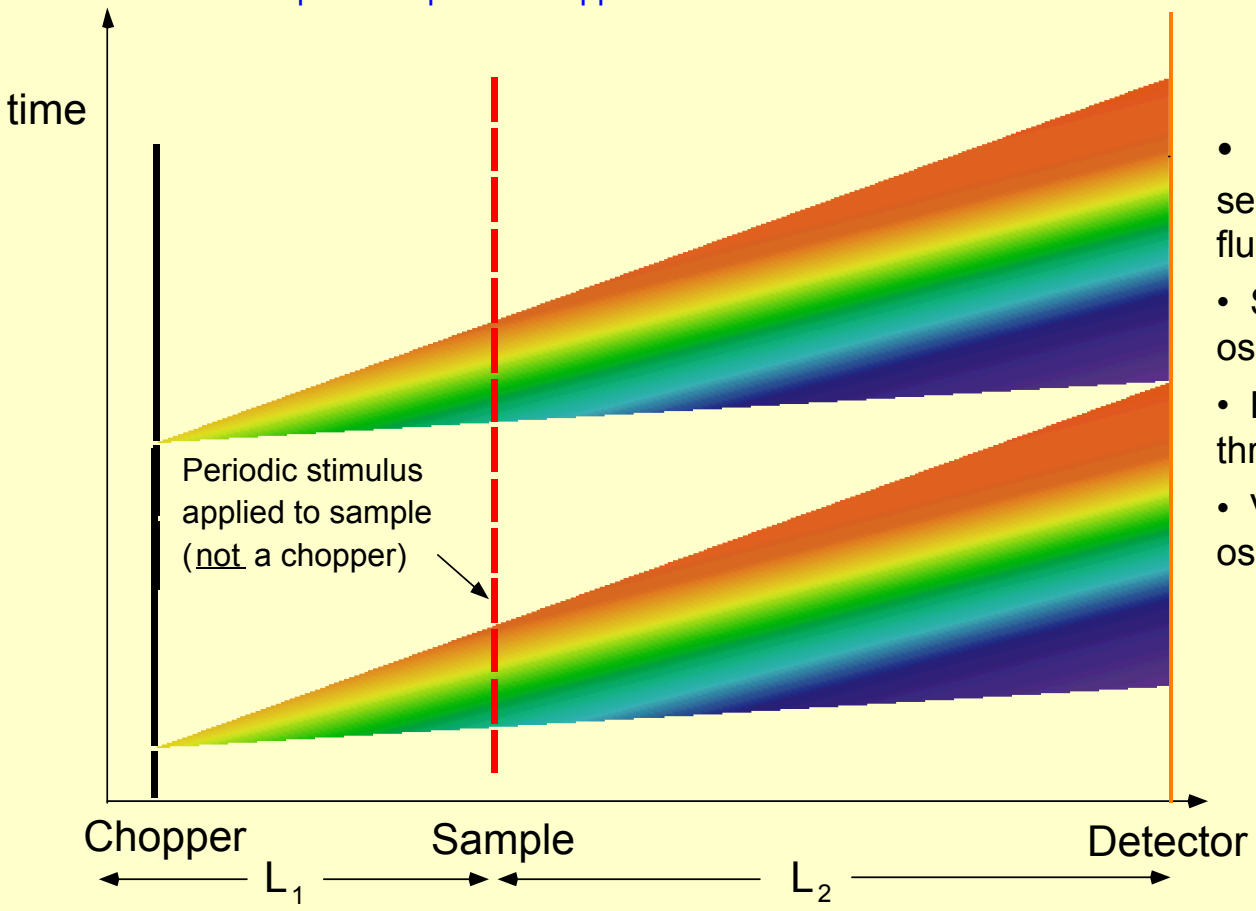
SNAP at SNS is designed specifically for diffraction studies at high pressures

There is also considerable interest in building dedicated instruments for very large magnetic fields



TISANE

With Chopper at 'Source' (first aperture of instrument),
Arrival Times at Detector are Correlated with
Sample's Response to Applied Stimulus



TISANE will provide access to time scales of (50 μs to 100 ms)

- Microstructural response of light sensitive materials, electro-rheological fluids, ferrofluids, liquid crystals
- Structure in complex fluids induced by oscillatory shear
- Biological processes, *e.g.* signaling through nerves
- Vortex structure as a function of oscillating driving current

R. Gähler

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Conclusions

We need better optical devices, polarizers, ...

We need to continue the trend toward instrumentation built around sample environments, SNAP, high magnetic fields … what else?

We need to develop more advanced in-situ capabilities for studying the processing and functioning of nanomaterials under real world conditions … what are they?

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