WASABI –Wide and Small Angles with Big Intensity

WASABI is a versatile instrument for simultaneous measurement of specular reflectivity, off-specular scattering, and grazing incidence neutron scattering (GINS), the latter comprises both small angle neutron scattering (GI-SANS) and grazing incidence diffraction (GID). 3-dimensional structures in soft and hard matter films will be probed on multiple length scales from nanometers to tens of microns. WASABI is expected to have a gain in count rate >x200 (x10 from moderator & bandwidth gain; x20 from focusing optics) as compared with the current FTS Magnetism Reflectometer for specular and off-specular reflectivity measurements.

Science Drivers

Functionality often arises at the mesoscale, where defects, interfaces, and non-equilibrium structures are formed.[1] Reflectivity measures scattering along the surface normal of the film and is related to the depth variation of chemical and magnetic structure. Off-specular scattering and GI-SANS arise from lateral inhomogeneities and provide information on two drastically different length scales determined by the resolution and the neutron coherence lengths. Off-specular scattering measures lateral inhomogeneity with a length scale ~0.1-10μm. GI-SANS measures the sizes and shapes of heterogeneous materials over lengths scales as large as ~100 nm. GINS establishes a *direct and precise correlation* between local interfacial characteristics and global physical properties. Challenges in mesoscale materials to be addressed with GINS include:

- Vertically aligned nanoscale architectures in which either the functionality or structure changes across the film depth. Examples include designing and tailoring functional oxide materials with exceptionally high ionic transport and systems such as lipid rafts in model bio-membranes.
- Topologically protected spin textures in memory technologies for development of novel materials that can mediate skyrmions.
- Exchange-coupled composite elements comprising soft and hard layers, e.g. for permanent magnet applications.
- Rheology studies of liquids and soft matter.
- Origin of flexomagnetism (i.e., influence of the strain tensor on magnetic structure).
- Self-assembly of colloids at charged surfaces.
- Influence of charged surfaces on magnetic phase separation in films.
- Influence of ion implantation (which is non-uniform with depth) on phase separation in oxygen dispersion strengthened steel and on stabilization of skyrmions.
- Response of confined ferrofluids to magnetic field.

Science Requirements

The studies described above need a new approach to instrument design that incorporates GINS as an optimized requirement rather than an add-on to a conventional reflectometer.

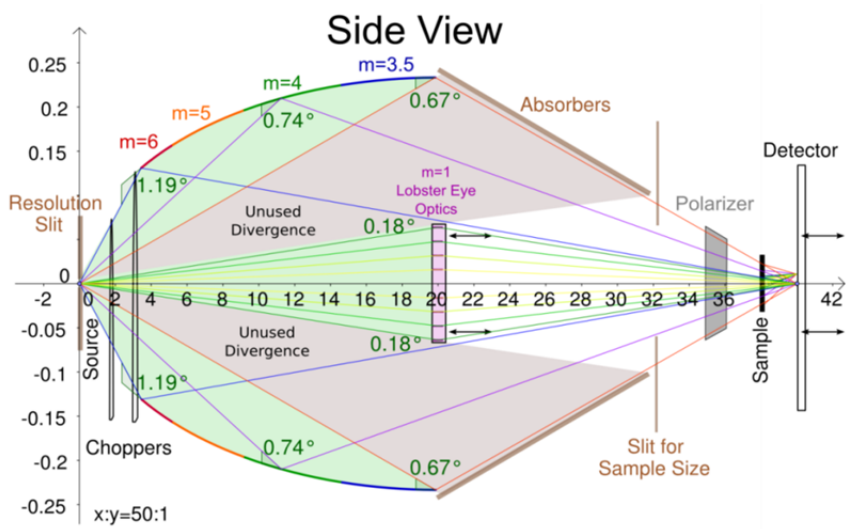
1. Q_z-range in a single setting $0.01\ Å^{-1} < Q < 0.10\ Å^{-1}$, Qy and Qx variable of (neutron wavelength λ, sample-detector distance and detector dimensions)
2. Sample sizes that range from 1 – 25 cm^2.
3. Flexibility for both unpolarized and polarized beam operation (with optional polarization analysis).
4. Low background (no direct view of the source from the sample position),
5. Integrated complex sample environments with an extended temperature range of 3 K < T < 750 K, magnetic field H <+/- 5T, electric field E, and pumped light optics.

[1] *From Quanta to the Continuum: Opportunities for Mesoscale Science*, a report from the Basic Energy Sciences Advisory Committee (2012); http://science.energy.gov/~/media/bes/pdf/reports/files/OFMS_rpt.pdf.

Technical Description

WASABI could be placed on the high intensity coupled moderator or possibly the 3 x 3 cm^2 face of the high peak brightness coupled moderator depending on final optics design. The low repetition rate and high brightness of the peak of STS is ideally designed for new generation GINS with polarized neutrons. The low repetition rate allows for a broad wavelength band necessary to obtain the wide Q range at one incident angle and to perform experiments at constant geometry. The optics design will maximize the intensity for GI-SANS (design illustrated has the sample at 38 m from the moderator). With an additional 2 m from sample to detector, WASABI will reach a maximum wavelength of 9.9 Å in the first frame. One or possibly two bandwidth choppers will define the wavelength band. The sample is vertical with horizontal scattering geometry. WASABI requires a 50×50 cm^2 detector with 1.5 mm horizontal and 2-2.5 mm vertical spatial resolution.

A proposed concept for WASABI utilizes a novel optics design that focuses the neutron beam at the detector position enabling the use of *large samples* in GI-SANS geometry. The focusing optics concept is a combination of elliptical mirrors and lobster eye optics (see figure). Table lists key WASABI parameters.



Focusing optics with focus at the detector position.

Key parameters of WASABI

Parameter	Description
Moderator	High-intensity coupled moderator or 3x3 cm^2 High-peak brightness moderator
Moderator–sample distance	30-40 m (depends on final optics design)
Sample–detector distance	1 – 2.5 m
Wavelength range	2 Å ≤ λ ≤ 26 Å
Resolution	adjustable: $0.01 \leq \Delta Q/Q \leq 0.1$
Detector	2-dimensional position-sensitive detector, 1.5 mm horizontal, 2-2.5 mm vertical spatial resolution with count rate of 0.5–1 M counts/s and a peak count rate of 5–10 M counts/s. The detector must have a broad dynamic range of ~10^7