VERDI – Versatile Diffractometer for Complex Magnetic Structures

The cold-neutron diffractometer, VERDI, optimized for studies of magnetism and large unit cell structures, will excel by its high-resolution at low-Q and a much-increased flux owing to the high brightness of the source at STS. This instrument will serve for both powder and single crystal studies under extreme conditions of temperature, pressure, or magnetic field. This instrument will be equipped with polarization capability. Although VERDI can be expected to have at least 5 times the count rate of the WISH instrument at ISIS, its versatility will make it a one-of-a-kind instrument.

Science Drivers

The ever increasing complexity of magnetic systems, which often involve coupled spin, orbital, and lattice degrees of freedom, calls for much improved instrumentation that provides high resolution at low-Q, high intensity, and reduced extrinsic background. VERDI will meet all these criteria and will be well adapted for in-depth magnetic structure studies as specified below:

- Complex incommensurate structures. VERDI will be optimally suited for studying complex incommensurate structures that arise in multiferroic compounds, one of the new emerging technologies for information processing. The high-resolution and the wide-Q coverage obtained by using a single-frame bandwidth will enable simultaneous characterization of crystal structure as well as local ferroelectric and magnetic properties in these materials.
- Reduced ordered magnetic moments and itinerant magnets. The 4d, 5d, and possibly 6d transition metal oxides are a fertile ground for studies of new magnetic phenomena driven by spin-orbit interaction. The extended nature of the magnetic electrons in such systems requires measurements at small wave-vectors to avoid form-factor suppression of the already weak magnetic signal.
- Magnetization density studies and short-range magnetic correlations. The polarization capability of VERDI will enable studies of the magnetization distribution across magnetic organic molecules as well as studies of the redistribution of electrons accompanying the combined magnetic–crystallographic transitions in martensitic materials. Wide-angle polarization analysis will allow the separation of nuclear, magnetic and nuclear spin-incoherent scattering for unambiguous magnetic diffuse scattering studies.
- Neutron diffraction under extreme conditions. Intriguing new phenomena in quantum materials occur at extreme low temperatures, high pressures, and high magnetic fields. A variety of materials—of which one can name the multiferroics, magnetocaloric materials, frustrated magnetic systems, and magnetic molecular materials—exhibit dramatic changes in their magnetic behavior under high pressures and/or applied magnetic fields.

Science Requirements

VERDI will be designed to provide maximum versatility as a powder or single crystal diffractometer, with or without polarization capability. The instrument requires:

1. The ability to reach low-Q, 0.1 $Å^{-1}$, with extremely low background; Q-resolution 0.2 to 0.4%.
2. Sample sizes 2 x 2 mm^2 to 10 x 20 mm^2.
3. A monochromatic mode supported by a Fermi chopper to improve signal-to-noise as needed.
4. Polarization analysis over 120 deg scattering angle, Helmholtz coils at the sample position are required to support xyz polarization analysis.
5. Adjustable beam divergence (powder: 0.2 to 1° horizontal, 2 to 3° vertical; single crystal up to 1 x 1°)

Technical Description

VERDI will optimally view either the high brightness or high intensity couple moderator, depending on optics design. The smaller moderator will better support the study of small samples. VERDI benefits from the 10 Hz repetition rate giving a large wavelength band per frame, allowing the instrument to be built at 40–60 m from the moderator. This long flight path allows VERDI to use the broader time pulses of the STS coupled moderators and the significantly higher peak intensity of the neutron pulses, compared with the de-coupled, poisoned moderators typically used on diffraction instruments.

It will operate as either a powder or single-crystal diffractometer as desired and will have an integrated polarization capability. The instrument will have a neutron bandwidth of 6.5–9.8 Å so that the desired Q-range can typically be accessed in a single frame. The elliptical guide system will provide sufficient flexibility to cover a wide range of incident beam divergences. This large range of desired divergence to support both powder and single crystal studies will likely require translating guide components. The instrument will include an oscillating radial collimator for background reduction. The ^{3}He detector array will cover 175° in the horizontal plane and extend to ±20° in the vertical. In addition to bandwidth neutron choppers, the beam line is envisioned as incorporating a Fermi chopper that can be translated into and out of the beam to provide a monochromatic beam for studies of diffuse scattering and in select cases to improve signal-to-noise.

Key parameters of VERDI

Parameter	Description
Moderator	High-peak-brightness coupled moderator, side b
Sample size	2×2 mm^2 to 1×2 cm^2
Moderator–sample distance	40–60 m
Sample–detector distance	2.0–3.5 m
λ Range	1.2 Å ≤ λ ≤ 14 Å
Resolution	$\Delta Q/Q$ 0.2-0.4%
Detector	0.8 cm diameter linear positive-sensitive detector, ^{3}He