HERTZ—High Energy Resolution Terahertz Spectrometer

HERTZ is a chopper spectrometer optimized for samples as large as 5 × 5 cm^2, a standard size on many thermal chopper and reactor based spectrometers, with a homogeneous and tunable intensity and divergence profile, complementary to the lower resolution spectrometer, CHESS. The high brightness of the STS coupled moderators combined with advancements in instrument design will enable at least an order of magnitude gain in performance when compared with current, state-of-the-art instruments internationally.

Science Drivers

HERTZ is optimized to provide a large, homogeneous beam to facilitate high-statistical measurements of large volume samples. The cold neutron energy scale is well suited to many critical problems of both experimental and theoretical interest such as quantum magnets, frustrated magnets, and heavy fermion superconductors. One of the strengths of inelastic neutron scattering (INS) is that the measured cross-section is simply related to the scattering function $S(Q,\omega)$, which is amenable to multiple theory or modeling approaches. As such, INS allows for close connections with theory and computation, and neutron data can often provide definitive tests of theoretical models.

HERTZ will provide a critical link between experiment and theory that is essential to enable progress in a number of forefront problems such as:

- Energy related materials including thermoelectrics where detailed microscopic understanding of heat transport derives from measurements of phonon or magnon dispersions and line widths.
- Exploration of competing and coupled orders in multiferroic materials where full understanding of the interplay between magnons and phonons requires detailed measurements of both excitation spectra across the full Brillouin zone with good energy resolution and separation of spin and lattice contributions requires polarization analysis.
- Complex materials in which magnetic scattering features are often weak (due to S = 1/2 entities) or diffuse (because magnetic correlations are short-ranged) using polarization analysis.

Science Requirements

Although CHESS is optimized to enable inelastic neutron scattering on small samples, there are a large number of problems where one would like to study larger samples with finer energy and wave vector resolution. Such measurements can yield high statistics data providing critical tests for theory and can allow experimental separation of collective modes in complex materials. Consequently, HERTZ is designed to enable the following:

1. A cold neutron direct geometry time-of-flight spectrometer optimized to provide a homogeneous beam as large as 5 × 5 cm^2. Crystals grown with techniques such as floating zone often reach this size along the growth direction. This instrument will also allow for higher energy (~1% of E_i or better) and wave vector resolution than the CHESS spectrometer.
2. The instrument will be designed to allow full three-dimensional polarization analysis to enable measurements of multiple components of the $S_{\alpha\beta}(Q,\omega)$ tensor.
3. The low repetition rate of STS will enable simultaneous measurements with multiple incident energies, greatly increasing measurement efficiency particularly in materials with excitations covering a broad range of energies.

Technical Description

Optimized for larger samples, HERTZ will view one of the larger coupled moderator faces, either the 3×6 cm^2 HPCM face 'b' or the 5×5 to 7×7 cm^2 face of the HICM depending on the optics design and space optimization. The neutron optics system will be designed to provide individual tuning of neutron beam size and vertical beam divergence at the sample position. The secondary flight path will be long, likely ~5 m, in order to achieve good energy resolution. The solid angle covered by the detector array will thus be smaller than at CHESS, perhaps ~π ster. The energy resolution defining chopper will have to provide short pulses, ~10 μs or less, and therefore a beam splitter design in the final part of the guide as prototyped at the ISIS LET instrument[1] will be considered. The energy resolution will be tunable in the 0.5–3.0% E_i range. The 10 Hz STS repetition rate coupled with a 25–30 m incident flight path means that all incident energies down to 1 meV can be accessed in the first frame using repetition rate multiplication methods.[2]

Like CHESS, polarization analysis will be essential for many magnetic experiments because the general science direction is toward systems with smaller moments (spin-1/2) with magneto-elastic effects or excitation continua, where traditional methods of isolating magnetic scattering (through temperature variation) are often inadequate. These requirements have the following implications:

- All ferromagnetic materials must be avoided within a radius of at least 2 m from the sample position.
- Strict limits must be imposed on the magnetic permeability of the steel of the tank and such components.
- Large coils for magnetic guide fields (several meters in diameter) must be incorporated in the design of the secondary spectrometer.
- There must be at least 50 cm of room between the guide exit and the sample position, and the beam must be shaped such that no diaphragm is needed between the guide exit and sample.
- A collimator between the sample and detector will be required.

Key parameters of HERTZ

Parameter	Description
Moderator	High-peak-brightness coupled moderator, side b or High intensity coupled moderator
Sample size	1×1 cm^2 to 5×5 cm^2
Moderator–sample distance	25–30 m
Sample–detector distance	4–6 m
Energy range	0.5 meV ≤ E_i ≤ 100 meV
Resolution	0.5–3% variable $\Delta E/E_i$; $\Delta Q < 0.02$ Å^{-1}
Detector	linear position-sensitive detector, ^{3}He

[1] R. I. Bewley et al., Nuclear Instruments and Methods in Physics Research A, 637 128 (2011).
[2] A special pulse shaping chopper supporting this configuration has been prototyped for the ESS T-REX project: J. Voigt et al., *Nucl. Instrum. Meth. A* **741**, 26-32 (2014).