ICANS XIV
14th Meeting of the International Collaboration on Advanced Neutron Sources
June 14-19, 1998
Starved Rock Lodge, Utica, IL

HET-II A Proposed Upgrade for HET, the High Energy Chopper Spectrometer at ISIS

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Abstract

We propose an upgrade to the high energy chopper spectrometer, HET, at ISIS. A supermirror guide will enhance the flux of thermal energy neutrons on to the sample, and a position sensitive detector array at 2.5m from the sample covering the angular range 3° to 150° and extending out to 30° above and below the equatorial plane will provide a five fold increase in solid angle over HET. An oscillating collimator will reduce the background scattering from massive sample environment equipment such as pressure cells.

HET, the high energy transfer chopper spectrometer[1] is a member of the original suite of instruments at ISIS, and became operational as the source came on line in 1985. The unrivalled access to a wide energy range at low momentum transfer offered unique opportunities for the study of magnetic excitations. Examples of work carried out on HET include experiments on rare earths[2], heavy fermion[3] and kondo systems[4] and high temperature superconductors[5]. In addition, studies of molecular dynamics have proved very effective. Measurements on single crystals have also produced many high profile publications[5,6,7] and the work on HET and MARI provided the impetus for the construction of MAPS, a spectrometer optimised for the study of excitations in single crystals, utilising a large array of position sensitive detectors (PSDs). The commissioning of MAPS will start in early 1999. With the advent of MAPS and in the light of recent developments in the use of neutron guides and PSDs there is now an opportunity to upgrade HET so it is complementary to both MAPS and MARI, and at the same time offers a dramatic increase in performance over the present instrument. In this paper we discuss the ideal specification for HET-II setting aside the limitations associated with building on a specific beamline.

The proposed layout of HET-II is shown in figure 1. The principle features of the upgrade are a supermirror guide for the incident beam and continuous coverage from 3° to 150°, with banks of PSDs extending out to 30° above and below the equatorial plane. In addition, a removable, oscillating collimator will reduce background scattering from difficult sample environment such as pressure cells. In the design, we are also keeping in mind the possibility that the performance of ^{3}He polarising filters may, at some time in the future, be such that it would be reasonable to provide the option for polarisation of the incident beam and polarisation analysis on the spectrometer.

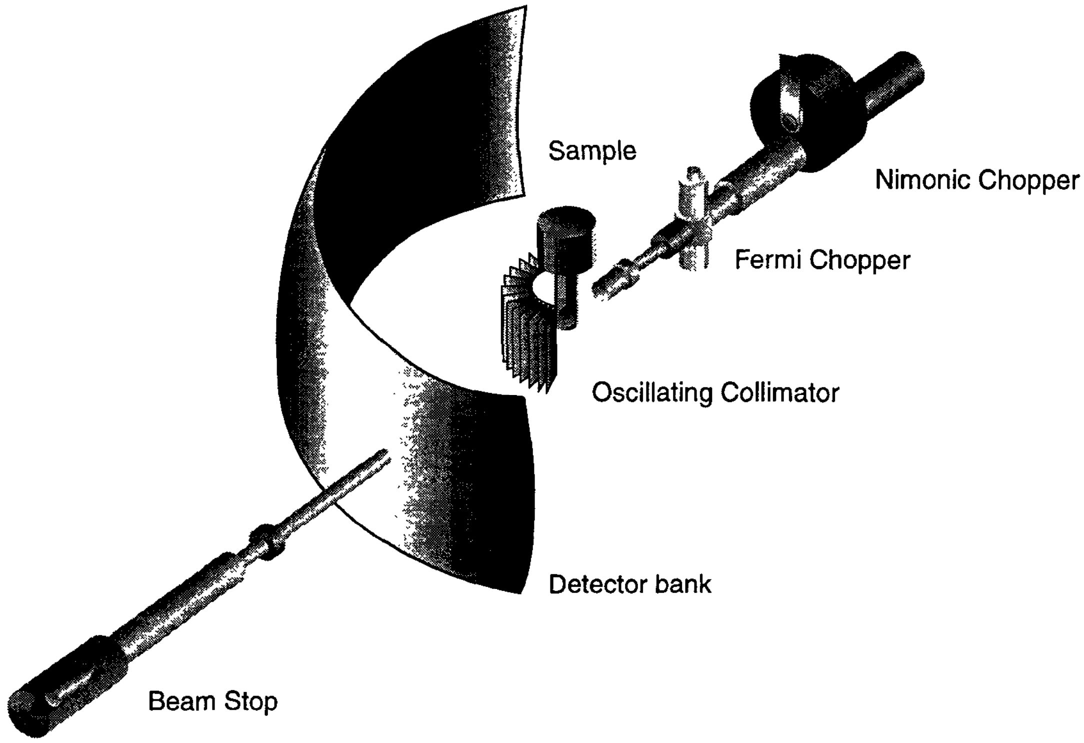

Figure 1. A schematic diagram of HET-II.

The present HET views the ambient pressure water moderator, which is poisoned at 1.5cm. The preferred choice of moderator for HET-II is a methane moderator, which offers a gain in flux of a factor of up to 10 at 20meV (figure 2).

The lengths of the primary flight path for HET-II are the same as those for HET. The nimonic or T_0 chopper will be located at 8.4m from the moderator with the Fermi chopper at 10m from the moderator and the moderator to sample distance of 11.2m. However, supermirror guides will be installed in three sections; between the moderator and the nimonic chopper, between the nimonic chopper and the Fermi chopper and between the Fermi chopper and the end of the incident beam pipe. Monte Carlo calculations for a guide with m=3 (figures 2) indicate that at low energy transfers a gain over HET of a factor of up to 100 can be achieved if HET-II was to view the methane moderator. The flux enhancement if HET-II was to view the water moderator rises to approximately 15 at 5meV. The same calculations suggest that the impact of the guides on energy transfer resolution is negligible, however, the increase in beam divergence caused by the guides will result in an increase in ΔQ for incident energies of below 100meV rising to 44% at 5meV as shown in figure 3. This loss in Q resolution could be recovered by installing a soller collimator at the end of the incident beam tube at the cost of flux. The ability to insert such a collimator when be required may be a feature of the design. The energy transfer resolution of HET-II will be the same as that of the 2.5m bank of HET, that is a HWHM of approximately 1.5 to 2.5% of the incident energy at the elastic line.

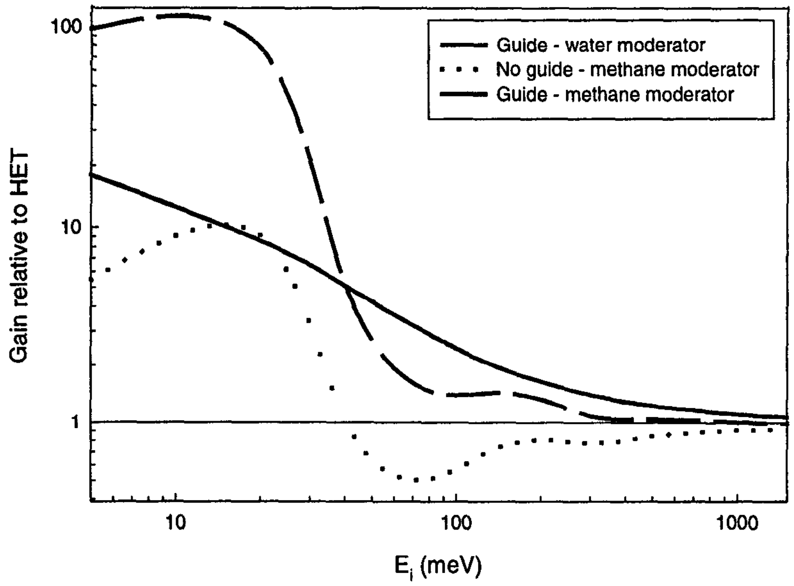

Figure 2. Anticipated gain in flux to the sample over HET, due to the installation of a guide and/or changing the moderator to methane.

HET is now equipped with beam defining jaws at the end of the incident beam tube. A further set will be installed in the Fermi chopper pit to reduce the penumbra.

The sample tank will, ideally, be cylindrical in geometry with a standard ISIS flange to accommodate all the standard ISIS sample environment equipment including the cryomagnet. However, the flange will be mounted on a goniometer assembly with vacuum bellows to provide limited movement on two arcs to facilitate easy alignment for single crystal samples. The tank will be lined with B_4C loaded epoxy to reduce background scattering and a cryo-pump will be fitted, as is the case on HET, to eliminate the build up of ice on cold samples over a period of time.

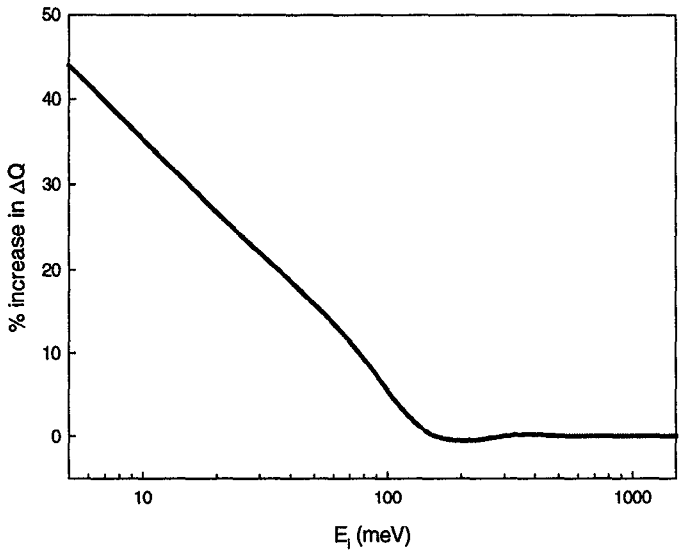

Figure 3. The calculated degradation in momentum transfer resolution as a function of incident energy arising from the use of a guide.

HET-II will use standard sample environment equipment such as CCRs and cryostats, however, the anticipated high sample throughput would justify the design and construction of a bespoke top-loading, rotating 4K CCR that would speed up sample changes for single crystal and polycrystalline samples.

The high flux and solid angle available on HET-II will facilitate the study of small sample volumes and presents the potential to use difficult sample environment such as pressure cells. In order to reduce background from sample environment an oscillating collimator will be available, surrounding the sample volume. We anticipate that the oscillating collimator will be easy to install and remove depending upon the requirements of the experiment.

Previous experience on MARI has shown the importance of vanes to prevent spurious scattering arising from reflections from the aluminium windows. In the case of HET-II we plan to stagger the position of the vanes across the face of the detector banks to reduce the number of gaps in Q,ω coverage for powder samples and care will be taken to keep the number and size of the vanes used to a minimum.

Three parallel banks of ^{3}He PSDs will be used to tile the angular range from -30 to 150° with a minimum angle of 3° on a secondary flight path of 2.5m, with detector coverage extending out to ± 30° in the azimuthal plane. The upper and lower banks will be filled with 1m PSDs, with the middle bank filled with 50cm tubes. This detector array represents a solid angle of 0.25πSr in the scattering angle range below 30°, a factor of approximately 2 increase over HET. The total solid angle of HET-II will be πSr, five times more than HET. This in itself represents a considerable gain, particularly when coupled to the gains achieved by installing the supermirror guides and viewing a methane moderator as discussed above. However, the advantages of such wide coverage with position sensitivity will have a more dramatic impact on the performance of the instrument. In total, HET-II will have over 50000 detector pixels producing a huge volume of information. Position sensitive detectors were installed on HET in May 1997. They cover the angular rang from 3° to 7° degrees on a flight path of 4m, and have already been used to great effect by several experimental teams[8]. The ability to tune Q resolution in the analysis software, and to extract arbitrary slices though the data provides a dramatic increase in flexibility, particularly for single crystal measurements.

The scientific opportunities offered by the upgrades we propose are many-fold. Increased flux will allow the use of lower sample volumes thus facilitating the study of new materials that are difficult to fabricate. High flux combined with the oscillating collimator provides the opportunity to make studies using difficult sample environment such as pressure cells or magnets, thereby open a wide range of parameter space. Short counting times also enhance the opportunities for parametric studies. The continuous detector coverage will make HET-II suitable for the molecular dynamics work which is currently carried out on MARI, but does not require the higher energy transfer resolution offered by MARI, and would benefit from higher data rates. However, the most dramatic improvement will be in the volume of information available, because such a wide area is tiled by position sensitive detectors. The ability to take arbitrary slices through four dimensional Q,ω space will provide unparalleled flexibility, particularly for single crystal experiments. Simultaneous measurements of phonons and magnetic excitation in single crystals will be possible in relatively short times with vast volumes of information attainable from only a small number of crystal orientations.

In conclusion, we have proposed an upgrade for HET that not only offers a dramatic increase in count rate, but also a huge increase in information volumes by virtue of a large bank of position sensitive detectors. The proposed instrument will complement MAPS which is optimised for higher resolution at higher energies, and MARI which also offers continuous detector coverage, but with better resolution and lower flux.

Further development in the HET-II project will be posted on the web at http://isis.rl.ac.uk/excitation/het/hetii.htm.

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