# The High Intensity Total Scattering Spectrometer (HIT)

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Abstract

The High Intensity Total scattering spectrometer (HIT) has been constructed and installed according to the previously reported design.[1] Preliminary results indicate that the performance of the spectrometer meets the design specifications.

## 1. Introduction

HIT is a total scattering spectrometer designed to measure the structure factor, S(Q), of liquids and amorphous solids at a high rate of data collection. The scientific program for which this spectrometer will be used includes the precise determination of S(Q) over a wide range of momentum transfer ($Q \leq 50\text{-}100\ A^{-1}$), systematic measurements



from many samples covering perhaps a wide range of compositions, measurements on small or absorbing samples and real time studies of structural changes in nonequilibrium states. The machine was therefore designed to have the capability of handling high rates of data collection but with reasonable momentum resolution and with good SN characteristics.

## 2. Summary of the Spectrometer Configuration

A layout of the spectrometer as installed at the H-3 beam hole of the KENS facility is depicted in Fig.1.

Figure 2 is a photograph of the machine in position.

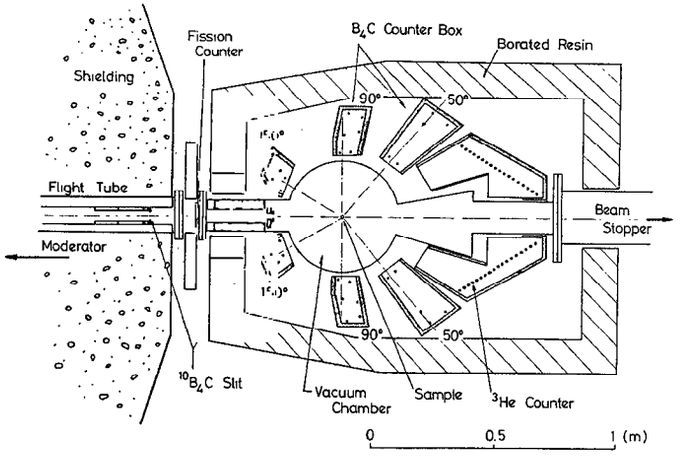


Fig. 1 Schematic diagram of HIT

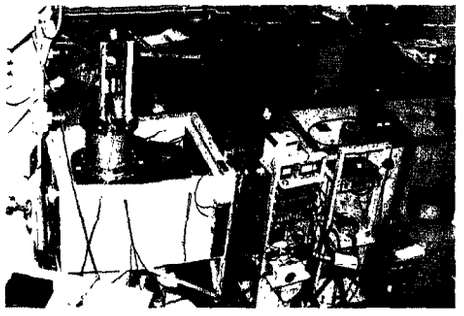

Fig. 2 Photograph of HIT

The machine has fifty He-3 counters (1/2" in diam., 12" long and filled to 20 atmospheric pressure) around the sample. Focussing geometries were adopted for the higher angle counters ($2\theta \geq 50°$), while those at lower angles were arranged to give approximately the same momentum resolution $\Delta Q$. At higher angles there are two counter banks at slightly differing scattering angles and data from the respective counter banks are combined in order to obtain better counting statistics. The lower angle counters have apertures which limit their active hight in order to maintain the momentum resolution at the required value. The spectra recorded by each counter is accumulated independently and the data in Q space is collated after the necessary corrections. The present counter configuration at lower angles is useful for time-dependent structural studies where relaxation times are of the order of 100 μsec.[1)]

The spectrometer has a 4.7 m long incident flight path with slits made from sintered plates of $^{10}B_4C$. The sample is mounted in a large scattering chamber which may be evacuated in order to avoid air scattering. The spectrometer is equipped with a sample changer which can accomodate up to six different samples (see Fig.3).



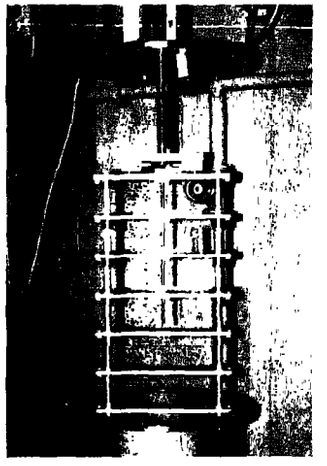

Fig. 3 Photograph of sample changer

The neutron signal from each detector passes through a pre-amplifier, a main (shaping) amplifier and a discriminator in slow NIM mode. It is then converted to a fast logic signal before being fed into a high speed time analyser[1)]. The spectrometer has 16 separate time analysers, each of which has 1 k 20 bit channels. The maximum data aquisition rate for each channel is several counts per μsec[1)].

## 3. Performance

### 3.1 Background

HIT has no Soller slit between the sample and the detector so that the solid angle of the detection can be large. This configuration, however, is more susceptible to background caused by air scattering around the sample. It is for this reason that HIT has been equipped with an evacuable scattering chamber.

Figure 4 displays scattered neutron TOF spectra measured with and without air in the scattering chamber. The strong air scattering signal is completely eliminated on evacuation, but an appreciable background persists at lower channels. This is probably due to epithermal neutrons

emerging from the beam exit of the biological shield and additional shielding is currently under construction to minimise this source of background.

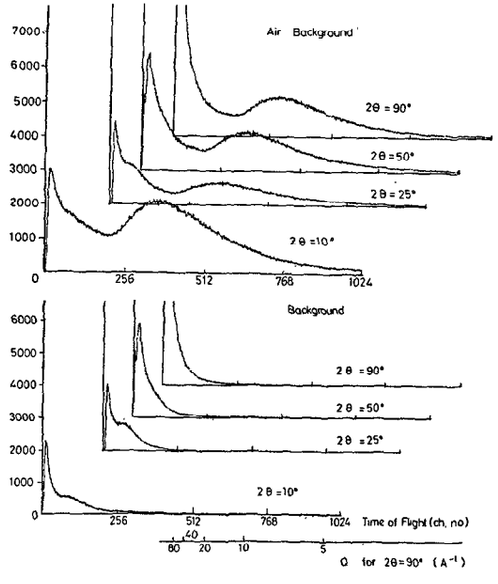


Fig. 4 Background with (upper figure) and without (lower figure) air scattering

3.2 Counting Rate

The capability for recording data at high counting rates is one of the most important characteristics of HIT and to examine its actual performance the following test measurements were carried out.



(1) Vitreous $SiO_2$

A sample of vitreous silica (1 cm in diameter, 5 cm long and about 9 grams in weight) was measured as a standard. Figure 5 shows typical spectra obtained with short measurement times. The actual counting time was only 90 sec, but although the counting statistics of the raw data are still rather poor (upper figure), the derived S(Q) (lower figure) is well defined, at least up to medium Q (~ $15A^{-1}$). For non-repetitive phenomena, therefore, our early results indicate that HIT will be useful for the measurement of time-varing S(Q) with relaxation times greater than 1 min.

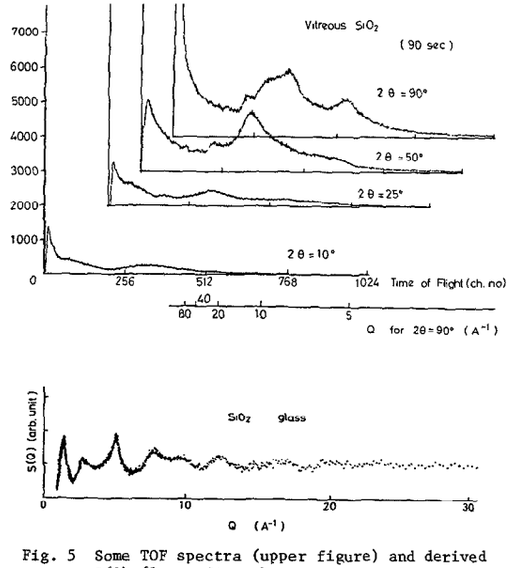


Fig. 5 Some TOF spectra (upper figure) and derived S(Q) (lower figure) for vitreous $SiO_2$ measured with 90 sec. The channel width is 4 μsec.

The counting statistics may, of course, be improved by extending the measurement time. Figure 6 shows some TOF spectra obtained from the same sample with a measuring time of 0.5 hours. The oscillation of S(Q) at high Q is very nicely defined up to about Q ~ 50$A^{-1}$.

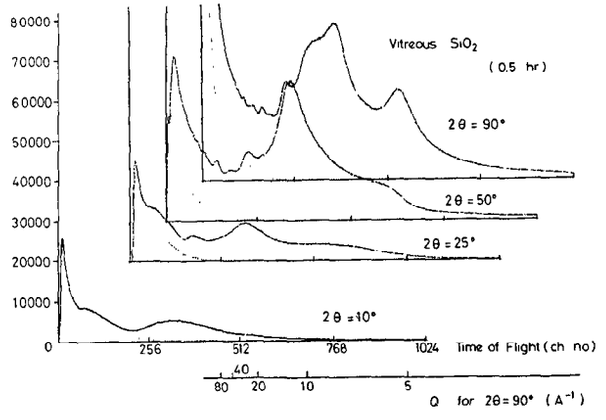


Fig. 6 Some TOF spectra for vitreous $SiO_2$ with a measuring time of 0.5 hours. The channel width is 4 μsec.

(2) Measurement on Small or Absorbing Samples

We anticipate that measurements on small or absorbing samples will be an important area of utilization of the machine, and, as an example of this kind, we have measured a sample of amorphous $Fe_{0.25}Ni_{0.55}Si_{0.1}B_{0.1}$. This was about 0.4 grams in weight and contained natural boron by 10 per cent. It was loaded into a vanadium cell of wall thickness 25 μm. A typical spectrum corresponding to a measuring time of 0.5 hours is shown in Fig.7. In spite of the relatively short measuring time the counting statistics and the



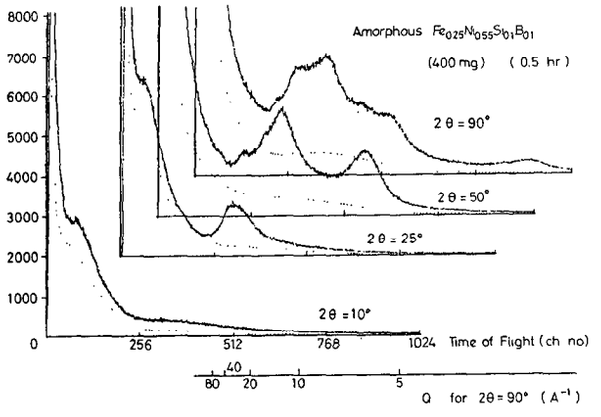


Fig. 7 Some TOF spectra obtained from a small and absorbing sample with a measuring time of 0.5 hours. The channel width is 4 μsec. The dotted lines indicate the pattern from the vanadium cell and instrumental background.

signal to background ratio are unexpectedly good. We have also measured another sample containing 40% natural boron (amorphous $Ni_{0.6}B_{0.4}$) and we found that even such a highly absorbing material was well within the range of practicable experiments. These early results encourage us to consider measuring amorphous semiconductors which exhibit photo-induced structural changes. For such measurements to be feasible, the sample must be thin enough for the bulk to be subjected to photon irradiation so that the total weight of the sample will be limited to ~0.1 g. Measurements on small samples containing expensive isotopes which provide information on partial structure factors provide another promising area of research.

### 3.3 Momentum Resolution

The momentum resolution of the spectrometer was monitored by using Bragg diffraction from a powder Si sample. The measured resolution which are close to the design values were about 0.6% at high Q for the back scattering counters, 1~3% for the medium angle counters and about 10% for forward counters. The resolution can be improved, if necessary, by using only data from the outside counters for higher angles, and by limiting the vertical length of the forward angle counters, although, of course, at the expense of a reduction in the counting rate.

### 3.4 Response of the Electronics

The maximum counting rate was found to be limited by the response time of the electronics, especially the main (pulse shaping) amplifier, rather than that of the gas proportional counter. In an attempt to increase the maximum counting rate, therefore, we tested a delay line clipping amplifier (Camberra Model 1411) and an active filtered amplifier (Camberra Model 2015/A). Typical dead times for 2015/A were found to be 2.3 μsec and about 6 μsec for shaping times of 0.5 μsec and 2 μsec respectively. The dead time of the 1411 with shaping time of 0.4 μsec was as short as 1.2 μsec. In Fig.6 the spectrum labelled $2\theta = 90°$ was processed through the 1411 while the other spectra were obtained using the 2015/A with shaping time of 0.5 μsec. In the former spectrum no saturation effect exists, but in the latter saturation clearly occurs in the epithermal region (at low channel number). These results demonstrate that the choice of amplifier is very important and for a high data rate capability delay line clipping amplifier is preferred to active filtered amplifier.



Acknowledgements

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Reference

1) N. Watanabe, K. Yamada, M. Misawa and T. Mizoguchi : High Intensity Total Scattering Spectrometer (HIT), KEK Report KEK Int. 80-1, KENS Report I (1980) p-73.