ICANS IX

INTERNATIONAL COLLABORATION ON ADVANCED NEUTRON SOURCES

22-26 September, 1986

THE NBS NEUTRON TIME OF FLIGHT SPECTROMETER

I.S. ANDERSON[1,2], T.J. UDOVIC[1], J.M. ROWE[1], J.J. RUSH[1] and J. LaROCK[1]

[1] National Bureau of Standards, Gaithersburgh MD 20899, U.S.A.

[2] Swiss Institute for Nuclear Research, CH-5234 Villigen

Introduction

A schematic outline of the new high resolution time-of-flight spectrometer which is designed for quasielastic or near elastic studies is shown in Fig. 1. This spectrometer which is presently undergoing commissioning tests is situated at a 15 cm diameter beam port at the NBS research reactor and will view the new D_2O ice cold source when installed (1). The spectrometer uses a double monochromator system followed by a simple Fermi chopper to pulse the resultant monochromatic beam. This decoupling of the monochromating and pulsing functions allows greater flexibility in optimizing the parameters of each independently. Since the instrument comprises a large detection area close to the reactor face, particular attention has been paid to proper design of the shielding of all parts of the spectrometer in order to reduce detected background. Initial optimization of the shielding allowed this background to be reduced to less than one count per minute per detector.

Monochromator

The double monochromator was chosen for several reasons:

a) the secondary monochromatic beam is removed from the primary beam thus facilitating the task of shielding against a significant fast neutron background,
b) the incoming energy may be readily selected from a continuous range without having to displace large components,
c) in cases where floor space is a constraint such as at beam positions close to a reactor face or moderator, then it is convenient to have the secondary beam parallel to the incident beam.

The effects of the second crystal on the monochromatic beam are threefold: the intensity is reduced by the peak reflectivity of the crystal; furthermore the effective mosaic spread of the system is reduced by a factor of $\sqrt{2}$ in the case of similar crystals and finally the beam divergences before the first crystal and after the second crystal in such a system are identical for similar crystals. The reduction in the effective mosaic can be allowed for by suitable choice of crystals while the correlation of the incident and exit beam divergences precludes the need for an in-pile collimator which would be difficult to access due to radiation problems since an easily accessible exit collimator is sufficient. However the use of a collimator between the two crystals is essential to reduce multiple reflections and allow complete flexibility in the choice of the incident energy resolution. Thus for two identical collimators of full width, a, before and after the second crystal, the effective beam divergence is given by $a/\sqrt{2}$ which is independent of the crystal mosaics. Thus the resolution in energy may be chosen at will within the constraints of intensity.

At present pyrolitic graphite crystals are used with individual mosaic spreads of 40^{o}. These are mounted on rotary tables which in turn may be translated parallel to the incident beam direction. A rotating shielding drum containing a collimator is situated between the two crystals. In normal operation the rotation of this drum is coupled to the translational movement of the crystals thereby assuring the automatic alignment of the collimator, however the drum may be turned independently to allow the collimator to be removed via a removeable plug in the monochromator shielding. The rotations of the two crystals and the collimator drum are directly coupled to vector resolvers as absolute encoders and in case of failure of these encoders a back-up system using optical switches is installed.

The incoming wavelength may be selected from a continuous range between 2.2 Å and 6.6 Å using this system. For wavelengths above 4 Å a cooled Be filter may lowered into the beam to remove neutrons from higher order reflections.

Chopper

This device is a multiple slit Fermi chopper which effectively decouples the neutron burst time from the beam parameters. The rotor consists of a hollow aluminium cylinder 7.6 cm in diameter and 12.7 cm high spinning about a vertical axis. Two slit packages are available which have slit widths of 0.0635 cm and whose curvature and lengths are optimized for 1.5 Å and 4 Å neutrons respectively. The chopper is driven by a two phase hysteresis motor at speeds ranging from 10000 to 18000 rpm depending on wavelength and frame overlap conditions. A security system monitors:
a) the current in the chopper,
b) synchronous rotation of the chopper and drive signal,
c) chopper vibration,
d) the temperature of the chopper bearings.
If an abnormal condition is sensed for any of these functions the chopper may be tripped and the data aquisition halted automatically.

Primary flight path

The chopper, second collimator and various other beam definition devices are mounted on an optical bench which allows for easy interchange of components without need for lengthy realignment. In particular the collimators may be exchanged or the positions of the collimator and chopper interchanged. Thus under normal conditions the chopper is situated as close as possible to the sample to reduce the time spread of the incident beam in which case a coarse small angle collimator positioned just inside the sample drum is used to reduce scattering from the chopper. However in cases where good beam definition is required for low angles the secondary collimator may be placed after the chopper with a resulting worsening of the energy resolution.

Sample chamber

The sample chamber which is still in the final stages of construction comprises many essential features. It consists of a cadmium lined aluminium drum with thin aluminium entrance and exit windows. The drum is designed to support a secondary vacuum such that it may be used as the outer wall of a sample cryostat thus reducing the amount of extraneous scattering material in the beam. Samples may be inserted into the drum from above by means of a removable flange mounted on a rotating high vacuum seal. This flange is coupled to a stepping motor and encoder such that the sample orientation can be easily adjusted under computer control. Thus the spectrometer can be readily used for elastic diffuse studies in single crystals. The whole drum may be also moved up and down relative to the beam in order to facilitate sample alignment.

An oscillating radial collimator whose function is to shadow the detectors from neutrons which do not originate from scattering in the immediate vicinity of the sample is placed between the sample container and the socondary flight path.

The primary flight path, sample drum and radial collimator are completely surrounded by shielding consisting of 10 cm of wax followed by 2.5 cm of boron carbide.

Secondary flight path and detection system

The secondary flight path consists of a steel vacuum chamber surrounded by shielding of 15 cm of wax followed by 2.5 cm of boron carbide on the outside and lined with 1 mm cadmium sheeting on the inside. The aluminium entrance window is bolted to the front of the flight path which in turn buts up against the sample chamber shielding. The total distance from the sample to the detectors is 2.28 m.

The detection system consists of 71, 46 cm active length, 2.5 cm diameter detectors filled with 4 atmospheres of ^{3}He covering the range of scattering angles between 25 degrees and 120 degrees. Similar detectors of 23 cm active lengts cover the angular range from 10 degrees to 25 degrees. The shorter detectors are necessary to reduce the detector height contribution to the momentum transfer resolution at low angles. At a later stage a small angle detection system will be implemented consisting of an array of 1.2 cm diameter, 46 cm active length position sensitive detectors allowing the Debye Scherrer rings to be mapped out directly under software control.

Electronics and data acquisition system

The spectrometer is controlled by a microVax II computer directly interfaced to a Camac system. The time of flight data is accumulated in a histogramming memory system residing in the Camac and may be transferred to the computer when required by DMA transfer. The memory/Time of flight interface includes functions which allow the data to be accumulated in different memory regions a feature which is useful for real time experiments.

Summary and future developments

A summary of relevant instrumental parameters is given in Table 1. The spectrometer is in the commissioning stage and as yet no experimental data is available though some additional features are being studied. Firstly if the standard collimators are replaced by reflecting sollers it may be possible to double the intensity for a given energy resolution. Furthermore the introduction of a vertically curved graphite deflector as the second monochromator crystal can significantly increase the effective flux for small samples.

Acknowledgements

The authors wish to acknowledge the support of the technical staff at the NBS reactor.

References

1. R.S. Carter and P.A. Kopetka, NBS Technical Note 1217 (1985) 64.

Table 1: Instrument Details

Beam Size	10 cm x 1 cm
Incident Wavelength	$2.2 < \lambda$ (Å) < 6
Incident Energy	$16.9 >$ E (meV) > 2.27
Collimation	10', 20', 40'

Elastic Energy Resolution (μeV)

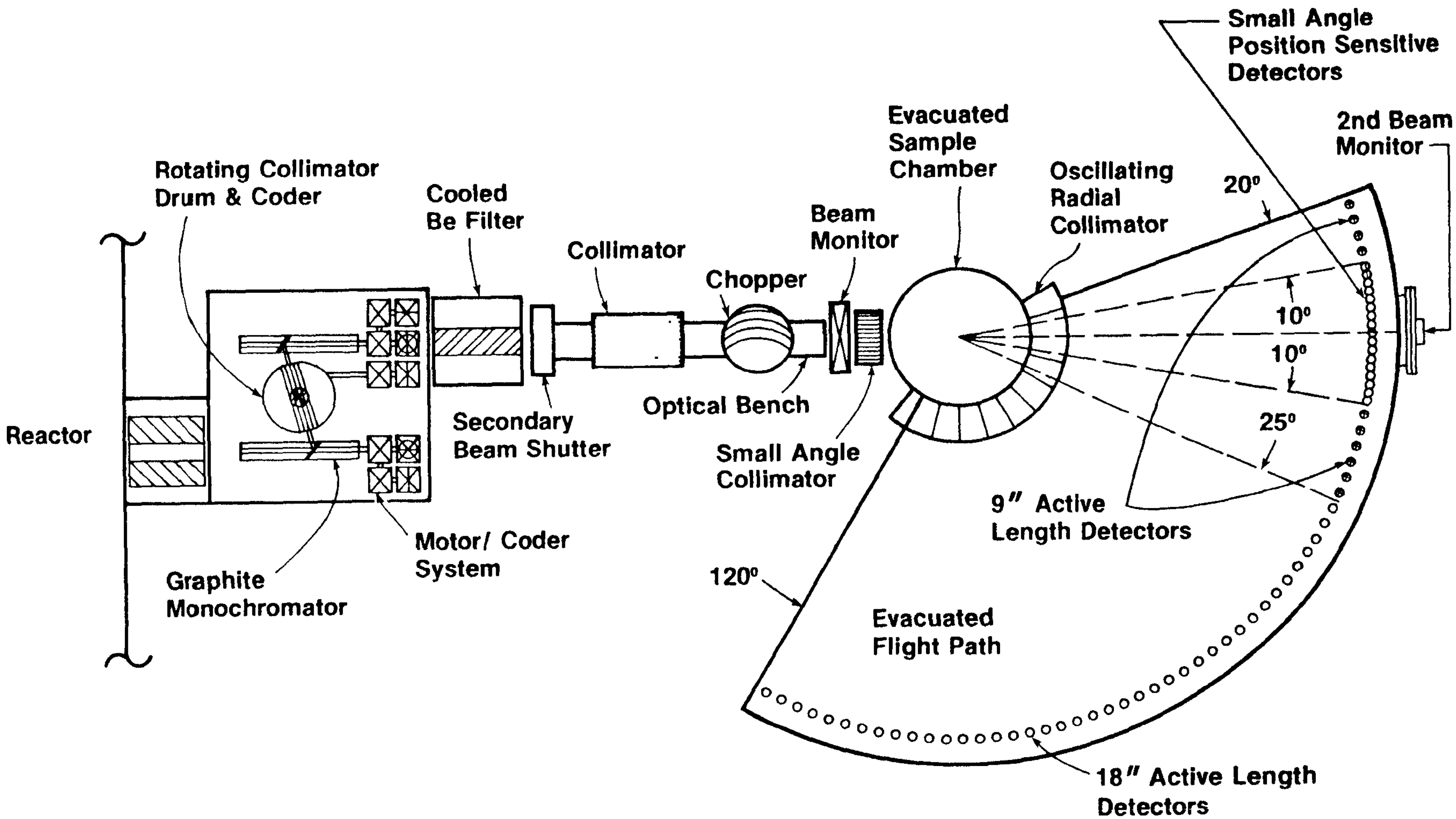
Wavelength Å	Collimation (min.) 40	20	10
4	140	80	50
6	30	20	18

Range of Scattering Angles	$1^\circ < 2\theta < 120^\circ$
Elastic Momentum Transfer	$0.01 <$ Q (Å^{-1}) < 4.9
Q Resolution	$\frac{\Delta Q}{Q} < 3\%$
Detectors	$120^\circ > 2\theta > 20^\circ$ 4 atmospheres ^{3}He- 2.5cm diameter, 46cm active length
	$25^\circ > 2\theta > 10^\circ$ 4 atmospheres ^{3}He- 2.5cm diameter, 23cm active length
	$10^\circ > 2\theta > 1^\circ$ 1.2 cm diameter linear position sensitive 46 cm. active length

Typical Applications:

The instrument is most suited to quasielastic and low energy inelastic studies, such as -

dynamics of hydrogen in metals
diffusion in superionic conductors
spectroscopy and diffusion of adsorbed and adsorbed molecular species
dynamics of polymers and biological molecules
intercalation compounds
hydrogen bonding studies
liquid crystals
tunnelling spectroscopy
elastic diffuse scattering.



The NBS Neutron Time of Flight Spectrometer