A Medium Energy Inelastic Spectrometer for SNS

A D Taylor
Neutron Division, Rutherford and Appleton Laboratories

1 Introduction

This paper identifies several active fields of inelastic neutron scattering which require a medium energy inelastic spectrometer covering a wide and variable region of Q and ω space with good resolution. A direct geometry spectrometer is envisaged. A suite of choppers, phased to the pulsed source, will provide incident energies in the range 20 meV < Eo < 140 meV. The secondary spectrometer will cover a wide angular range $-10^{\circ} < \phi < 135^{\circ}$. The spectrometer's performance characteristics will be optimised to achieve a resolution $\Delta E_o/E_o$ of ∿ 2½% in the energy range 20 meV < E_o < 60 meV. Intensity at the sample will be some 10^3 - 10^4 n cm^{-2} s^{-1}. A dense net in Q space of, typically, 0.1 $Å^{-1}$ steps over the large angular range will facilitate the interpolation of constant ϕ scans to constant $|Q|$. Such a specification represents a significant improvement over what is currently available on steady state sources.

2 Scientific Background

Excitations

Time-of-flight is particularly well suited to the study of polycrystalline and amorphous systems. (The study of the amorphous state may be identified as a 'growth area' as progress is made from the relatively simple ordered state to disordered problems, eg amorphous metals). Requirements for coherent density of states measurements are:

- Dense coverage at low Q so that all coherent features are observed.
- Large Q range so that a proper averaging of <u>Q.U</u> over the Brillouin Zones is achieved.
- Incident energies in the range 20 meV < E_o < 60 meV with $\Delta E_o/E_o$ ∿ 4-5% at 2½% at 60 meV.

S(Q,ω) Studies of Liquid Systems

A dense net in Q space over a wide Q range is required for these studies, typically 100 ϕ scans at Q increments of 0.1 $Å^{-1}$. Resolution requirements are similar to those for density of states measurements ($\Delta E_o/E_o$ ∿ 4-5% at 20 meV; $\Delta E_o/E_o$ ∿ 2-3% at 60 meV) but incident energies up to ∿ 140 meV will be needed to increase the kinematic region probed.

Magnetic Scattering Laws

The form factors of magnetic systems place an upper bound of ∿ 5 $Å^{-1}$ on Q. The energy of excitations in ionic magnetic systems lies in the range 0-40 meV. Thus the specification of this spectrometer is ideally suited to study these inelastic magnetic systems.

A wide range of Q and ω is needed to study the paramagnetic or critical temperature region where the relatively smoothly varying scattering law gives information on the interaction constants of magnetic systems. There is also much interest in measuring the spin-spin correlation function for disordered systems such as magnetic metal glasses and spin glasses.

Molecular Spectroscopy

In molecular spectroscopy, the resolution requirements for this spectrometer are at their most severe, for there is always the unfavourable comparison with optical techniques. The need to separate peaks is at its greatest for energy transfers, ħω, < 20 meV. For example, $\Delta E_o/E_o$ = 2.5% (0.5 meV at 20 meV) would allow a peak separation of ∿ 0.2-0.3 meV at ħω ∿ 10 meV. E_o of 60 meV with ΔE_o ∿ 1.5 meV would adequately cover the range 15 meV < ħω < 50 meV, and $\Delta E_o/E_o$ of 5% is more than sufficient at E_o = 140 meV to study hydrogenous modes. If required an improvement in the 20 meV resolution may be achieved at a severe intensity cost by mismatching the chopper with the source.

Assignments in more complex systems, and the fitting of more precise models for the potential in simple systems, will be facilitated by studying intensity variations of a peak with both temperature and Q. The latter requirement can only be achieved if a wide range of scattering angles is available. Studies of a possible weak dispersion with Q of some modes require both this angular range and good resolution.

3 Choice of Design

Only a direct geometry instrument with a wide angled secondary spectrometer, allowing large and variable regions of Q, ω space to be probed, can satisfy the requirements of section 2. In a matched instrument the moderator pulse width dictates the chopper characteristics, leaving only the geometry of the primary and secondary flight paths, L_o and L_1, and the chopper to sample distance, D, as variables. (D may be chosen to be ∿ 1 m without much loss in generality). The specification of $\Delta E_o/E_o = 2\frac{1}{2}\%$ then limits the geometry to specific (L_o, L_1) pairs, differing in performance only in intensity which is proportional to $1/L_o\,(L_o + D)^2$. The physical size of the secondary spectrometer imposes further constraints: the minimum distance for a spectrometer with a horizontal scattering plane is L_o = 12 m (L_1 = 4 m); the minimum approach if the scattering plane is vertically downwards is L_o = 9 m (L_1 = 5 m). The intensity at the sample of these spectrometers favours the vertical geometry by a factor 2.3.

4 Instrumental Description

The instrument will be located on a "high resolution" moderator. A monochromatic incident beam will be provided by a family of choppers (typically at 20 meV intervals), each matched to the moderator pulse at a specific energy. Demands on chopper technology are not severe, the moderator pulse varying from 24 μs at 20 meV to 5.3 μs at 140 meV. The chopper will be located 9 m from the moderator and will spin at a frequency of 300 Hz (6 ν_{SNS}). In addition a crude chopper before the main device will be required to reduce fast neutron background and prevent 'order' contamination.

The layout of the spectrometer and the proposed detector pattern is shown in figure 1. The 2 mm thick Li^6 scintillator elements are arranged at low angles on Debye Scherrer cones. In the intermediate angular range, a central strip is retained offering tighter Q resolution for single crystal experiments. The 4.5 m secondary flight path is evacuated in two regions. The neighbourhood of the sample may be reduced quickly to a cryogenic vacuum and may be let up to atmosphere independent of the secondary spectrometer box, which is maintained at a rough vacuum to minimise scatter. Internal collimation in the secondary spectrometer provides mechanical strength and limits the volume viewed by the large detector array.

FIGURE 1 MEDIUM ENERGY INELASTIC SPECTROMETER