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TIME-OF-FLIGHT INELASTIC SCATTERING

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1. INTRODUCTION

Thermal neutrons travel at a velocity of approximately 2 km s^{-1}. As a consequence, the velocity of a neutron and hence its energy can be determined from its time-of-flight over a distance of a few metres. By fixing the energy of the neutrons incident on the sample and measuring their energy after scattering, or by fixing the energy of the scattered neutrons and determining their energy before scattering, the energy transferred from neutron to sample can be determined. This is the basis of time-of-flight (TOF) spectroscopy.

These two scenarios are referred to as direct and indirect (or inverted) geometry spectroscopy respectively. I will discuss the relative merits of both techniques and the different ways they are employed to address scientific problems. I will also draw on some scientific examples to illustrate the advantages and disadvantages of techniques or instrument designs.

At pulsed sources all spectrometers are TOF spectrometers because in this way the high peak flux and inherent time structure are utilized optimally. On steady state sources however, choppers can used to provide the pulse structure, and TOF spectrometers provide additional and complementary capabilities to triple-axis spectrometers (TAS).

The TOF technique has the following advantages:

- measurements are performed simultaneously over a broad range in momentum transfer/energy transfer ($\boldsymbol{Q}$,ω) space, making it an ideal technique for surveying,
- the instruments all tend to be of fixed geometry, which can have advantages for time dependent measurements or when measuring under difficult sample environment conditions.

F. Hippert et al. (eds.), Neutron and X-ray Spectroscopy, 457–482.

To set against the above there are the following disadvantages:

- TOF spectrometers offer less flexibility in the selection of scans and the tuning of resolution,
- it is difficult to collimate the scattered beam before detection in the wide detector arrays usually found on TOF spectrometers,
- wide detector arrays are not compatible with standard polarization analysis techniques. It is only now with the development of hyperpolarized ^{3}He filters and some innovative solid state devices that there are practical solutions for polarizing a scattered beam over a wide angular range.

In general, TOF instruments are well suited to broad surveys of ($\boldsymbol{Q}$,ω) space while TAS instruments are better suited to detailed investigations at well-defined ($\boldsymbol{Q}$,ω) points. Recent developments in both TOF and TAS instrumentation however, mean that this distinction is becoming increasingly less valid and the choice of the most appropriate instrument is often based on more subtle factors. TOF instruments do not have the ability a TAS instrument has to perform directly scans along well-defined crystallographic directions at fixed energy transfer or to scan energy transfer at a fixed point in the reciprocal lattice.

2. CLASSES OF TOF SPECTROMETERS

Time-of-flight spectrometers may be divided into two classes:

- ***Direct geometry spectrometers:*** in which the incident energy, E_i, is defined by a device such as a crystal or a chopper, and the final energy, E_f, is determined by time-of-flight or
- ***Indirect (inverted) geometry spectrometers:*** in which the sample is illuminated by a pulsed white incident beam and E_f is defined by a crystal or a filter and E_f is determined by time-of-flight.

The figure 1 [1] shows examples of generic direct geometry and indirect geometry types. In the following paragraphs I will describe the characteristics of instruments in each class and provide some scientific examples.

2.1. DISTANCE-TIME PLOTS

Distance-time plots illustrate the mode of operation of an instrument and are a useful way of understanding contributions to the energy resolution and the optimization of a spectrometer. Figures 2a and b are distance-time plots for a direct and an indirect geometry spectrometer respectively.