TIME OF FLIGHT SPECTROMETER WITH OPTICAL POLARISER

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§1. Introduction

The optical technique for neutron polarisation has the advantage of combining relatively high polarisability with high reflectivity. In ideal cases, nearly 100% polarisability and 50% reflectivity with respect to the incident unpolarised neutron beam can be achieved. This technique is particularly appropriate for pulsed cold neutrons.

Firstly, for cold neutrons the glancing angle of the polariser magnetic mirrors with respect to the incident neutron beam can be large. The critical angle for total reflection by a $Fe_{45}Co_{55}$ magnetic mirror is, for example, approximately 25 minutes for 4 Å neutrons. Technical difficulties associated with accomodating small take of angles are therefore reduced. Secondly, polychromatic neutrons avail themselves to study by time of flight techniques. For the TOP spectrometer, cold neutron beams in the range of 4 Å – 12 Å are accepted from the neutron guide tube C_3.

Thirdly, applications of the Larmor precession of the neutron spin around an applied magnetic field may open new fields in low energy neutron spectroscopy. The spin rotation provides a probe, additional to that afforded by the neutron velocity, for monitaring energy changes on scattering by samples.$^{1)}$

We have recently completed construction of an time of flight spectrometer with Optical Polariser (TOP).$^{2)}$ The design concept of this TOP spectrometer has already been outlined in the previous KENS Report$^{2)}$. We describe here the performance of the completed spectrometer and, in the last section, we show some preliminary experimental results.

§2. Performance of the Spectrometer

A schematic diagram of the TOP spectrometer is shown in Fig. 1. The instrument consists of a neutron polarising system, a magnetic guide channel with a neutron spin flipper and a diffractometer with two independently-movable detector arms. The present arrangement is that designed for polarised neutron diffraction experiments, but the instrument can also accomodate inelastic TOF measurements$^{3)}$ if additional components such as a precession magnet, polarisation analysers etc. are used. These latter components are, at present, at the design stage.

The neutron polariser consists of Soller-type $Fe_{1-x}Co_x$ magnetic mirrors inserted in an electromagnet which produces a maximum field of about 0.25 Tesla. Efficient polarisers are still being developed and the spectrometer was therefore designed such that the reflected (polarised) beam direction can be varied by ≤5° with respect to the incident neutron beam. The magnetic channel is composed firstly of a permanent magnet producing a vertical field of 100 Oe which is at a separation of 100 mm from the polarising magnet. This guide is followed by a Drabkin-type spin flipper$^{4)}$. The flipper consists of two coils which produce a variable magnetic field along the beam direction. The coupling between the guide and the flipper, therefore, should be arranged such that outside the two systems all changes in the polarisation direction are adiabatic. Following the flipper there is a further coil producing a field along the beam direction which serves to maintain the neutron polarisation to the sample position. An electromagnet producing a variable field of up to 1.2 Tesla in a 50 mm air gap is mounted on the sample table. This magnet is designed to be rotatable around the horizontal axis by 360° and, as the sample table may also be rotated through 360° about the vertical axis, the field can be applied in any chosen direction. The sample table drive is controlled by a dedicated micro computer NEC-PC8001 to within 1/100° accuracy. Scattered beams within the range $-20^\circ \leqslant 2\theta \leqslant 110^\circ$ can be detected by two independently movable detector tables which are connected to the sample table.

The total flight path from the moderator to the detectors is 21.0 m. The guide tube section ends at 16.40 m from the source face. The central medium size computer is responsible for data acquisition and handling, but the dedicated micro computer is used to control the spin-flipper system. If required, the neutron polarisation may be flipped by π every pulse and, eventually polarisation dependent scattered signals will be easily obtainable. A block diagram of the operating system and a time chart are illustrated in Fig. 2. An overall view of the TOP spectrometer is given in Fig. 3.

§3. Polarisation of Neutrons

The attainment of high neutron polarisability over the entire wavelength range from 4 Å to 12 Å depends on the balance between the effective nuclear and magnetic scattering amplitudes in the polarising magnetic mirror$^{5)}$. Among the best polarising mirror materials are magnetized thin films of $Fe_{45}Co_{55}$ evaporated onto polymer substrates.

These substrates which are comprised mainly of $-(CH_2)_n^2-$ units have small, negative coherent scattering amplitudes. Further, when such plastic films are uniformly stretched their surface quality is relatively good.$^{6)}$

Although such curved Soller-type magnetic mirrors can provide polarised neutron beams with cross-section areas as large as 10 cm^2, the production process for high quality mirrors is laborious. In our case at least 40 sheets of evaporated $Fe_{1-x}Co_x$ films are required for polarisation of the 20 x 50 mm^2 neutron beam. The first such polariser is currently being manufactured although, in the meantime, we have made measurements of polarising efficiencies and transmissions using prototypes of somewhat smaller dimensions$^{2)}$. The polarising efficiency was determined by measuring the flipping ratio from the 111 reflection of a Heusler analyser crystal$^{7)}$ placed at the sample position. Up until the time of this report we have obtained results for the wavelength region 4 Å-6.5 Å. A typical time of flight scan is depicted in Fig. 4. The measurements for $Fe_{25}Co_{75}$ on Myler and $Fe_{25}Co_{75}$ on another commercial polymer film, OPP, gave maximum flipping ratios of 6.5 and 12.5 respectively for 4 Å. For the latter, the flipping ratio was almost independent of the wavelength within the range 4 Å-6.5 Å, although within this range the former showed some variation. Our results indicate that $Fe_{25}Co_{75}$ on OPP has a polarising efficiency of about 93%. The flipping efficiency of the Drabkin-type flipper system was also proved by inserting a tunable Mezei-type π-flipper$^{8)}$ between the paired coils. Our results indicated that the flipper system works satisfactorily.

These recent measurements have confirmed that the present configuration of the TOP spectrometer meets the design performance as a polarised neutron diffractometer. After completion of the fun-size polarising mirrors we will commence full operation.

Finally, as an indication of the type of initial measurement that is being made, we shown in Figure 5 polarisation dependent diffraction patterns from Fe-Pd bilayer films. These bilayers are currently being studied to probe interfacial magnetic properties.[9]

References

1) F. Mezei; Z. Phys. 255 (1972) 146

2) Y. Endoh and Y. Ishikawa; KENS Report I (1980) 149

3) F. Mezei; Nu. Inst. Met. 164 (1979) 153

4) G.M. Drabkin et al.; Sov. Phys. JETP 29 (1969) 261

5) J.B. Hayter, J. Penfold and W.G. Williams; J. Phys. E 11 (1978) 454

6) Y. Sasaki and Y. Endoh; Res. Rept. Lab. Nucl. Sci. Tohoku Univ. 13 (1980) 92

7) The crystal was kindly loaned from Prof. Y. Ito, ISSP, Univ. of Tokyo

8) J.B. Hayter; Z. Phys. B 31 (1978) 117

9) M. Sato, K. Abe, Y. Endoh and J.B. Hayter; J. Physl C 13 (1980) 3563
T. Shinjo, S. Hine and T. Takada; 1977 Proc. 7th Int. Conf. Vac. Congr. and 3rd Int. Conf. Solid Surfaces. Vienna ed R. Dobrozemsky (Ham. Austria: Berger & Söhne) 2655

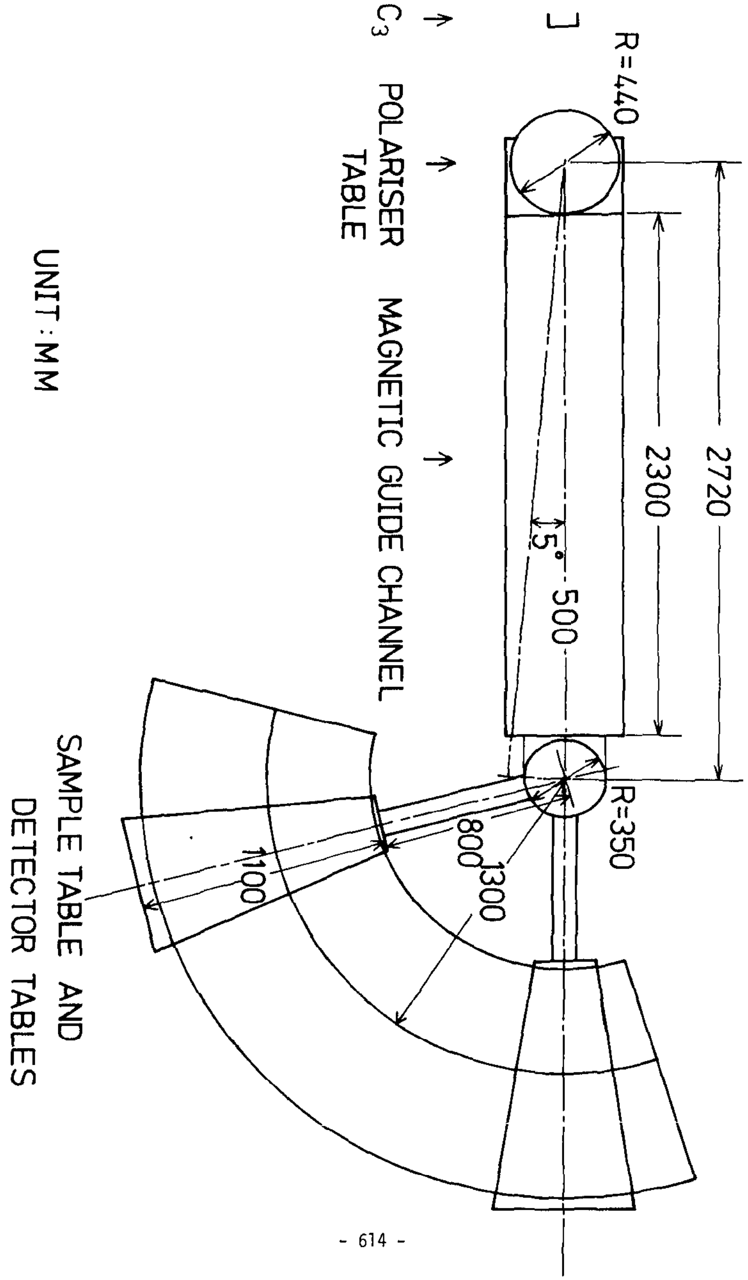

Fig. 1. Schematic drawing of the TOP spectrometer

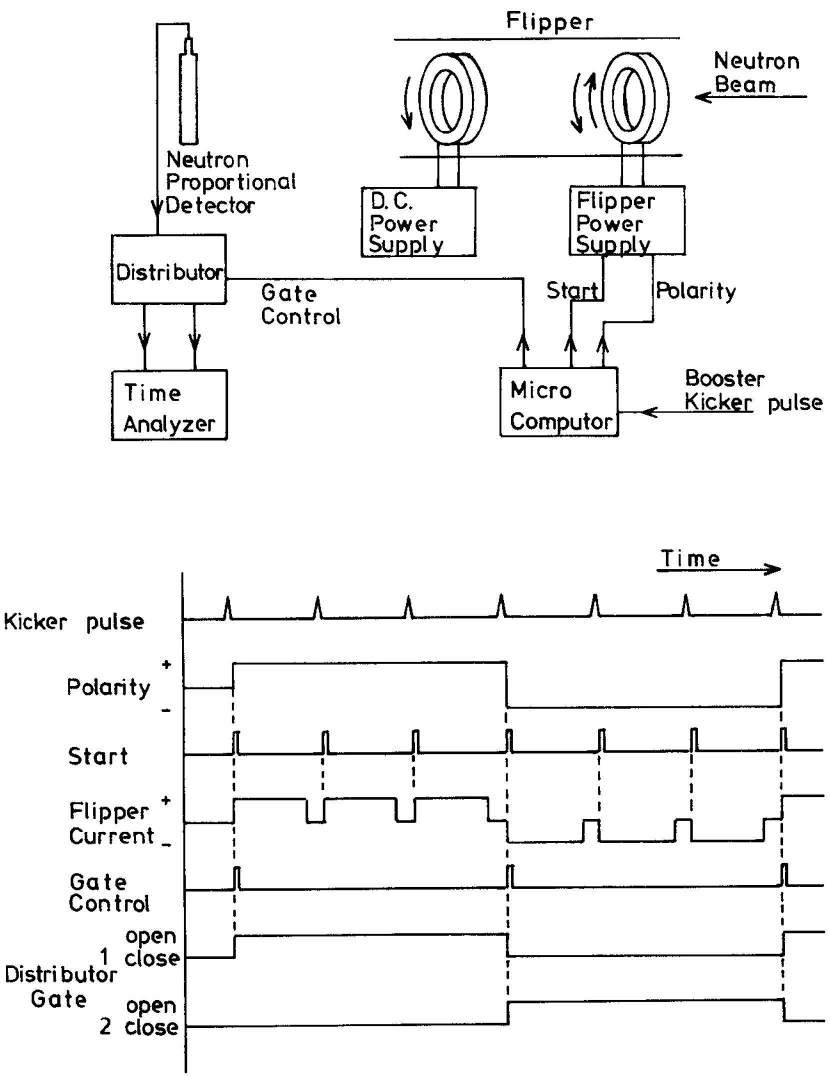

Fig. 2. Diagrams of TOP operation and its time chart

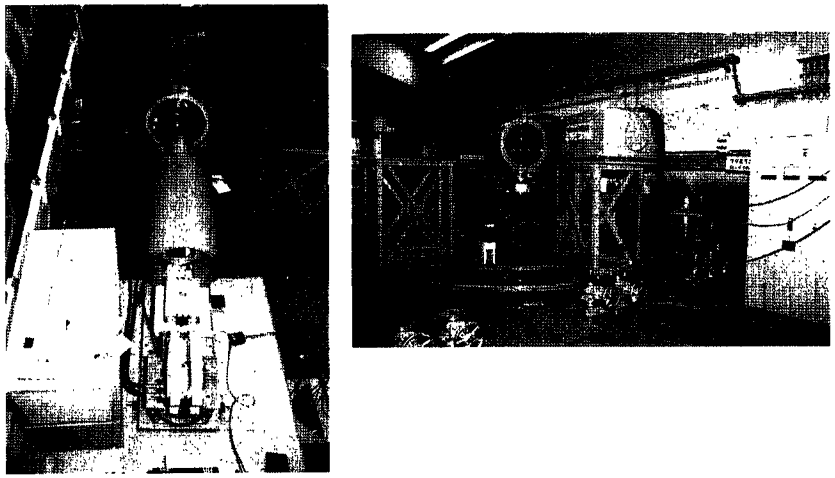

Fig. 3. Overview of TOP

TOP

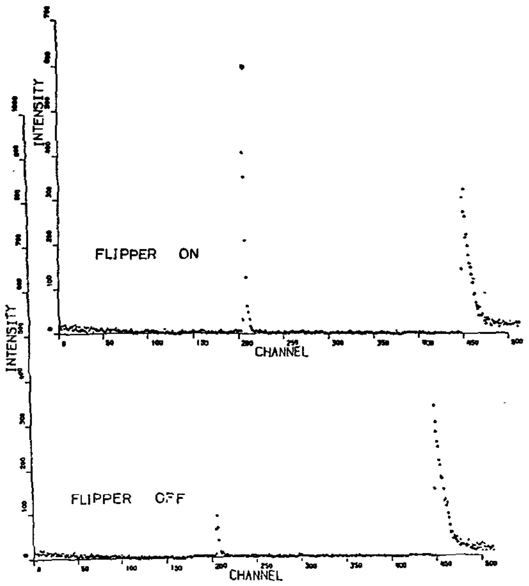

Fig. 4. TOF diffraction patterns of the 111 reflection from the Heusler analyser. The analyser crystal was in a field of 0.95 Tesla. The Bragg angle θ was 45°, so that 4.0 Å neutrons were counted by the detector.

TOP

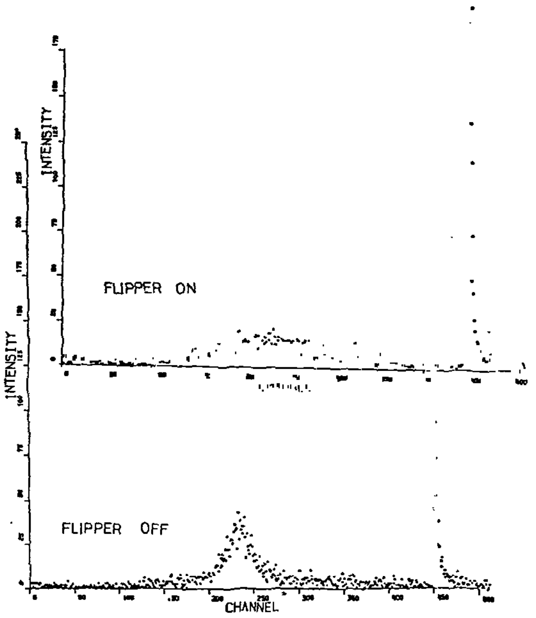

Fig. 5. TOF diffraction patterns from Fe-Pd bilayers at ambien temperature. The period of a bilayer is 55 Å and the present sample has 100 layers. The Bragg angle θ wa set at 3.2°.