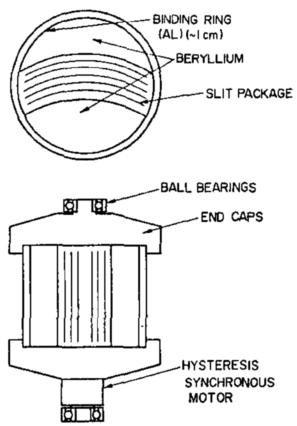
Report on the Guide, Chopper and Polarised Beam Session

by J.M. Newsam and W.G. Williams

Ideally, a neutron guide would allow the transport of neutrons within a particular energy range over the required distance without loss and without disturbing the intensity distribution within the beam. In practice such conditions cannot be realised and to estimate the effect of the various influencing factors on the properties of the transported beam, a Monte-Carlo type computer simulation is necessary. Such simulations have highlighted problems such as that of illumination and indicated interesting variations in beam asymmetry with guide configuration. However, the experience at KENS suggests that even sophisticated simulations may give optimistic predictions of guide performance. The transmission of guides may be improved some 10 % by using Ni^{58} in place of natural Ni for the neutron reflector although, because of cost and availability, natural Ni has been chosen for the KENS and SNS guides. Alefeld suggested that a less costly way to improve the effective performance would be to use a single tapered Ni^{58}-coated section at the end of the guide. Alefeld also queried the necessity of curving guide tubes, it being possible to remove the signal from fast neutrons electronically. Williams, however, explained that although curved

guides were not mandatory for removing the fast neutrons, for many reasons, such as the difficulty in estimating the fast neutron background, it was undesirable to view the moderator directly.

Considerable progress has been made at both ANL and the Rutherford Laboratory in the techniques of manufacture, control and phasing of high angular velocity choppers. The SNS and ANL choppers have similar slit packages although their frame and support systems differ (see Figures 1 and 2). Both designs have evolved over a long period and their present operational status represents no mean technical achievement. The difficulty of phasing choppers rotating at ≥16000 r.p.m. to an impishly varying mains frequency had long been a worry at the operating facilities of ANL and LASL.



SLIT PACKAGE : $5 \times 10\,cm^2$
ABSORBERS 0.53mm B-FIBRE /AL COMPOSITE (3 FIBRE LAYERS)
SLITS 2.0mm AL SPACERS
ROTOR : DIAMETER 150mm
SPEED 16,200 r.p.m. (270Hz)
OPTIMUM ENERGY : 160 meV

FIGURE. 1. SCHEMATIC DIAGRAM AND SOME CHARACTERISTICS OF THE PRESENT ANL FAST CHOPPERS

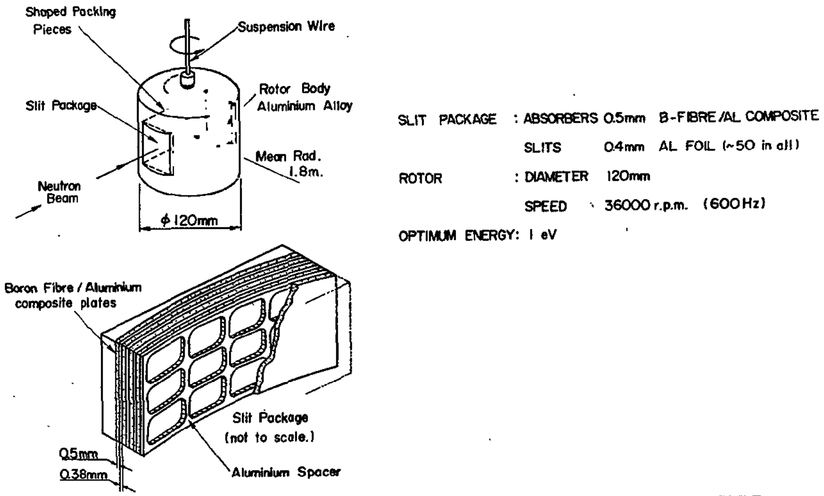


FIGURE. 2 SCHEMATIC DIAGRAM OF THE CONSTRUCTION AND SOME CHARACTERISTICS OF THE PRESENT SNS FAST CHOPPERS

The performance of the SNS and ANL choppers appears to be quite similar and the discussions about these velocity selectors were mainly concerned with mechanical details, in particular the chopper bearings. Carpenter described how at ANL, heating in the bearings due to their rotation in the earth's magnetic field was reduced by using magnetic shielding and that ca 0.5 torr of He gas was preferred to a complete vacuum to increase heat dissipation and prevent loss of grease. These bearings are also elastically mounted and have light shells so as to minimise load. Stewart mentioned that self-aligning bearings were found necessary at the tests for the SNS to prevent a skipping-rope action during running. It is clear that the design of these high velocity choppers is a considerable technical achievement and the associated technology may well find applications in fields far removed from neutron scattering.

The operation of the low-velocity choppers used as tail-cutters before the curved guide tubes at KENS was described by Furusaka. Rather than using a feed-back circuit to control phasing, these choppers are driven by stepping motors which are activated by pulses derived from a signal received from the accelerator control. By supplying only the number of pulses required to complete one revolution between each neutron burst the phase of the chopper can be maintained to within the required accuracy. Further details of the control circuit are available in KENS Report I.

On the subject of polarised beams, all the participating laboratories agreed that any future programs on pulsed sources will depend heavily on the development of successful polarising filters. This is the only type of neutron polariser that has a broad band polarising capacity. They can also accept the full incident beam divergence.

Polarising filters operate by either spin-dependent scattering or spin-dependent resonance absorption. Of the three independent development programs in progress, two are based on the former and one on the latter.

1. Spin-dependent scattering

A target of polarised protons acts as an efficient polarising filter for neutrons over a wide energy range $0 < E < 1$ meV. Such filters will therefore be useful for producing incident polarised beams although, because they operate through differential scattering of the two spin states, they are unlikely to be used as analysers in full polarisation analysis instruments. High proton polarisations ($\sim$ 70%) are required and there now seems to be two technically feasible methods of achieving this.

Both use methods for transferring the easily-attainable electron polarisation in a paramagnetic dope ion into the proton spin system.

(a) Dynamic Polarisation

This is historically the most tried technique and is being pursued at KEK in a collaborative effort with the High Energy Physics group. A spectrometer designed by Newsam et al. employing a dynamically polarised proton filter will be installed at KENS in early 1981. One difficulty in the neutron application is that of restricting the quantity of He^3 in the beam path. This is used as a refrigerant and has a large absorption cross-section. Masaike, however, explained that by careful design He^3 could be completely excluded from the line of the beam.

(b) Spin Refrigerator

The spin refrigerator principle for polarising protons, first introduced by Langley and Jeffries some 15 years ago, is now being applied as a neutron polarising filter in a collaboration between the Argonne and Los Alamos Laboratories. The best results have been obtained with single crystal of yttrium ethyl sulphate (YES) in which 0.01% of the Y^{3+} atoms are replaced by the paramagnetic dope Yb^{3+}. Yb^{3+} acts as an effective $s = \frac{1}{2}$ paramagnetic ion with a highly anisotropic g-factor ($g_c \sim 3.3$, $g_a \sim 0$) and when a single crystal is rotated

about the b axis with an applied H in the ac plane, the spin dynamics is such that the high Yb^{3+} polarisation which is generated when H//c can be transferred to the proton spin system. Typical experimental conditions are:
magnetic field (poor homogeneity) $H \sim 1.5T$, temperature $\sim$ 1K, spinning frequency $\omega \sim 100$ Hz. The main attraction of the technique is its simplicity compared with dynamic polarisation though there is a limitation with materials – YES is the only suitable material so far found. However, unlike dynamic polarisation, the method has received very little development attention in the past. A prototype system is nearing completion and neutron tests are scheduled for early 1981. To date, about 60% proton polarisation has been achieved,as indicated by 'H-nuclear magnetic resonance measurements. There do remain some experimental difficulties such as the change in filter thickness during rotation. However, the nuclear relaxation time at 1K is ca 20hrs and pumping takes typically 2 mins so that it may be feasible to halt crystal rotation while neutron measurements are made. If further improvements can be made, this technique may well prove the most attractive and further work should therefore be encouraged.

2 Spin-dependent resonance absorption

The resonance absorption method first demonstrated for polarised 149 Sm nuclei is now being applied to other polarised nuclei by the Rutherford Laboratory. The method is technically simpler than those previously described since it relies on the static polarisation of appropriate nuclei when they are cooled to dilution refrigerator temperatures. The main disadvantage of the method is that it can only be used at the nuclear resonance energies, although it is clear from the paper of Williams (see above) that the useful energy range may be extended by a suitable choice of nucleus or of combimations of nuclei.

Any polarised beam work on the new pulsed sources will rely on the development of polarising filters. These filters are expensive to produce in comparison with other instrument components. It is gratifying to note that three fundamentally different methods are being investigated within ICANS, thus making the optimum use of our resources and effort. This should ensure that polarising filters will be in routine use within the next few years.