and budgetary restrictions are severe) are far outweighed by gains in available beam area and current. This supports the qualitative observations of previous work (Nunes, 1974). It is hoped that this study will help to stimulate the proliferation of SANS instruments as, in this author's opinion, the full potential of this very valuable technique is yet to be realized.

References

ALBERI, J., FISCHER, J., RADEKA, V., ROGERS, L. C., SCHOENBORN, B. (1975). *IEEE Trans. Nucl. Sci.* **NS-22**, 1, 255–268.

HAYWOOD, R. C. G. & WORCESTER, D. L. (1973). *J. Phys. E*. **6**, 568–571.

HENDRICKS, R. W. (1976). *Trans. Am. Crystallogr. Assoc.* **12**, 103–146.

HEWAT, A. W. (1975). *Nucl. Instrum. Methods*, **127**, 361–370.

ILL Annual Report (1976). Pp. 24–26. Institut Laue-Langevin, BP 156X, 38042-Grenoble, France.

NSF (1978). *Chem. Eng. News*, Jan. 2, p. 22.

NUNES, A. C. (1973). *Nucl. Instrum. Methods*, **108**, 189–191.

NUNES, A. C. (1974). *Nucl. Instrum. Methods*, **119**, 291–293.

NUNES, A. C. & SHIRANE, G. (1971). *Nucl. Instrum. Methods*, **95**, 445–452.

NUNES, A. C. & ZACCAI, G. (1975). *Brookhaven Symposia in Biology*, No. 27, VII-49-56.

SCHMATZ, W., SPRINGER, T., SCHELTEN, J. & IBEL, K. (1974). *J. Appl. Cryst.* **7**, 96–116.

WITZ, J. (1969). *Acta Cryst.* **A25**, 30–42.

J. Appl. Cryst. (1978). **11**, 464–465

Design Study of a Time-of-Flight Small-Angle Diffractometer for a Pulsed Neutron Source*

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A design study was made of a neutron small-angle scattering (SAS) instrument for use at Argonne National Laboratory's proposed Intense Pulsed Neutron Source, IPNS-II (Carpenter & Werner, 1976; Werner, 1977; Carpenter, 1977). The instrument design incorporates several features: a converging-slit collimator, wavelength band-limiting choppers, capacity for large samples, and a two-dimensional detector. Machine design-dependent parameters are considered in a Monte-Carlo code that produces estimates of the instrumental resolution function and available flux at the sample. It was found that the calculated flux on sample exceeds that at steady-state reactor instruments of comparable resolution.

Pulsed neutron sources can provide higher effective neutron fluxes than are available at high-flux research reactors (*e.g.* the peak thermal flux at IPNS-II is 10^{16} n cm^{-2} s^{-1}). Most measurements currently performed use very efficient instruments based on steady-state monochromatic neutron beams; however, the increasing need for neutron SAS instrumentation and the advent of next-generation pulsed sources dictate the further development of neutron SAS facilities that utilize time-of-flight (TOF) techniques. Recently, at Dubna (Cser, 1975) and Harwell (Mildner & Windsor, 1978), TOF instruments have been tested at pulsed neutron sources.

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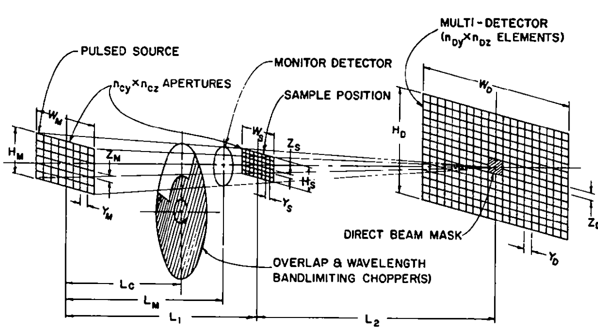

Fig. 1. Schematc diagram of IPNS small- angle diffractometer. The collimating system is represented only by entrance and exit apertures, but channels are assumed to be continuously defined.

A schematic design of the neutron (TOF) instrument is shown in Fig. 1, and appears to resemble a steady-source instrument. However, in the steady-state instrument, the incident wavelength λ_0 is fixed by a crystal or drum velocity selector and a range of wave-vector change $\mathbf{Q} = 2\pi/\lambda_0\,(\mathbf{\Omega}_f - \mathbf{\Omega}_i)$ is scanned by use of an array of detectors. Here $\mathbf{\Omega}_i$ and $\mathbf{\Omega}_f$ are incident and scattered neutron direction vectors. In the time-of-flight instrument, a wide range of incident wavelengths is used, and the time at which neutrons started at the pulsing device is known. Neutrons are sorted by wavelength according to their time of flight $t = (m/h)L\lambda$ across the known path $L = [L_1 = L_2(\mathbf{\Omega})]$ and the wave-vector change $\mathbf{Q}$ for each wavelength λ is determined for each direction $\mathbf{\Omega}_f$ $(h/m) = 3955{\cdot}91$ Å m s^{-1}). Since a wide band of wavelengths is used, the time-of-flight instrument spans a greater range of $\mathbf{Q}$ than a steady-state instrument with the same angular range.

The two-dimensional converging-slit collimator (represented in the figure only by the entrance and exit apertures) consists of channels which converge at a point on the detector and is incorporated to increase the area of source and sample that can be used in a small-angle scattering instrument. There is negligible sacrifice in resolution. Thus, for a source having 10 × 10 cm area, the sample area may be as large as 5 × 5 cm. The wavelength range is great enough to enable a large range of $\mathbf{Q}$ to be covered in a single run, but is restricted by the condition against 'frame overlap' (faster neutrons from one pulse may not overtake slower ones from a previous pulse). The condition is

$$\frac{1}{f_c} \geq \frac{h}{m} L(\lambda_{\max} - \lambda_{\min}).$$

Thus, the frequency of pulses f_c and the wavelength range ($\lambda_{\max}$, $\lambda_{\min}$) are established by choppers which run at a sub-multiple of the source frequency.

Fractional wavelength resolution is less than 1% for all wavelengths of interest. Therefore the resolution function is dominated by the geometric contribution. To establish the resolution as a function of position on the detector, the diffractometer was simulated using Monte Carlo techniques. The calculation accounted for all channels of the multiple channel converging collimator, for angular uncertainties due to finite moderator, sample, and detector elements, for timing uncertainties in a detector (0·03 m thick) and for finite source pulse width. The resolution, given as $Q_{\mathrm{FWHM}} = 7 \times 10^{-4}$ Å^{-1}, is constant over most of the **Q** range. The range of **Q** covered in a single measurement is $Q_{\min} = 5 \times 10^{-4}$ Å$^{-1} < Q < Q_{\max} =$ 0·2 Å^{-1}, when $\lambda_{\min} = 2$ Å, and $\lambda_{\max} = 10$ Å. In this wavelength range, the time average flux on the sample would be 2×10^5 n cm^{-2} s^{-1} for a cold moderator at IPNS-II.

The parameters of the diffractometer are $L_1 = L_2 = 8$ m, $L_0 = L_1 + L_2 = 16$ m, $Y_S = Z_S = 0{\cdot}25$ cm, $Y_M = Z_M = Y_D = Z_D =$ 0·5 cm, and $f = 30$ Hz. We plan to publish a more detailed account of this study in the near future either in *Nuclear Instruments and Methods* or in this journal.

References

CARPENTER, J. M. (1977). *Nucl. Instrum. Methods*, **145**, 91–113.

CARPENTER, J. M. & WERNER, S. A. (1976). *Uses of Advanced Pulsed Neutron Sources*, Report of a Workshop held at Argonne National Laboratory, October 21–24, 1975, Report ANL-76-10 Vol. 2. Argonne National Laboratory, Argonne, Illinois 60439, USA.

CSER, L. (1975). *Neutron Scattering for the Analysis of Biological Structures*, pp. VII.3–VII.29, Symposium at Brookhaven National Laboratory, 1975, Report BNL-50453, Brookhaven National Laboratory, Upton, New York 11973, USA.

MILDNER, D. F. R. & WINDSOR, C. G. (1978). In preparation.

WERNER, S. A. (1977). 7th IEEE Particle Accelerator Conference, June 1977, Chicago, Illinois. Special Issue, *IEEE Trans. Nucl. Sci.*, Vol. **NS-24**.