AN ANCIENT FORM OF POSITION-SENSITIVE DETECTOR - THE INDIVIDUAL COUNTER ARRAY

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1. INTRODUCTION

Large position sensitive detectors (PSDs) have been very successful as high efficiency neutron powder diffractometers (1) (2) (3). Complete powder patterns can be obtained within minutes, making possible real-time measurements of structural changes accompanying chemical and electrochemical reactions (4).

Of course, the angular resolution of such machines is determined by the diameter of the sample, and not simply by the resolution of the detector itself. In this paper we will argue that since sample diameters are usually 5mm to 10mm, it is possible to use an array of individual counters of similar diameter rather than a true PSD. Such a low to medium resolution INDIVIDUAL COUNTER ARRAY (ICA) can be made more efficient than the true PSD, produces an identical diffraction pattern, and has several practical advantages.

For high resolution powder diffraction, it has already been demonstrated (5) that an ICA, in this case associated with Soller collimators, is again the most efficient solution. This is because the sample volume (and intensity) of a high resolution PSD decreases quadratically with the diameter of the sample. The only alternative to very small samples would be a large sample-detector distance, and then large vertical divergences cannot be achieved because of mechanical limitations on gas-filled PSD apertures; again intensity is lost.

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2. RESOLUTION OF THE ICA

Samples used on D1B, the true PSD at the ILL, are typically 5mm to 10mm diameter. We therfore propose to compare such a PSD with an ICA of 5mm counters viewing a 5mm diameter sample, though in practice we might choose a somewhat larger counter, more typical of the usual sample diameter. Such counters, filled with He3 to a pressure of say 10 atmospheres, could be mass produced and readily available commercially.

The response expected of such an ICA of circular 5mm counters, compared with that obtained with a true PSD, is shown in Fig. 1. The resolution is obviously similar for both PSD and ICA, but one might think that the PSD could be more efficient, since there is overlap between the response of adjacent elements, while the ICA cannot detect neutrons falling between counters. It is also implied in Fig. 1a

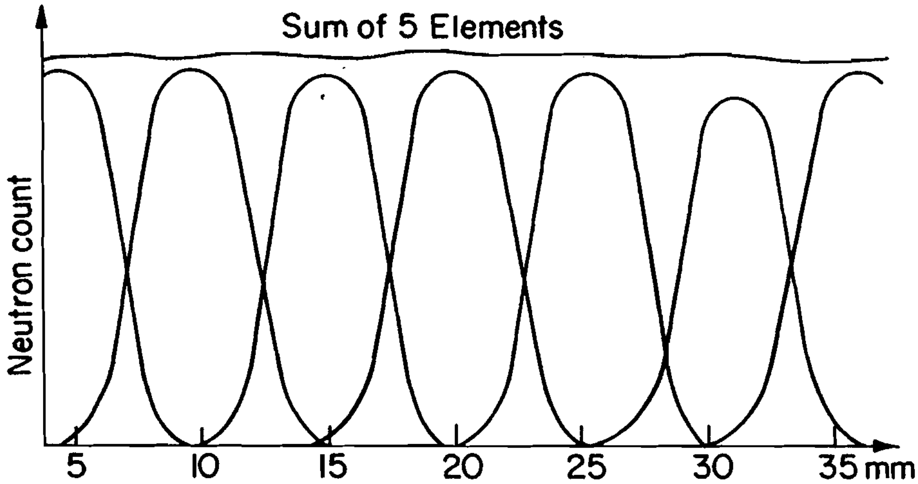

Fig. 1a Response of a modern PSD (D1B) to a line source (1).

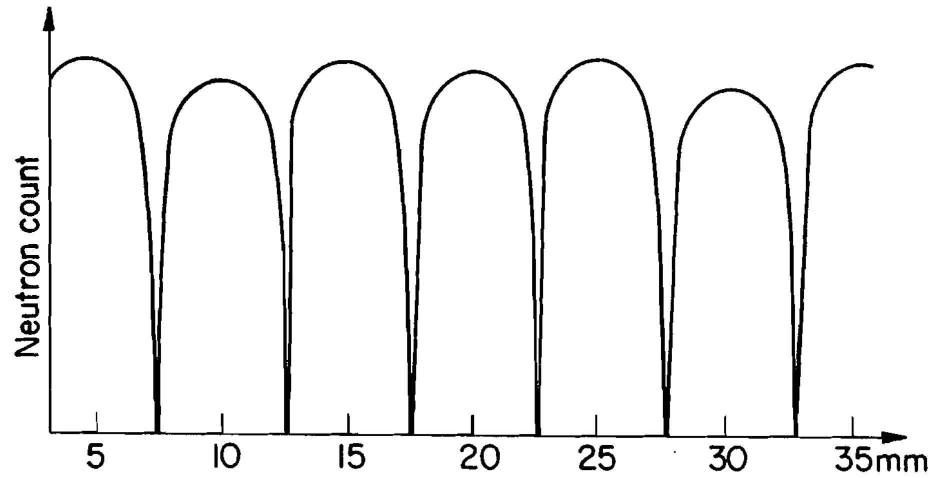

Fig. 1b Response of an ICA of 5 mm circular counters to a line source.

that it is important that the PSD response be uniform (sum of 5 cells), while the ICA response is strongly periodic. However, we must not confuse detector resolution (for a line source) with diffractometer resolution (for a real sample): in practice both machines will give equally good diffraction patterns if correctly used.

By correct use, we mean that both the PSD and the ICA must be scanned over at least a small angular range (6). Otherwise, neither machine will give sufficient points to define a diffraction line profile (unless the detector elements are made much smaller than the sample, which is a more expensive solution). A scanning ICA and a scanning PSD will then give identical diffraction patterns, with sufficient points for profile analysis: a stationary PSD with a uniform detector response is a pre-Rietveld concept, since even chemical kinetics needs line profile analysis to extract peak intensities.

Consider the response of a scanning ICA with rectangular counters. Such rectangular counters would be used in practice to improve efficiency by reducing dead space between elements. The response of a rectangular counter scanning a rectangular sample is the convolution of two rectangles - a triangle (Fig. 2a). A triangle is also the response of a Soller collimator, and when two triangles are folded together (convoluted) an almost Gaussian response results (Fig. 2b). The approximation is even better for circular samples and circular counters, but this is not important. The essential point is that when incident beam divergence, monochomator mosaic, secondary collimation and detector response are all folded together in a scanning ICA or

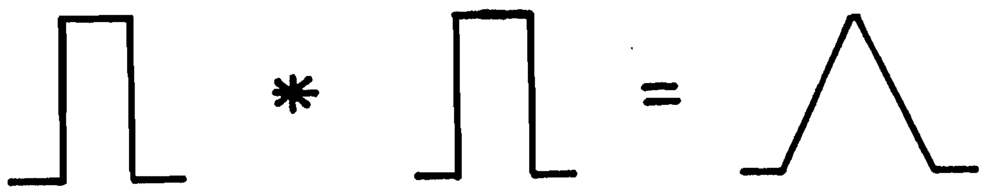

Fig.2a Convolution of rectangular counters and samples.

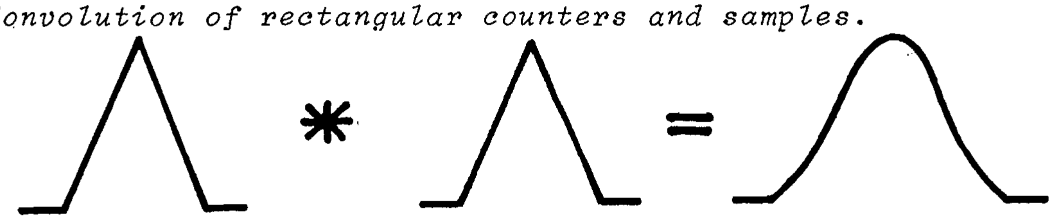

Fig.2b Convolution of this result with primary collimation.

PSD, the detailed response of one component, the detector, is not important (provided that it is periodic and composed of identical elements). The resolution of the complete machine is essential, not just the resolution of the detector itself.

3. EFFICIENCY OF THE ICA

Figure 1 still implies that an ICA is less efficient than a PSD, even if rectangular counters are used to fill some of the dead space between elements. In practice, the opposite is true, for simple mechanical reasons. Individual counters of such small cross-section can support much higher gas pressures than can an extended PSD. Even circular 5mm He3 counters at 10 bars collect about 50% of 2A neutrons, which already compares favourably with a modern PSD. In practice, rectangular detectors would be almost totally efficient, even at short wavelengths.

However, the big intensity advantage of an ICA comes from the increased solid angle that can be covered. The most efficient ^{3}He PSDs are limited to "bananas", at most 100mm high. Individual high pressure detectors could be two or three times as long, and an ICA built with a stack of such detectors would cover an area two or three times as great. A 200mm high detector at 1.5 m would match the 300mm high monochromator at 2.25 m planned for the new ILL powder machines.

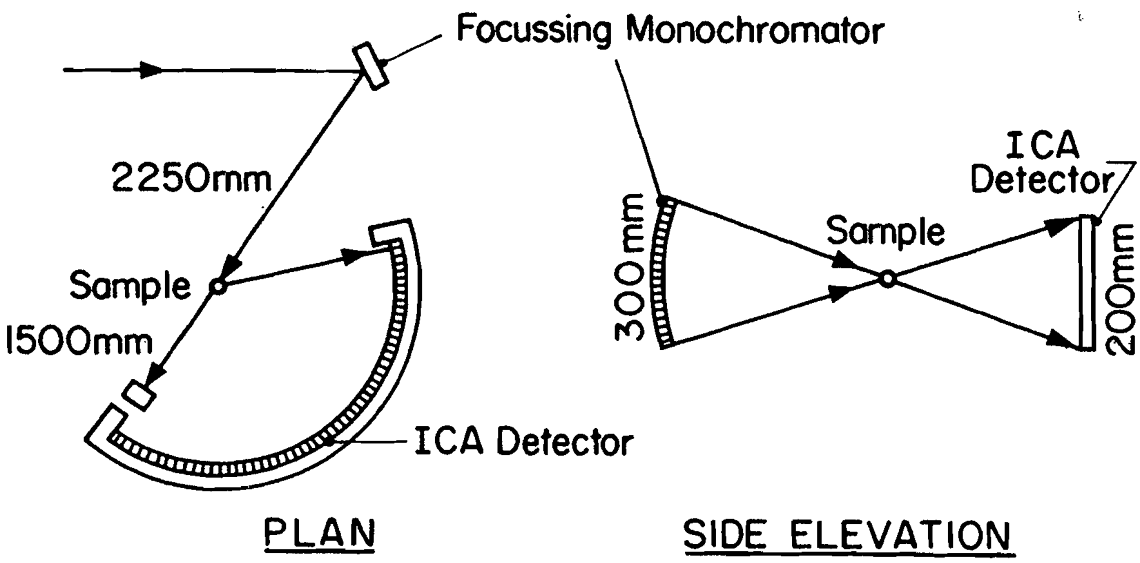

Fig. 3 Geometry of a high efficiency neutron powder diffractometer with an array of 5-10 mm diameter counters 200-300 mm high

Such large vertical divergences (up to 10 degrees) are already accepted on even high resolution machines such as D1A, with only small line broadening and asymmetry at low angles.

4. PRACTICAL ADVANTAGES OF A SCANNING ICA

The commercial cost of an array of several hundred individual counters would not be very different from the nominal cost of a large PSD. Individual counters can be mass produced and then selected for uniformity, while the construction of a PSD is the work of an artisan -bad elements cannot be changed later. The associated electronics for individual counters can again be mass produced, and available commercially. Count rates for an ICA are limited only by the count rate for a single element, and not by that of the complete PSD.

5. IN DEFENCE OF THE TRUE PSD

The ICA only competes with the true PSD for powder and liquid diffraction, where the number of elements in a 1-D detector is relatively small, and where the detector can be scanned. 2-D detectors for single crystals and small angle scattering require many more elements, and cannot be scanned in the same way. It is here that the effort on position sensitive detectors should be concentrated.

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