Detector development at the ISIS facility

P. L. Davidson, E. M. Mott, N. J. Rhodes, and M. W. Johnson
Rutherford-Appleton Laboratory
Chilton, Didcot, Oxon, OX11 OQX
UNITED KINGDOM

1. INTRODUCTION

For many years the Rutherford Appleton Laboratory has had a neutron detector development programme. It was undertaken to see if the limitations inherent in conventional He^3 detectors (their speed, efficiency at high neutron energies and rigid geometry) could be overcome by scintillator technologies. It was also underpinned by the fact that it can cost tens of millions of pounds to double the intensity of a neutron source but a few thousand pounds can in some cases double the performance of a neutron scattering instrument if its detection system is improved.

The detectors developed up to the present date have been based on Li^6 doped glass scintillator and have been successfully installed and run routinely on the HRPD, LAD and IRIS instruments at ISIS. In fact all the present ISIS instruments make use of the Li^6 glass scintillator technique within their monitors - which comprise small beads of scintillator supported on fine glass filaments in a reflecting housing and viewed directly by a single photomultiplier tube (PMT). The glass scintillators have performed well, with intrinsic backgrounds and γ sensitivities within original specifications. However, it has become clear that on many instruments the neutron background is so low, it is these quantities that are the most important in determining the ultimate signal to noise achievable.

To overcome the background and γ sensitivity problems studies have been made of Li^6 loaded ZnS scintillator. This has proved so successful that it is likely this technology will form the basis of our detector programme over the next few years.

2. THE TECHNOLOGY

Zinc sulphide and Li^6 (as LiF - 25% by weight) are held in a resin in 0.5 mm sheets. We now have a company in the UK who can supply this material at ~ £0.15/cm^2. The resultant material is largely opaque (only about 10% of normally incident light is transmitted) but ~ 20% of the light from a scintillation event at the centre emerges, and the figure is of course higher as the event nears the surface. It is therefore preferable to view both sides of the scintillator if possible. Despite the relative opacity the method works well because each neutron event produces ~ 50,000 photons, a figure about 10 times higher than than for the Li loaded glass scintillator.

If a single sheet of ZnS scintillator is viewed directly by a photomultiplier tube the n efficiency is ~ 20% at a wavelength of 1Å, while the γ-sensitivity and intrinsic background are essentially zero. This is because the pulse height of the neutron event is very large compared to that for γs (see Figure 1) and by suitable choice of discriminator level the γ sensitivity can be reduced to 10^{-7} or 10^{-8} without substantially lowering the neutron count. For detectors that use more complex geometries, the light received by the PMT is very much reduced. This results in a train of single photo-electron pulses from the PMT that must be integrated to identify neutron event reject γ events. This type of design has slightly worse gamma rejection (10^{-6}), and longer dead times (2-5 µsec), but can provide detectors with high spatial resolution ~ 3 mm and detectors with high neutron detection efficiency.

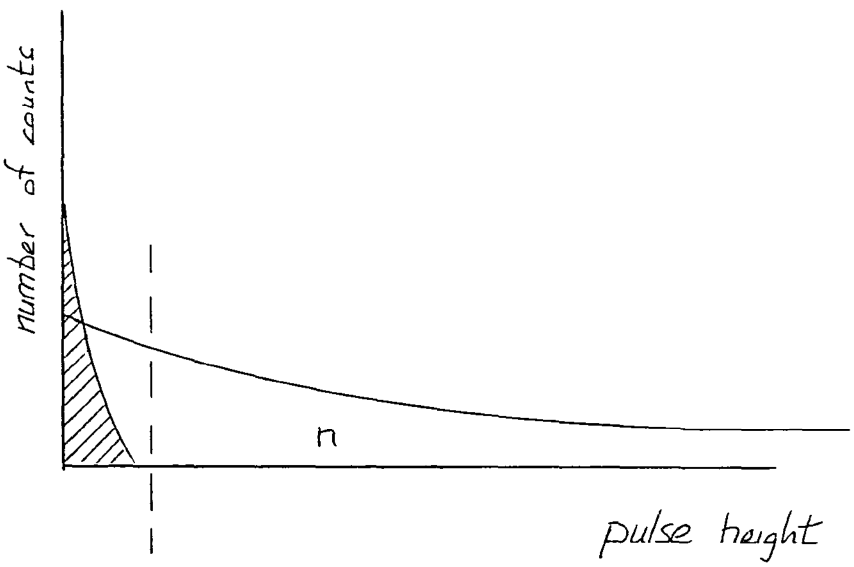

Fig. 1 Pulse height of neutron event.

3. APPLICATIONS

Test modules currently being constructed for the SANDALS instrument which requires very good efficiencies at high neutron energies together with a need for large detector areas (a total of 3 m^2 is required). The result is the module shown in Figure 2. Interestingly the light emitted from the scintillator elements scatters between the parallel sheets at a grazing angle with good efficiency. Figure 3 shows the relative efficiency of such a device compared with a He^3 tube. It has an absolute efficiency of 50% at 10 eV, representing a gain of ~ 3.5 over a conventional He^3 tube. It is also relatively cheap to make. Estimates of component costs are in the range £110 per 20 x 1 cm detector, plus £80 for electronics and HT supplies.

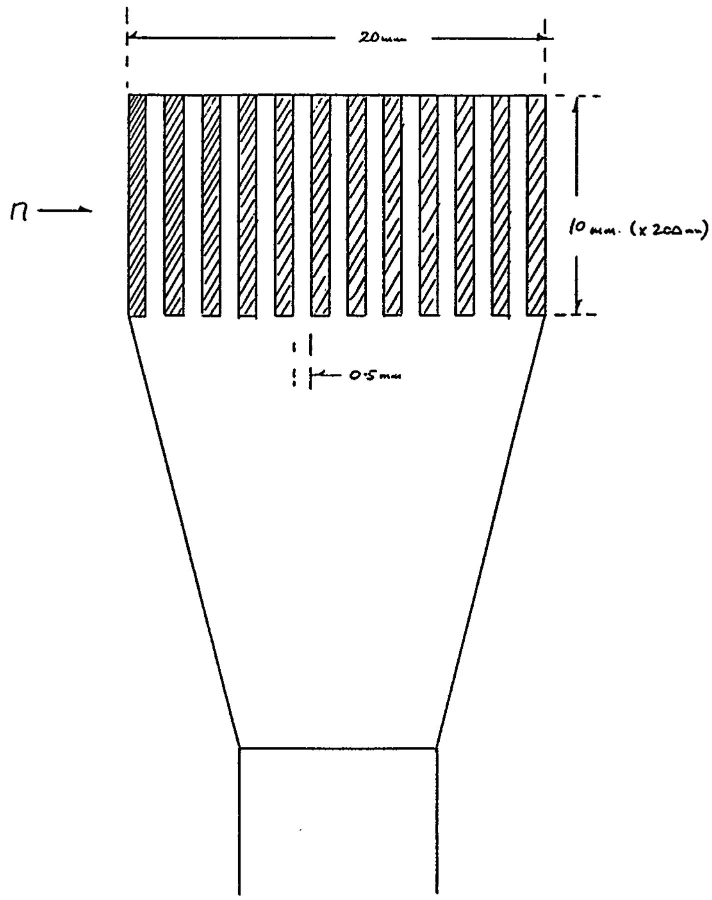

Fig. 2 Test module for the SANDALS instrument.

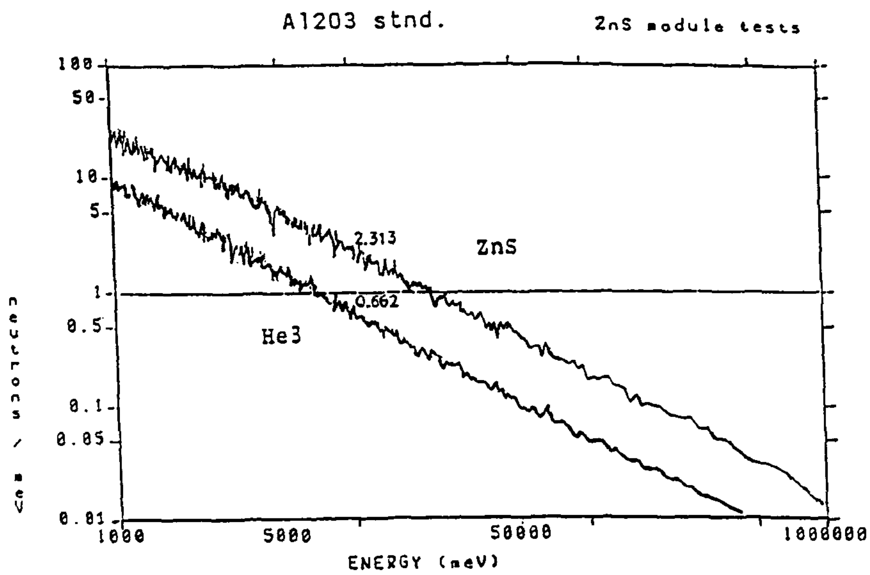

Fig 3. Relative efficiency comparison.

Finally, it should be pointed out that the ZnS scintillator is highly suitable as a material for constructing area position sensitive detectors. We have built a prototype area detector with 5 mm resolution over and area of 100x100 mm, in which individual detector elements are viewed by optic fibres. This compares very favourably with the glass scintillator Anger Camera technique, as shown in Figure 4, where the (0 0 20) from SrF_2 is shown as an observable peak when recorded by the ZnS detector. Signal to background ratios are often in the region of several thousand to one and this is illustrated in Figure 5 where the (001) reflections from SrF_2 are shown on a log scale. As final illustration of the low noise characteristics, Figure 6 shows an inelastic feature recorded on the ZnS module in an off-Bragg position. As far as we know peaks of this sort have not been recorded in position sensitive area detectors for single crystal samples before.

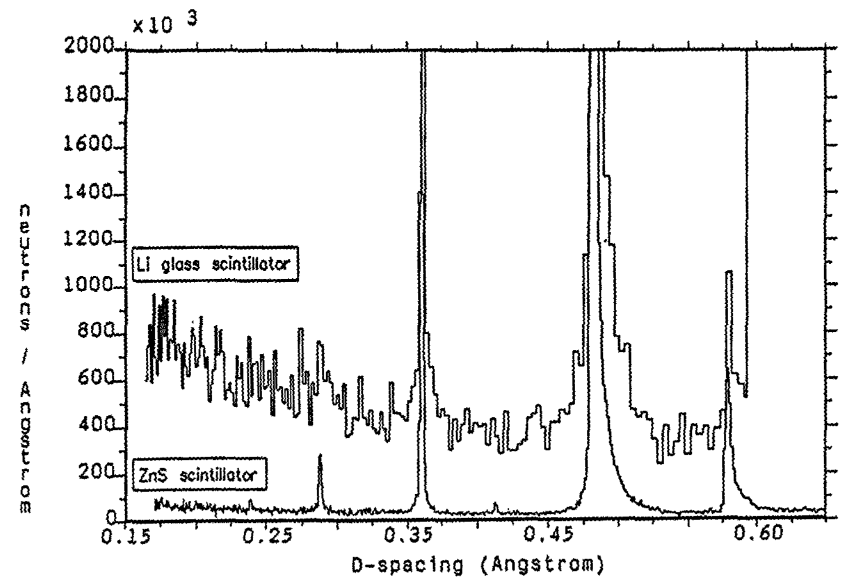

Fig. 4 ZnS module tests—short d-spacing response.

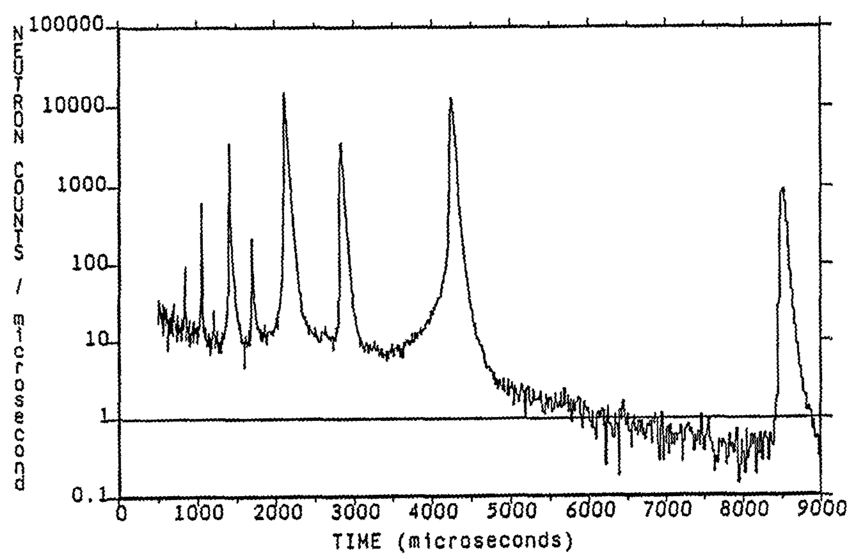

Fig. 5 ZnS module tests—short d-spacing response.

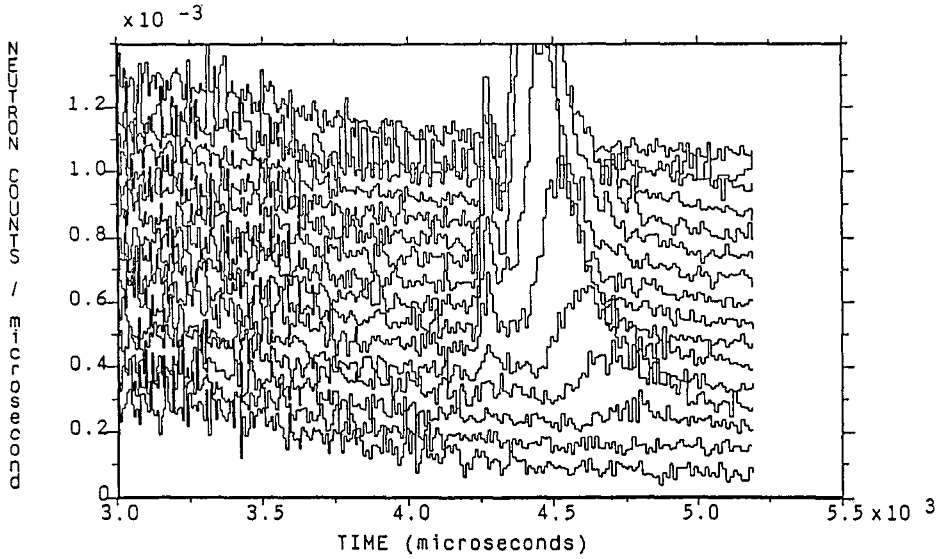

Fig. 6 ZnS module tests—short d-spacing response.

4. CONCLUSION

The use of zinc sulphide scintillators opens the possibility of building cheap, efficient neutron detectors which should have a profound effect on the performance of future neutron scattering instruments. If the potential for building two dimensional position sensitive detectors is realised it will provide a tremendous step forward for single crystal instrumentation.