Development of ^{6}Li glass scintillator in Japan

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The conventional gas proportional counter is often used because of its high efficiency of neutron detection. The gas amplification in the proportional region gives a good signal to noise ratio. However, it has one disadvantage, namely, a long dead time (i.e. several μsec) because it takes more than several μsec for ions to reach to the cathode. In time-of-flight measurements the dead time of detectors is a big problem, since in the TOF method the peak flux of neutrons is more important than the time-averaged flux. Unless

all the neutrons reaching the detectors in one burst can be separately detected, high flux pulsed neutron source cannot be used efficiently. The pulse created in the detector by an incident neutron must therefore be prompt. A type of detector which appears to meet the dead time requirement is the scintillator. We attempted to make a ^{6}Li-glass scintillator with the co-operation of the NIKON camera-company, and two kinds of scintillators were successfully produced. The ^{6}Li-glass scintillators which are shown in Fig. 1, have diameters of 2" and thicknesses of 0.6 mm, 1 mm and 2 mm respectively.

The performance of our ^{6}Li-glass scintillator was tested by using a ^{226}Ra-Be neutron source, ISSP-spectrometers at JAERI and the Tohoku PNS. Figure 2 shows the pulse height distribution of the ^{6}Li-glass scintillator when the Ra-Be neutron source was used. Since Ra-Be also emits γ-rays, a γ peak is also apparent. When neutrons diffracted from a Cu-single crystal are used, the intensity of the γ-peak decreases to a low value as shown in Figure 3.

We monitored the thickness dependence of the neutron peak position, intensity, signal to noise ratio and resolution by making measurements with the 0.6 mm, 1.0 mm, and 2.0 mm scintillators. The results are summarized in Table 1. The peak position reflects the efficiency, of which the P.M.T. receives the scintillation photons. The intensity corresponds to the neutron detection efficiency of the scintillator. Good resolution implies that we can separate the neutron peak easily by using a single channel discriminator. The scintillators which had a good S/N ratios also had a low background. Both the peak position and resolution appear not to depend on the thickness in this region. Overall, the scintillator of 1 mm thickness appears to represent the best choice, although if a lower background is required, that of 0.6 mm might be preferred.

The neutron detection efficiency of the ^{6}Li glass scintillator was tested by comparing its efficiency with that of a $^{10}BF_3$ proportional counter. Figure 4 shows the results. The measurement was carried out with monochromatic neutron beams (λ = 2.44 Å). The rocking curve of the 200 reflection from a single crystal of Ag_3SI was measured with both a $^{10}BF_3$ counter (2" in diameter and about 30 cm in length) and a ^{6}Li-glass scintillator (2" in diameter and 1 mm in thickness). The neutron detection efficiency of the ^{6}Li-glass scintillator is about 90 % at λ = 2.44 Å, which is close to the value calculated from the estimated the cross section of ^{6}Li in the scintillator.

ANL groups have tested the pulse height distribution of our glass scintillator, making as direct a comparison as possible with a 1 mm thick sample of similar material sold by Nuclear Enterprises, NE 905. Their results indicate that our glass scintillator gives 90 % of the light output of NE 905.

The glass scintillator has the advantage of allowing the possibility of the large area detectors. If a proper method for defining the position of the scintillation event can be developed, it may be used in a PSD.

We considered the possibility of using the optical fibres to link the scintillator to the photomultiplier tube in a similar fashion to that reported by workers at the Rutherford Laboratory.

The pulse height after the photomultiplier for this system is

estimated by the following expression:

$$I = N_p \cdot \xi \cdot \eta \cdot \zeta \cdot G \cdot q \cdot \sigma/j$$

where

N_p is the number of emitted photons per captured thermal neutron in the glass,

ξ is the efficiency of the collection of photons in the photomultiplier,

η is the quantum efficiency of the photocathode,

ζ is the collection efficiency of the first dynode,

G is the gain of the photomultiplier,

q is the charge of one electron,

σ is the transmission efficiency of the fibre optic bundles, and

j is the number of branches in one fibre optic bundles.

When we use the following values;

N_p = 4000 photons/n, ξ = 70 %, η = 20 %, ζ = 50 %, $G = 1.3 \times 10^7$ (R 1250), $q = 1.6 \times 10^{-19}$C, σ = 20 %, j = 3, the pulse height, I, is estimated as 39 pico coulomb. If we use a charge sensitive preamplifier (4.5 mV/pc), the pulse height on output is about 170 mV which is enough for the signal to be distinguished above background level. We are currently producing such a position sensitive scintillator detector. The number of scintillator elements is 84 and the number of photomultiplier is 9.

Table 1 Performance of Glass Scintillators of various thickness

	Peak Position	Intensity	S/N	Resolution
0.6 mm thickness	1	1	1	1
1.0 mm thickness	∿1	∿1.2	0.6∿0.7	∿1
2.0 mm thickness	∿1	∿1.1	0.3∿0.4	∿1

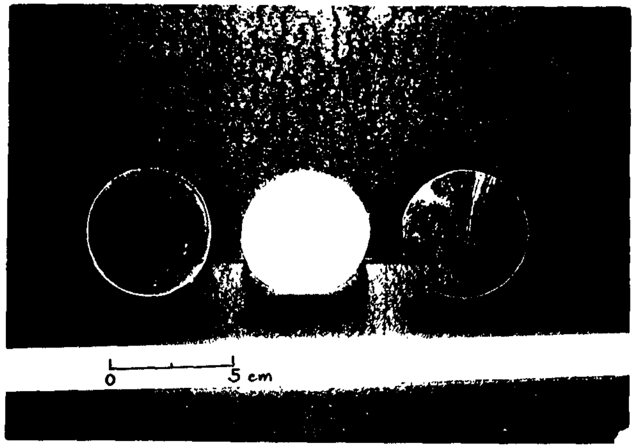

Fig. 1 ^{6}Li glass scintillators. The thicknesses are 0.6 mm, 1.0 mm and 2.0 mm respectively. A layer of TiO_2 has been painted on the surface of the 1.0 mm scintillator to use as a reflector.

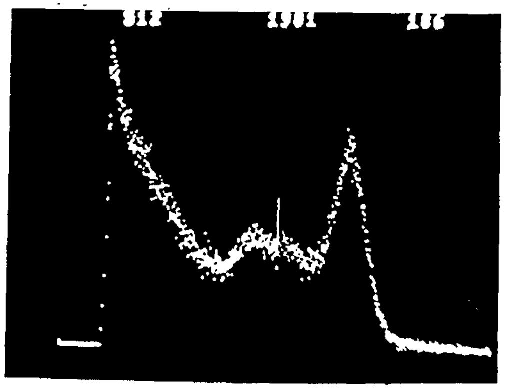

Fig. 2 The pulse height distribution obtained with the Ra-Be neutron source.

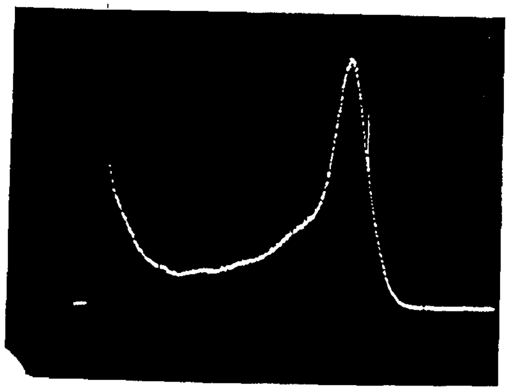

Fig. 3 The pulse height distribution measured using diffracted neutrons.

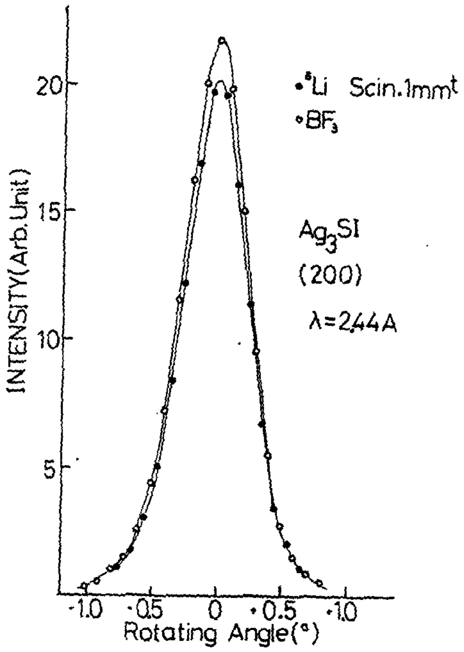

Fig. 4 A comparison of the neutron detection efficiencies of the glass scintillator (1.0 mm in thickness) and a $^{10}BF_3$ proportional counter (30 cm in length) at λ = 2.44 Å.