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Several experiences of using Li-glass scintillators

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ABSTRACT

This paper describes several experiences using Li-glass scintillators as neutron detectors in KENS. Detectors reported in this paper are an epithermal and thermal neutron beamline monitor, a semicircle one-dimensional position sensitive detector and an annular detector. These are specially designed, constructed and equipped in the real spectrometers in KENS.

I. INTRODUCTION

^{6}Li glass scintillators have several advantages as well as disadvantages. The advatages are as follows: 1) The dead time is less than 100 nsec, and 2) It is easy to modify the shape artificially, and the disadvatages are as follows: 1) It is sensitive for γ- ray, and 2) It produces small amounts of photons. With the use of the advatages of the scintillators we have specially designed three kinds of detectors, those are, an epithermal and thermal neutron beamline monitor[1)], a semicircle one-dimensional position sensitive detector[2)] and an annular detector[3)].

II. NEUTRON BEAMLINE MONITOR

Conventionally, fision detectors made of thin layers of $^{235}U_3O_8$ powder are equipped to monitor the intensity of the neutron beam. In spite of good signal to noise ratio, they have some disadvantages such as slow response and complex efficiency vs energy relationship at epithermal energies. On the contrary, our detectors using ^{6}Li glass scintillator (GS) have the advantageous to overcome such problems, i,e., they are prompt and have a simple efficiency vs energy relationship over the cold and epithermal range of neutron energy. To cover the whole area of neutron beam cross section homogeneously and to realize minimum attenuation of the incident beam, we have decided to use GS in powder form.

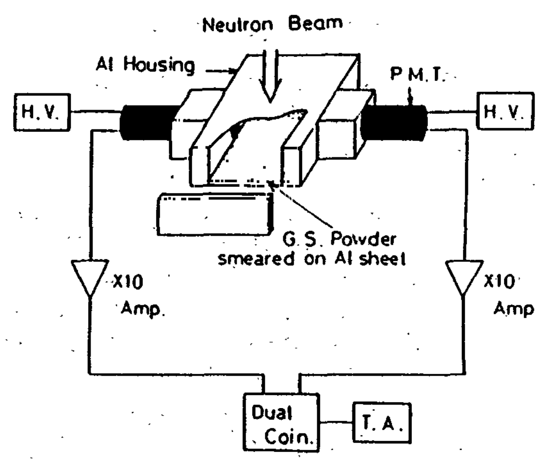

Fig. 1. The layout of the neutron beamline monitor.

Fig.1 shows the layout of the new type of monitor system using GS powder. 0.8 mg/cm^2 GS powder of 95 μm diameter in average is coated on a thin aluminium square sheet 6x6 cm^2 in area, 0.2 mm in thickness. A pair of photomultipliers (PMTs) is attached to the side of the housing. The output signals of these PMTs are fed to a 2-input coincidence circuit to remove electric noise.

The neutron counting efficiency ic controlled by changing the quantity of GS powder coating. As a matter of fact, the same type of GS monitor is put to practical use for transmission measurements by increasing the counting efficiency with the use of the thick GS powder coating.

These detectors have been equipped in KENS's thermal neutron small angle scattering instrument (WIT).

III. ANNULAR DETECTORS

Annular ^{6}Li glass scintillators are designed and constructed for the detector system of WIT since the small-angle neutron scattering (SANS) pattern on the area detector is annular about the beam center for the case of the isotropic scattering sample. If an annular detector is provided in SANS, the data handling system including electronics becomes extremely simple. Since a large and continuous Q range is required, annular detectors with different radii are preferable.

Pieces of Li glass scintillators (2 mm in thickness) were stuck on the surface of the annular transparent acrylic resin with optical cement. The ring was wrapped with aluminum foil to reflect scintillation photons escaping out of the acrylic resin. As shown in Fig. 2., eight PMTs were coupled to the rear side of the annular acrylic resin. Thickness of the acrylic resin has been determined to be 5 cm so that any position where a scintillation event occurs can be subtended directly by more than two PMTs, to allow detection of scintillation photons in coincidence.

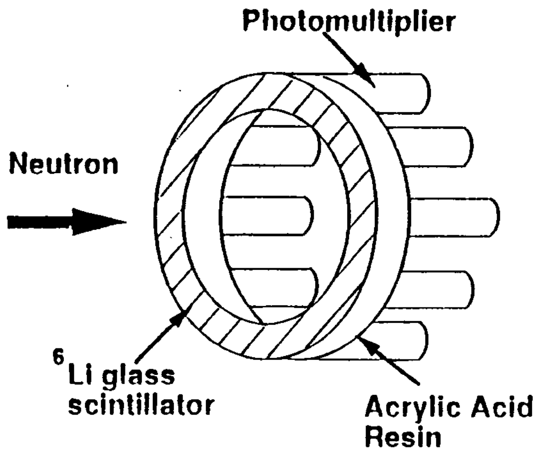

Fig. 2. The couplig of the photomultiplier tubes and the annular acrylic resin.

The width of the ring defines the spatial resolution. The resolution of the momentum transfer Q for small angle (=2πφ/λ, where φ is a scattering and λ is a wavelength) is written as follows:

$$\Delta Q/Q=\Delta\phi/\phi,$$

$$\Delta\phi^2=\Delta\phi^2{}_{col}+\Delta\phi^2{}_{det},$$

where $\Delta\phi^2{}_{col}$ and$\Delta\phi^2{}_{det}$ are the fluctuations of the scattering angle which come from the collimator divergence and the width of the ring detector, respectively.

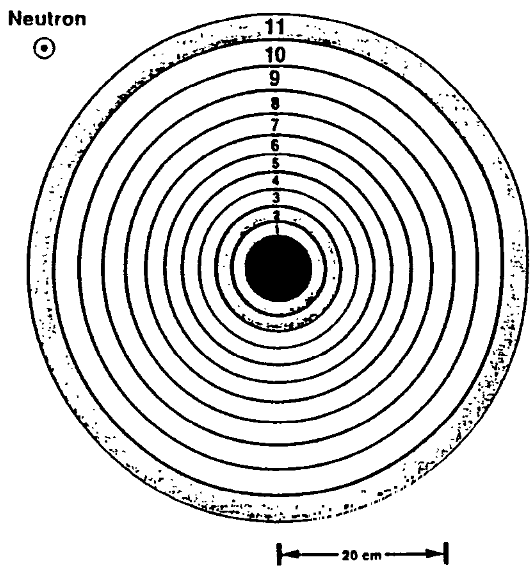

Fig. 3. The whole assembly of the annular detectors equipped in WIT.

The whole assembly of the annular detectors is given in Fig. 3, where #1 and #2 are not used for measurement any more because the foot of the incident beam profile touches them, and #11 is neither used because PMTs are not yet installed there. The radius and the widths of 12 annular detectors are tabulated with Q range covered using neutrons of wavelength between 0.4 A and 6 A in Table I.

The Q-range covered by the detector assembly is from 0.027 A^{-1} to 0.967 A^{-1} when neutron wavelengths from 0.5 A to 6 A are used.

IV. SEMICIRCLE ONE-DIMENSIONAL POSITION SENSITIVE DETECTORS

When a one-dimensional position sensitive detector (PSD) is used on a time-of-flight(TOF) single crystal diffractometry, a two-dimensional area of reciprocal space can be accessed, because white neutrons of continuous wavelength are used in TOF diffractometry.

To test the feasibility of the method, we have used the linear gas proportional PSD and found the several problems. First,the range of scattering angle is very limited, and the positional resolution at the end part of the detector becomes extremely poor since the detector is linear and the diffractd neutron injects obliquely there. Secondly, the detector has a long dead time (*i.e.* several μsec). Especially,in TOF measurements the dead time of detectors is a big problem, since the peak flux of neutrons is more important than the time-averaged flux,and all the neutrons reaching the detectors in one burst must be separately detected.

Ring NO.	Mean R mm	Delta R mm	scattering angle 2θ	q min A^{-1}	q max A^{-1}
1	49	16	14.1mrad	0.015	0.178
2	68	18	19.7	0.021	0.248
3	88	18	25.5	0.027	0.320
4	109	20	31.6	0.033	0.397
5	131	20	37.8	0.040	0.476
6	154	22	44.7	0.047	0.562
7	179	24	51.8	0.054	0.651
8	206	26	60.0	0.063	0.750
9	235	28	68.1	0.071	0.855
10	266	30	77.0	0.081	0.967
11	299	32	86.2	0.090	1.083

Table I

To solve the above problems, a semicircle one dimensional PSD using ^{6}Li-glass scintillators (GSs) has been constructed. The GSs respond to the neutron detection very quickly (70 ns), and have the advantage of allowing the possibility of a semicircle detectors since it is easy to modify the shape artificially . A fibre optic encoding method is applied for position definition of the one-dimensional PSD for the TOF single crystal diffractometry, since in this method the over all dead time of the PSD can be guaranteed to be less than 1 μsec.

We have constructed a new semicircle one dimensional PSD. The PSD is now installed at the four circle single crystal diffractometer (FOX) .

The layout of the PSD is shown in Fig. 4. A scintillation element is cylindrical, 3mm in diameter and 30 mm in height. A total of 384 scintillator elements sits side by side and forms a semicircle 45cm in radius. Flexible plastic optical fibres (3mm in diameter) are connected to both ends of the scitillator element. One detector element consists of 3 scintillator elements, so the size of the detector element is 9mm x 30mm. This size is adopted by considering the divergence of the incident beam and the normal degree of mosaicity in a single crystal specimen. The lowest and the highest scattering angle are 10.6 degree and 167.8 degree, respectively. An azimuthal angle of one scintillator element subtended by a sample is 3.82 degee.

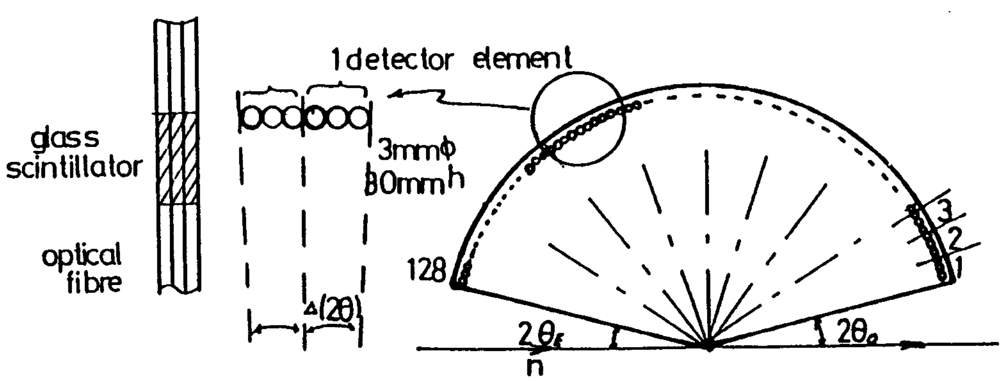

Fig. 4. The layout of the semicircle one-dimensional position sensitive detectors equipped in FOX.

References
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2) N.Niimura, K.Aizawa, A.Ishida, M.Ueno, M.Hirai, U.Sangawa and K.Yamada, to be submitted in J. Appl. Cryst.
3) N.Niimura, I.Kawada, M.Isobe, F.Okamura and K.Yamada, to be submitted in J. Appl. Cryst.

Q(C.C.Wilson): What is the angular resolution of the linear PSD on the 4-circle diffractometer i.e. What is L_2, the secondary flight path.

A(N.Niimura): Angular resolution is determined just by the size of one pixel, that is, 9 mm x 30 mm. L_2 is fixed to 45 cm.

Q(I.Kanno): In the neutron beam monitor with glass scintillator powder, how do you transport the photons to the photomultiplier? Do you use any reflector in the box? Are several sheets used?

A(N.Niimura): The photons are transported though the air. No reflector. Aluminum sheet itself is a reflector. One sheet.

Q(H.M.Shimizu): What is photon collection efficiency of your powder Li glass scintillator?

A(N.Niimura): I did not calculate it, but it is just the solid angle subtended by the photomultiplier, if we neglect the absorption loss of photons in the air.