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Detection characteristics of vertical Bridgman grown stilbene crystals for gamma rays using ^{60}Co, ^{137}Cs and ^{22}Na gamma ray sources

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Abstract

Trans-stilbene crystals were grown by vertical Bridgman technique with modified growth vessel. Energy response to ^{60}Co and ^{137}Cs was done for the grown crystal. The time resolution study has been carried out for the BGO–stilbene phosphor combine using ^{22}Na (511 keV) gamma source.

Keywords: Detection characteristics; Vertical Bridgman technique; Stilbene crystals

1. Introduction

Scintillation response of stilbene has been evaluated for different heavy ionizing particles [1]. Theoretical aspects of rise time and its dependence on particle energy of stilbene scintillator are discussed [2]. Stilbene scintillator has been widely used as a particle identifier to measure neutron flux against gamma ray background [3]. The pulse shape analysis is used to investigate the energy dependence of proton, alpha and other radiation rise times of stilbene scintillator [4,5]. The discriminating characteristics are attributed to differences in the fast component of the scintillation decay times of particles with varying energy loss or stopping power $dE/d\alpha$ [6]. Linearity of scintillation response of proton (0.35–15 MeV) and electron (0.31–0.99 MeV) has been studied [7]. The gamma, alpha and the neutron gamma pulse shape discriminations have been carried out using stilbene scintillator [8]. The directional anisotropy in scintillation response has been measured for fast neutrons by changing the direction of incident neutrons [9].

In the present experimental study, the energy response of the grown stilbene crystal for ^{60}Co and ^{137}Cs gamma sources was carried out. The time resolution of BGO–stilbene phosphor combine has been studied using ^{22}Na (511 keV) gamma source.

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2. Experiment

Trans-stilbene crystals were grown from vertical Bridgman technique using the Merck grade zone purified starting material. The grown crystals were cut and polished by using inner diameter cutter with slow rotation. The element 1 cm thick and 1.5 cm diameter was used for the study. The response of the detector to radio active gamma sources is investigated. The *trans*-stilbene crystal was mounted on the PMT of 1 in. diameter model HAMAMATSU photomultiplier R1924 with optical grease without any air bubble for good transmission of scintillation light to photocathode. The PMT is biased through a set of RC filter used to bias up to −1.0 kV. The output from the detector is used to derive the energy and the time information as shown in Figs. 1 and 2, respectively. The time information is derived by processing the signal through timing filter amplifier (ORTEC TFA-863), which filters the fast time components only. Constant fraction discriminator (CFD) (Canberra 2126Q) gives the time at which the input crosses the set threshold and thereby removes the noise from the required signal. The signal is further handled by the gate and delay generator (ORTEC GG8010), so as to get the clean trigger.

The energy information is derived by processing the signal through the shaping amplifier (ORTEC 572, 0.5 μs shaping time constant) and analog to digital converter (ORTEC 811). The relative performance of the sample in terms of timing was measured by recording output from the time

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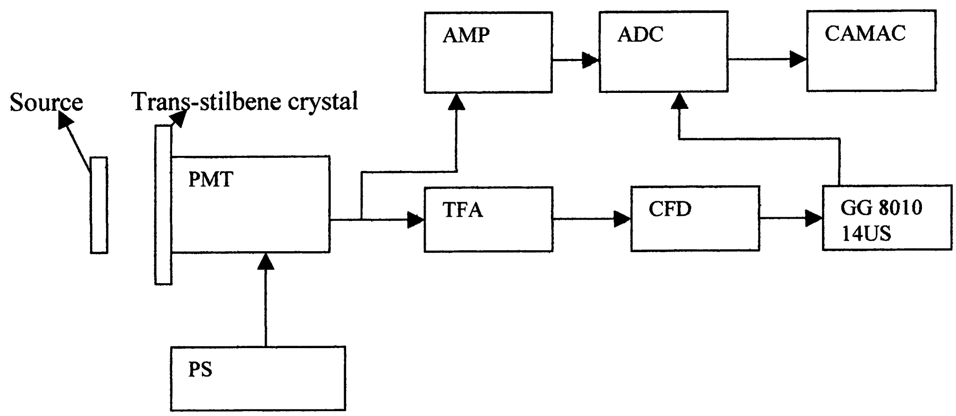
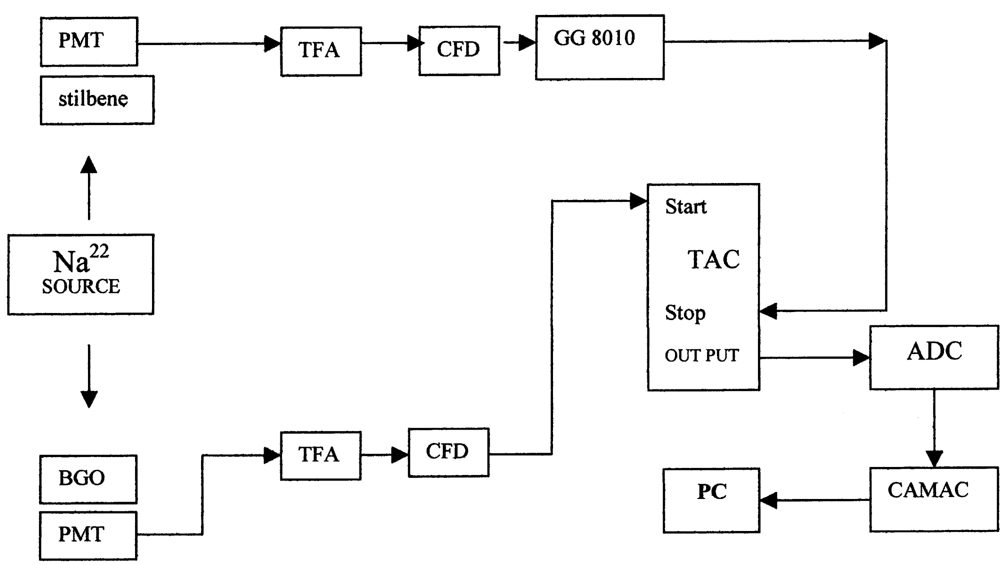


Fig. 1. Energy resolution setup.



ADC-Analogue to Digital Converter

TFA-Timing Filter Amplifier

CFD- Constant Fraction Discriminator.

GG8010- For Delay Purpose (To get rid of piling up).

CAMAC- Computer Automated Measurement And Control.

PMT-Photo multiplier tube.

Fig. 2. Time resolution setup.

to amplitude converter (TAC) started by the *trans*-stilbene sample and stopped by the Bicron BGO (2.5 in. hexagon × 2 in. long). The circuit used is shown in Fig. 2. The timing resolution (full width at half maximum) of the TAC with the ^{22}Na source is 8.5 ns without gate setup.

3. Results and discussion

The scintillation response of anthracene and stilbene to low energy protons and X-rays has been investigated. It was observed that both anthracene and stilbene show linearity with pulse height energy vs. energy for X-ray and non-linearity for low energy protons [10]. The experimental data and the theoretical values were evaluated for the response of stilbene to D, H_2, He and protons of different energy, and it was shown that non-linearity exists between the particle energy and scintillation response [1,2]. Due to low atomic number of the elements in *trans*-stilbene, it yields good Compton continuum with sharp Compton edge. The scattering of incident photon energy and the momentum gained by the electron is due to Compton scattering. The maximum energy transfer to the electrons (Compton continuum with sharp Compton edge) for Compton scattering is a vital factor in the scintillation materials made of low atomic number. The maximum energy transfer to the Compton electrons by the gamma ray of energy (E_γ) is given by the relation

$$\text{Compton edge}: \quad T_{\max} = \frac{E_\gamma}{1+2\alpha}$$

where

$$\alpha = \frac{E_\gamma}{m_0c^2}$$

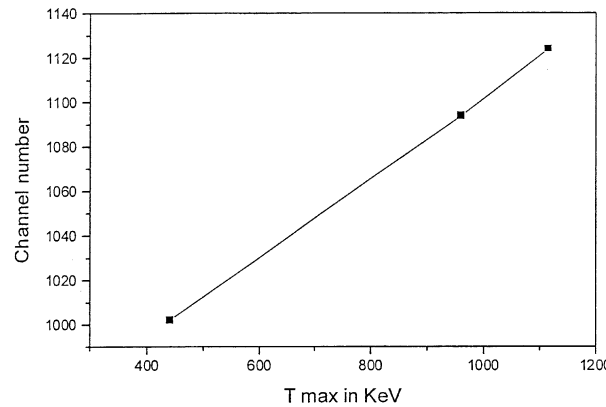


Fig. 4. Plot of $T_{\max}$ vs. channels.

Using the above relation [11], the maximum energy that can be transferred to electron by means of gamma rays from ^{137}Cs and ^{60}Co sources are deduced. By using the gamma ray energies 662, 1173.21 and 1332.47 keV, the maximum energy transferred to the electrons ($T_{\max}$) was determined by using the above relation, and Compton edge is calculated to be 477.65, 963.2 and 1117.62 keV, respectively. The energy spectrum (Fig. 3) obtained using two sources exhibits peaks at 1002, 1094 and 1129 channels, respectively. The Compton edge points were taken from the hump peak of the Compton edge from the freedom software. When the graph is (Fig. 4) plotted between the channel number and maximum energy transferred (also known as Compton edge), the three data points were collinear. In Fig. 4, the *X*-axis is the calculated Compton edge, the maximum energy that can be transferred from the actual gamma energy and the

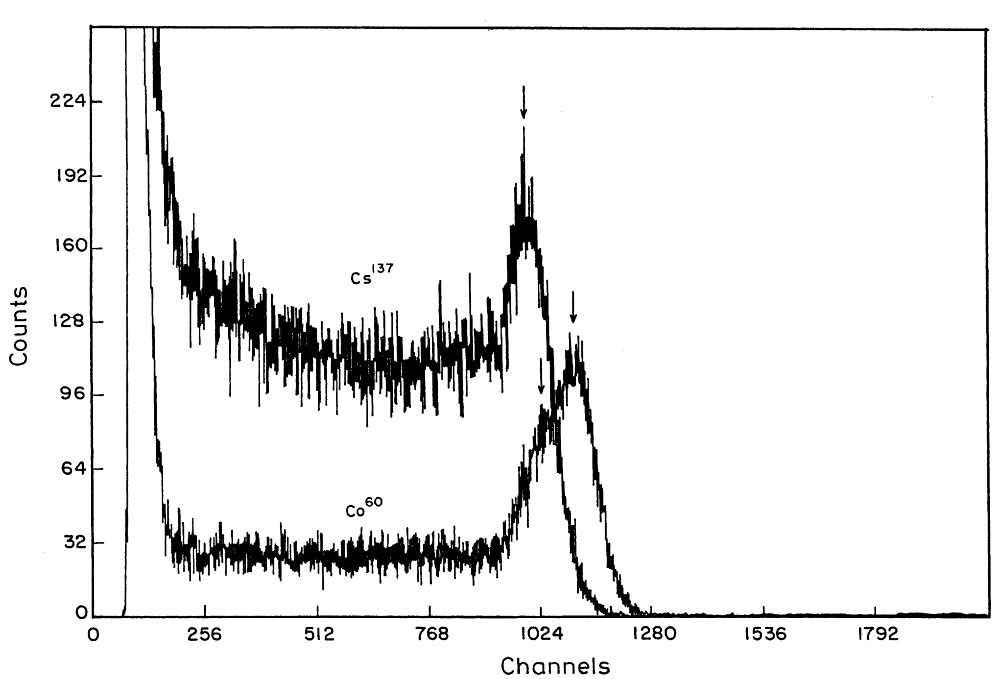


Fig. 3. Energy resolution spectrum of stilbene for ^{60}Co and ^{137}Cs source.

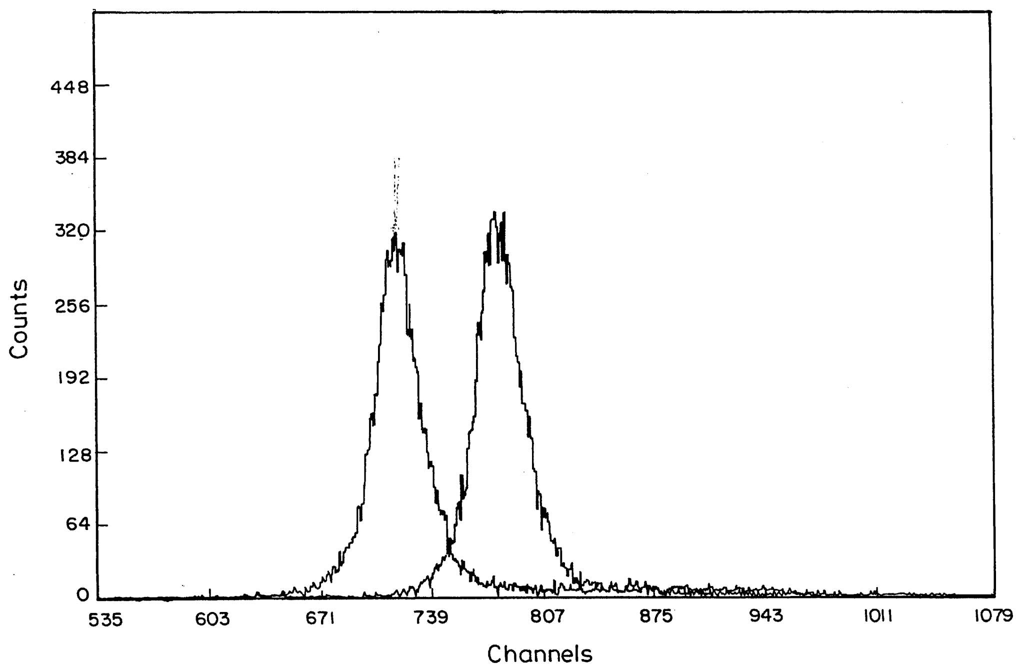


Fig. 5. Time resolution spectrum of BGO–stilbene using ^{22}Na gamma source.

Y-axis is the measured Compton edges in channels from Fig. 3.

The time resolution studies were carried out for BGO–stilbene combine using ^{22}Na (511 keV) gamma by means of TAC setup. The start pulse was given to stilbene crystal and the stop pulse to Bicron BGO crystal standard. The time resolution spectrum (Fig. 5) was also recorded by introducing delay time of 15 ns. The shift in the counts for 15 ns delay was measured and time/channel was measured. By using the FWHM of the curve obtained by using TAC setup, it was observed that time resolution for BGO–stilbene combine for ^{22}Na 511 keV gamma ray source was 8.5 ns. Decay time is measured by taking the slope of the stopping curve since the output of TAC is stopped by *trans*-stilbene. The stopping part is only due to stilbene scintillation decay time. The decay time is given by the formula

$$\tau = \frac{\Delta t}{[2.3026\{\log(t_1) - \log(t_2)\}]}$$

where Δt is the differential time from the graph, and t_1 the counts number corresponding to the upper end of the differential time, and t_2 the counts number corresponding to the lower end of the differential time (Fig. 5). The decay time is less because the time resolution was done with BGO, which is slow and stilbene is having very fast decay time. So the combined effect for time resolution is seen as 8.5 ns and stilbene alone shows the decay time as 5.1 ns.

4. Conclusion

The time resolution studies have been carried out for grown stilbene crystal with 1.5 cm diameter and 1 cm thick sample. The time resolution observed was 8.5 ns for BGO–stilbene combine using ^{22}Na (511 keV) gamma source. The energy spectrum was taken for ^{137}Cs and ^{60}Co gamma source, and it was observed that the three data points of Compton edges corresponding to respective gamma energies and the channel numbers were collinear. The BGO–stilbene combine can be used for evaluating the decay time of scintillator having decay time larger than 5.1 ns.

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