PULSE SHAPE DISCRIMINATION CHARACTERISTICS OF STILBENE CRYSTAL, EJ-299-33 AND ^{6}Li LOADED PLASTIC SCINTILLATORS FOR A HIGH RESOLUTION CODED-APERTURE NEUTRON IMAGER

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ABSTRACT

Pulse shape discrimination performances of single stilbene crystal, EJ-299-33 plastic and ^{6}Li loaded plastic scintillators have been compared. Pulse Gradient Analysis pulse shape discrimination algorithm has been tested for each scintillator sample, assessing their neutron/gamma separation. In this study each scintillator sample was irradiated with a ^{252}Cf neutron source and, a real-time fast digitiser was used to collect the data. The figure-of-merit was utilised to compare the discrimination quality of the tested scintillator samples.

1. Introduction

Pulse shape discrimination (PSD) is a well-established method of separating fast neutron and gamma-ray interactions within organic scintillation medium. The method is based on the difference in the decay time of fluorescence emitted within an organic scintillator as a result of an interaction between the ionising particle and the scintillant. The fluorescence decay time observed for heavy ionising particles, such as protons, is longer when compared to electrons [1]. Fast neutrons and gamma-ray photons interact with an organic scintillant predominantly through elastic scattering with a proton and Compton scattering, respectively. Consequently, the fluorescence decay rate exhibited by recoil protons and recoil electrons (Compton scattering) can be compared to infer the origin of the interaction [2]. The difference in the fluorescence decay rate formed a basis for neutron/gamma PSD techniques in organic scintillators.

In this paper, PSD performance of three different scintillator types is analysed. Pulse Gradient Analysis (PGA) [3] method is applied aiming to identify the most suitable scintillator material for a real-time scintillation based coded-aperture neutron detector. In order to evaluate neutron/gamma separation performance of the scintillator, the figure-of-merit (FOM) values were estimated for each scintillator sample.

2. Experimental Method

Three different organic solid scintillator types were in turn irradiated with a ^{252}Cf source located at Lancaster University, Lancaster, UK. Single stilbene crystal (20 mm diameter, 20 mm thick) - was provided by Inradoptics [4], whereas pure PSD plastic scintillator sample (25 mm diameter, 25 mm thick – sample number 5706) and ^{6}Li loaded PSD plastic scintillator sample (40 mm diameter, 25 mm thick – sample number 9023) were both provided by the Lawrence Livermore National Laboratory (LLNL), USA.

The back of each scintillator sample was covered with EJ-510 reflective coating and each sample was then coupled to an ET Enterprises 9107B PMT with EJ-550 silicone grease. The PMT module supplied by ET Enterprises was enclosed in a light-proof tube. Depending on the scintillator type the positive high voltage supply, connected to the cathode of the PMT was varied between 850 V and 900 V. The PMT anode was connected to a real-time Mixed Field Analyser (MFA) developed by Hybrid Instruments Ltd. [5]. Experimental setup is shown in
Fig. 1.

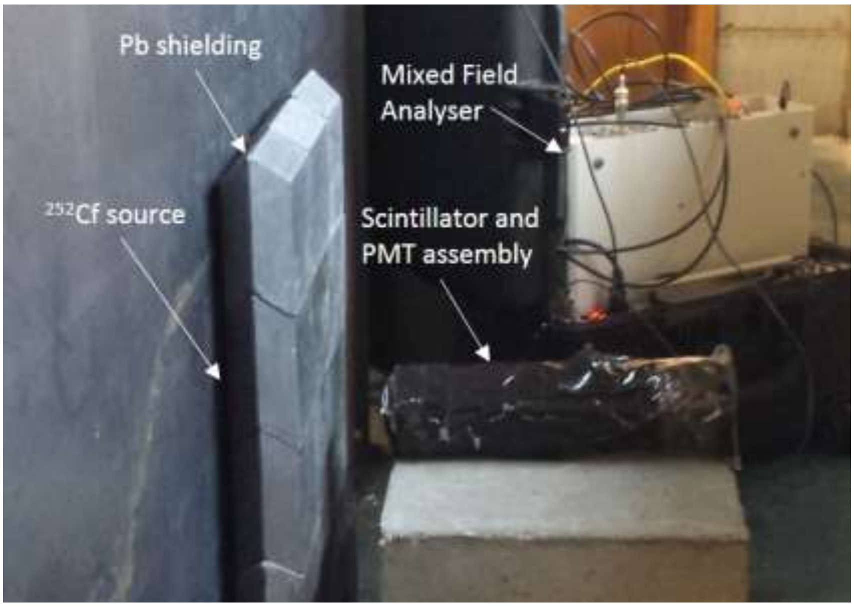

Fig 1. Experimental set-up. ^{252}Cf source is located in the centre of a water filled, metal tank. During the experiments the source is moved to the edge of the tank pointed by the arrow on the left.

Discrimination data were collected from the MFA digitiser for each scintillator sample. MFA is already programmed to discriminate neutrons and gamma-rays based on PGA algorithm and, the results corresponding to each scintillator sample, were then compared.

3. Results

Number of events were plotted against the discrimination index, which was calculated as a ratio of *first integral* over *second integral*. It was used to assess the separation of neutron and gamma-ray events. The FOM as defined in Eq. (1) was calculated for each scintillator to compare their performance in separating neutrons from gamma-rays. Results are presented in Table 1.

$$FOM = \frac{Peak\ separation}{FWHM_{\gamma} + FWHM_{n}} \quad (1)$$

Scintillator	Exposure time	FOM
^{6}Li Loaded plastic	30 min	-
PSD plastic	30 min	0.551
Stilbene crystal	30 min	0.941

Tab 1: FOM calculations for each scintillator

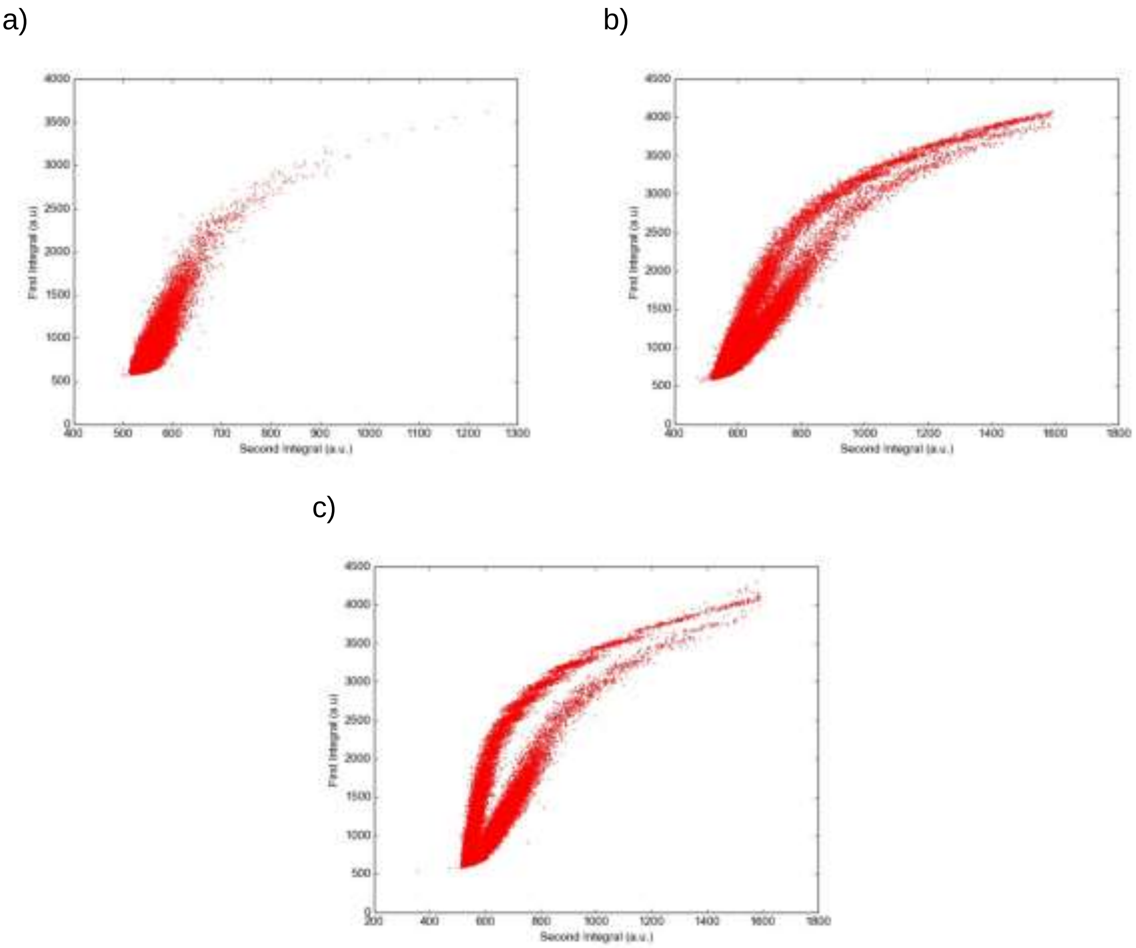

Fig 2. Scatter plots using PGA - first integral against second integral for each scintillator sample: a) ^{6}Li loaded PSD plastic b) pure PSD plastic c) single stilbene crystal (Note: all the plots presented in the paper were produced using Matplotlib package.)

Discussion

Separation quality between neutrons and gamma-rays has been assessed by comparison of FOM values for each scintillator sample. There is a clear indication based on FOM values, as well as scatter plots in Fig. 2 that single stilbene crystal presents superior separation quality.

Although PGA algorithm failed to separate neutrons from gamma-ray photons within ^{6}Li loaded plastic scintillator (see Fig.2. a), FOM value for the pure PSD plastic scintillator suggests relatively good discrimination performance. This difference in separation quality between two plastic scintillators is related to the scintillator loading, which enables neutrons thermalised within the detector to be captured by high capture cross-section ^{6}Li. As such, ^{6}Li loaded plastic scintillator can be beneficial for certain application but neutron capture events are difficult to separate from gamma-ray photons as presented in this and previous studies [6].

Acknowledgments

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