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Application of Digitized Pulse Shape Discrimination (PSD) Technique on Organic Scintillation Detectors

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1. Introduction

Detecting fast neutron requires discriminating neutron from background gamma ray since gamma radiation is also emitted by excited nuclei which produce neutrons [1]. Among several methodologies to distinguish these radiations with their properties, e.g. detection frequency or radiation energy, difference in radiation pulse shape could be utilized with gas detectors or scintillation detectors.

Recent advances in the analog-to digital convertor (ADC) chip performance, digital pulse processing (DSP) technique became available. In the case of the analog PSD systems, complex analog circuit are often necessary to perform the PSD, which can cause some noise. However, digital PSD using DSP techniques has advantages of eliminating additional analog circuit, increasing convenience and providing real-time measurements. Also, these advantages can reduce noise.

In this research, neutrons and gamma rays were measured with two organic scintillation detectors, stilbene and EJ-301 detectors, both combined with high-speed digitizer. The digital PSD algorithm was applied and the PSD properties of these two detectors are described herein, including their implications.

2. PSD Technique

Due to different mechanisms with the scintillation material, incident neutrons and gamma ray have different ratio of prompt to delayed fluorescence. This provides possibility of PSD [2].

One of the common PSD methods, charge comparison method uses the ratio of total charge, Q_{total}, to charge in the slow component (due to delayed fluorescence), Q_{slow}, as shown in Fig. 1 [3].

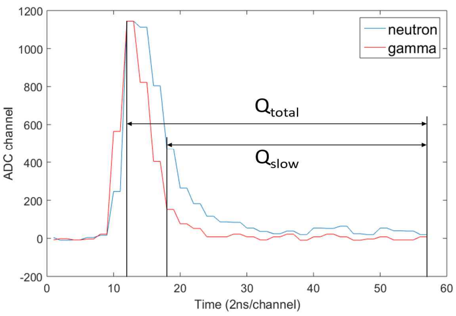

Fig. 1. The charge comparison method with neutron and gamma pulse using EJ-301 detector

The figure of merit (FOM) should demonstrate the degree of separation and resolution of the PSD property such as Q_{slow}/Q_{total}. The FOM could be defined as below.

$$FOM = \Delta / (\Delta\gamma + \Delta n)$$

Δ is separation between two peaks while $\Delta\gamma$ and Δn are full width at half maximum (FWHM) of gamma and neutron, respectively, as shown in Fig. 2 [4].

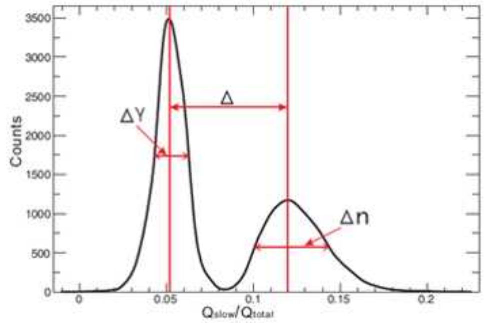

Fig. 2. The distribution of PSD properties [5]

3. Measurement

Neutrons from ^{252}Cf were measured using stilbene scintillator (2 in × 2 in, Inrad Optics) combined with H6525 PMT (Hamamatsu) and EJ-301 scintillator detector (2 in × 2 in, Eljen Technology) for 20 mins. The neutron source was located 25 cm away from the detector and its calibrated activity was 62.67 μCi.

The scintillation detector was connected to DT5730 fast digitizer (14 bit, 500 MS/s, CAEN) so that The measured signals could be processed in a PC through a fast digitizer. Finally, PSD algorithms were applied to the result signals to distinguish neutrons and background gamma rays using MATLAB software.

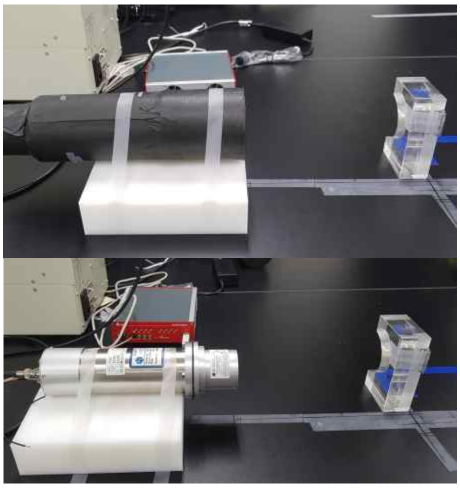

Fig. 3. Configuration of the experiment with stilbene detector (above) and EJ-301 detector (below)

4. Results and Discussions

4.1 Figure of Merit (FOM)

Table I shows the FOM value according to the thresholds. The highest FOM values were achieved, when both stilbene and EJ-301 detectors have high threshold values.

Table I: The FOM of Stilbene Detector and EJ-301 Detector

Detector	Thresholds (ADC Channel)	FOM
stilbene	300	1.377
	350	1.423
	400	1.464
	450	1.495
	500	1.526
	1000	1.781
EJ-301	300	1.132
	350	1.165
	400	1.325
	450	1.351
	500	1.373
	1000	1.534

Based on the same threshold value, the FOM value of stilbene was greater than that of EJ-301. Both stilbene detector and EJ-301 detector have the FOM value of 1.5 or more at a threshold value of 1000. The discrimination capability of two scintillation detectors could be interpreted as 'excellent.'

4.2 The Absolute Detection Efficiency

The absolute detection efficiency is the number of neutron counts produced by the detector per neutron emitted from the source. Table II shows the absolute detection efficiency according to the thresholds.

Table II: The Absolute Detection Efficiency of Stilbene Detector and EJ-301 Detector

Detector	Thresholds (ADC Channel)	The number of neutron Measured	The absolute detection efficiency
stilbene	300	135001	5.82 x 10^{-02}
	350	112612	4.86 x 10^{-02}
	400	96698	4.17 x 10^{-02}
	450	84467	3.64 x 10^{-02}
	500	74667	3.22 x 10^{-02}
	1000	31286	1.35 x 10^{-02}
EJ-301	300	176181	7.60 x 10^{-02}
	350	153083	6.60 x 10^{-02}
	400	133575	5.76 x 10^{-02}
	450	119822	5.17 x 10^{-02}
	500	108940	4.70 x 10^{-02}
	1000	58463	2.52 x 10^{-02}

The absolute detection efficiency decreases as the threshold increases. The absolute detection efficiency of EJ-301 was greater than that of stilbene based on the same threshold. But the absolute detection efficiency of stilbene was greater than that of EJ-301 based on the same FOM value.

5. Conclusion

In this paper, PSD properties of stilbene and EJ-301 detectors were explored. The result of FOM value and absolute detection efficiency showed the preference to stilbene and EJ-301 detector, respectively.

With digital PSD, desirable results could be achieved with precise and reliable data. Digital PSD application on other types of detectors and using other algorithms could be future work of this study.

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