Pulse shape discrimination in Boron codoped $Gd_3Ga_3Al_2O_{12}$(Ce) and CsI(Tl): A comparative study

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Introduction

Rare earth doped single component aluminum garnet GGAG:Ce (gadolinium gallium aluminum garnet) has attractive scintillation properties such as light yield (54,000 ph/MeV), energy resolution (6% at 662 keV) and high density (6.7 g/cm^3) [1]. This crystal has been studied with various codopants, out of which codoping with boron has shown the best scintillation and timing properties. Presently, it is used in various applications such as gamma spectroscopy, charged particle identification and X-ray imaging. CsI:Tl scintillator is often used for charged particle spectroscopy owing to its excellent light output (64,000 ph/MeV), two decay times of 680 ns and 3000 ns and its cost effectiveness [2]. One common feature of both these crystals is their variable decay time for various exciting particles. Pulse shape discrimination (PSD) technique can therefore be employed for the detection of alphas, neutrons and gammas using CsI:Tl and GGAG:Ce,B. Moreover, the development of new photo sensors has further opened gateways for compact detector geometry. Both GGAG:Ce,B and CsI:Tl has peak emission at 550 nm but GGAG:Ce has an upper hand in being denser and non-hygroscopic.

This paper discusses the PSD characteristics of CsI:Tl and of GGAG:Ce,B coupled to photomultiplier tube and to SiPM using charge integration based digitizer.

Experimental details

Single crystals of GGAG:Ce,B were grown using Czochralski technique, while CsI:Tl crystals were fabricated by Bridgeman method. One sample each of dimension 18×18×10 mm^3 was cut and polished from the grown crystals of CsI:Tl and GGAG:Ce,B. Crystals were coupled to Hamamatsu R1306 PMT using optical grease. In SiPM based experiments, a light guide was used to mount large crystals on SiPM (SenSL C type) of 6×6 mm^2 active area. Charge integration based pulse shape discrimination was done with Am-Pu as alpha and Co-60 as gamma source. A CEAN make 14 bit, 16 channel digitizer (V1730) with a sampling rate of 500 MS/s was used. The discrimination is measured by a dimensionless parameter given by [3]

$$PSD_{Digitizer} = 1 - \frac{Q_S}{Q_L} \tag{1}$$

where Q_S and Q_L are the charge integrated in the short and long gates of digitizer respectively. Fig. 1 shows PSD measurement setup used in the present work.

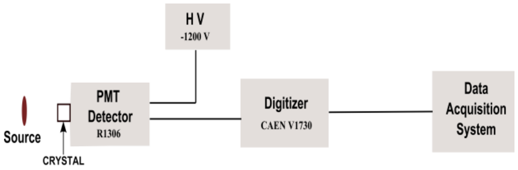

Fig.1 A block diagram of PSD measurement setup using digitizer.

Results and discussion

Fig.2 shows normalized scintillation decay curves of CsI:Tl and GGAG:Ce,B detector obtained using a fast digital oscilloscope. Decay plots clearly depict that the decay time of GGAG:Ce,B is longer for alphas than for gammas, a behavior opposite to that of CsI:Tl crystal. The measured scintillation decay parameters are given in Table-1. In GGAG:Ce,B, longer decay time for alpha excitation indicates the probable role of defect centers in crystal's scintillation kinetics. A similar behavior has been observed in YAG:Ce single crystal [4].

Table-1: Scintillation decay parameters

Crystal	Alpha		Gamma	
	τ_1(ns)	τ_2(ns)	τ_1(ns)	τ_2(ns)
CsI:Tl	300	700	700	3500
GGAG:Ce,B	61	488	104	501

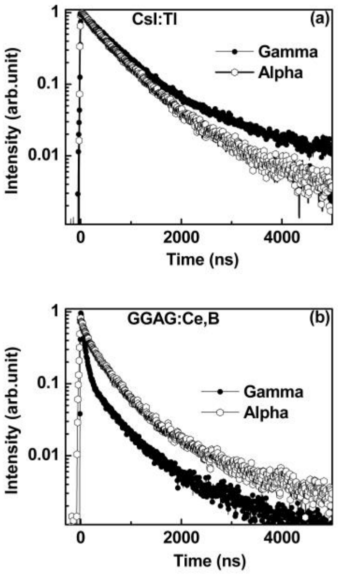

Fig.2 Normalized scintillation decay plots.

Fig.3 shows scattered PSD plot and its projection on Y-axis over the entire energy range for both the crystals. From the projected plots, the separation between alpha and gamma is calculated in terms of figure of merit (FOM) given by

$$FOM = \frac{\Delta T}{\tau_\alpha + \tau_\gamma} \qquad (2)$$

where ΔT is separation between alpha and gamma peaks and τ_α, τ_γ are their FWHMs.

The FOM values for CsI:Tl and GGAG:Ce,B detectors are measured to be 2.41 and 3.42 respectively. This suggests that GGAG:Ce,B to be a better choice for PSD measurements when energy values are greater than 122 keV.

Exponential decay curves of both the crystals when mounted on SiPM through a light guide have also shown a similar dependence on alpha and gamma excitations as that measured with the PMT.

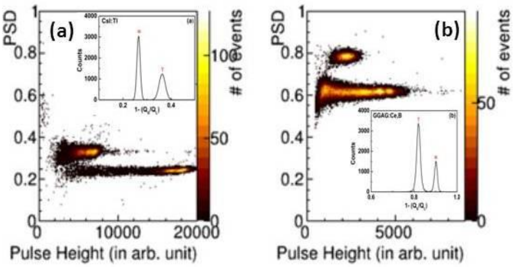

Fig.3 Scattered and Projected (inset)PSD plots.

FOM values are 1.54 and 1.71 for CsI:Tl and GGAG:Ce,B SiPM based detectors respectively. Lower FOM in GGAG:Ce,B coupled with SiPM is due to the noise contribution from crosstalk and afterpulsing. This can be further improved by using better back-end electronics and data acquisition system.

Conclusion

The ability to discriminate alpha and gamma is observed to be better in GGAG:Ce,B than in CsI:Tl crystals when coupled with PMT. However, lower FOM values obtained when crystals are coupled with SiPM are expected to increase with further optimization of digitizer.

References

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