A new phoswich design of CsI:Tl /GGAG:Ce,B scintillators for pulse shape discrimination

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Introduction

Scintillators are characterized by a wide range of properties such as light output, energy resolution, decay time, luminescent efficiency etc. depending on the constituting material. An appropriate combination of two distinct scintillators having different scintillation decay pulse shapes can result in a desirable discrimination property. A phoswich detector is one such example which is a combination of two or more scintillators coupled with a single photo-sensor. Based on its applications, there are mainly two types of phoswich designs. One is used in measuring DOI (depth of interaction) bydetermining which scintillator absorbed the radiation and the number of photons measured. The other is used for PID (particle identification) when a signal is generated simultaneously from all the scintillators [1]. Some of the common phoswich combinations of single crystal scintillators are NaI(Tl)/CsI(Na), NaI(Tl)/CsI(Tl) and NaI(Tl)/CaF_2(Eu).

We have recently reported that single crystals of $Gd_3Ga_3Al_2O_{12}$:Ce,B (GGAG) has better ability to distinguish alpha and gamma radiations in comparison with CsI:Tl [2]. In this communication, some investigations were carried out to explore the possibility of using the combination of GGAG:Ce,B and CsI:Tl as a phoswich system. These scintillators have different scintillation decay kinetics depending on the ionization density which makes them promising for distinguishing alpha, gamma and other charged particles over a wide range of energies.

Experimental details

In an optimized combination, a disk of 25 mm diameter and 1 mm thick GGAG:Ce,B is kept in contact with CsI:Tl scintillator of 25 mm diameter and a thickness of 10 mm. This combination is mounted on a Hamamatsu PMT using optical grease. An Am-Pu alpha source emitting 5.3 MeV alpha particles was directly coupled to a GGAG disk and was collimated using Al foil such that all radiations fall on GGAG disk only. A Cs-137 (662 keV) gamma source was kept in front of the phoswich detector such that it deposits its energy in both scintillators depending on their nature and stopping powers. Signals from the phoswich were recorded in a 1 GHz Tektronics digital storage oscilloscope. Phoswich signal is fitted in a multi exponential decay equation to calculate mean lifetime and comparing with those of recorded with individual scintillators.

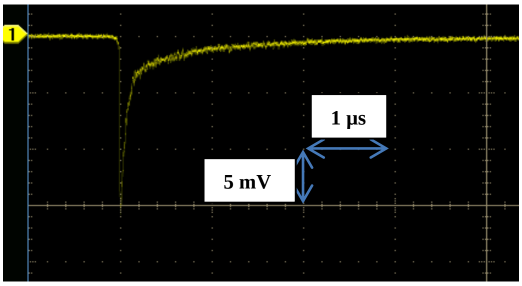

Fig. 1 The scintillation decay curve for alpha and gamma sources measured with phoswich design of GGAG:Ce,B and CsI:Tl scintillators.

Results and Discussion

Fig. 1 represents a typical signal drawn from a GGAG/CsI phoswich for alpha and gamma sources. The generated pulse has more than two decay components due to the ionization density dependence of multi component decay mechanism of the phoswich crystals [2]. Our phoswich entities GGAG:Ce,B and CsI:Tl have

Table.1 Decay components of alpha and gamma from CsI:Tl, GGAG:Ce,B and phoswich.

		Decay components					Mean Lifetime (ns)	
		Alpha		Gamma			Alpha	Gamma
GGAG:Ce,B	τ (ns)	104	501	61	488		422	275
	A	0.58	0.48	1.1	0.14			
CsI:Tl	τ (ns)	320	762	778	3506		650	1966
	A	0.35	0.44	0.67	0.12			
Phoswich	τ (ns)	73	776	46	712	2982	469	1719
	A	0.007	0.0009	0.004	0.003	0.0007		

two decay components (fast and slow) and their relative ratio depends on the nature of the incident radiation i.e. alpha or gamma [2]. Thus, a phoswich system comprising of GGAG:Ce,B and CsI:Tl scintillators is also expected to show multi component decay kinetics depending on the excitation mechanism. The fitted decay components (τ and A) for alpha and gamma along with the mean decay time of individual scintillator and GGAG/CsI phoswich are given in table 1.

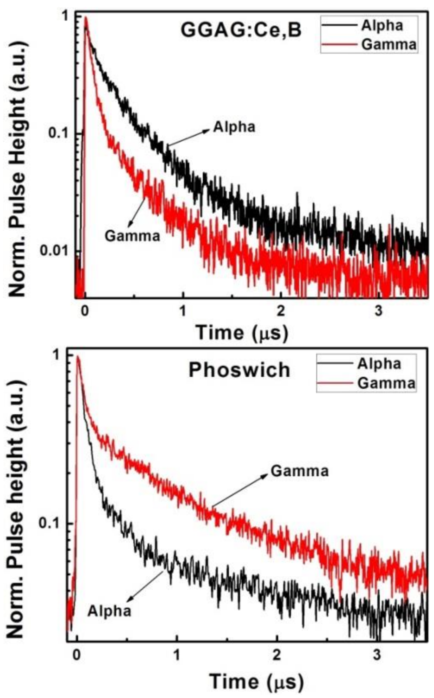

Fig. 2 Alpha and gamma decay curves of GGAG:Ce,B and phoswich.

The table shows that the decay curves of the combined phoswich system is a culmination of decay components of CsI:Tl and GGAG:Ce,B. Fig. 2 shows the pulse shapes of decay curves from GGAG:Ce,B and phoswich detector distinguishing alpha and gamma radiation. The decay for gamma rays slows down in phoswich combination while it accelerates compared to the alpha radiation decay in a GGAG:Ce,B scintillator. This can be attributed to the slow decay component added by the CsI:Tl crystal in the phoswich design. The alpha radiation completely stops in GGAG:Ce,B scintillator while gamma deposits maximum energy in CsI:Tl crystal. The noticeable difference in pulse shapes and mean decay times indicate that the PSD is better in GGAG/CsI phoswich system when compared to that of the individual scintillator's.

Summary

By comparing the decay kinetics of GGAG/CsI phoswich with the individual scintillators of GGAG:Ce,B and CsI:Tl, we observed better discrimination ability in the phoswich system. More experiments are in progress to measure the figure of merit for the combination of thin and fast scintillator i.e. GGAG:Ce,B with the slow and thick CsI:Tl detector to discriminate charged particles and gamma rays.

References

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[2] Rawat S. *et al*., *Nucl. Inst. Meth. Phys. Res. A*, **840** (2016) 186-19.