Characterisation of 1″×1″ $LaBr_{2.85}Cl_{0.15}$:Ce crystal for γ-rays

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Introduction

Lanthanum Halides are the most sought-after scintillators because of their excellent energy resolution and high γ-ray detection efficiency. Lanthanum Bromide is the most widely used of all Lanthanum Halide scintillators [1]. Researchers are trying to improve further the performance of the Lanthanum Halide scintillators by growing crystals of similar structure, co-doping with various elements, etc[2]. $LaBr_{2.85}Cl_{0.15}$:Ce is an outcome of a similar quest. $LaBr_{2.85}Cl_{0.15}$:Ce, henceforth referred to as LBC has been grown by Scionix Holland BV, and it contains Chlorine in addition to Lanthanum and Bromine[3]. We have investigated the various properties of the LBC crystal relevant for the detection of γ-rays. In addition, ^{35}Cl has a large cross-section for reaction with fast neutrons, which makes LBC a possible scintillator for neutron detection as well. The response of LBC for fast and thermal neutrons has also been measured.

This work reports on the characterisation of a 1″×1″ LBC crystal for γ-rays. We have studied various properties of the LBC crystal, namely linearity of response, energy and timing resolutions, γ-ray detection efficiency and internal activity.

Experimental Details

A 1″×1″ LBC crystal was coupled to a 2″ ET-9266B PMT manufactured by ET Enterprises. The output of the PMT was fed to a homemade pre-amplifier. Fig. 1 presents the typical spectrum of LBC acquired using γ-ray sources of ^{133}Ba, ^{137}Cs, ^{22}Na, and ^{60}Co. In addition, we also used an Am-Be source for high energy 4.4 MeV γ-rays. Fig. 1 clearly shows that the LBC crystal is able to resolve 1274 keV γ-ray from ^{22}Na in between 1173 and 1332 keV γ-rays from ^{60}Co. This demonstrates the excellent energy resolution of LBC as compared to the conventional NaI(Tl) scintillator. Moreover, Fig. 1 also shows the internal activity of the LBC crystal. The internal activity in LBC is due to the presence of ^{138}La and ^{227}Ac impurities, clearly visible above 1400 keV in the spectrum.

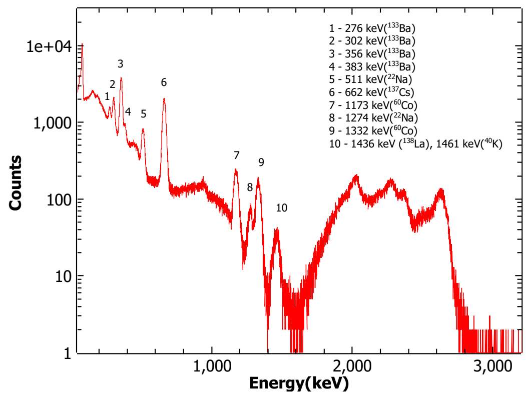

FIG. 1: Typical spectrum of LBC crystal for various γ-ray sources.

Energy signal was acquired from the 6th and the 8th dynode for two different data sets to study the linearity of response for γ-rays. Fig. 2 presents the channel number vs γ-ray energy plot when the signal is tapped from the 8th dynode. It also presents the linear fits to the data showing the extent of linearity in the

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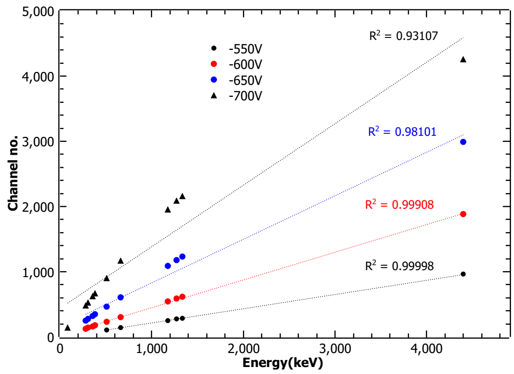

FIG. 2: Channel number vs energy plot when the energy signal is tapped from the 8th dynode.

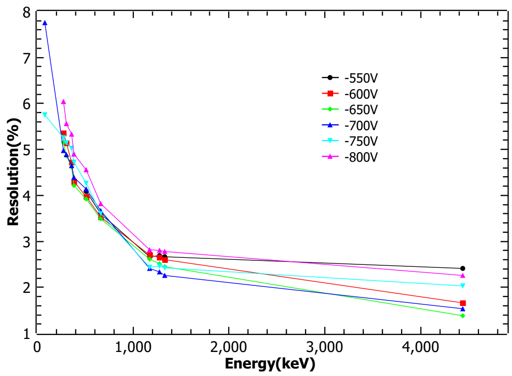

FIG. 3: Energy resolution vs γ-ray energy plot when energy signal is tapped from the 8th dynode.

detector's response. The detector is perfectly linear at a low operating voltage of -550 V. As the operating voltage increases; the detector becomes increasingly non-linear. At the operating voltage of -700 V, the detector is highly non-linear.

Fig. 3 presents the energy resolution for different γ-ray energies when the energy signal is drawn from the 8th dynode. We have obtained an energy resolution of $\sim$3.8 % at 662 keV when the detector is operated at a bias voltage of -800 V with the signal drawn from the 8th dynode. However, it is to be noted that the detector's response becomes highly non-linear at this high operating voltage.

The crystal's intrinsic full energy detection

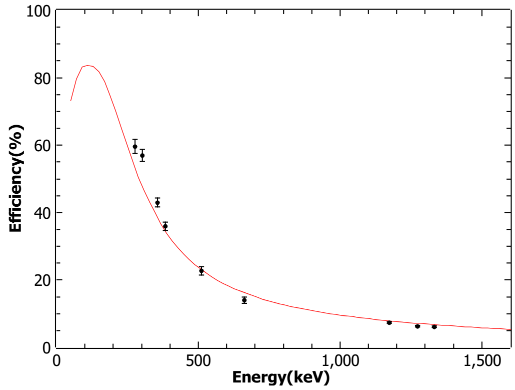

FIG. 4: Intrinsic full energy detection efficiency vs the energy of γ-ray.

efficiency was also measured using various γ-ray sources. Data was acquired for 6 hours with each γ-ray source. The source was placed at a distance of 35 cm from the detector. The detector's response was simulated using the Monte Carlo simulation toolkit GEANT4 [4]. Fig. 4 presents the crystal's intrinsic full energy detection efficiency for different γ-ray energies. The solid line shows the result of GEANT4 simulations. The measured efficiencies agree well with the simulated efficiencies. No significant difference in the LBC crystal performance was observed compared to standard $LaBr_3$:Ce.

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References

[1] I. Mazumdar *et al.*, Nucl. Instrum. Methods Phys. Res. A **705**, 85 (2013).
[2] S. Panwar *et al.*, Nucl. Instrum. Methods Phys. Res. A **982**, 164567 (2020).
[3] V. Ranga *et al.*, Nucl. Instrum. Methods Phys. Res. A **1041**, 167369 (2022).
[4] S. Agostinelli *et al.*, Nucl. Instrum. Methods Phys. Res. A **506**, 250 (2003).