Determination of Quantum Efficiency of $LaBr_3$:Ce Crystal using SiPM

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Introduction

The importance of scintillation detectors in nuclear γ-ray spectroscopy is well established for many decades. The synthesis and commercial production of new scintillation crystals with superior detection properties are part of continued global efforts. The recent discovery and marketing of Lanthanum Halide crystals, namely Lanthanum Bromide and Lanthanum Chloride bear testimony to these efforts. A complete characterisation of such crystals involve determination of all the major properties like, energy and timing resolution, homogeneity, uniformity of response, linearity etc. The quantum efficiency or light yield of scintillators is one of the most important properties of such scintillation detectors. The Lanthanum Bromide ($LaBr_3$:Ce) has best energy resolution of all known scintillators primarily because of its much higher light yield per MeV deposition of radiation energy. The light yield of $LaBr_3$:Ce is much higher than the time tested scintillators like NaI(Tl), CsI(Na) etc. This contribution presents the result of our efforts to determine the absolute quantum efficiency of Lanthanum Bromide crystals using SiPM readout. Traditionally, scintillator crystals are coupled with photo multiplier tubes (PMT) for generating the electronic signal. Nowadays, silicon photo multipliers (SiPM) have started to replace PMTs because of their insensitivity to magnetic field, low operating voltage and small sizes. Here we report the comparison of light output of different scintillator crystals and for the first time, determination of the quantum efficiency of $LaBr_3$:Ce using SiPM.

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Light Output From Different Scintillator

The first part of the measurements involved a comparative study of the light output from different scintillator detectors like, $LaBr_3$:Ce, $CeBr_3$, NaI(Tl), CsI(Na), BGO, CsI(Pure), and NaI(Pure). For the comparative study of the light output (or the pulse height output) each crystal was coupled to ET-9266B PMT of 2" diameter having ten stages. Homemade, active voltage divider and charge sensitive preamplifier were used [2]. Energy signals were taken from the last dynodes to compare light output of each detector. A ^{137}Cs radioactive source with 661.7 KeV ray was used. Photo peak position was observed on AD413 Quad 8K channel ADC. Photo Peak position from each detector corresponded to light out-

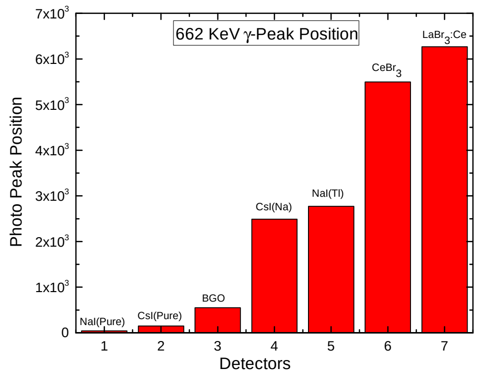

FIG. 1: 662 γ-ray Photo Peak Position from different scintillators.

put of crystal. Figure 1 shows that $LaBr_3$:Ce has highest light output of all the crystals and the pulse heights are in exact ration of the known light outputs from these crystals.

Measurement from SiPM

The second part of the measurements involved determination of the absolute light yield of the $LaBr_3$:Ce crystal using SiPM chips. The 25.4 mm × 25.4 mm crystal from Saint Gobain Inc. was viewed by 6mm × 6 mm SiPM from SensL having 18,980 pixels with each pixel of size 35μ. The SiPM was mounted on printed circuit board (PCB) designed using OrCAD [5] software for read out signal. Output signal (V_0) was measured on an oscilloscope using 662 keV γ-rays from ^{137}Cs source. The total charge generated by the visible photons impinging upon the SiPM pixels was determined. By using the known value of the quantum efficiency of the SiPM and the measured total charge, the number of visible photons impinging upon the SiPM was determined. After applying necessary corrections the number of visible photons produced for 1 MeV γ-ray energy was found out to be 57,675 for $LaBr_3$:Ce at 380 nm. The corresponding quantum efficiency of detector is 18.8%. This is in very good agreement with what is determined from optical measurements and quoted by the manufacturer [3].

FIG. 2: SiPM coupled with 1" $LaBr_3$:Ce

Conclusion

In this work we have tried to determine the light yield of Lanthanum Bromide scintillator using both relative and direct methods. In the first part we describe the determination of the light yield by comparing the output pulses from different scintillators with known light yields. In the second part we make efforts to determine the absolute light yield by direct measurement using SiPM. Our measured value is in good agreement with the light yield determined by optical methods. It is to be noted that the primary sources of uncertainties associated with our result are the reflection/absorption of the light from the SiPM window, the wavelength dependent spread in quantum efficiency of the SiPM in producing electron-hole pairs etc. The determination of these errors are in progress and will be presented in the meeting. In past, sophisticated and costly optical instruments have been used to measure the quantum efficiency [4]. The technique used here is cost effective and gives reliable estimate of quantum efficiency of scintillator crystals.

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