Testing and characterization of a scintillator based position sensitive detector assembly for a one-shot gamma ray scanning setup

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Introduction

In nuclear physics a subject of primary interest and research deals with attaining high precision 3D-position information regarding events occurring within detectors using the most advanced technologies- both on the hardware as well as the electronics phase. It is well known from literature that a position determination of an interaction within the detector yields better spectrum information [1]. Position sensitivity can be improved on the hardware level using detectors with multiple segments, achieved either physically or electrically. In recent years, much advancement [2] has been achieved using electrically segmented HPGe detectors, which further employ pulse shape analysis (PSA) at the signal processing stage. Using 2D-electrical segmentation and PSA method, a position sensitivity of below 1mm has been achieved for single interaction events [3]. In order to achieve a detector's response to radiation at different positions, scanning concept is utilized. One of the scanning techniques applicable is the conventional coincidence scanning method [4], which has been, over the years of development, found out to be the slower method. The other faster method involves a one-shot scanning technique [5].

In this paper we report, in part, a work of similar nature. We are developing a one-shot scanning setup and as a part of the setup, a position sensitive photo-multiplier (PMT) with multiple anode wire readouts, coupled to a high density scintillator material has been tested and the preliminary results reported here. The principle governing detection in such an assembly is based on the precision achieved in being able to locate the point of interaction within the PMT. As a consequence, a higher number of anode wires lead to more accurate position information regarding an event occurring within the anode matrix of the PMT.

The Cerium doped Lutetium Yttrium Orthosilicate- LYSO crystal used is of high density and has high light yield, specially procured in order to have a larger number of photons incident on the PMT photo-cathode, which would lead to lesser statistical fluctuation in signal collection. The cylindrical LYSO's dimensions have been optimized using GEANT4 simulation toolkit; it has been optically coupled to the PMT's front face using silicon grease.

Fig. 1 LYSO (Ce) crystal and R2486-03 Hamamatsu PMT

Experimental Details

The 3" diameter R2486-03 circular envelope position-sensitive PMT used has a bialkali photocathode, a 12-stage coarse mesh dynode structure, and multiple anode wires (16x16) crossing each other in X-Y direction. Output signal from each anode is divided through external resistive chains and derived from X-Y electrodes as position signals. This cross-wired anode configuration can yield spatial resolutions up to 0.3 mm for 565 nm spot light source of 1mm diameter, with a light intensity of 4,000 photoelectrons [6]. The Cerium doped Lutetium Yttrium Orthosilicate: LYSO ($Lu_{1.8}Y_{0.2}SiO_5$:Ce) used is a high density scintillation material with a short decay time~40 ns. The high density (approx. 7.4 gm/cc) leads to a high light yield (32 photons/keV) and subsequently improved energy resolution (~8-10% for 511 keV) [7].

The 3 mm thick LYSO crystal used here has a 3" diameter matching the PMT to which it has been coupled head-on. In order to ensure that γ-rays above 50 keV suffered negligible attenuation, the setup was given a Teflon tape coating, an aluminium foil layering and finally a black insulated tape covering in order to reduce light reflections from the surface; the entire setup was placed in a 5mm thick aluminium cylinder to provide mechanical stability and shielding (Fig 2). The PMT was supplied with -1000 V bias and anode signals were observed in an oscilloscope. The setup was tested with a γ-ray (^{137}Cs) and signals were observed on a 300 MHz oscilloscope on a preliminary basis.

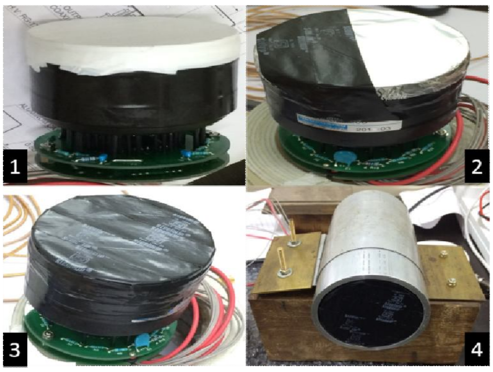

Fig. 2 Stages of LYSO (Ce) – R2486-03 coupling

Results

The PMT-LYSO assembly was tested at a bias voltage of -1000 V, with a ^{137}Cs γ-source and the signals were studied on a preliminary basis on an oscilloscope. Individual anode chains corresponding to the X and Y directions have their corresponding readouts (two in number, from the beginning and ending of each chain). It was observed that the typical pulses corresponding to each end of the anode chains measured around 400-500 mV in amplitude. When the source was removed, it was observed that the internal radioactivity of LYSO, originating due to the decay of ^{176}Lu to ^{176}Hf, contributed significantly to the background.

Further characterization of PMT signals using NIM modules and VME electronics, where the anode signals would be amplified and fed into ADC VME module, to gain more information is under process.

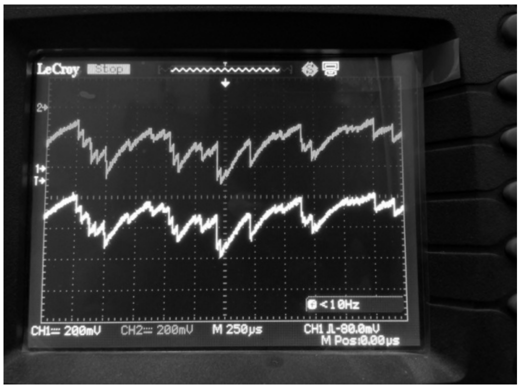

Fig. 3 Oscilloscope signal corresponding to one end each of X (bottom signal) and Y (top signal) anode chain.

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