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A Depth Encoding Detector with a Position Sensitive Photomultiplier Tube for PET

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INTRODUCTION

The depth-of-interaction (DOI) of gamma rays degrades the spatial resolution uniformity across the field-of-view for PET images. This effect, commonly referred to as a parallax error, causes the radial elongation artifact which has long been recognized as an obstacle to high resolution PET in 2D data acquisition mode. Especially in full 3D data acquisition mode, the parallax error limits the system volumetric spatial resolution even in the FOV center with increasing the acceptance angle. This degradation of spatial resolution can be overcome by decreasing the length of the scintillation crystals at the sacrifice of sensitivity. The method for eliminating the parallax error without reducing sensitivity is to use the detector module that measures the DOI of incident gamma rays [1]. A detector unit having a depth encoding scheme was designed and a prototype unit has been constructed and evaluated.

MATERIAL AND METHOD

The detector unit consists of four crystal blocks in a 2x2 array optically coupled at the bottom face to a position sensitive photomultiplier tube (PS-PMT), which has a size of 25 mm square with a 16 channel (4x4) metal dynode. Each crystal block, which is optically separated from other blocks by PTFE tape, has a size of 8 mm x 8 mm x 30 mm and consists of 12 Gd_2SiO_5:Ce (GSO) crystal elements in a three-stage rectangular array whose single size is 3.8 mm x 3.8 mm x 10 mm. The crystal element of photon absorption is identified by the relative ratios of each dynode signal of the PS-PMT. Optimal positioning characteristics is achieved by arranging the light coupling at each contact face of crystal elements. Constructing four units of the three-stage crystal blocks faced to one PS-PMT, we have a 4 (transaxially) x 4 (axially) x 3 (in depth) multi-crystal detector with 48 crystal elements.

To evaluate feasibility of the detector unit, we measured the distribution of output signals from the PS-PMT with the GSO blocks for irradiation of ^{137}Cs gamma rays. This configuration is applicable to LSO crystals because LSO has the almost same refractive index and more light output compared with GSO. Our proposed detector is a much reliable and simple unit for volume PET devices because the proposed DOI scheme does not need additional photo-detectors and combination of different type of scintillators.

RESULTS AND DISCUSSION

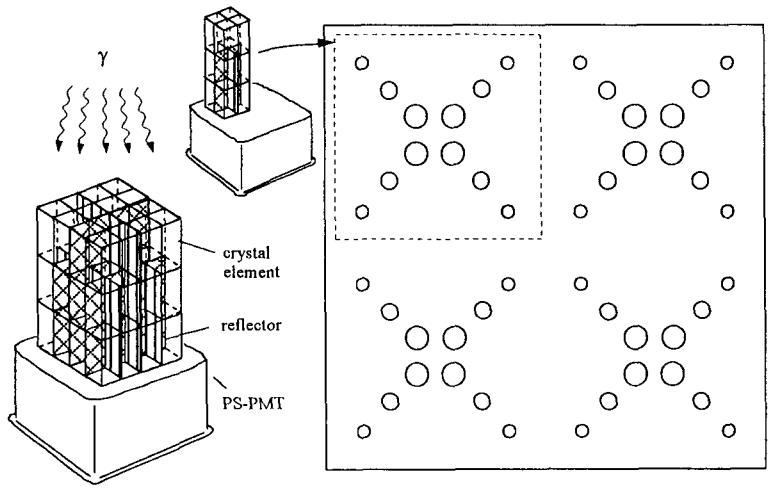
Fig.1 shows a schematic diagram of the detector unit and the 2D flood histogram formed during broad irradiation of gamma rays over the detector unit. The bottom layer crystals are optically coupled to the PS-PMT. Its output channels are used in Anger-type positioning logic for detector element identification from single events using discrimination for energy window above the Compton edge.

Fig.2 shows an example of the 2D flood histogram for broad irradiation of ^{137}Cs gamma rays in the case of only one crystal block optically coupled to a quadrant of the square

window of the PS-PMT. The signals were integrated over 0.5 μsec. The positioning performance is very clear and each crystal element is easily identified with dividing into 12 regions that correspond to each crystal element. This experimental result suggests that the proposed detector unit become one solution for a development toward succeeding DOI detectors for volume PET with high spatial resolution.

CONCLUSION

Our proposed detector is much reliable and simpler for PET because the proposed DOI scheme does not need additional photo-detectors and combination of different type of scintillators.



(A) DOI detector unit (B) 2D histogram

Fig.1. (A) Schematic drawing of the DOI detector unit and (B) the 2D flood histogram formed from ratios of the PS-PMT signals during broad irradiation of gamma ray over the four layered detector.

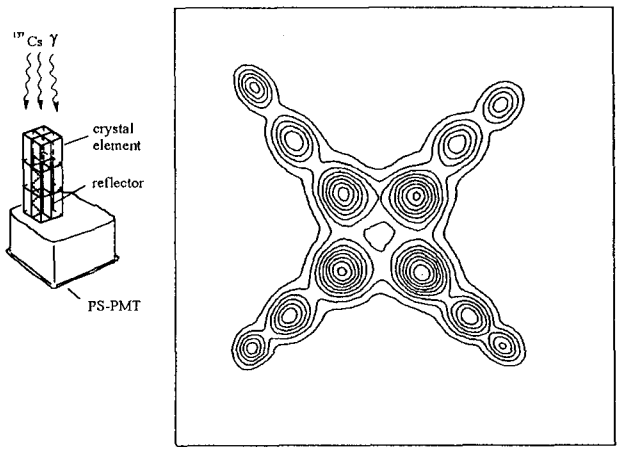


Fig. 2. 2D flood histogram for broad irradiation of ^{137}Cs gamma rays in the case of only one GSO block detector optically coupled to a quadrant of the square window of the PS-PMT.

REFERENCE

[1] Murayama, H., Ishibashi, H., Uchida, H., Omura, T., Yamashita, T.: Depth Encording Multcrystal Detectors for PET. IEEE Trans. Nucl. Sci., 45, 1152-1157, 1998.