Evaluation of the 256ch Flat Panel PS-PMT on Positioning Image Histogram for PET

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ABSTRACT

For a next generation PET that realizes high sensitivity and high resolution, we proposed a design of a depth of interaction detector. A unit of the detector is constructed of four stages rectangular blocks of 2 by 2 Gd_2SiO_5: Ce (GSO) crystal array optically coupled to position sensitive photomultiplier tube (PS-PMT). The 256ch flat panel PS-PMT is under development by Hamamatsu Photonics K.K., JAPAN. It has large cathode area, 51.7 by 51.7 mm^2, and the ratio of the effective area to external size is about 90%. The feature will contribute high packing fraction, accordingly high sensitivity. The 256 anodes are arranged in 16 by 16 at intervals of 3.0 mm. So as to evaluate the detector capability for identifying crystal of interaction, we got positioning image histograms with coupling a 16 by 5 array of GSO crystals, 2.9 by 2.9 by 7.5 mm^3, to the PS-PMT by irradiating a gamma ray uniformly from a point source. Flat panel PS-PMT is a new promising device for PET. We need to evaluate it if its performance is sufficiency. The performance was compared to the one with a 16ch PS-PMT.

Keywords: Nuclear medicine, positron emission tomography, position sensitive photomultiplayer tube.

1. INTRODUCTION

PET detector requires detecting 511keV gamma ray more accurately and more efficiently. In order to realize higher spatial resolution, although physical limit as positron range and angular deviation, scintillation crystals need to be as small as possible. Additionally the PET detector needs depth of interaction (DOI) function in order to reduce degradation of spatial resolution about peripheral part [1]. Consequently it is high positioning and high energy resolution that the important characteristic of the photomultiplayer tube (PMT). For the commercially available 16ch position sensitive PMT (PS-PMT) the ratio of the effective area to externality is 45%. So using the PS-PMT for photo detector, the system loses packing fraction and the system is out of high sensitivity. For that purpose, 64ch flat panel PS-PMT (R8400-00-M64 by Hamamatu Photonics K.K., JAPAN) was produced. It has been realized that the ratio is 90% [2]. Now to achieve more closely anode intervals than the 64ch one, 256ch flat panel PS-PMT is under development by Hamamatsu Photonics K.K., JAPAN. It is great advantage for PET detector that we proposed.

2. MATERIALS AND METHODS

The appearance of a 256ch flat panel PS-PMT is shown in Fig. 1 a). Its external size is 51.7 x 51.7 x 14.7 mm^3 as well as a 64ch one. The 256ch anodes are arranged in 16 x 16 matrix. And each anode size for 256ch is 3.0 x 3.0mm^2 while 64ch one's size is 6.0 x 6.0mm^2. Fig.1c) and d) show the uniformity of the 256ch flat panel PS-PMT at the cathode and the anode, respectively. The peripheral area is lower sensitivity than the central area for anode signal. A bottom view of a resistor-chain for the PMT is illustrated in Fig. 1 b). The resistor-chain connects adjacent anodes through a resistor of 1k ohm except the outer line anodes that is required additional gain to make uniform sensitivity all over the useful area. Then anode readout lines are united at each corner and a crystal of interaction is identified by Anger type calculation with the four anode signals. The PMT also has an output of dynode signal. It is used as a timing signal. The performance of 256ch flat panel PS-PMT was compared to the one of a 16ch PS-PMT (H6568MOD by Hamamatsu Photonics K.K., JAPAN), which had been considered as a candidate of the PS-PMT used for our DOI detector. 16ch PS-PMT has 4 x 4 matrix anodes of 4.0 x 4.0mm^2 in each size. The crystals used in all experiments are 2.9 x 2.9 x 7.5mm^3 GSO. We took multilayer polymer mirrors for a reflector covering crystals. It is 65 micrometer in thick and has 98% reflection [3].

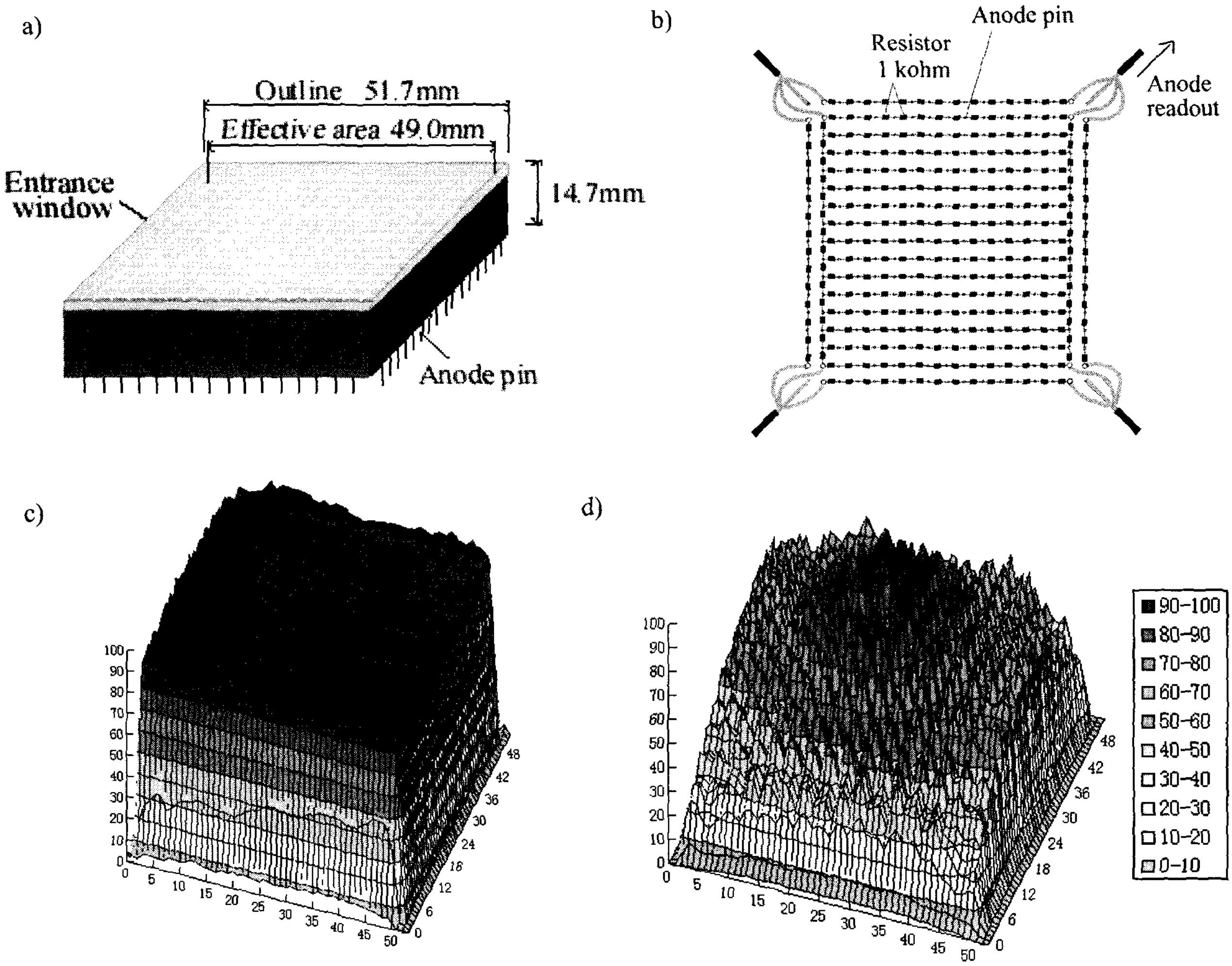

Fig. 1: a) Appearance of a 256ch Flat Panel PS-PMT, b) a bottom view of a resistor-chain and the uniformity of c) the cathode sensitivity and d) the anode sensitivity of 256ch Flat Panel PS-PMT.

3. EXPERIMENTS AND RESULTS

3.1 Comparison of Energy Resolution

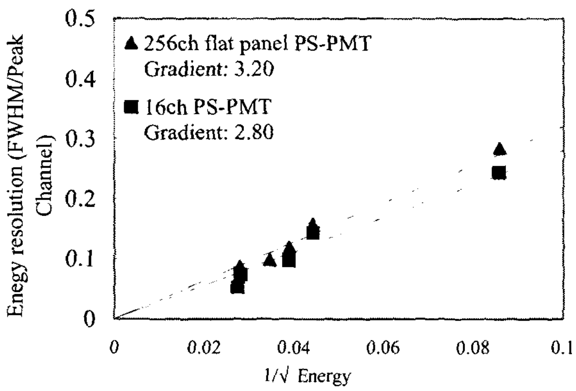

Fig. 2: Comparison of energy resolution

Fig. 2 shows energy resolution of 256ch flat panel PS-PMT and 16ch PS-PMT. Irradiating a gamma ray from Co-60, Co-57, Na-22, Mn-54, and Cs-137 point sources to a GSO crystal, the pulse height spectra were recorded with

Multi-Channel Analyzer. The crystal was placed on a center anode. The resolution is inversely proportional to the square root of the number of photoelectrons per event in the PMTs.

3.2 Comparison of Response Function

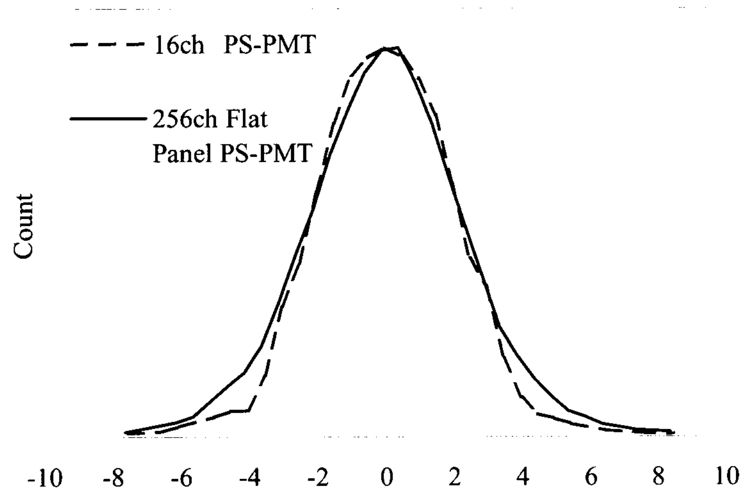

Fig.3: Comparison of Response function

Fig.3 shows the response function to GSO crystal about the 256ch flat panel PS-PMT and the 16ch PS-PMT. The Cs-137 point souse was used and irradiated to a GSO crystal. One center anode output was measured with making a GSO crystal move linearly at 0.5mm steps. The horizontal axis is the distance from the center anode and the vertical axis is nomarized at their peaks. Standard deviation for the 16ch and the 256ch flat panel PS-PMT's response function was 1.97 and 2.18, respectively.

3.3 Performance of 256ch Flat Panel PS-PMT in crystal identification

For the purpose of the irradiation performance test, the GSO crystals were used for a 16 x 5 array detector, although the 256ch flat panel PS-PMT has capacity for a 16 x 16 array of these crystals, whose size will be 48 x 48 mm^2. Two experiments were performed. At first, the 16 x 5 array of the crystals was mounted at the middle of the 256ch flat panel PS-PMT. The second, the array was mounted at the periphery. To irradiate gamma rays from a Cs-137 point source uniformly, the source was placed at 22cm above from the detector. Fig.4 a) shows the positioning image maps at middle and peripheral parts, and Fig. 4 b) shows the associated profiles which locations are suggested as profile 1 and 2 in Fig. 4 a).

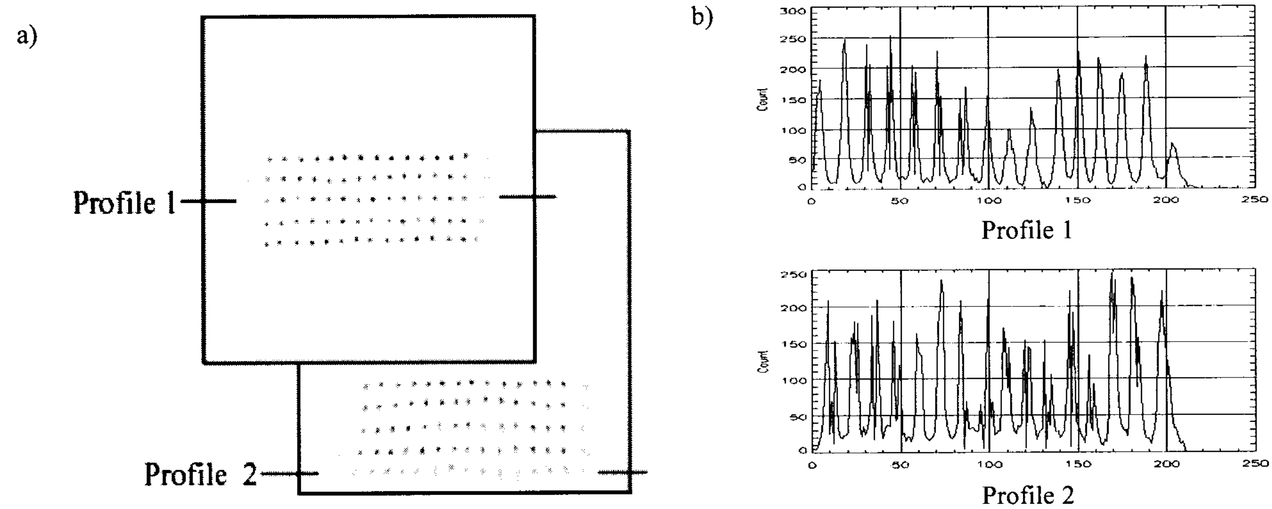

Fig. 4 a) Positioning image maps, b) profiles at the middle and periphery part of the 256ch Flat Panel PS-PMT useful area

4. DISSCUSSION AND CONCLUSION

From Fig. 2, the effective quantum efficiency of the 256ch flat panel PS-PMT is calculated as 77% to the one of the 16ch PS-PMT. The deference of the resolution results from PMT characteristics such as photocathode sensitivity and photoelectron collection efficiency. The manufacturer suggested that the 256ch flat panel PS-PMT is designed to have comparable characteristics with the 16ch one. Since the 256ch flat panel PS-PMT used in our experiment is under development, it is expected to improve the effective quantum efficiency at the stage of mass production. In Fig. 3, we have different response functions. One of the reasons is considered due to the thickness of entrance window, which is 2.0mm for 256ch flat panel PS-PMT, and 0.8mm for 16ch PS-PMT. In Fig. 4 the profiles prove 256ch flat panel PS-PMT works enough for the identification of one stage GSO crystals sized 2.9 x 2.9 x 7.5mm^3 array. It also seems to work enough for the identification of two stages due to the narrow peaks in the profiles. The four–stage DOI detector that we proposed identifies crystals of interaction by making two positioning image maps with pulse shape discrimination [1]. Each map provides information of the two stages with the same pulse shape. Therefore the 256ch flat panel PS-PMT is expected to utilize for a photo-detector of the four-stage DOI detector.

5. REFERENCES

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