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Light Collection in the High Energy X-ray Detector with the Pixelated CdWO4 Scintillator using Monte Carlo Method

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1. Introduction

The image detector in the systems, which use the high energy x-ray as the IGRT (Image-Guided Radiation Therapy) and the container cargo inspection, is divided into two type, one of which use the direct conversion method, and the other of which use indirect conversion method[1-4]. The performance of indirect detectors, which use the scintillator as $CdWO_4$, BGO, CsI, NaI, etc., are effected by optical properties of scintillator and geometrical condition of scintillator [4,5]. Some of generated lights by interaction between x-ray photons and scintillator are collected at the photo-sensor and others are absorbed in scintillator or escape out of detector. In order to make the high performance image detector, detector should be able to gather the generated lights as much as possible. To minimize the loss of generated lights, thickness of scintillator is to be chosen appropriately. Therefore, the quality of the image detector using the pixelated scintillator is determined by scintillator size, reflectance of scintillator surface, electric noise, etc.

The $CdWO_4$ is suitable for use as the x-ray converter due to high density, high light yield, suitable refractive index, low afterglow, etc. [5]. So, it is mainly has been used in the detector for the high energy x-ray imaging. In this paper, we calculated the change of acquisition signals according to the change of $CdWO_4$ scintillator thickness using Monte Carlo method.

2. Methods and Results

2.1 Monte Carlo Simulation Model

The simulation process, which is generated lights inside the pixelated scintillator volume, is collected on a photo-sensor as shown in Figure 1, was executed using Monte Carlo N-Particle transport code (MCNP version 6, RSICC, Oak Ridge, TN) and DETECT2000 (Laval University, Quebec) code for x-ray photons and lights transport. In this study, we used the model with a pixelated $CdWO_4$ scintillator. The size of a pixelated scintillator was set to 4×4 mm^2 and thickness was set to various range from 5 mm to 40 mm for Monte Carlo simulation. The density and refractive index of $CdWO_4$ scintillator is 7.9 g/cm^3 and 2.3. Surface condition of

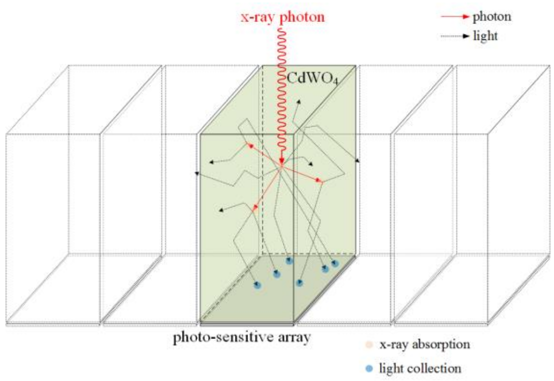

Fig. 1. Schematic of x-ray photon and light transport inside the pixelated CdWO4 scintillator.

scintillator are metallic type surface without light detection planes (bottom plane) as shown in Figure 2. And the reflectance of each plane without light detection plane was set to 96% like other reflection materials [6]. X-ray sources for simulation are mono-energy of 1 ~ 9 MeV. In order to consider the depth-dependent simulation, the scintillator model is filled with sublayers of 10 um. Absorbed energy in each sublayer was calculated using MCNP6. And light collection efficiency on photo-sensor was calculated using the results of transport simulation of a light that is generated in each sublayer. As shown in Figure 3, the number of light was calculated using each simulation results.

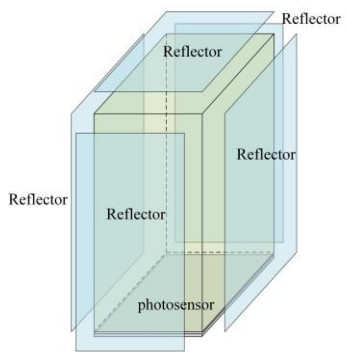

Fig. 2. The surface condition of pixelated scintillator model; all surface without bottom plane is consist of reflector (reflection coefficient 0.95, METAL).

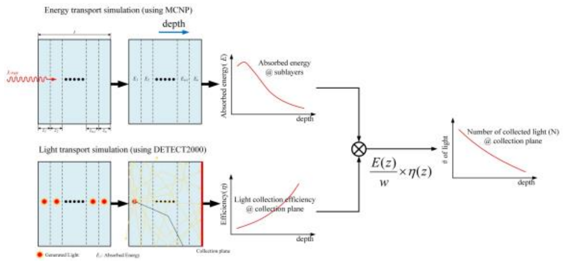

Fig. 3. The calculation process of the number of collected light on photo-sensor using Monte Carlo simulation results.

2.2 Light Collection of Scintillator

Figure 4 presents amounts of collected light on detection plane of scintillators (50 ~ 400 mm thickness) without reflectors on the surrounding plane using mono-energetic x-ray of 1 ~ 9 MeV. As shown in graph, the relationship of the number of collected light and the scintillator thickness is not linear. Optimal point on changing curves is located at thickness range of 1 ~ 2 cm. In the case of scintillator with reflector, the range of optimal point is higher than a scintillator without reflector as shown in Figure 5.

3. Conclusions

In this study, we carried out a study the correlation between the number of collected light and the change of thickness of scintillator using Monte Carlo method. As shown in results, the optimal thickness of a scintillator should be properly selected depending on the incident x-ray energy. In case of without reflector, the scintillator thickness range for x-ray detection is thinner than other cases (with reflector). In the case of a scintillator with reflector, number of collected light and the optima thickness of a scintillator is higher and thicker than scintillator without reflector. Therefore, selection of scintillator thickness depend on x-ray energy and reflector of the scintillator surface.

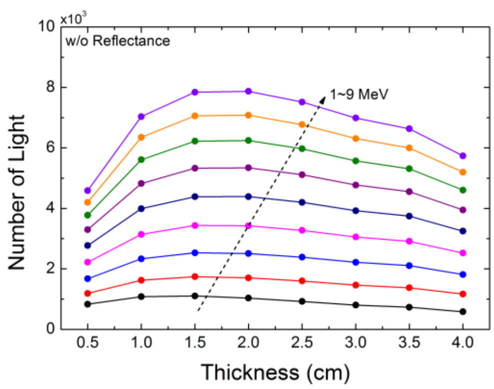

Fig. 4. The changing curve of the number of collected light on detection plane without reflector of scintillator.

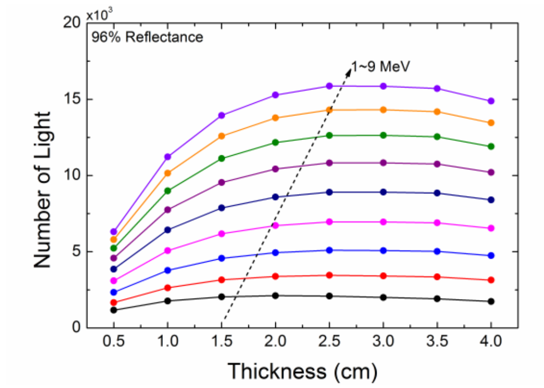

Fig. 5. The changing curve of the number of collected light on detection plane with 96% reflector of scintillator.

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