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Feasibility Study of Diffusion Film for the Light Guide of Gamma Ray Imaging System

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** Short Paper*

Abstract: A light guide improves the spatial resolution of a gamma ray imaging system by diffusing the scintillation light. Similarly, light diffusion film, which has been applied to flat-panel-display engineering, spreads the light from the light guide panel. In this study, we adopted light diffusion film for the light guide of a gamma ray imaging system, and evaluated its diffusion characteristics. We compared the light diffusion performance of the film to an ordinary acrylic plate. As a result, the diffusion film widely spreads scintillation light. As for the thickness of the light guide, we acquired more distinct images with three films overlapped than with an acrylic plate. We expect light diffusion film to be a promising candidate for light guides in gamma ray imaging systems.

Keywords: Diffusion film, Light guide, Gamma ray imaging system

1. Introduction

Two types of gamma ray detectors for nuclear medicine imaging systems are the direct-conversion detector and the indirect-conversion detector. The direct-conversion detector converts incident gamma ray photons directly into electric charge from electron-hole pair. The indirect-conversion detector has a scintillator that converts gamma ray photons to low energy photons, and the converted photons are collected by photodetectors [1]. For this reason, the indirect-conversion detector is called a scintillation detector. A scintillation detector is used in positron emission tomography (PET) and single-photon emission computed tomography (SPECT).

In the scintillation detector, a light guide is located between the scintillator and the photodetector to spread scintillation photons, as shown in Fig. 1. Fig. 1 shows a gamma ray imaging system with a conventional light guide (left), and with the suggested diffusion film light guide (right). When D_1 and D_2 are the distances of the interaction site from the center of the photo-sensor, and when S_1 and S_2 are amplitudes of photo-sensor signal, ideally, the relationship between the two factors is inversely proportional. The concrete formulas are as follows [1].

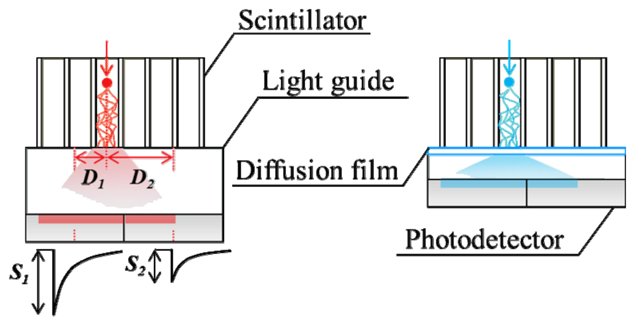


Fig. 1. A simple diagram of the scintillation detector with a conventional light guide (left), and with a diffusion film light guide (right).

$$D_1 \propto (S_2 \times D)/(S_1 + S_2) \quad (1)$$
$$D_2 \propto (S_1 \times D)/(S_1 + S_2) \quad (2)$$
$$(D = D_1 + D_2) \quad (3)$$

Thus, the interacted position is calculated according to the ratio from reacting to the detector. When the scintillation photons create wide diffusion, the accuracy of the interacted position is increased, and dead space of the detector is reduced, so that the spatial resolution of the detector is improved with the light guide [2, 3]. Acrylic

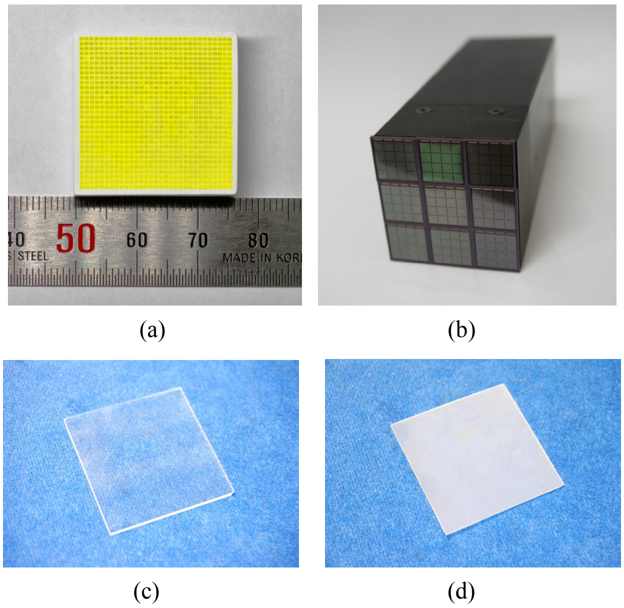


Fig. 2. Detector component (a) Ce:GAGG scintillator, (b) SiPM photo-detector, (c) acrylic plate, (d) diffusion film for the light guide material.

plate and glass of about 1 to 2 mm are generally used for the light guide of a gamma ray imaging system.

In this study, we adopted thin diffusion film for the light guide of the gamma ray imaging system, instead of conventional material like an acrylic plate or glass. Diffusion film was originally designed for light diffusion in light emitting diode (LED) monitors. The thickness of diffusion film is far less than conventional light guides for gamma ray imaging systems, so better performance can be achieved with a more compact detector configuration. The performance of the diffusion film as a reasonable material for a light guide was evaluated and compared to an acrylic light guide.

2. Methods and Materials

2.1 Scintillation Gamma Ray Detector

The gamma ray imaging system consisted of a Cerium-doped Gadolinium Aluminum Gallium Garnet ($Gd_3Al_2Ga_3O_{12}$, further named as Ce:GAGG) scintillator array and a silicon photomultiplier (SiPM) based photodetector, as shown in Fig. 2.

Ce:GAGG has a higher light output and longer emission light wavelength than the generally used Lutetium Yttrium Orthosilicate (LYSO) scintillator. These properties cause a larger signal when coupled to an SiPM, and higher energy resolution, so it is suitable for a gamma ray imaging system [4]. The scintillator array was composed of 31 × 31 Ce:GAGG pixels (Furukawa). The dimensions of each Ce:GAGG crystal pixel were 0.7 × 0.7 × 5mm^3, and the area of the scintillator array was 26.7 × 26.7 mm^2. The reflection material was Barium Sulphate ($BaSO_4$), and it filled 0.1 mm inter-pixel gap.

A MatrixSM-9 (SensL) 12 × 12 pixelated SiPM was used for the photodetector. The size of the detection region was 47.8 × 46.31 mm^2. One SiPM array was composed of 4 × 4 SiPM pixels, and only four arrays were used for the experiments due to the different size of the scintillator array and photodetector. Matrix9, software from SensL, was used for data acquisition.

2.2 Light Guide

The acrylic plate is a common material for the light guide of gamma ray imaging system. In this experiment, 2 mm thick acrylic plate was used to compare performance against diffusion film. It was coupled to the SiPM and Ce:GAGG scintillator using BC630 (Saint-Gobain Crystal) optical grease. It can transmit about 95% of the 280 to 700 nm wavelength light, so it is appropriate for coupling the Ce:GAGG, where the peak emission wavelength is 520 nm [5].

The TDF127 (Toray), a polyester light diffusion film for thin film transistor-light emitting diodes, was used for the diffusion film light guide [6]. It was developed for a light diffusing and bright line shielding as the back light unit of a liquid crystal display. The thickness, haze, and transmittance of one diffusion film are 145µm, 87.5 ± 5%, and 73 ± 5% respectively. The diffusion film was overlapped without optical grease. The light guide shown in Figs. 2(c) and (d) were coupled between the scintillator array and photodetector.

2.3 Experimental Setup

The SiPM and Ce:GAGG were put in an acrylic holder, and covered with a dark box to block out light. We supplied 5 V to the Matrix-EVB communication board, and 39 V to the SiPM module with a constant threshold voltage and bias voltage. We used an acrylic plate and various numbers of overlapped diffusion films as a light guide to compare the light spread level of each state. A Sodium-22 (Na-22) point source (511 keV) was used to evaluate the configured detection system.

2.4 Data Acquisition and Analysis

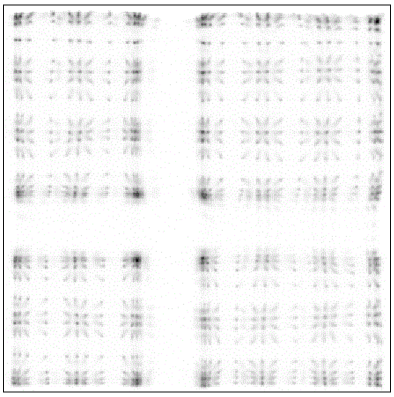
We acquired information about the detected array number, pixel number, and energy using the region-of-interest mode in the Matrix9 [7]. This information was generated in all detector areas, but we used only the data from four arrays on which the scintillator was placed. Weighted Anger logic was applied to localize each detected position. The detection area was regarded as an x-y plane from coordinates -1 to 1. We obtained the flood map images and profile of the distinct pixels. We also created an energy histogram for each light guide condition.

3. Results

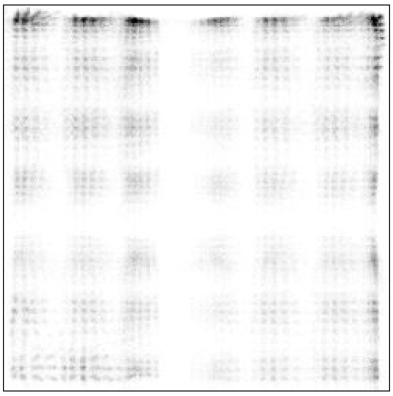
The experimental conditions were standardized in Table 1. The Anger positioned flood map images of each light guide condition are shown in Fig. 3. In the flood map

Table 1. Operating parameters of SiPM.

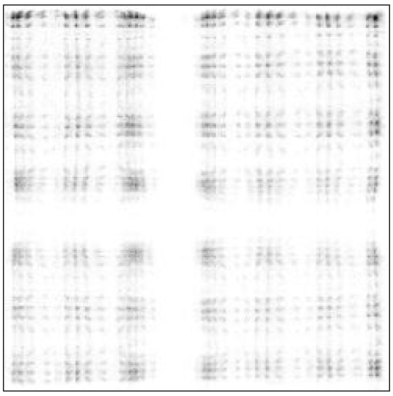
Properties	Values
Bias voltage	31 V
Pixel threshold voltage	0.4 V
Array threshold voltage	0.5 V
Runtime	600,000 ms



(a)



(b)



(c)

Fig. 3. The flood image of the system with (a) no light guide, (b) an acrylic light guide, (c) diffusion film.

image without any light guide, the directional and overlapped pixels are shown. The pixels were distinguished for the conventional acrylic plate light guide. Pixels were most clearly distinguished, while less light loss occurred, with the three diffusion film light guide. The films discriminated the pixels more distinctively than the acrylic plate, especially at the edge.

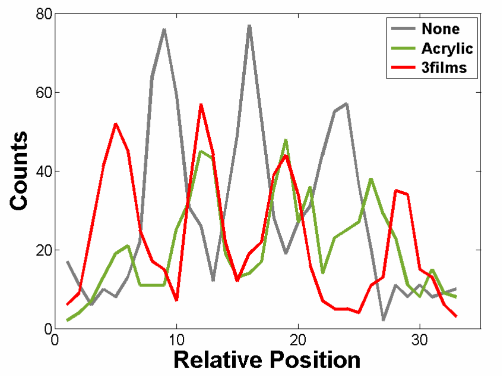


Fig. 4. The profile of four pixels from flood images.

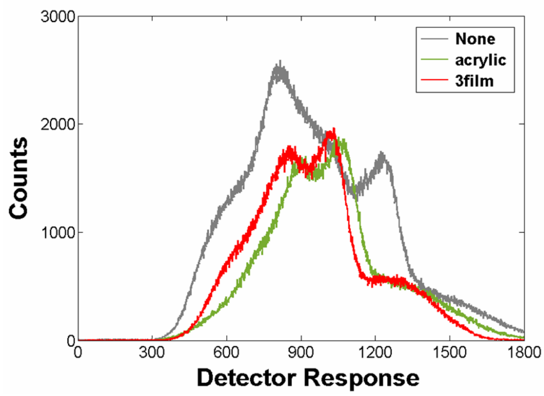


Fig. 5. The energy histogram of the Na-22 point source for each light guide conditions.

Fig. 4 shows the profile of a same four pixels from flood map images. Only three peaks were distinguished without the light guide because of the insufficient light diffusion for positioning the events. The peaks for the three diffusion films were most clear in the profile of the four pixels from flood map images. Four peaks also appeared from the acrylic plate, but the peak values (especially at the edge) were smaller than the peak values from diffusion film.

Fig. 5 shows the energy spectrum of the Na-22 source under each light guide condition. The spectra were similar when the light guide is used, regardless of material.

4. Conclusion

In this study, we evaluated the performance of diffusion film as the light guide for a gamma ray imaging system. The detection system was composed of 0.7 $\times$ 0.7 $\times$ 5 mm^3 pixelated Ce:GAGG crystal, an SiPM photodetector, and a light guide between the two components mentioned above. Various numbers of diffusion films and the conventional acrylic plate were adopted as a light guide.

Under the same experimental conditions, diffusion film offered excellent light diffusion performance, compared to conditions without a light guide and from using the acrylic plate. Because of this diffusion excellence (thin and manageable properties) diffusion film can be an alternative to the conventional light guide, and acceptable in a compact gamma ray imaging system.

The white cross patterns in the flood images were due to the gap between the detector arrays. We can improve the image quality by using a detector with smaller gap. We will perform additional experiments by varying the material of the light guide, and using different kinds of film coupled with optical grease on diffusion film as a light guide.

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References

[1] Simon R. Cherry, James A. Sorenson, Michael E. Phelps, “Physics in nuclear medicine, chapter 13 - The Gamma Camera: Basic Principles”, Elsevier Health Sciences, pp.195-208, 2012.

[2] J. Kang, Y. Choi, K. J. Hong, W. Hu, J. Y. Hwang, H. K. Lim, Y. Huh, S. Kim, K. B. Kim, J. W. Jung, Y. H. Chung, B. T. Kim, “PET Detector Configuration with Thick Light Guide and GAPD Array Having Large-Area Microcells,” IEEE Nuclear Science Symposuim & Medical Imaging Conference, 2010 IEEE, vol.6, pp.2495-2499, Jun, 2010. Article (CrossRef Link)

[3] S. Surti, J. S. Karp, R. freifelder, F. Liu, “Optimizing the performance of a PET detector using discrete GSO crystals on a continuous light guide”, IEEE Transactions on Nuclear Science, vol.47, no.3, pp.1030-1036, Jun, 2000. Article (CrossRef Link)

[4] J. Y. Yeom, S. Yamamoto, S. E. Derenzo, V. C. Spanoudaki, K. Kamada, T. Endo, C. S. Levin, “First Performance Results of Ce:GAGG Scintillation Crystals with Silicon Photomultipliers,” IEEE Transactions on Nuclear Science, vol.60, no.2, pp.988-992, April, 2013. Article (CrossRef Link)

[5] Detector Assembly Materials [Online]. Available: Article (CrossRef Link).

[6] LCD Diffusion Film [Online]. Available: Article (CrossRef Link).

[7] Matrix System User Manual [Online]. Available: Article (CrossRef Link).

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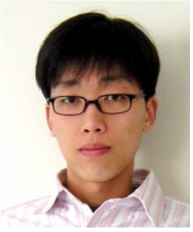

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