Apply the Light Guide to Improve the Light Collection Efficiency of the Gamma Ray Camera

Suyeon Hyeon, Jihwan Boo, Seoryeong Park, and Manhee Jeong*

Nuclear & Energy Dept., Jeju National University, 102 Jejudaehak-ro, Jeju-si, Jeju-do, 63243

**Corresponding author: mhjeong@jejunu.ac.kr*

INTRODUCTION

- Coded-aperture imaging (CAI) systems are being developed for environmental monitoring and nuclear safety. In particular, portable devieces can be used effectively in the fields of homeland security and the application of nuclear plants.
- Cerium doped Gd2Al2Ga3O12 (GAGG(Ce)) has a relatively high density (6.63 g/cm3), excellent energy resolution, and high light yield (50,000 photons/MeV).
- Silicon photomultiplier (SiPM) operates at a lower voltage than conventional PMT and can be compacted.
- GAGG(Ce) pixel does not exactly match the SiPM sensor, the light generated in the scintillator may be lost to the gap area between the SiPM pixels, and the leaked light may react with the adjacent pixel to cause problems due to optical cross-talk.
- We conducted to apply a light guide to improve light collection efficiency and reduce optical cross-talk between adjacent SiPM pixels. We compared the gain, energy spectrum, angular resolution, and image quality based on the application of the light guide.

MATERIALS AND METHODS

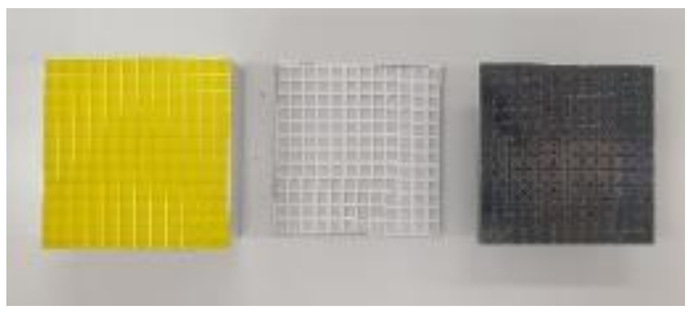
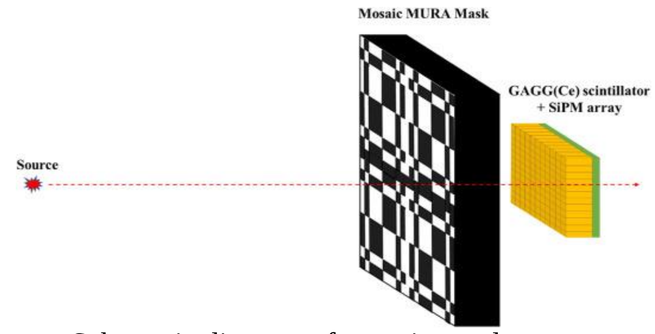


Image of the GAGG(Ce) (left), light guide(center), and SiPM(right) used in the experiment.

Light guide side view and parameters.

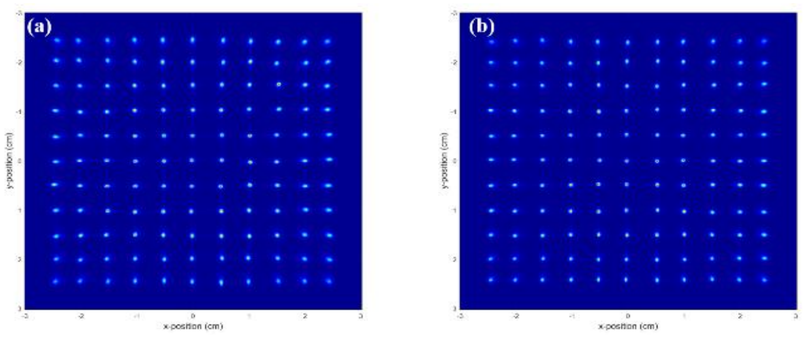
❖ Main parameter of the components.	
Scintillator pixel size	4 x 4 mm^2
Detector pixel size	3 x 3 mm^2
Detector pixel gap	1.2 mm
Mask pixel size	0.42 x 0.42 cm^2
Mask material	Tungsten (ρ = 19.3g/$cm^{3)}$



Schematic diagram of experimental setup

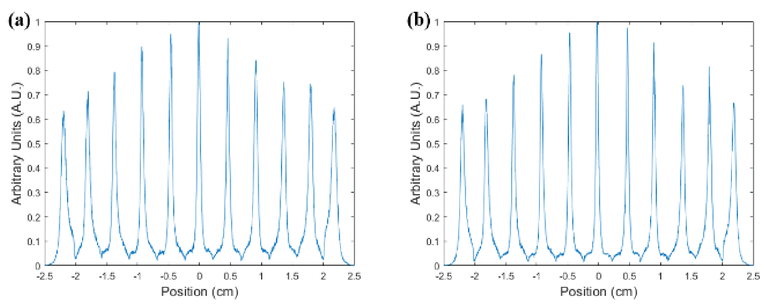
RESULTS

❖ 2D flood map



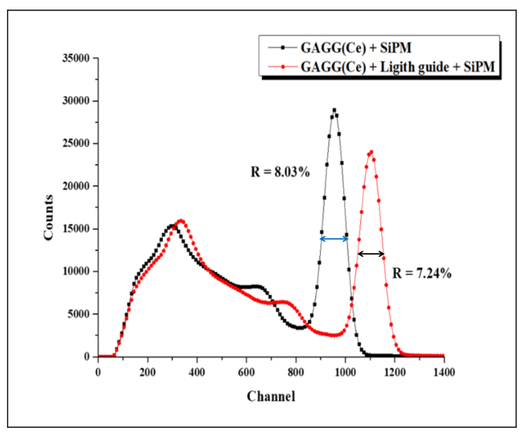
The image of the 2D flood map of the array coupled without the light guide (a), and with the light guide (b).

❖ 1D- sum profile



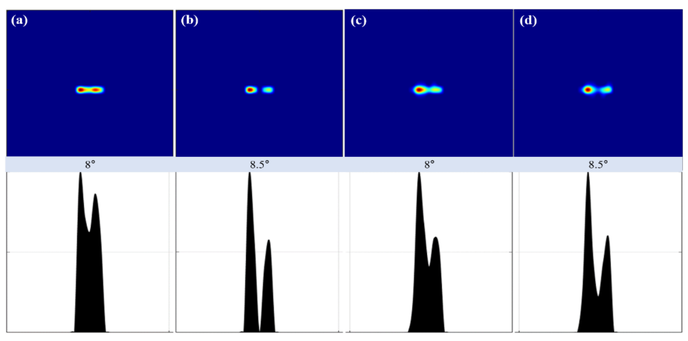
The image of the 1D-sum profile of the array coupled without the light guide (a), and with the light guide (b).

❖ Energy spectrum



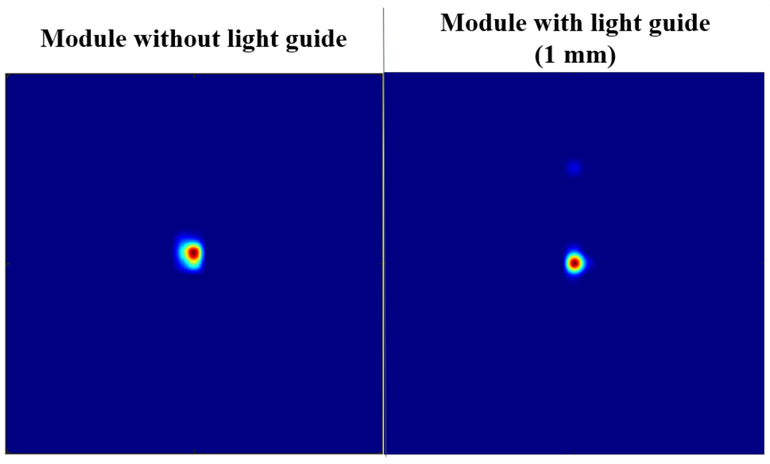
Comparison of energy spectrum according to light guide application.

❖ Angular resolution



Reconstructed images when light guide is not applied are (a) and (b), and (c) and (d) are the images when ligh guide is applied.

❖ Comparison to Image quality



Reconstructed image for a point source of ^{137}Cs at a distance of 0.5 m.

❖ Comparison of metrics for image quality evaluation.

	GAGG(Ce) + SiPM	GAGG(Ce) + light guide + SiPM
PSNR	28.49	39.28
NMSE	9.07×10^{-4}	1.04×10^{-4}
SSIM	0.9157	0.9824

CONCLUSION

In this study, the effects of the light guide combined between scintillator and SiPM array to increase the amount of light collection efficiency was investigated. By applying light guide, we confirmed that it can improve energy resolution with increasing amount of light, and improve metrics of quality for reconstructed images. It was confirmed that the gain increased by 16.03% on the energy spectrum due to an increase in the amount of light collected while the light guide was applied. Also, when comparing PSNR, NMSE, and SSIM values for the images reconstructed between the module without the light guide and the module coupled with the light guide, it was determined that an improved image was obtained.

ACKNOWWLEDGEMENTS

This work was partly supported by Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (MOTIE) (20181520302230) and by the Nuclear Safety Research Program through the Korea Foundation of Nuclear Safety (KoFONS) using the financial resource granted by the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea (No. 1903011-0119-CG100).

REFERENCE

[1]Manhee Jeong, Benjamin Van, Byron T.Wells, Lawrence J.D'Aries, and Mark D. Hammig, Scalable gamma-ray camera for wide-area search based on silicon photomultipliers array, American Institute of Physics, 2018.

[2]Joshi, S., Coded Aperture Imaging Applied to Pixelated CdZnTe Detectors, Ph.D. Thesis, University of Michigan, 2014.

[3]Keigo Hirakawa, CROSS-TALK EXPLAINED, IEEE International Conference on Image Processing, p. 1, 2008.

[4]H.-C. Liang, M.-L. Jan, W.-C. Lin, S.-F. Yu, J.-L. Su and L.-H. Shen, Development of an LYSO based gamma camera for positron and scinti-mammography, p. 1, 2009.

[5]Seoryeong Park, Jiwhan Boo, Mark Hammig, Manhee Jeong, Impact of aperture-thickness on the real-time imaging characteristics of coded-aperture gamma cameras, Nuclear Engineering and Technology, Volume 53, Issue 4, Pages 1266-1276, 2021.