Large-Area Compton Camera for Three-Dimensional Imaging of Radioactive Contamination in Concrete

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1. Introduction

A Compton camera provides distribution of gamma-ray sources by confining the location of the sources to conical surfaces based on Compton scattering kinematics. The camera is theoretically able to provide three-dimensional images using parallax information among the obtained conical surfaces. However, when the source-to-detector distance is farther than the extent of the component detector of the camera, the parallax among the conical surfaces becomes too small to obtain three-dimensional images. Thus, to utilize the parallax information, the extent of the component detectors should be sufficiently large.

In this point of view, a Large-Area Compton Camera (LACC) prototype has been developed in Hanyang University using large monolithic scintillation detectors [1]. In the present study, the developed LACC prototype was tested to demonstrate the three-dimensional imaging capability of radioactive contaminations inside concrete bricks or a wall.

2. Prototype setup

The developed LACC prototype had each plane with a 27×27 cm^2 monolithic NaI(Tl) scintillator (Scintitech, MA, USA) and a 6×6 array of 5×5 cm^2 square PMTs (XP3290; Photonis, France). The thicknesses of the scintillators for the first and second planes were 2 cm and 3 cm, respectively. The first and the second planes were separated by 25 cm. The raw pulses from each detector were collected by the dedicated signal processing circuits and data acquisition system developed in the previous study for a single detector [2].

3. Experimental results

Two measurements were performed with the LACC, to demonstrate the three-dimensional imaging capability. Fig. 1 shows the experimental setup of the two experiments.

Fig. 1. Experimental setup for the experiment using a stack of bricks (left) and a building wall (right).

In the first experiment, a 7.6 μCi ^{137}Cs point source was placed inside a stack of bricks (density: 1.9 g/cm^3). The ^{137}Cs source was located on the axis of the LACC at a distance of 0.3 m. The resulting Compton images were reconstructed by back-projection and maximum-likelihood expectation-maximization algorithm (MLEM). With a 300-second measurement, resulting Compton images were reconstructed as shown in Fig. 2. In the reconstructed images, the location of the sources was accurately localized within the error of voxel size (=0.01 m) of the image space.

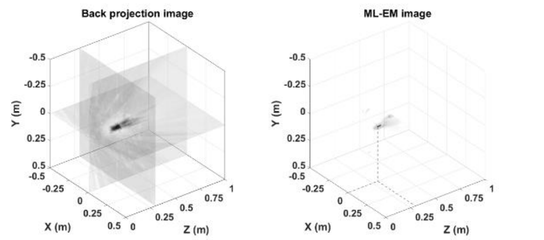

Fig. 2. Reconstructed Compton image by back-projection (left) and MLEM (right) for the ^{137}Cs at (0.0 m, 0.0 m, 0.3 m) inside the stack of bricks.

The second experiment was conducted with a concrete building wall which thickness is about 25 cm. The source-to-detector distance was set to be 30 cm. To demonstrate a multitracing capability of the LACC, a 7.6 μCi ^{137}Cs point source and a 3.0 μCi ^{60}Co point source were placed behind the wall simultaneously. The coordinates of the ^{137}Cs and ^{60}Co sources were (−0.1 m, 0.0 m, 0.3 m) and (0.1 m, 0.0 m, 0.3 m), respectively. The measurement time was 300 seconds. Fig. 3 presents the back-projection Compton images for each radioactive source. The resulting images show that the locations of the both sources were clearly localized at the true source positions. The images also show that there is no significant interference between the two sources.

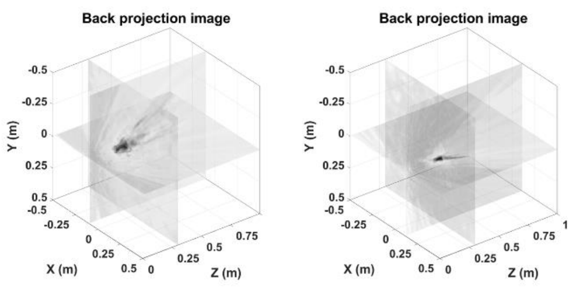

Fig. 3. Reconstructed Compton images for the ^{137}Cs (left) and ^{60}Co (right) behind the building wall.

4. Conclusion

In the present study, the three-dimensional imaging capability of the LACC prototype system was evaluated with various experiments. The results of this study served to demonstrate the great potential of the LACC for the application of the radioactive contamination monitoring, especially hot-spot in a radioactive waste drum or a concrete wall. In the near future, we will conduct various experiments for more realistic cases.

REFERENCES

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