Improving Imaging Resolution of a Table-top Compton Camera for ^{99m}Tc by Using Average Interaction Depth Method

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1. Introduction

Currently, various different types of Compton cameras are under development for different purposes such as γ-ray astrophysics, homeland security, nuclear medicine, and molecular imaging [1-4]. Our group has developed a table-top Compton camera composed of two planar type position-sensitive semiconductor detectors as well as a double-scattering Compton camera [3].

In a previous research [5], the performance of the table-top Compton camera was evaluated for various detector parameters such as Doppler energy broadening in the scatterer detector, discrimination level, and energy and spatial resolutions of the detectors. It was found that the spatial resolution of the absorber detector is the limiting factor for the imaging resolution of the Compton camera system mainly because each center of detector segment was considered as the position at which all of the interactions occur. It was also found that the imaging resolution was significantly deteriorated for low-energy photon sources such as ^{99m}Tc (= 140 keV), which is popularly used in nuclear medicine imaging applications. In the present study, the imaging resolution of the Compton camera for ^{99m}Tc was improved by using the 'average interaction depth (AID) method,' which is previously developed in our research group [6].

2. Methods

A table-top Compton camera is composed of a double-sided silicon strip detector (DSSD, 50 × 50 × 1.5 mm^3), which has 16 orthogonal strips on each side, as scatterer detector and a 25-segmented germanium (25-SEGD, 50 × 50 × 20 mm^3) as absorber detector (Fig. 1). The distance between these two component detectors was 6 cm, and the source-to-scatterer detector distance was also 6 cm. Because the absorber detector has considerably large size of segments (10 × 10 × 20 mm^3) compared to the scatterer detector (3 × 3 × 1.5 mm^3), it is a very rough assumption for the absorber detector that all of the interactions occur at the center of a segment, especially for low energy photons having low penetration power.

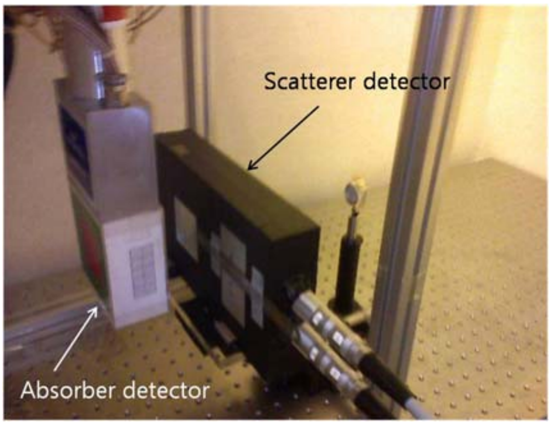


Fig. 1. Table-top Compton camera.

In the present study, the 'AID method' was applied to the absorber detector to improve the imaging resolution of the Compton camera for the low energy photon source, ^{99m}Tc. In the AID method, the depth of an interaction position is estimated based on the previously calculated data of the average interaction depth in the absorber detector, instead of simply taking the central depth (= 10 mm) as the interaction depth.

The Compton camera was modeled in detail, and the Monte Carlo simulation, using the GEANT4 detector simulation toolkit [7], was used to determine the relation between the average interaction depth and the photon energy deposited in the absorber detector. The Compton scatter images were reconstructed by using the simple back-projection algorithm.

3. Results

The average interaction depths as a function of the deposited photon energy in the absorber detector was determined by using 1.1 × 10^5 effective events obtained from a simulation (Fig. 2). Then, the data was fitted using the 3rd order polynomial equation as follows:

$$AID = a + bE + cE^2 + dE^3 \quad (1)$$

where the AID is in cm, E is the energy deposited in the absorber detector in keV. The coefficients of the fitting equation were calculated: a = 12.33, b = -0.354, c = 0.00348, and d = -1.026×10^{-5}. The result shows that the central depth (= 10 mm) is significantly different from the average interaction depth point; note that the maximum average interaction depth was only ~3.5 mm.

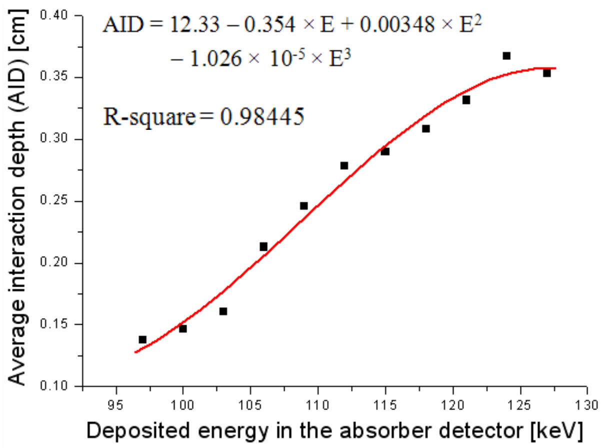
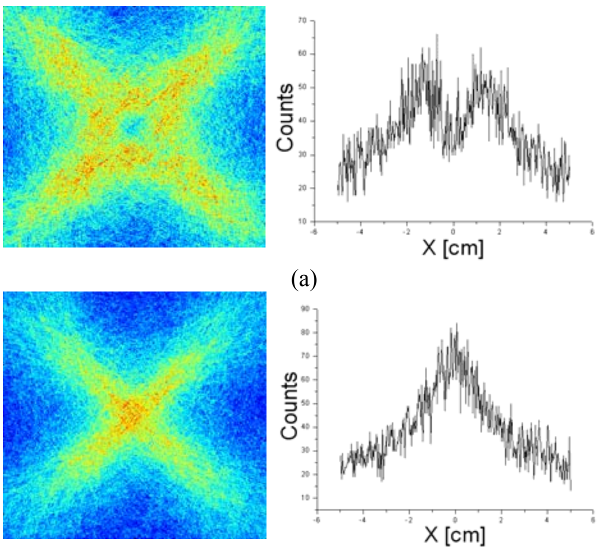


Fig. 2. Average interaction depth as a function of photon energy deposited in absorber detector for ^{99m}Tc. The symbols represent the simulation data, and a solid line represents the 3^{rd} order polynomial fit.

Fig. 3 shows Compton scatter images and its profiles for two different cases: (a) without using the AID method and (b) with using the AID method. It can be seen that the peak of profile is depressed at the central part in case (a), while the peak is dramatically recovered in case (b). These results indicate that the interaction positions in the depth direction should be determined very accurately, especially for low energy photon sources.



(b)

Fig. 3. 2-dimensinal Compton scatter images and their profiles for ^{99m}Tc for (a) without using the AID method and (b) with using the AID method.

3. Conclusions

In the present study, the imaging resolution of a table-top Compton camera was significantly improved by using the AID method. The imaging resolution, however, is still very poor for the low energy photon source ^{99m}Tc and it remains a very challenging issue to further improve the imaging resolution of table-top Compton camera by lowering discrimination level and enhancing energy and spatial resolution of the component detectors.

Acknowledgments

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