Elimination of Background Radiation Using a BGO Scintillator for a Subminiature Gamma Camera in Robotic Surgery

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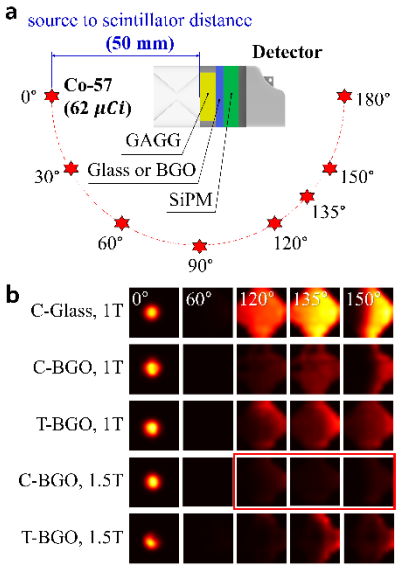
During robot-assisted cancer surgery fluorescence imaging is often used to identify metastatic involvement of nearby tissues, but its reliance on optical contrast limits reliable detection of tumors located deep beneath the surface. For such deeply seated lesions, developed gamma probes (e.g., SENSEI) have started to be employed; however, because they provide only counting information, they cannot intuitively visualize the spatial extent or distribution of the lesions in real time.

To overcome this limitation, we designed a highly compact cylindrical gamma camera ($\emptyset 12\ mm \times 40mm$) tailored for robotic systems and capable of visualizing deep tumors. However, the strict 12 mm trocar diameter constraint makes it difficult to incorporate dedicated lateral shielding structures within the device, leaving the detector vulnerable to radiation incident from the lateral and posterior directions. As a countermeasure, we have previously reported an alternative shielding approach, in which the conventional light guide is replaced with a BGO-based phoswich assembly that exploits its high gamma attenuation capabilities [1]. The impact of BGO geometry and thickness on performance was examined using three detector variants: a standard cylindrical glass light guide (C-Glass), a cylindrical BGO phoswich (C-BGO), and truncated-cone BGO phoswich (T-BGO).

Experimental results showed that the C-Glass configuration exhibits pronounced background sensitivity to gamma rays incident from roughly 120°-150°, whereas the BGO-based designs suppress background counts in this angular range by about 75%. Under frontal irradiation at 0°, the BGO phoswich detectors maintained signal levels comparable to those of the C-Glass design, and image analysis confirmed substantial background reduction around 135°, previously identified as the most vulnerable direction. Collectively, these results support the use of a BGO-based phoswich as a dual-purpose component that provides both light guiding and effective shielding in a miniaturized robotic gamma camera. Ongoing repeated experiments are being performed to investigate the effects of scintillator-related parameters, such as thickness and assembly tolerance, on the detector performance.



(a) Detector configuration and placement of the point source from the detector front (0°) to the back (180°), (b) imaging results, indicating that the C-BGO 1.5T provides the most effective performance for lateral gamma rays.

1. M. Park et al., "Gamma-ray Probe Endoscope using Phoswich Structure & Pulse Shape Discrimination System," 2024 IEEE NSS MIC RTSD, 2024, pp. 1-1.

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