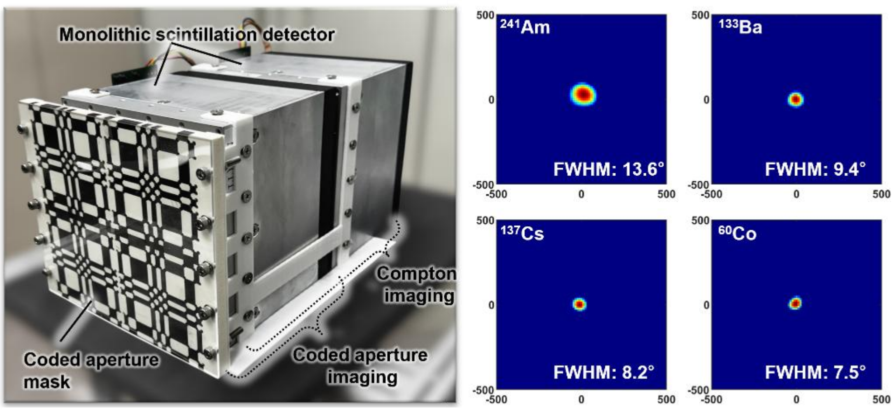
pFGI: A High-Sensitivity Portable Fast Gamma Imager Using Large-Area Monolithic NaI(Tl) Scintillation Detectors

Goeun Lee[1], Junyoung Lee[1], Taehyeon Eom[1], Jaeho Cho[1], Sehyun Jang[1], and Chan Hyeong Kim[1*]

[1]*Department of Nuclear Engineering, Hanyang University, Seoul, Republic of Korea*
Corresponding Author Email: chkim@hanyang.ac.kr

Portable gamma-ray imaging systems offering high imaging sensitivity and adequate resolution over a broad energy range are recognized as highly useful tools for applications in environmental remediation and nuclear industry in general [1]. While imaging systems using semiconductor detectors offer superior portability, they suffer from limited sensitivity due to their small sensor volume [2]. To address this issue, a high-sensitivity portable gamma-ray imaging system, named the portable Fast Gamma Imager (pFGI), was developed using two monolithic position-sensitive NaI(Tl) scintillation detectors and a tungsten collimator mask. Each detector consists of a monolithic NaI(Tl) crystal measuring 14.6 × 14.6 × 2.5 cm³, optically coupled to a 3 × 3 array of square-type photomultiplier tubes. Two detectors separated by 16 cm are used for Compton imaging (CI). The mask is made of 6 mm-thick tungsten blocks assembled on a polyvinyl chloride foam panel, following a 2 × 2 mosaic of rank 19 modified uniform redundant array (MURA) pattern. The mask is positioned 4.2 cm from the front detector for coded aperture imaging (CA). To achieve high imaging sensitivity and adequate resolution across a wide energy range, a hybrid imaging method combining CI and CA modalities was employed for all gamma rays, regardless of their energies. The system's performance was evaluated under several source conditions. The pFGI showed good imaging resolution (<14° FWMH) over a broad energy range (59.6–1,332 keV). Furthermore, it also demonstrated exceptional imaging sensitivity, successfully imaging a 235 μCi ^{137}Cs source located 20 m away in 2 min. This performance is notable given that the dose rate due to the presence of the ^{137}Cs source was only 0.0015 μSv/h at the front surface of the system, which corresponds to ~1.5% of the background radiation level. The performance suggests potential to expand the applications of gamma-ray imaging in many areas including nuclear remediation, decommissioning, and long-range source localization in industrial environments.



The developed pFGI (left) and reconstructed hybrid CI/CA images for different nuclides (right)

1. L.E. Smith, Z. He, D.K. Wehe, G.F. Knoll, S.J. Wilderman, "Design and modeling of the hybrid portable gamma camera system," *IEEE Trans. Nucl. Sci*. 45, 963 (1998).
2. Iltis, A., Snoussi, H., Magalhaes, L. R. de, Hmissi, M. Z., Zafiarifety, C. T., Tadonkeng, G. Z., & Morel, C. "Temporal Imaging CeBr3 Compton Camera: A New Concept for Nuclear Decommissioning and Nuclear Waste Management," *EPJ Web of Conferences*, 170, 3 (2018).