

A prototype coded aperture imaging-based radiation localization and identification system

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Gamma imaging is an effective tool with wide range of applications including homeland security, medical diagnostics, decommissioning of nuclear facilities and in nuclear emergencies. It relies on position-sensitive detection techniques to reconstruct the spatial distribution of incident photons with high efficiency and energy resolution. Typical detector technologies employed include various scintillator crystals coupled to photomultiplier tubes or SiPMs, as well as semiconductor detectors such as CdZnTe (CZT) and high-purity germanium (HPGe).

In this work, a prototype Coded Aperture Imaging based Radiation Localization and Identification System (RLIS-CAI) is developed using a 22 x 22 pixelated CZT detector module having a granularity of 2 mm x 2 mm and with a typical energy resolution of ~3 % at 662 keV (Cs-137). The encoded mask has been built using a Tungsten-Nickel (W-Ni, W>90%) alloy-based rank-11 mosaic MURA (Modified Uniformly Redundant Array) pattern.

The feasibility of the prototype system was established through a Geant4 based simulation framework. The geometry of detector-mask-source planes and the spacings among these were optimized based on the simulation results. A Python based custom data acquisition, analysis and user interface software was developed and integrated with this system to acquire multi-pixel ADC-histogram spectrum and perform energy calibration along with heat-map, reconstructed image display. The image reconstruction is based on the balanced correlation and expectation maximization algorithms to accurately localize the gamma-source from the encoded image at the detector plane. Further, a precision mechanical enclosure for the CZT detector module was developed with a provision of holding self-supporting, stackable W-Ni based coded masks of varying thickness. The prototype RLIS-CAI system was tested for accurate identification and precise localization of the laboratory gamma sources (Ba-133, Na-22, and Cs-137) with an approximate angular resolution of ~ 4.6 degree over the field-of-view (FOV) of ~ 44 degree.

This paper details the development and test results of the prototype RLIS-CAI System.

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