Design and Calibration of Large Field of View Dual-particle Time-Encoded Imager Based on Depth of Interaction Detector

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Global concern for the illicit transportation and trafficking of nuclear materials and other radioactive sources is on the rise, with efficient and rapid security and non-proliferation technologies in more demand than ever. This issue highlights the importance of the effective control of nuclear and radiation materials at national and international cross points such as borders, ports and airports. Time-encoded imaging could be useful for searching potential radioactive sources for preventing illicit transportation and trafficking of nuclear materials.

A 2-D, dual-particle, time-encoded imager based on depth of interaction (DOI) detector was developed for gamma-ray and neutron source imaging. The imager mainly consists of a central detector, a cylindrical coded mask and a drive unit. An EJ276 plastic scintillator (Size: Φ3 cm×15 cm) couple to two silicon photomultiplier was designed as a depth of interaction detector for neutrons and gamma-rays. The position resolution of the DOI detector was approximately 4.4cm. The cylindrical coded mask consisted of the polyethylene (PE) and brass to shield the fast neutron and gamma-ray. The thickness of the brass for gamma-ray modulation and PE for fast neutron modulation was 0.9 cm and 6 cm, respectively. The order of the mask was 61×19 and the open fraction was about 50% (589 mask elements and 570 apertures). The height of each layer was about 1.63 cm. For easy processing, the 19 layers of mask designed to be identical according to the Uniform Redundant Array (URA). Each layer is rotated at different angles (horizontal unit) from each other, randomly. The cylindrical mask was fixed on a rotation table and driven by a step motor.

The response function of the time-encoded imager was simulated using MCNP 5. In the simulation, the horizontal and vertical field of view range was 0°~360° and -60°~60°, respectively; the neutron and gamma-ray sources were set as Cf-252 and Cs-137 at three meters from the detector. The classical Maximum Likelihood Expectation Maximization (MLEM) method was used in image reconstruction. The ‘multi-detector’ filtering method was proposed to denoise for this imager. The rotation speed of the mask was set as 200 s/ revolution during the measurement. A Na-22 gamma-ray source was placed in different position to determine the field of view (H: 0°~360°; V: -55°~55°); A shielded DT neutron source at 20.4 meters standoff was detected to verify the performance of the imager. The source could be located within 2400s (Approx. 2800 counts) and the angular resolution was better than 3.5°.