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#7-196 NANOPIX3: a compact multimodal gamma spectro-imager for enhanced imaging

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Across nuclear sectors, localizing, visualizing and identifying radioactive objects is crucial for security and safety. With uses ranging from waste management and decommissioning to nuclear medicine and homeland security, finding so-called radioactive hotspots has been at stake for many decades. For over thirty years, CEA List has been working on compact and miniaturised gamma imaging systems based on semiconductor hybridised pixelated detectors from the Medipix collaboration, Timepix, and developed the Nanopix gamma camera prototype, today used in the field. This system uses a MURA rank 7 coded aperture and a sensitive area of about 2 cm^2 for 1 mm thick. However, despite its performance, the system lacks a spectroscopic information and has a narrow field of view (44°) that can interfere with real-life conditions. In a scene with multiple radioactive sources of various energy ranges and activities, some hotspots can easily be overshadowed by the intensity of others while some, located further than the field of view, will not be localised at all.
Recent developments using a newer Medipix technology, Timepix3, gave birth to a new prototype of the most compact and miniaturised coded-aperture spectro-imaging system in the world, Nanopix3. Nanopix3 is composed of a Timepix3 detector and a rotating coded-aperture managed by two micro-motors. While the former technology only gave access to information about the position and the time of interaction or about the energy deposited in a synchronous way, the latest gives simultaneously access to all three values as a continuous flow of data. This difference in operation allows Nanopix3 to couple different modalities of imaging: coded aperture imaging and Compton imaging. Pairing both techniques brings the advantages of both into a single camera while minimising their respective drawbacks. Reconstructing hotspots images in coded-aperture modality can be tricky if the source is located on the edge of the fully coded field of view (FCFOV) of the camera. In this area, called the partially coded field of view (PCFOV), hotspots will be reconstructed as well as artefacts, or ghost sources, that appear mathematically during the reconstruction of the image. Late studies have shown that it is possible to extend the size of the reconstructed gamma image to include both the PCFOV and FCFOV, which eventually, provide to the camera a much wider field of view in coded aperture modality. Still, this method does not help distinguishing the real source from the so-called ghost one. The use of Compton imaging comes as a decision support by providing localisation information on a field of view of 2π sr. We tested Compton imaging in laboratory conditions and were able to reconstruct Ba-133, Na-22, Cs-137 and Co-60 radionuclides. In a complementary way, bringing spectroscopic information into the measurement, thanks to spectroimaging, helps to identify gamma-emitting radioisotopes by analysing their specific spectral signature. Timepix3's spectroscopic abilities make it possible to reconstruct energy peaks up to 1.5 MeV and laboratory tests showed an energy resolution of 5.6 keV (9.4 %) at 59.5 keV for Am-241, 27.24 keV (4.1 %) at 661.7 keV for Cs-137 and 47.4 keV (3.5 %) at 1.332 MeV for Co-60 using a 1 mm thick CdTe semiconductor hybridised Timepix3 chip. Reconstructing hotspots by taking into account the energy spectrum can reveal some hidden hotspots that were obscured by other sources, providing complementary information about the different elements in a scene. With up to four different radionuclides in a single measurement in laboratory conditions, it is possible to identify each hotspot independently. Nanopix3 will also be tested on the field in forthcoming measurements.
Overall, the development of Nanopix3 provides a solid foundation for the future of compact gamma imaging systems, offering enhanced and more complete analysis to end users by performing spectro-imaging in two different modalities, coded aperture imaging and Compton imaging, and responding to the ever-increasing need for safety and security in the nuclear industry.

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