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Performance of a novel gamma-ray imager for nuclear security applications

Gamma-ray and neutron imaging technologies have many potential applications in nuclear security, safeguards, waste management and decommissioning. In particular, gamma-ray imaging enables one to remotely locate, identify, and quantify gamma emitting radionuclides, including; Naturally Occurring Radioactive Materials (NORM), industrial, medical or special nuclear materials (masked or shielded). These technologies can provide crucial information for the development of an efficient decommissioning plan, a survey of an area at a nuclear facility and a secondary inspection of a passing cargo at border crossing, amongst other applications. There are varying types of imagers, each one with its own capabilities, strength and weaknesses namely coded aperture imagers, Compton imagers and compressive imagers with rotary masks. Gamma-ray imaging can be made with technologies that have different capabilities such as energy resolution and efficiency, and many of our applications may demand one or the other characteristics. For example, a high resolution detector such as an HPGe (Hyperpure Germanium) can only be grown and produced in small sizes crystals and thus would have lower efficiency compared to large volume but lower resolutio NaI (Sodium Iodide) detectors. Depending on the radiation field and situation to be investigated and imaged, one would need to use one imager type or another and sometimes several. The development of a good graphical user interface, software for spectral analysis and decision making, are also important aspects when considering radiation imaging technologies.
Previously, twelve imaging technologies were demonstrated and tested for safeguards application during a workshop organized by the IAEA at the Seibersdorf laboratories in 2015, from which a report was drafted by the Joint Research Centre (JRC). In the field of nuclear security, and within the technical subgroup of the Border Monitoring Working Group, the JRC organised a week long measurement campaign (in May 2017) to assess the capabilities and performance of five different gamma-ray imagers in a number of nuclear security scenarios. It was shown that systems could not easily be comparable as they had quite different performance capabilities. Earlier from 2012 to 2014, within an EU funded project (SCINTILLA), a CZT based gamma-ray imager was tested at the JRC as part of a tool box to develop systems for the detection of difficult to detect nuclear and radioactive materials as well as He-3 free radiation portal monitors. All of the above activities and projects, and many others, have shown good progress in the maturity of the gamma-ray imaging technologies, developed initial testing procedures/assessments and thus contributing to technology development and innovation.

This paper describes the performance of a gamma-ray imaging system that satisfies some if not most of the above requirements for use in nuclear security particularly, but also in nuclear safeguards and decommissioning. In essence, the system is based on the theory of compressed sensing and employs rotary masks that perform compressive measurements and considerably reduces the number of measurements (and time) required to reconstruct an image. The described imager can image a wide energy range over a wide field of view. Emphasis will be given to nuclear security applications to combat the illicit trafficking of nuclear materials and other radioactive sources out of regulatory control. The development of testing and assessment procedures for imagers, which would lead to better standardisation as performed within the ITRAP+10 project for all available families of radiation detection instruments, shall also be reported on.

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