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#11-45 Development of new acquisition techniques for portable gamma-ray imaging

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Portable gamma-ray imaging is an emerging field in nuclear instrumentation, with applications in radiation safety, waste management, decommissioning, environmental and security applications. It provides users with a single portable instrument to detect, identify and localize radioactive material. Most imagers are based on position sensitive spectrometric detectors, including scintillators (NaI, CsI, GaGG) associated with small photodetectors (SiPM, APD) or semiconductors (HPGe, CdTe, CdZnTe). Intrinsic qualities of a detector are its sensitivity and its spatial and energy resolution. Compactness and robustness are also key criteria for achieving portability. In our system, named NuVISION, we chose to use CdZnTe (CZT) detectors, a room-temperature semiconductor whose properties are well suited for medium energy photons (few hundreds of keV).
Existing gamma imagers are also based on various imaging techniques. Among them, most popular are pinhole collimators, coded aperture masks and Compton imaging. Each kind of imaging technique has its own strengths and weaknesses.
• Pinhole imaging has low efficiency and narrow field of view but good contrast, good angular resolution and ability to work at very high fluxes.
• Coded aperture imaging has a high efficiency and good angular resolution but a limited field of view, poor contrast and less tolerance to high fluxes.
• Compton imaging is efficient for high-energy photons and provides a large field of view but often has a poor angular resolution and low tolerance to high fluxes. For designing a gamma-ray system, we face many tradeoffs as the various applications addressed have conflicting requirements in dose rate (from nSv/h to Sv/h), field of view (up to 4pi steradians), angular resolution (down to few degrees), type of object (point source or complex shapes). The solution we have investigated is to combine several techniques i.e. use coded aperture and Compton imaging simultaneously. Their good complementarity is a way to get more flexibility. To cover high dynamic ranges in count rate, gamma-ray imagers can switch between several acquisition modes: event-by-event list mode, photon-counting image mode acquisitions with or without spectrometry or even integration mode imaging for dose rate above Sv/h.
Beyond instrument specification, the concept of usage may depend on application. The most common way of working with gamma ray imagers is to perform a long exposure static acquisition on a tripod. However, other needs have emerged: surveillance or monitoring of an area with moving vehicles or pedestrians, embedding on a ground robot or drone, hand held source search and area survey.
To fulfill such requirements we have developed for the NuVISION imager a toolkit of acquisition techniques that we will present.
This gamma imager is composed of a 10 to 16-cm^3 CZT
3D position sensitive segmented detector, a highly integrated readout and a FPGA/CPU based processing and control platform, peripherals (inertial sensors, telemeter, visible camera, etc.). The operating energy range is from 20 to 1400 keV. Coded aperture works on the full range. Angular resolution is typically 2.5° and results mainly from mask pattern used. Compton imaging can only work above about 300 keV. Its angular resolution improves with energy and is around 10° at 662 keV. It results from the combination of Doppler broadening effect with detector spatial resolution and energy resolution.
The coded aperture and Compton imaging operate simultaneously. In particular, the Compton imaging, that is capable of detecting a source from any direction is used to constraint coded aperture reconstruction and avoid artefacts due to out-of-field sources.
Our imager works in three main modes:
• Static acquisition, using a fixed acquisition set-up.

• Scan mode, using a pan/tilt mount to acquire data on a field larger than actual mask field of view.
• Dynamic mode, for mobile set-ups.

In particular, we have developed a motion compensated dynamic imaging technique that enable to use the camera as an handheld device, embedded on a vehicle or conversely, to follow activity of mobile objects, even with weak sources requiring 10 seconds to be localized. We applied this technique to area monitoring for security, by integration inside a videosurveillance system.

Real life examples from the field will be presented for applications in radiation safety, decommissioning and security.

These evaluations show the potential of having in a single hardware platform combining imaging and spectrometry, enabling with appropriate software to build a smart and versatile tool for radiation instrumentation.

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