3D Position-Sensitive Semiconductor Detectors for Nuclear Fuel Imaging

Mounia Laassiri[1,*], Vikram Rathore[2], Matti Kalliokoski[1], Peter Andersson[2], Peter Dendooven[1]

[1]Helsinki Institute of Physics, University of Helsinki, Gustaf Hällströmin katu 2, FI-00014 University of Helsinki Finland
[2]Department of Physics and Astronomy, Uppsala University, Lägerhyddsvägen 1, 751 20 Uppsala, Sweden
*Corresponding author, mounia.laassiri@helsinki.fi

The Passive Gamma Emission Tomography (PGET) device was approved by the IAEA for spent nuclear fuel safeguards inspections at the end of 2017 resulting from the JNT 1510 project. It is based on a collimator, consisting of a linear array of narrow slits with a pitch of 4 mm, with a relatively small CZT (cadmium-zinc-telluride) gamma ray detector behind each slit [1,2]. The detectors have a good energy resolution, enabling them to collect tomographic data in 4 user-defined energy windows. Because of the small detectors, the probability that a gamma ray is fully absorbed, providing ideal imaging information, is small. Large CZT detectors would have a higher probability for detecting the full energy of gamma rays, increasing the sensitivity and image quality (in terms of statistics and contrast-to-noise ratio) of the PGET device. However, a large CZT detector would cover more than one collimator slit, requiring position sensitivity to determine through which slit a gamma ray travelled in order to maintain image spatial resolution. In addition to utilizing the position sensitivity along the direction of the collimator, which gives transaxial position information, we are investigating to what extent Compton imaging can provide information on the origin of a gamma ray along the axis of a spent fuel assembly (SFA). This opens the prospect of creating 3D images with the PGET device in a single axial position, adding axial information to the current 2D transaxial images. The imaging detector technology being developed is also useful for other than safeguards applications, such as the non-invasive post-irradiation examination of nuclear fuel to characterise its important properties [3].

We are studying the performance of a PGET device that uses state-of-the-art 3D position-sensitive semiconductor gamma ray detectors. CZT and germanium detectors are being considered. A Monte Carlo (MC) model of the PGET device was set up using the Geant4 framework. The MC model was used to simulate the performance of both large position-sensitive CZT detectors and small CZT detectors as installed in the PGET device. The performance of these detectors was compared. Tomographic measurements with a position-sensitive germanium detector and rod-shaped Cs-137 sources mimicking spent fuel were performed at Uppsala University. Compton imaging was demonstrated with a germanium imaging spectrometer and a Cs-137 point source at the University of Helsinki. The status and prospects of the project will be reported.

Keywords: passive gamma emission tomography, PGET, CZT detector, Compton imaging, spent fuel

References:

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This work is financially supported by the Swedish Research Council, grant number 2017-06448, by the Swedish Foundation for Strategic Research, grant number EM-16-0031, and the forum for Nordic Nuclear Safety, grant number NKS_R_2022_136.