LAWRENCE LIVERMORE NATIONAL LABORATORY

LLNL-TR-730135

Characterization of a spectroscopic detector for application in x-ray computed tomography

A. A. Dooraghi, B. J. Fix, J. A. Smith, S. G. Azevedo, W. D. Brown

April 27, 2017

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Characterization of a spectroscopic detector for application in x-ray computed tomography

Alex A Dooraghi, Brian J Fix, Jerel A Smith, William D Brown, Stephen G Azevedo, Harry E Martz

Recent advances in cadmium telluride (CdTe) energy-discriminating pixelated detectors have enabled the possibility of Multi-Spectral X-ray Computed Tomography (MSXCT) to incorporate spectroscopic information into CT. MultiX ME 100 V2 is a CdTe-based spectroscopic x-ray detector array capable of recording energies from 20 to 160 keV in 1.1 keV energy bin increments. Hardware and software have been designed to perform radiographic and computed tomography tasks with this spectroscopic detector. Energy calibration is examined using the end-point energy of a bremsstrahlung spectrum and radioisotope spectral lines. When measuring the spectrum from Am-241 across 500 detector elements, the standard deviation of the peak-location and FWHM measurements are ±0.4 and ±0.6 keV, respectively. As these values are within the energy bin size (1.1 keV), detector elements are consistent with each other. The count rate is characterized, using a nonparalyzable model with a dead time of 64 ± 5 ns. This is consistent with the manufacturer's quoted per detector-element linear-deviation at 2 Mpps (million photons per sec) of 8.9% (typical) and 12% (max). When comparing measured and simulated spectra, a low-energy tail is visible in the measured data due to the spectral response of the detector. If no valid photon detections are expected in the low-energy tail, then a background subtraction may be applied to allow for a possible first-order correction. If photons are expected in the low-energy tail, a detailed model must be implemented. A radiograph of an aluminum step wedge with a maximum height of about 20 mm shows an underestimation of attenuation by about 10% at 60 keV. This error is due to partial energy deposition from higher-energy (> 60 keV) photons into a lower-energy (~60 keV) bin, reducing the apparent attenuation. A radiograph of a PTFE cylinder taken using a bremsstrahlung spectrum from an x-ray voltage of 100 kV filtered by 1.3 mm Cu is reconstructed using Abel inversion. As no counts are expected in the low energy tail, a first order background correction is applied to the spectrum. The measured linear attenuation coefficient (LAC) is within 10% of the expected value in the 60 to 100 keV range. Below 60 keV, low counts in the corrected spectrum and partial energy deposition from incident photons of energy greater than 60 keV into energy bins below 60 keV impact the LAC measurements. This report ends with a demonstration of the tomographic capability of the system. The quantitative understanding of the detector developed in this report will enable further study in evaluating the system for characterization of an object's chemical make-up for industrial and security purposes.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

LLNL-TR-730135