Purpose: One way to greatly reduce the incidence of metal artifacts produced in kilovoltage (kV) CT images is by using megavoltage (MV) photons that penetrate high-Z objects, thus providing a measurable signal. For dose-efficient imaging, a high detective quantum efficiency (DQE) MV detector is desired. This study validates the coupled radiation and optical Geant4 simulation results against experimental data from various prototype pixelated scintillator MV detectors and determines the essential optical parameters which control the detector performance.

Methods: Experimental data obtained with a 6MV radiation source from 8 different detectors was considered. The detectors used CsI, CdW and BGO as scintillating crystals and polystyrene septal wall material. Accurate Geant4 models of the detectors were implemented and coupled radiation and optical simulations were performed. The unknown optical properties of the models were determined by minimizing the difference between the modulation transfer functions (MTF) of the simulated data obtained with the slanted slit technique and the experimental MTFs. With the set of optical properties fixed, further simulation validation was performed against the experimental normalized noise power spectrum (NNPS(f)) and the experimental DQE(f) curves for each detector. All the simulations were performed on a computer cluster deployed on the Amazon EC2 platform.

Results: The optimal values for the free optical parameters are 10%, 95% and 90% for the top surface reflectivity, the crystal-septa surface reflectivity, and the Lambertian component contribution to the reflected beam from the crystal-septa interface respectively. The absolute difference between experimental and simulated data was below 10% for all the data sets.

Conclusions: To our knowledge this study is the first to present a full optical and radiative DQE(f) model using Geant4 that shows an excellent match with experimental data. The model indicates that improved performance can be obtained using more specular septa which are optically opaque.

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