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A feasible study of scintillator-based detectors for PCCT with variance Cramer-Rao Lower Bound(CRLB) in basis material decomposition.

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In the field of clinical Computer Tomograpy(CT), the application of photon-counting detectors(PCDs) is expected to have large potential to bring the next breakthrough for the industry. In recent years, a small number of companies has developed Photon Counting CT(PCCT) prototype scanners equipped with direct-conversion PCDs based on room-temperature semiconductors, such as Silicon, CdTe and CdZnTe (CZT). These room-temperature semiconductors are considered as the most promising materials for PCDs in PCCT. However, specific drawbacks of these direct-conversion detectors are in evidence, such as the occurrence of charge sharing and charge trapping, leading to increasing of the image noise and unstable detector operation state. In addition, high purity semiconductor wafers with a very low defect concentration are required in fabrication process of PCDs, which may negatively affect the cost-effectiveness of production. In this work, we introduced a scintillator-based detector coupled with the CMOS-based photosensor, as an alternative detector technology roadmap for the PCCT medical imaging applications.

To study the feasibility of the scintillator-based PCD, we develop a Monte Carlo simulation framework for the detector evaluation. The framework includes the simulation of detector and ASIC. In the detector simulation, we took into account of the X-ray interactions with detector bulk material, as well as the optical process. In the signal processing simulation of the ASIC, there have a charge sensitive amplifier, a high pass filter and photon counting modules. We subsequently use the framework to compute the expected energy spectrum of a CeBr3-based PCD prototype with sub-mm pixel sizes. According to the experimental result, CeBr3 crystal have a density of 5.1g/cm3, a high light yield of 60000/MeV and a fast scintillation decay time of 20ns. According to the reconstructed spectrum, the scintillation-based detector shows lower energy resolution than the semiconductor-based detector with a same pixel size, but also less the K-edge escaping photon contributions from the adjacent pixels in the spectrum. An analysis of the variance Cramer-Rao Lower Bound(CRLB) in basis material decomposition of single detector pixel is finished with the simulation result. According to our primary estimation, the scintillator-based detectors is proved to have comparative performance of CRLB to Si and CZT detector under a X-ray flux of 50Mcps/mm2.

According to this study, scintillator materials with better energy resolution and faster decay time can significantly improve the CRLB performance of the detector system. In our next plan, more in-depth research will be performed to validate the practical utilization of this technical method, including the material uniformity, hygroscopic property, scintillation property, detector dicing and encapsulation. This work provides evidence that it may be feasible to develop scintillator-based detectors for PCCT that can compete with CdTe and CZT detectors under lower X-ray flux.

Authors: ZHONG, Tao (ShanghaiTech University); LAI, Xiaochun

Co-author: LI, He

Presenter: LI, He

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