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GaAs Photon-Counting Detectors for High-Flux Spectral CT: A Competitive Alternative to CdTe and Si

Since their discovery by Röntgen in 1895, X-rays have played a pivotal role in medical diagnostics. Computed tomography (CT) imaging, in particular, is widely used due to its availability, low cost, high spatial resolution, and rapid image acquisition. Conventional CT systems employ scintillator-based energy-integrating detectors (EIDs), which record only the total energy deposited by polychromatic X-rays without resolving individual photon energies. In recent years, semiconductor-based photon-counting detectors (PCDs) have emerged as a transformative technology in CT imaging. Unlike EIDs, PCDs are based on semi-conductors and photon counting ASICs, can directly convert X-rays into electronic signals, enabling energy discrimination for each single photon. The PCDs offers superior spatial resolution, zero electronic noise, and material differentiation.

Photon-counting CT (PCCT,also known as Spectral CT) represents a major advancement in spectral imaging, leveraging PCDs fabricated from room-temperature semiconductor materials such as cadmium telluride (CdTe), cadmium zinc telluride (CdZnTe), and silicon (Si). However, current PCD technologies face limitations: CdTe/CdZnTe detectors are prone to polarization under high X-ray flux and suffer from non-uniform response, while silicon detectors exhibit low detection efficiency for photons above 20 keV due to their relatively low atomic number, leading to Compton scattering and crosstalk between pixels.

Gallium arsenide (GaAs) has recently gained attention as a promising PCD material due to its excellent charge transport properties and mature fabrication techniques. In this study, we investigate the temporal performance of a chromium-compensated GaAs (GaAs:Cr) detector under typical CT X-ray flux conditions. The detector features a pixelated anode array and a planar cathode, coupled with a photon-counting application-specific integrated circuit (ASIC) for signal processing. Experimental results demonstrate outstanding temporal stability, with output counting rate variations of $(0.017 \pm 0.24)\%$ for 1 s exposures and $(0.018 \pm 0.19)\%$ for 30 s exposures. Furthermore, the GaAs detector maintains stable performance under extremely high X-ray flux without observable polarization, highlighting its potential for robust and high-performance PCCT system applications.

Based on the current evaluation results, we demonstrate that GaAs-based detectors are a feasible and competitive option for PCCT, with potential advantages over existing solutions.

Workshop topics

Applications

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