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Optical detection of ultrafast electrons for applications in Positron Emission Tomography (PET)

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Positron Emission Tomography (PET) is a unique medical imaging modality that can detect the specific chemical tracers within the patient body and is used every day in clinics to detect cancers. Recently developed time-of-flight PET uses arrival timings of the annihilation photon pairs to increase the image quality. Conventional scintillation-based detection, however, poses limits to the temporal variance due to the stochastic diffusion of charge carriers that will result in scintillation photons. In our effort to significantly reduce the temporal variance, or coincidence time resolution (CTR), we seek to use an alternative detection of charge-carrier-induced optical properties modulation, without diffusion time. At SLAC's MeV-UED facility, we used the ultrafast electrons with known arrival timing to induce the changes in the complex refractive index and read out the modulation with optical pulses. By using an interferometric detection method utilizing bi-refringent delays, we report our results obtained from the high bandgap material of ZnTe (bandgap at 560nm). The optical probe wavelength was scanned from 560-690nm, and the modulation strength started at 1.7% which increased to a maximum of 12.7% at 630nm. After 630nm, the modulation decreased to 8.7%, indicating the importance of probe wavelength in maximizing the detected optical modulation. Further characterization of the optical modulation induced by ionizing radiation will bring critical insight into the optical modulation-based radiation detection, enabling ultra-precise CTR for applications in PET.

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