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Perpendicular photonic devices for scintillation detectors

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In the quest for optimized time-of-flight scintillation detectors, an important physical barrier is the statistical variation of photon production, propagation, extraction and detection. While nothing can be done for the isotropic production of scintillation light, we simulate a way to alter propagation and extraction of optical photons from the scintillator, using photonic crystal (PhC) slabs organized in a perpendicular orientation to the photodetector surface. We try different designs using several approaches such as Rigorous Coupled Wave Analysis, Plane Wave Expansion, Guided Mode Expansion and Finite-difference time-domain methods, implemented in proprietary and open-source software. We compare the results of different optical simulations that demonstrate the ability of designed PhC slabs to bend light towards its extraction surface, reducing the propagation modes of light within the scintillator. This reduces the corresponding statistical variation, the main obstacle in achieving superior timing results. These designs are developed using the characteristics of commonly available materials such as Silica (SiO2), Gallium arsenide (GaAs) and niobium pentoxide (Nb2O5) and in dimensions within the machining capabilities of available deposition and printing methods. To investigate the performance of optimized PhC slab design, a domain of hexahedron with dimension of 2.4x2.4x2.1μm has been simulated via FDTD. The lateral energy flux ratio to source radiation has been improved by around 30% for target wavelength of 375nm. Simulated PhC slabs are ideal for soft scintillators, such as organic ones, but can also be applied to standard crystals, and can be used either as separators in pixels or the metascintillator paradigm. Further investigation on the optimized design of PhC slabs is taking place through development of automatic optimization routines, with optimization potential depending on the wavelength and favored incidence angle of the chosen scintillating light.

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