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The extraction of scintillation light from an inorganic scintillator is one of the major bottlenecks in Time-of-Flight Positron emission tomography (ToF-PET) as it directly affects the energy and time resolution of the gamma detector. The most widely used crystal in PET system is LYSO:Ce doped. Having a high index of refraction (IR = 1.82), the amount of light collected to the photo-detector is limited by total internal reflection (TIR): For crystals with high aspect ratios, as the ones used in PET scanners, up to 50% of the scintillation light will not be collected, even if Teflon wrapping and optical coupling are used. Photonic crystal slabs (PCS), defined as thin dielectric layers structured with a 2D or 3D periodic pattern, offer the possibility to increase this efficiency. A higher light output, combined with a reduction of the average path length of the photons in the crystal before their extraction, leads to a more precise evaluation of the particle time detection. This also implies a better coincidence time resolution (CTR). Together these will translate to ToF-PET reconstructed images with a better signal to noise ratio, which will lead to a better diagnosis, faster exams, and the possibility to reduce the patient dose.
For our application, PCS need to be as well as an optical layer that is transparent for the emission spectrum of the LYSO. We have developed the nano-fabrication technology needed to realize the required large nanostructures needed to cover the scintillator readout face. This layer, when applied to the scintillator, helps overcome the TIR due to diffraction effects.
Here we present our work focused on the simulations of the PCS parameters in order to optimize this effects. Using two different simulation tools, GEANT4 and CAMFR, we were able to take into account the geometry and configuration of the crystal to treat (wrapping, coupling, photo-detector, etc.). Optimization has been performed to find the best PCS pattern for a large variety of configurations. For the first time we produced centimeter size specimens patterned fully. We will present the results for LYSO that show a gain in light yield with respect to the same configuration without the PCS. Preliminary results shows also better performances from both the light yield and the timing point of view. In-depth analysis is currently underway. Details on the simulation steps, production process and characterization of the PCS will be presented.
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