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Metascintillators: a new approcah in radiation imaging

In the last years, new solutions in both hardware and software have resulted in significant improvements in effective sensitivity in Positron Emission Tomography (PET). This improvement is mainly achieved by increasing the thickness of the gamma detectors (reducing time and spatial resolution), increasing the number of detector rings (increasing the economic cost) or developing gamma detectors based on faster scintillators with improved electronics. The third option
is related to the potential of adding TimeOf-Flight (TOF) information on the event characterization.
TOF is the time necessary for the electron-positron annihilation produced gammas to be detected. Without TOF information, it is not possible to know the position along the Line of Response (LOR) where the e +-e- annihilation process took place. However, when this information is available, it is possible to narrow down this position more precisely, being able to better model the annihilation photon emission probability distribution. The reduction through TOF improves the statistical properties of the PET image and leads to an improvement of the signal-to-noise ratio (SNR). Currently, the best TOF values are close to 205 ps in commercial devices.
This work aims to carry out a study based on simulations in order to achieve better TOF values through metascintillators. We define as meta-scintillators the composite topologies of scintillating and lightguiding materials, arranged to produce a synergistic effect at some step of the scintillation process, from gamma absorption to light detection, combining thus the favorable physical characteristics of their constituting components. One way is to place two scintillators with different properties in close enough proximity, so that the recoil electron resulting from the photoelectric conversion of a gamma ray in one material can reach the second one and deposit part of its energy in it.
Hence, it is possible to use a highZ material benefiting from its stopping power and design a geometrical topology that brings fast optical photon emitters close enough, resulting in a substantial probability of recoil electrons crossing through them. Thus, some optical photons will be produced according to the fast kinetics of the second material. The role of prompt photons and ways to produce them have been first described.
Based on this concept, we simulated a first generation of composite metastructures including a high-Z host and a fast emitter, cut in layers with thicknesses significantly less than the recoil electron range and arranged in geometrically periodic alternating positions. In this context we performed simulations building a metascintillator consisting of LYSO as dense scintillator and EJ232 plastic
scintillator (Eljen technologies) as a fast scintillator with GATE 8.2. We simulated a planar source emitting 1Million of 511 keV gammas impacting perpendicular or parallel to the layers of the metamaterial.
The recoil electron resulting of the gamma interaction with the material has been studied, as well as the energy sharing between materials. Several thicknesses of both materials have been simulated in order to optimize the energy deposit in both. The results for efficiency and energy distribution for different thicknesses in the perpendicular configuration are presented.
In a future work, different options as fast scintillators will be tested, such as CdSe/CSe nanoplatelets and perovskites. The simulation tool developed here is being further adapted to include electromagnetic interactions, for the adaptation to systems including photonic crystal slabs and high quality nano-machined reflectors to improve the light collection efficiency of the prompt photons.

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