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10ps Time-of-Flight PET scanner: From Hope to Practice

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The future generation of radiation detectors is more and more demanding on timing performance for a wide range of applications, in particular for time-of-flight (TOF) techniques in PET cameras.
There is in particular a consensus for gathering Europe's multi-disciplinary academic and industrial excellence around the ambitious challenge to develop a 10 ps TOF PET scanner (TOFPET). The goal is to reduce the radiation dose (currently 5-25 mSv for whole body PET/CT), scan time (currently > 10 minutes), and costs per patient (currently > 1000 € per scan), all by an order of magnitude. To achieve this very ambitious goal it is essential to significantly improve the performance of each component of the detection chain: light production, light transport, photodetection, readout electronics.
The possibility to reach 10 ps time-of-flight resolution at small energies, as required in PET scanners, although extremely challenging, is not limited by physical barriers.
This talk will show how progress in nanotechnologies open new perspectives for the development of meta-scintillators, a new class of multifunctional multi-intelligent scintillators.
Indeed, a number of disruptive technologies, such as multifunctional heterostructures, combining the high stopping power of well know scintillators with the ultrafast photon emission resulting from the 1D, 2D, or 3D quantum confinement of the excitons in nanocrystals, photonic crystals, photonic fibers, as well as new concepts of 3D digital SiPM structures, open the way to new radiation detector concepts with unprecedented performance.
A first generation of metascintillators will be presented (Fig. 1), allowing an improvement by a factor of 2 in time-of-flight resolution (and therefore in PET equivalent sensitivity) as compared to the state-of-the art, and perspectives for an ultimate gain of 20 (time-of-flight resolution of 10 ps) will be discussed.
Fig.1: First generation of metascintillators showing: right, 2 LYSO/EJ232 metapixels 3x3x25mm, middle: two 4 x 4 matrices of metapixels, left: 2 8 x 8 matrices of metapixels.

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