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10ps Time-of-Flight PET scanner with a new generation of SiPMs: From Hope to Practice

The potential of photon detectors to achieve precise timing information is of increasing importance in many domains, e.g. PET and CT scanners in medical imaging and particle physics detectors. The goal to increase by an order of magnitude the sensitivity of PET scanners and to deliver, via time-of-flight (TOF), true space points for each event, requires a further quantum step in time resolution, reaching eventually 10ps in coincidence (CTR) @511keV to be compared to about 200ps obtained with state-of-the-art silicon photomultipliers (SiPM) in the Siemens Biograph Vision PET scanner. The interest 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.
Such a 'paradigm'shift must go hand-in-hand with a similar break with traditional methods.
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 combining transformation optics light concentrators, hyperbolic metamaterial QE increase, ultra-fast, backside illuminated silicon cell and ultrafast electronics directly integrated in the device will offer new perspectives for the development of new concepts of 3D digital SiPM structures and open the way to new radiation detector concepts with unprecedented performance.
The ultimate goal will be creating a Quantum Silicon Detector (QSD), with close to 100% PDE even with non-collimated light, a few ps Single Photon Time Resolution (SPTR), ultra-high cell density, negligible correlated noise and beyond state-of-the-art primary noise, opening new prospects for the construction of very compact, low power and ultrafast photodetectors with space-time imaging capability.

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