ID contributo: **112** Tipo: **non specificato**

Digital Photon Counting (DPC, dSiPM) technology - Scalable light detection for high sensitivity medical systems

sabato 6 settembre 2014 17:50 (20 minuti)

Solid-state light detectors have significant advantages over photomultiplier tubes (PMT's) such as ruggedness, compactness and insensitivity to magnetic fields, low operating voltage, power consumption and large scale fabrication possibilities using proven technologies and processes such as CMOS.
Recently, the Silicon Photomultiplier (SiPM) gained momentum as a candidate to replace PMT's in particular applications requiring precise timing and/or low-level light detection. The timing resolution of detectors is of particular interest not only for applications such as Time-of-Flight whole-body PET (WB-ToF-PET), increasing signal-to-noise ratio (SNR) and thus relative sensitivity enabling essentially lower dose/dynamic imaging. In addition, precise timing information can be a benefit also for applications such as in-beam therapy monitoring or organ specific imaging due to reduced or suppressed background. In addition, their compact size and insensitivity to magnetic fields enable opening new areas of application such as PET/MR.
Since solid state detectors can be configured and adapted more easily than PMT's new and more efficient detector designs are enabled (e.g. 1:1 coupling). However, as miniaturized SiPM's allow attaining much more information about the source of light, this represents a challenge: this information needs to be channeled, transferred and processed. In the case of analog sensors this has to be accomplished by mixed-signal processing with extensive electronics using ASICs. The fully digital approach laterally embedded in CMOS, utilizing the intrinsically binary nature of Single-Photon-Avalanche-Diodes (SPADs) operated in Geiger-Mode avoids this additional complexity and, as will be shown, maintains intrinsic performance. The digital approach will be compared to the analog one. Early digitization also aids in scaling up such technology on all levels: power supply, configuration, data readout and timing. Inherent digitization plus integration at sensor level are key to an all-digital subsequent data chain and large-scale application possibilities while maintaining intrinsic performance parameters such as timing and energy resolution. This will be demonstrated on first application examples, for instance a prototype PET ring and a Cherenkov light detector.

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Classifica Sessioni: Technology session I