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Digital SPAD Scintillation Detector Simulation Flow to Evaluate and Minimize Real-Time Requirements

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Radiation detection used in positron emission tomography (PET) and calorimetric systems exploit the timing information to remove background noise and refine the position measurement through time-of-flight information (TOF). In PET, very fine time resolution (in the order of 10 ps FWHM) would not only improve contrast in the image, but would also enable real-time image reconstruction without iterative or back-projected algorithms. The current performance limitations will be pushed off through the optimization of faster light emission mechanisms (prompts photons), after which the burden of timing resolution will fall to the readout optoelectronics. Digital SPAD arrays offer compelling possibilities to minimize timing jitter in these future detector systems such per-cell timestamps granularity and per-cell configuration parameters, providing a highly flexible signal processing environment. However, processing hundreds of timestamps per detection event places a toll on the real-time processing, which increases rapidly with embedded channel count. Furthermore, if the processing is sent to an external device such as an FPGA, the bandwidth and related power requirements also increase.

The goal of the presented simulation flow is to determine how many timestamps are actually required to reach the 10 ps FWHM CTR range for PET. Using this information, designers can estimate the compromises between timing performance, bandwidth requirements, data transmission, power consumption and real-time dataflow processing in the DAQ at the chip and system level. In a typical PET configuration with a standard LYSO, the simulations indicate that a digital SPAD array only needs as few as four photon timestamps to reach within 3% of the best possible timing. Similarly, a modified LYSO with 2.5% prompt emission rate would need 30 to 40 photon timestamps to reach 3% of the optimal timing. The real-time burden is thus very different in both situations. New SPAD devices should be designed to maximize performance for both current and future scintillation materials.

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