Photon-to-Digital Converters for Wavefront Sensing

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Abstract

We are developing a new single photon counting detector technology based on the 3D assembly of Single Photon Avalanche Diodes (SPAD) onto CMOS electronics which renders a digital readout of the photon counts. In particular, we have developed a fast-timing Time-to-Digital Converter (TDC) readout in array with embedded advanced signal processing. We call this combination of SPAD, TDC and embedded processing a Photon-to-Digital Converter (PDC).
A SPAD is an reverse biased photodiode set above its breakdown voltage. The arrival of a photon triggers an avalanche of current which is controlled by the quenching circuit next to the photodiode. In the case of a PDC, each SPAD has its own CMOS quenching circuit. The output of the quenching circuit provides a digital signal which is used to timestamp and process the photon. While SPADs benefit from cooling, they do not require it for operation. Each SPAD has a Time-to-Digital Converter (TDC) to precisely timestamp each photon with a resolution of 17.5 ps FWHM. Finally, the timestamps can be processed on-chip to reduce the large quantity of data to output. The processing can consist of timestamp sorting, skew correction, and others.
PDCs offer a new dimension for wavefront sensing by measuring the timestamps of the incoming photons. Filtering and processing of incoming photons based on their timestamp, position, and correlation with external signals can increase wavefront sensing accuracy, therefore, leading to improved AO control and better delivered image quality. For example, in the case of the pyramid wavefront sensors, the timestamp can be correlated to the position in the modulation cycle, and using this information in the wavefront reconstruction process can lead to increased sensitivity. The paper will explain the functionality of PDCs and their possible operation as wavefront sensor.

Keywords: SPAD, Photon, to, Digital Conveter, PDC, Time, to, Digital Converter, TDC, CMOS, Wavefront Sensing

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