SwissSPAD3 – a dual-gate photon-counting SPAD sensor for widefield FLIM imaging

Arin Can Ulku*, Andrei Ardelean*, Paul Mos, Edoardo Charbon, Claudio Bruschini
Advanced Quantum Architecture Laboratory (AQUA), School of Engineering (STI)
Ecole polytechnique fédérale de Lausanne (EPFL), 2002 Neuchâtel, Switzerland
E-mail: arin.ulku@epfl.ch
*Equal contributions

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Standard CMOS-based single-photon avalanche diodes (SPADs) have made great progress during the past 17 years, thanks to their photon-counting properties, exquisite temporal resolution, absence of readout noise, natively digital nature, and high speed [1]. The design of SPAD imagers has immediately followed, with increasing resolution up to the Megapixel frontier achieved in 2019, and application in (Quantum-)Image Scanning Microscopy, FCS, and FLIM. Building on the SwissSPAD2 sensor [2], we developed SwissSPAD3, a large gated binary SPAD sensor of 500×500 pixels with state-of-the-art sensitivity and noise. In intensity mode, the sensor delivers ¼Mpixel binary frames at 49.8 kfps (which can be accumulated as in Fig. 1 left), whereas photon detection is virtually shot noise and pile-up limited. SwissSPAD3 features rolling shutter readout and a dual-gate shutter mechanism which enables 100% duty cycle (Fig. 1 top centre). Gate lengths as short as 1 ns have been achieved, with substantially improved skew over the whole pixel array (Fig. 1 top right). First FLIM images are shown in Fig. 1 bottom; effective PDE is enhanced by microlenses deposited directly on pixels. Ongoing work includes phasor-based real-time on-FPGA data processing.

Figure 1: Left: 16-bit intensity image of USAF pattern (gate fully open); Top: gating diagram (centre) and characterisation with the shortest gates (right); Bottom: intensity (centre) and FLIM (right) image of mammal colon cells, H&E stained (relative lifetime before calibration).