Perspective on SPAD based detectors for quantum imaging and microscopy

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ABSTRACT *(250 WORDS)*

Quantum imaging and microscopy profit from entangled photons to surpass the boundaries of classical optics, thus improving image resolution and sensitivity, hence the need of time-resolved single-photon detectors, capable to detect photon coincidences with sub-nanosecond precision. Thanks to their single-photon sensitivity, readout noise absence, low-voltage operation, and high framerate, detectors based on Single-Photon Avalanche-Diodes (SPADs) are particularly suited for quantum imaging and microscopy techniques. In this work we discuss strengths and weaknesses of different SPAD based architectures, highlighting those to be exploited at best as quantum imagers, and eventually providing guidelines towards next-generation ideal quantum imagers. In particular, we ascertained three key features for optimal detection of entangled photons, namely spatial resolution (to reconstruct the image), photon coincidence detection capability (to distinguish entangled photons from background), and event driven-readout (to optimize throughput when photons are very sparse). The discussed architectures are classified as analog or digital Silicon Photomultipliers (SiPMs), SPAD arrays, or SiPM arrays. Analog SiPMs are many microcells (SPAD and quenching resistor) connected together and provide a comprehensive analog output current. Digital SiPMs include microcells, each with a SPAD and its own front-end, and provide at the output a digital pulse for each SPAD ignition. SPAD arrays are made of pixels comprising SPAD, front-end circuit and other processing electronics. Conversely to the other three, SPAD arrays are capable of spatial resolution at single-SPAD level and, in addition to the possible implementation of quantum-specific on-chip processing, thus we identified them as the forefront detector type for quantum imaging and microscopy.

Keywords: quantum imaging; entangled photons; SPAD imager; SPAD; coincidence detection; Geiger-mode APDs.

ABSTRACT *(150 WORDS)*

Quantum imaging and microscopy profit from entangled photons to surpass the boundaries of classical optics, thus improving image resolution. Thanks to their single-photon sensitivity, readout noise absence, low-voltage operation and high framerate, detectors based on Single-Photon Avalanche-Diodes (SPADs) are particularly suited for this application field. In this work we discuss strengths and weaknesses of different SPAD based architectures, highlighting those to be exploited as quantum imagers, eventually providing guidelines towards next-generation quantum imagers. In particular, we ascertained three key features for optimal detection of entangled photons, namely spatial resolution, photon coincidence detection capability, and event driven-readout. The discussed architectures are classified as analog or digital Silicon Photomultipliers (SiPMs), SPAD arrays, or SiPM arrays. Among the four, just SPAD arrays are capable of spatial resolution at single-SPAD level and, through the possible implementation of quantum-specific on-chip processing, thus we identified them as the forefront detector type for quantum imaging and microscopy.