SPAD Modules at Telecom-Wavelength for Industrial Implementation

Patrick Runge

Fraunhofer Heinrich Hertz Institute, Einsteinufer 37, 10587 Berlin, Germany

InGaAs(P)/InP single-photon avalanche diodes (SPADs) are central components for SWIR quantum applications in the industry, due to the cryogenic-free operation compared to SNSPDs. Our goal is to supply field-ready compact SPAD modules with a fibre -coupled PCB-in-plain package.

Our chips are guard-ring free planar surface-illuminated SAGCM (separate absorption, grading, charge, and multiplication) layer structure, packaged in hermetic butterfly housings with an integrated 3-stage TEC and single-mode fiber pigtail (FC-PC). The C-band chip uses an InGaAs/InGaAsP absorption layer.

The C-band module achieves at 233 K and 25% photon detection efficiency (PDE), a DCR of 1.5 kcps, an afterpulse probability (APP) < 0.5% at 10 µs hold-off, and a timing jitter (FWHM) of 162 ps. With TEC cooling to −50 °C the DCR drops below 1 kcps already at 18% PDE. The O-band module achieves at 229 K a DCR below 100 Hz for 22.5% PDE and as low as 40 Hz at 15% PDE (Fig. 1), approaching SNSPD performance without cryogenic infrastructure. At 233 K the DCR remains below 1 kHz for a PDE up to 35.5%, with a timing jitter below 200 ps (FWHM) and an APP below 1% at 8 µs hold-off. The NEP at 1310 nm is more than fivefold lower than the best reported InGaAs/InP SPADs and more than one order of magnitude lower than Ge-Si SPADs.

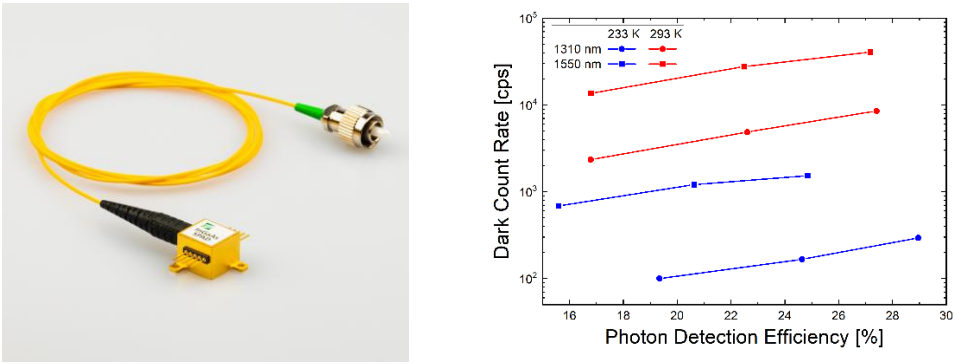

Fig. 1: *Fiber-coupled SPAD butterfly module with integrated TEC and DCR versus PDE.*

For single fibre WDM-QKD, a QBER estimation for a 625 MHz time-bin BB84 QKD protocol (800 ps time bins, 2.2 dB receiver loss) yields 0.49% over 100 km at 233 K with 30% PDE, an improvement of 91 km versus prior C-band results at comparable PDE. TEC-free room-temperature operation achieves a QBER of 4.11% over 83 km, enabled by the ultra-low O-band DCR.

These presented performance matches commercially available butterfly modules and exceed state-of-the-art table-top systems. Our SPAD modules do have a fully European supply chain. Configurating the SPAD as a negative feedback avalanche diodes (NFAD) inside the module, has been demonstrated as well.

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References

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