Reaching the Intrinsic Performance Limits of Wide Superconducting Nanowire Single-Photon Detectors

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Despite decades of materials and fabrication research, superconducting nanowire single-photon detector (SNSPD) performance has never met theoretical expectations [1]. The best-performing detectors are those that can operate at the highest bias current. The maximum operating current of a given detector is limited by current crowding at the detector edges caused by lithographic defects and, as wire width increases, Meissner screening. We developed a method to eliminate edge-induced current crowding using current-biased superconducting rails placed on either side of the detector [2]. Using this technique, we reduce the dark counts by ***ten orders of magnitude*** for a 100µm-wide detector that exhibits saturated internal detection efficiency of near-infrared photons. We show efficient detection of mid-infrared (4µm) photons on a 20µm-wide wire—twenty times wider than prior state of the art for this wavelength range. The rails allow in-situ tuning from an edge-limited regime where dark counts are dominated by edge-induced vortices to a material-limited regime where dark counts are dominated by vortex-antivortex unbinding in the bulk material of the detector. This regime is the intrinsic performance limit of the detector—it depends only on temperature and superconducting properties of the material. This paves the way for the development of arbitrarily large detectors with near-zero dark count rates.

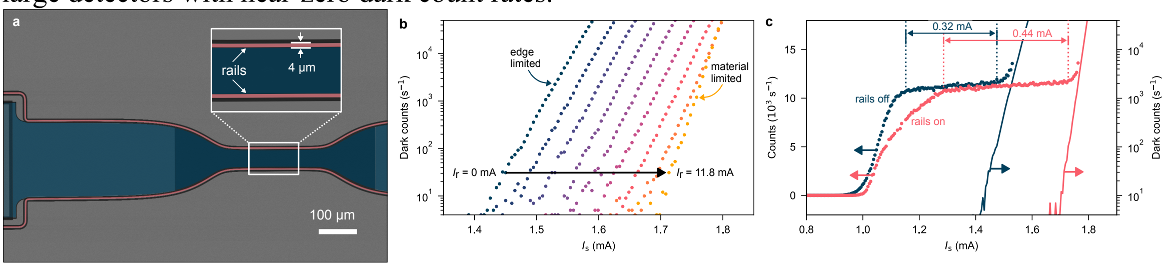

Fig. 1: (a) *False-color SEM image of a 50µm-wide SNSPD with rails.* **(b)** *Dark counts of a 50µm-wide SNSPD onset at higher bias currents (I_s) as rail current (I_r) is increased.* **(c)** *The 1550nm photon count rate plateau of a 50µm-wide SNSPD is extended by flowing current through the rails.*

References

[1] Vodolazov, Phys. Rev. Appl 7, 034014 (2017); [2] Parzuchowski *et al.*, arXiv:2601.15971v2 (2026)

Funding acknowledgement

This research was funded by NIST, University of Colorado Boulder, University of Colorado Denver, NASEM and the DARPA DSO Synthetic Quantum Nanostructures program.