Mid-Infrared NbN Superconducting microstrip single-photon detectors via Helium Ion Irradiation

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Mid-infrared (mid-IR) single-photon detection is important for applications including spectroscopy, biomedical imaging, chemical sensing, and astronomy. However, the low photon energy makes efficient detection challenging, and conventional semiconductor detectors often suffer from limited efficiency and high noise. Although superconducting nanowire single-photon detectors (SNSPDs) perform well at visible and near-infrared wavelengths, achieving both high sensitivity and practical operation in the mid-infrared remains challenging [1].

Superconducting microstrip single-photon detectors (SMSPDs) [2] provide an attractive alternative, offering larger device dimensions, higher critical currents, and competitive timing performance. However, NbN- or NbTiN-based SMSPDs still struggle to achieve high intrinsic detection efficiency (IDE) beyond 3 μm, and the relationship between detection (threshold) current and photon energy in the mid-infrared regime remains poorly understood [2,3].

Here, we demonstrate NbN SMSPDs fabricated from 5 nm-thick NbN films and irradiated with a high He^+ dose of 1×10^{17} ions cm^{-2}. The devices exhibit saturated IDE extending to wavelengths up to 5 μm and achieve a minimum system timing jitter of ~28 ps at 1064 nm. Measurements of the detection current over a broad photon-energy range (3.1–0.25 eV, corresponding to 400–5000 nm), are well described by a vortex-assisted hotspot model. Intrinsic dark counts at 0.3 K were below 10^{-3} cps [4]. Our results demonstrate that ion-irradiated NbN SMSPDs can achieve high photon sensitivity, low timing jitter, and ultra-low dark counts across the mid-IR spectrum.

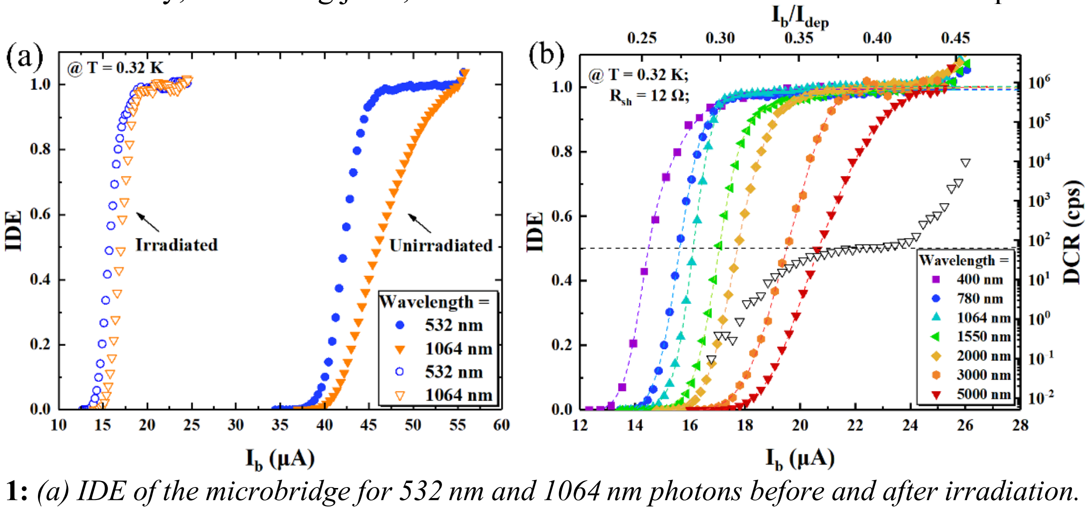

Fig. 1: *(a) IDE of the microbridge for 532 nm and 1064 nm photons before and after irradiation. (b) Bias-current dependence of IDE (left) and background DCR (right) for the microbridge with a 12 Ω shunt resistor. Dashed lines show sigmoidal fits. For 5 μm photons, IDE reaches unity at $I_b > 24$ μA ($I_b/I_{dep} \approx 0.425$); a horizontal line indicates IDE = 0.5, and the black triangle denotes the background dark count rate with single-mode fiber coupling.*

Funding acknowledgement
This work was supported by the Quantum Science and Technology-National Science and Technology Major Project (Grant No. 2023ZD0300100), the National Natural Science Foundation of China (Grant No. 62371443). W.-J. Zhang acknowledges additional support from the Youth Innovation Promotion Association, CAS (Y2023071).

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