You *Can* Have It All: Fast, Efficient, Number-Resolving SNSPDs with Scalable Readout

Daniel W. Sorensen[1,2], Martin J. Stevens[2], Lynden K. Shalm[1,2,3], Dileep V. Reddy[2,3]

[1]Department of Electrical, Computer and Energy Engineering, University of Colorado, Boulder, CO USA

[2]Physical Measurement Laboratory, National Institute of Standards and Technology, Boulder, CO USA

[3]Department of Physics, University of Colorado, Boulder, CO USA

Superconducting nanowire single-photon detectors (SNSPDs) are critical, enabling components in quantum optics applications that demand high-speed, low-jitter detection of single photons with near unity system detection efficiency (SDE).[1,2] However, intrinsic trade-offs between metrics such as efficiency and maximum count rate make it difficult to realize devices capable of state-of-the-art performance on multiple fronts simultaneously, standing in the way of applications that require state-of-the-art performance in multiple fronts simultaneously. Additionally the digital ‘click’ signal from a traditional SNSPD offers no photon-number resolution (PNR), making it difficult for experiments that need to distinguish between single and multi-photon events. SNSPD systems addressing these challenges are increasingly common,[2,3,4] but they all rely on additional experimental burdens like cryogenic readout electronics or complex multiplexing schemes that make them difficult to implement at scale.

Here we present an SNSPD platform that can optimize all of these metrics simultaneously in a single pixel read out with standard room-temperature amplifiers and a timetagger. We demonstrate devices that combine near-unity SDE with exceedingly fast recovery times, enabling high-efficiency photon detection at rep-rates above 17 MHz. This far exceeds the performance of comparable single-pixel SNSPDs. This is enabled by a novel niobium-titanium-nitride material platform combined with an optimized high fill-factor microwire geometry. We can distinguish between single- and multi-photon detection events with high fidelity using simple room-temperature readout circuitry, bypassing cryogenic amplifiers or multiplexing schemes that stand in the way of truly scalable PNR. Together these performance metrics represent a transformational shift in capability for experiments that demand scalable, state-of-the-art single photon detection.

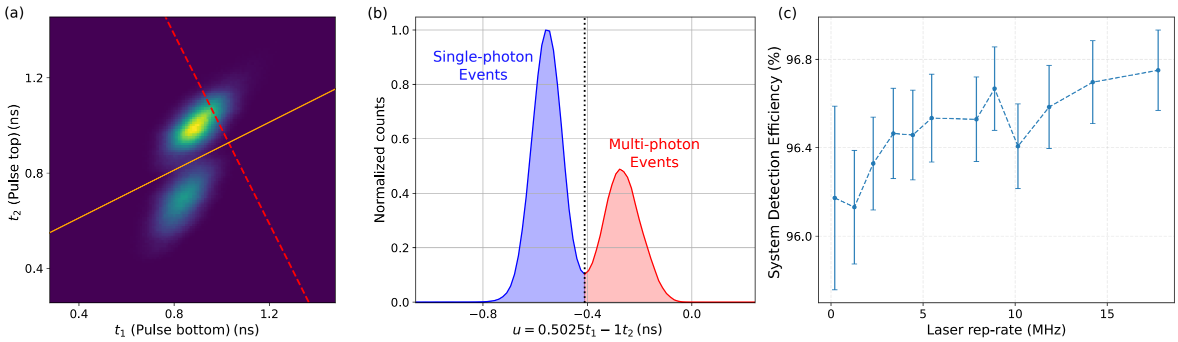

Fig. 1: ***(a):*** *2D Histogram measuring arrival times of the bottom (t_1) and top (t_2) of SNSPD rising edges with respect to pulsed laser source.* ***(b):*** *Projecting the 2D histogram to the coordinate $u = 0.5025t_1 - t_2$ allows peaks corresponding to single and multi-photon events to be well resolved.* ***(c):*** *Measured SDE over a range of pulsed laser rep-rates show >96% detection efficiency through 17 MHz.*

References

[1] D. V. Reddy et al., Optica 7, 1649–1653 (2020). Optica Publishing Group.
[2] C. Ding et al., ACS Photonics 12, 4924–4931 (2025). American Chemical Society.
[3] T. Schapeler et al., Phys. Rev. Appl. 22, 014024 (2024). American Physical Society.
[4] D. Zhu et al., Nano Lett. 20. 3858-3863 (2020). American Chemical Society