Controlling the recovery time of the superconducting nanowire single-photon detector with a voltage-controlled cryogenic tunable resistor

Hui Wang[1], Nikita D. Orlov[1], Niels Noordzij[2], Thomas Descamps[3], J. W. Niels Los[2], Val Zwiller[2], Iman Esmaeil Zadeh[1,2]

[1] *Department of Imaging Physics, Delft University of Technology, 2628CN Delft, The Netherlands.*

[2] *Single Quantum B.V., 2628 CH Delft, The Netherlands.*

[3] *Department of Applied Physics, Royal Institute of Technology (KTH), SE-106 01 Stockholm, Sweden.*

Superconducting nanowire single-photon detectors (SNSPDs) have emerged as promising single-photon detectors due to high detection efficiency, excellent time jitter, and a broad spectral range. However, the maximum count rate is fundamentally limited by the efficiency recovery time. Introducing a serial resistor with the SNSPD can accelerate the current recovery. Since the detection efficiency increases with the bias current, faster current recovery helps to shorten the efficiency recovery time. However, this approach introduces a trade-off between the recovery speed and the saturation of internal detection efficiency, ultimately the risk of latching, when the serial resistor is too large. On the other hand, it is time-consuming to experimentally determine an optimal value for the resistance through repeated trials. In this work, we present a cryogenic tunable resistor integrated with an SNSPD, as shown in Fig. 1(a), enabling in-situ optimization of the efficiency recovery time.

The tunable resistor consists of a metal heater over a NbTiN channel, which are insulated by a thin SiO_2 layer. By adjusting the local Joule heating power of the heater, we modulate the normal resistance of the constricted superconducting channel. As shown in Fig. 1(b)-(c), we experimentally measure the output pulses, and the efficiency recovery curves at various heater currents I_h. The output pulse decay time constant decreases with an increasing I_h, i.e. a larger serial resistance, indicating faster current recovery. However, the fastest efficiency recovery is achieved at an optimal heater current $I_h = 64$ μA. Beyond this threshold, the efficiency recovery decelerates due to the reduction in the saturation length of the internal detection efficiency, as shown in Fig. 1(d).

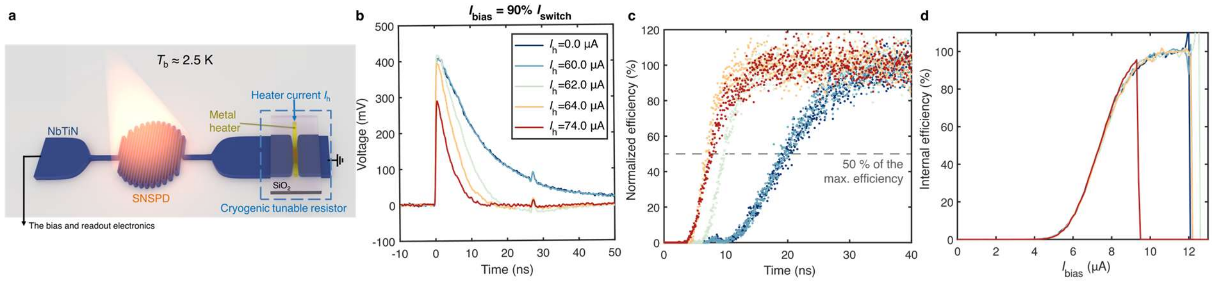

Fig. 1: *a, Illustration of a cryogenic tunable resistor in series with an SNSPD and its electronic readout circuit. b, Amplified output waveforms of the SNSPD event with various heater current I_h at the wavelength of 1548 nm. c, Histogram of the normalized detection efficiency as a function of the time delay after one detection. d, Internal detection efficiency curves. Adapted from Ref. [1]. Licensed under CC BY 4.0.*

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References

[1] H. Wang, N. D. Orlov, N. Noordzij, T. Descamps, J. W. N. Los, V. Zwiller, and I. Esmaeil Zadeh, Appl. Phys. Lett. 127 (2025).