Overcoming the Reset Time Trade-offs in SNSPDs

Towsif Taher[1], Dileep V. Reddy[2], Fadri Grünenfelder [1], Gabriel Wittenberg[1], Raphaël Houlmann[1], Tiff Brydges[1], Rob Thew[1], Boris Korzh[1]

[1]Group of Applied Physics, University of Geneva, CH-1211 Geneva, Switzerland
[2]National Institute of Standards and Technology, Boulder, CO 80305

Recent advances in quantum communication, photonic quantum computing, and quantum metrology are driving the need for single-photon detectors capable of operating at count rates of hundreds of MHz to GHz while maintaining high efficiency and stable operation. Superconducting nanowire single-photon detectors (SNSPDs), while offering excellent performance at detection rates up to tens of MHz, are constrained by an intrinsic trade-off between electrical reset time and electrothermal stability: reducing the reset time increases the maximum count rate but can destabilize the electrothermal dynamics and induce latching. A common approach to increasing the detection rate is spatial multiplexing of multiple SNSPD pixels [1–3], which reduces the kinetic inductance of each element while maintaining high optical absorption. However, existing multiplexed architectures face several scalability challenges. Electrically multiplexed detectors require careful crosstalk suppression between pixels, which can limit achievable reset times. In addition, large detector arrays are constrained by the limited number of available cryogenic readout channels. Furthermore, in fiber-coupled configurations, the number of usable pixels is restricted by the optical mode area. These limitations motivate the investigation of electrothermal stability limits in individual SNSPDs together with scalable readout architectures that preserve high optical absorption efficiency.

Here, we first experimentally probe the electrothermal stability boundary for a superconductor (NbTiN)–substrate (SiO_2/SiN) system by integrating SNSPDs with on-chip resistive impedance-matching networks (Fig. 1(a)) that precisely control the load impedance seen by the nanowire. By independently varying the nanowire kinetic inductance and load impedance while maintaining a constant $\sqrt{L_k}/R_L$ ratio, we map the latching stability boundary predicted by electrothermal models [4] and determine the minimum achievable reset time. We then extend this study to scalable on-chip readout architectures (Fig. 1(a)) designed to maintain impedance matching while suppressing electrical crosstalk between detector pixels. Finally, we explore integrating multiple SNSPDs with impedance-matching networks along photonic waveguides (Fig. 1(c)), where engineered optical absorption enables highly efficient and uniform photon detection across the array. We present the recent results from these studies here. Together, these studies explore a pathway toward scalable high-speed SNSPD systems by combining impedance-engineered electrothermal stability with waveguide-integrated detector arrays.

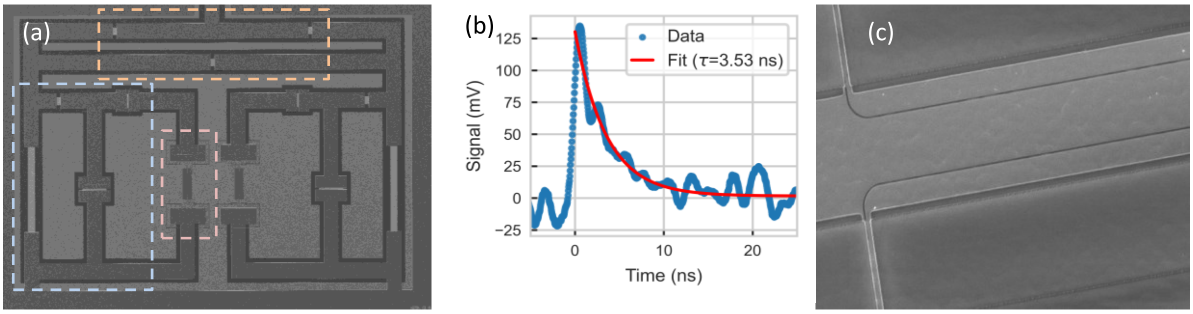

Fig. 1: *(a) SEM image of SNSPDs (red) with impedance matching network (blue) and multiplexed readout (yellow), (b) Reset time of an impedance-matched SNSPD with* 20Ω *load impedance (c) SEM image of multiple nanowires on SiN waveguide.*

References: [1] Resta, Giovanni V., et al., Nano Letters 23.13 (2023): 6018-6026. [2] Craiciu, Ioana, et al., *Optica* 10.2 (2023): 183-190. [3] Stasi, Lorenzo; Taher, Towsif, et al., *ACS Photonics* 12.1 (2024): 320-329. [4] Kerman, Andrew J., et al. Journal of Applied Physics 113.14 (2013).