Developing Superconducting Nanowire Single Photon Detectors with Photon Number Resolving Capability

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Superconducting Nanowire Single-Photon Detectors (SNSPDs) are the leading single-photon detection technology, offering system detection efficiencies (SDE) >90%, sub-50 ps timing jitter, and ultralow dark-count rates (DCR) spanning ultraviolet to mid-infrared. However, their inherently binary response precludes photon-number resolution (PNR), which is critical for quantum-optical protocols such as boson sampling, quantum state tomography, and photonic cluster-state generation.

Spatial multiplexing addresses this limitation by distributing photons across an array of independent SNSPD pixels, with the total photon number inferred from triggered-pixel count. This work targets a waveguide-integrated, ~130-pixel PNR-SNSPD on a Si_3N_4 strip-loaded lithium niobate platform, designed to resolve up to 20 photons at SDE >90%. NbTiN thin films (6–8 nm) deposited via DC magnetron sputtering ($Nb_{0.7}Ti_{0.3}$ target) yield critical temperatures Tc = 6–9 K. Our detectors are patterned in 3 steps by electron-beam lithography (EBL), with Ti/Au contacts defined in the first EBL step, nanowires patterned and etched with $SF_6/CHF_3/O_2$ reactive-ion etching in the second step, and Ti/AuPd resistors defined in the third step.

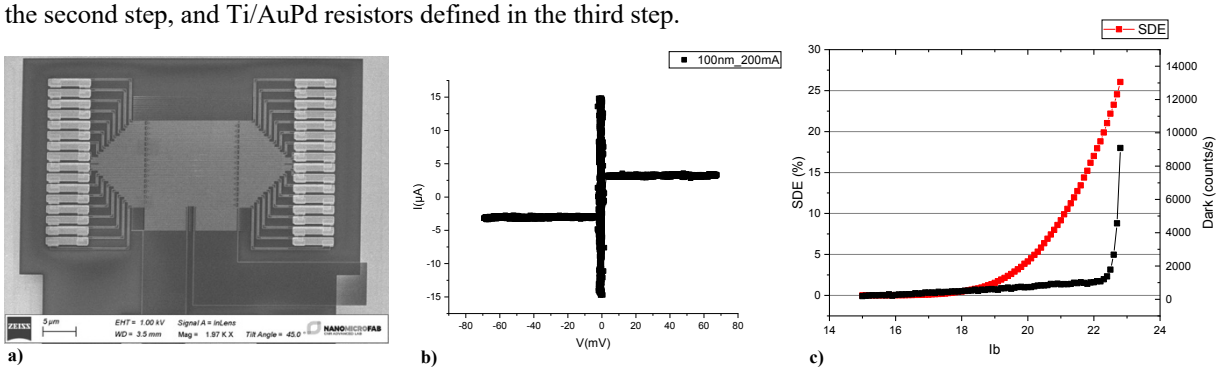

***Fig. a** – SEM image of the 32-Pixel Spatially multiplexed SNSPD with PNR. **Fig. b** – Current–voltage (IV) curve. **Fig. b** – System detection efficiency (SDE) vs bias current (I_b) for the NbTiN nanowire with 100 nm wide and 8 nm thickness.*

Devices are characterised at ~2 K in a closed-cycle cryostat with on-chip gold mirror coupling. Fabricated 100 nm-wide, ~8 nm-thick NbTiN nanowires exhibit Tc ≈ 7.5 K and Ic ≈ 23 μA. Building on prior demonstrations of spatially multiplexed PNR detectors — notably the 24-pixel SSPD-based photon-number-resolving detector reported by Mattioli et al. (2016). A 32-pixel PNR device has been successfully fabricated and awaits full optical characterisation (SDE, DCR, timing jitter), representing a significant milestone toward the complete 130-pixel waveguide-integrated PNR detector.

Funding acknowledgement:

This work has been funded by INFN through the CSN5_UniDet project and PRIN 2022 (Grant No. 2022R7RSHL) NINE "Integrated hybrid quantum detector", funded by Next Generation EU – Mission 4 – Component 2 – CUP B53C24006700006. The author also gratefully acknowledges the support of the Istituto Nazionale di Fisica Nucleare (INFN) for the Ajeethkumar Rengarajan's PhD scholarship that made this research possible.

References:

[1] Mattioli, F., Zhou, Z., Gaggero, A., Gaudio, R., Leoni, R., & Fiore, A. (2016). Photon-counting and analog operation of a 24-pixel photon number resolving detector based on superconducting nanowires. *Optics Express*, *24*(8), 9067–9076.