Current-Crowding-Free Superconducting Nanowire Single-Photon Detectors Enabled by Local Helium Ion Irradiation

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Superconducting nanowire single-photon detectors (SNSPDs) play a pivotal role in quantum technologies such as quantum photonic integrated circuits. Their near-unity detection efficiency, low timing jitter, high count rates, and low dark count rates, even for near-infrared wavelengths, make them ideal for demanding applications such as photonic quantum computing or quantum key distribution. However, simultaneous optimization of multiple performance metrics remains challenging, and techniques to enhance individual parameters without affecting others would be advantageous. For example, helium ion irradiation of SNSPDs significantly enhances their detection efficiency but also leads to a reduction in switching current [1, 2]. Another challenge is current crowding in the bends of the typically meander-shaped geometry of SNSPDs: Current crowding leads to an increased current density and once it exceeds the critical current density of the superconductor, the SNSPD switches to the normal conducting state [3, 4]. Such a reduction in switching current limits not only the signal-to-noise ratio of the voltage pulses that the SNSPD generates, but also the sensitivity and detection efficiency, which increase as the switching current approaches the depairing current.

Here, we present a technique to enhance the sensitivity of SNSPDs by local helium ion irradiation while preserving the high switching current of unirradiated devices. Local ion irradiation of the straight parts of the SNSPD increases the sensitivity of the straight parts and reduces their switching current *density*. However, since the bends are the limiting factor for the switching current of unirradiated SNSPDs, local and moderate helium ion irradiation of the straight detector parts does not reduce the overall switching current as shown in Figure 1. It is only when irradiated with fluences higher than 80 ions/nm² that the switching current of the straight detector parts is lower than that of the bends, so that current crowding no longer plays a role. After applying this technique to SNSPDs with 250 nm wide wires, they show unity internal quantum efficiency for 1550 nm photons and a switching current of (22.3 ± 0.5) µA.

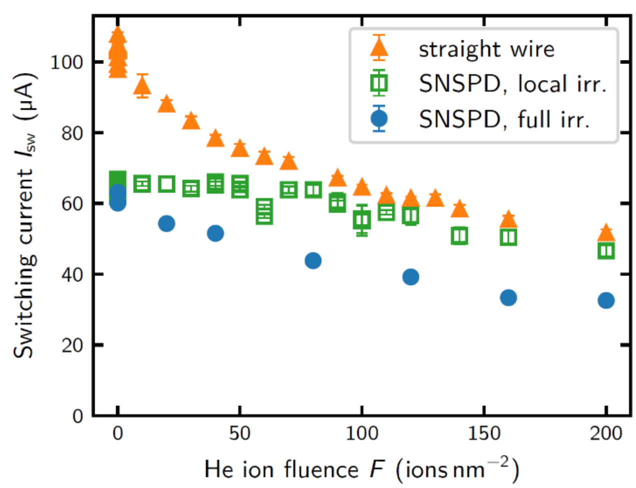

Fig. 1: Switching current I_{sw} vs. He ion fluence of straight wires and SNSPDs. For locally irradiated detectors I_{sw} stays constant until it coincides with I_{sw} of the straight wires. For fully irradiated SNSPDs it decreases continuously.

Our results show that by locally irradiating the straight parts of SNSPDs with helium ions, one can obtain current-crowding-free SNSPDs with significantly enhanced sensitivity or increase their detection efficiency without affecting their switching current.

References

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