Measuring Hotspot Size in SNSPDs

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We present new evidence that a photon absorbed in a WSi- or MoSi-based superconducting nanowire single-photon detector (SNSPD) leads to a region of suppressed superconductivity (or "hotspot") that is approximately as wide as the nanowire itself. This helps substantiate the recent findings of Renema et al. [1] in NbN nanoconstrictions. Those results [1] were based on a form of detector tomography adapted to devices with a very small absorption cross-section, and thus very low system detection efficiency. Here, rather than simply extracting the POVM elements, we follow the tomography scheme developed by Akhlaghi et al. [2] to find the one- and two-photon system detection efficiencies in high-efficiency meander detectors.

The system detection efficiencies can be decomposed as products of coupling efficiency, absorption efficiency, and one- and two-photon internal quantum efficiencies. Only the latter quantities depend on the bias current. The two-photon efficiency contains the probability that two incident photons are both coupled to and absorbed in the active area of the detector, creating two hotspots, as well as the probability that these two hotspots overlap. At sufficiently high bias currents in our devices, the one- and two-photon detection efficiencies plateau, indicating that the internal quantum efficiencies are close to 1. By comparing the plateaued values of the one- and two-photon system detection efficiencies, we can extract the probability that two hotspots overlap. Using

this overlap probability and a straightforward geometric approach, we can determine bounds on the size of each hotspot relative to the active area of the detector.

Our results provide strong evidence that the region of suppressed superconductivity resulting from absorption of one photon has an area of ~100 nm x 100 nm or larger in 8 different WSi and MoSi devices, close to the ~130-160 nm widths of the wires. The fact that such a large area of suppressed superconductivity does not lead to a click suggests that the local temperature does not exceed the critical temperature for breaking superconductivity, and that the term "hotspot" is somewhat misleading.

Finally, we observed additional nonlinearities (likely due to current rebiasing [3]) at laser repetition rates as low as 1 MHz. Such nonlinearities can lead to anomalously high count rates and unreliable data. This highlights the importance of performing detector tomography, and of doing so under the same conditions as in an experiment.

[1] J. J. Renema et al., Phys. Rev. Lett. 112, 117604 (2014).
[2] M. K. Akhlaghi, et al., Optics Express, 19, 21305 (2011).
[3] A. J. Kerman et al., J. Appl. Phys. 113, 144511 (2013).

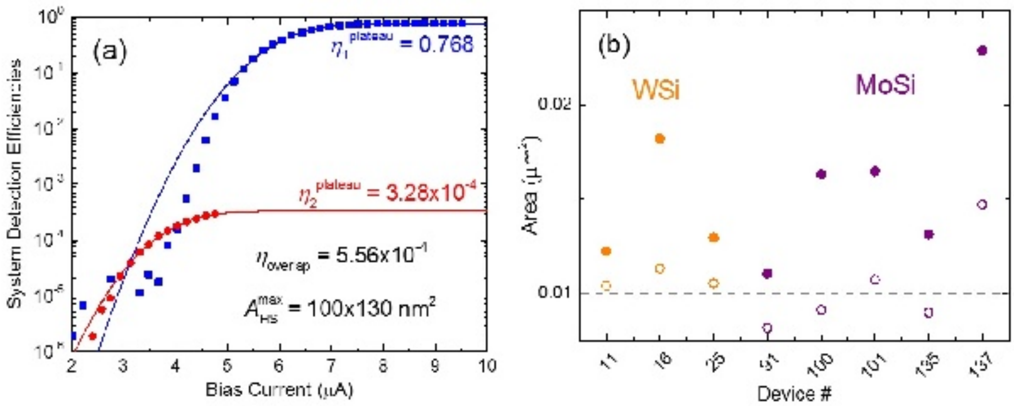

Fig. 1. (a) Values of 1- and 2-photon (blue squares and red circles, respectively) system detection efficiencies derived from detector tomography of a MoSi SNSPD (device #135). The detector has ~130 nm-wide nanowires, is operated at ~750 mK and is excited with a ps pulsed laser with 1550 nm center wavelength and 250 kHz repetition rate. (b) Maximum (solid circles) and minimum (open circles) hotspot area consistent with the measured values of η_1 and η_2 for several WSi (orange) and MoSi (purple) devices. All values lie near or above the dashed line, which indicates an area of 100×100 nm².