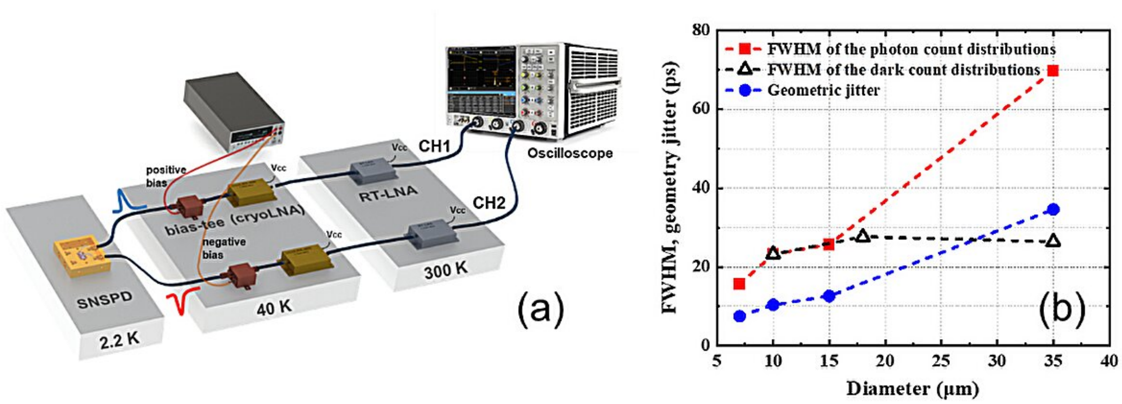
PHYS.ORG

Geometric origin of intrinsic dark counts in superconducting nanowire single-photon detectors

December 29 2023



To probe the spatial information of dark counts, we introduced the differential readout method, which utilizes two identical readout channels for tracing the output signals produced by the same dark count event. Two bias-tees (Mini-Circuits, ZX86-12G-S +) were applied to separate the bias current and output signals. The signals from the two different terminals of the nanowire, which had opposite polarities, were then amplified. In our experiments, two sets of amplifiers were used for different SNSPDs. For devices with a large active area (65 × 130 μm^2 in this paper), commercial room-temperature low-noise amplifiers (RT-LNAs: RFbay, LNA650) were used with a nominal gain of 50 dB. For devices with a smaller active area (≤35 × 35 μm^2 in this paper), homemade cryogenic low-noise pre-amplifiers (cryoLNAs) mounted on the 40 K-stage and second-stage homemade RT-LNAs were adopted, as illustrated in Figure(a), to further reduce the contribution of the electrical noise. The cryoLNAs had a nominal gain of 32 dB and power consumption of approximately 20 mW, with a 3-dB bandwidth of 1 GHz, and a noise temperature less than 15 K. The second-stage homemade RT-LNAs had a nominal gain of 20 dB with a 3-dB bandwidth of 600 MHz. The amplified signals, as illustrated in Figure(b), wesre finally recorded by an oscilloscope (Keysight, MOSV204A) simultaneously. The sampling rate of the oscilloscope was set to 80 Giga-samples per second with a discrimination level of approximately 15% of the maximum amplitude to increase the time resolution and reduce the influence of reflections from the meander nanowire. Credit: Xingyu Zhang, Xiaofu Zhang, Jia Huang, Can Yang, Lixing You, Hao Li, et al.

In a recent leap forward for quantum computing and optical technologies, researchers have uncovered an important aspect of photon detection. Superconducting nanowire single-photon detectors (SNSPDs), pivotal in quantum communication and advanced optical systems, have long been hindered by a phenomenon known as intrinsic dark counts (iDCs). These spurious signals, occurring without any real photon trigger, significantly impact the accuracy and reliability of these detectors.

Understanding and mitigating iDCs are crucial for enhancing the performance of SNSPDs, which are integral to a wide range of applications, from secure communication to sensitive astronomical observations.

A team headed by Prof. Lixing You and Prof. Hao Li from Shanghai Institute of Microsystem and Information Technology (SIMIT), Chinese Academy of Sciences (CAS) employed a novel differential readout method to investigate the spatial distribution of iDCs in SNSPDs with and without artificial geometric constrictions. This approach allowed for a precise characterization of the spatial origins of iDCs, revealing the significant influence of minute geometric constrictions within the detectors.

The study revealed that the iDCs in SNSPDs are predominantly caused by a few specific geometric constrictions, regardless of the overall device size. The findings suggest that by targeting and modifying these constrictions, it might be possible to substantially reduce the occurrence of iDCs. The study is published in the journal *Superconductivity*.

This breakthrough has profound implications for the future of quantum technology and optical systems. By mitigating the issue of dark counts, the accuracy and reliability of photon detection can be significantly improved, paving the way for advancements in secure quantum communication and enhanced sensitivity in astronomical observations.

More information: Xingyu Zhang et al, Geometric origin of intrinsic dark counts in superconducting nanowire single-photon detectors, *Superconductivity* (2022). DOI: 10.1016/j.supcon.2022.100006

Provided by Shanghai Jiao Tong University Journal Center