Single-photon detector based on superconducting nanowire transmission line

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The superconducting nanowire single-photon detector (SNSPD) plays an important role in quantum information processing, optical space communication, astronomical observation, and biological sensing. With the continuous advances in recent years, the SNSPD has achieved near-unity efficiency, few-ps jitter, 100s-MHz count rate, spectral sensitivity from UV to mid-IR, and sub-1-cps dark count. Though individual devices have demonstrated exceptional performances, the electrical readout of large arrays of detectors remains an outstanding challenge.

Here, we report on a scalable array architecture for SNSPDs by using superconducting nanowire slow-wave transmission line. As shown in Fig. 1, in this architecture, we connected a chain of specially designed 80-nm-wide parallel wire detectors using 300-nm-wide delay lines. Due to the anomalously high kinetic inductance of the thin-film superconducting nanowires, we were able to engineer the nanowires into a microstrip transmission line with a group velocity as low as 1.6% *c* (*c* is the speed of light in vacuum). Such low group velocity allowed us to create a compact on-chip delay directly integrated with the detector segments. When a photon hits a detector segment, it excites a pair of counter-propagating electrical pulses, which are registered on both terminals of the detector chain. Using simple timing logic, we can resolve the location of the photon. More interestingly, due to internal reflections of the electromagnetic waves, the pulse shapes of the electrical signals carry very distinct fingerprints that can be used to resolve multi-photon events. The device architecture is useful for large-scale on-chip coincidence detection for quantum information processing. We also expect the superconducting nanowire transmission line to be a promising platform for developing compact, low-noise, on-chip microwave components.

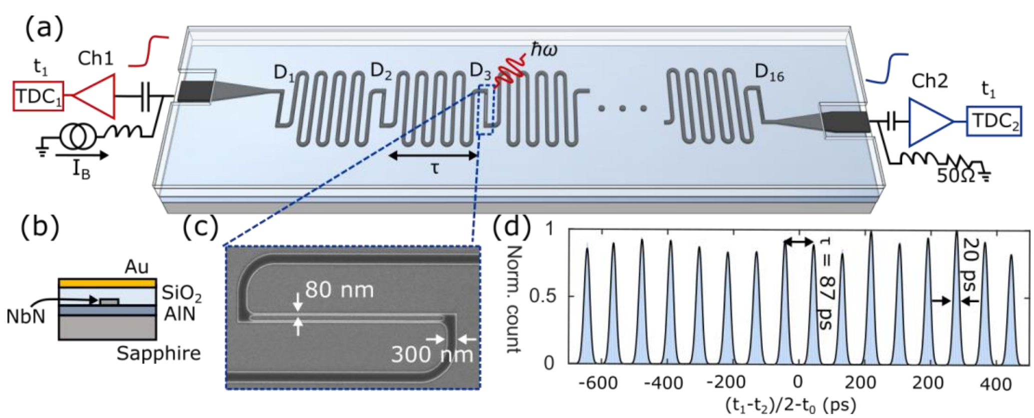

Fig1. A 16-element SNSPD array based on superconducting nanowire delay lines. (a) A chain of detector segments connected using nanowire delay. Photon absorption excites a pair of counter-propagating pulses, whose arrival time on both terminals are registered using time-to-digital converters. (b) Cross-sectional view of the device layers. The NbN nanowire, SiO_2 spacer, and Au top ground plane form a microstrip transmission line. (c) Scanning electron micrograph of a detector segment. (d) A histogram of differential time from single-photon detection events.