Waveguide coupled WSix superconducting nanowire single photon detectors

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Superconducting nanowire single-photon detectors (SNSPDs) based on amorphous WSi are excellent single-photon detectors at near-infrared wavelengths, with demonstrated system detection efficiency (SDE) up to 93%, jitter as low as 150ps, dark count rates (DCRs) of ~ 1cps, and reset times of ~40 ns at 1550 nm [1]. To date, SNSPDs have been successfully deployed in deep space optical communication demonstrations [2,3]. Here, we report our efforts to integrate SNSPDs with low stress silicon nitride (SiNx) waveguides and ring resonators to enable on-chip spectral filtering with photon counting capability. We have demonstrated WSi-based superconducting nanowire single-photon detectors coupled to SiNx waveguides with integrated ring resonators. This photonics platform enables the implementation of robust and efficient photon-counting detectors with fine spectral resolution near 1550 nm.

Images of our device architecture are shown in Fig. 1. Light is coupled into an input waveguide, which is coupled to a drop-port waveguide through a ring resonator. At the termination of the drop port, light is evanescently coupled to a WSi-based SNSPD in a hairpin geometry. Simulations indicate lengths on the order of tens of microns are necessary for efficient coupling to the SNSPD, and we implemented 40 μm long hairpins. An additional inductor section in series with the SNSPD absorber prevents latching [4]. Fiber couplers, consisting of self-aligned inverse-taper couplers suspended above etched v-grooves, allowed light to be coupled on and off the chip, as previously demonstrated in Ref. 5. Separate through- and drop-port fiber couplers were fabricated for each SNSPD to allow for independent characterization of the resonator and detector.

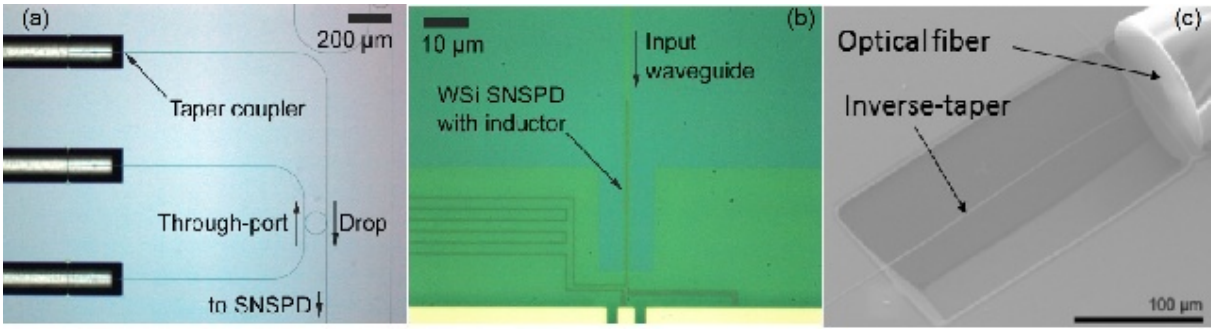

Fig. 1. (a) Optical micrograph of the waveguide architecture. A ring resonator passes a narrow band of light to the drop-port waveguide that is coupled to a SNSPD. Three fiber taper couplers allow for efficient coupling of light into the device and independent analysis of the resonator and detector. (b) Optical micrograph of the WSi-based SNSPD and input waveguide. The SNSPD inductor prevents latching. (c) SEM micrograph of the self-aligned inverse-taper couplers suspended above the etched v-groove. The depth of the v-groove allowed the fiber to be self-aligned to the inverse-taper height. The fiber was butted up against the inverse-taper to couple light onto the chip.

Devices were fabricated on Si wafers with 400 nm of low-stress SiNx deposited by low-pressure chemical vapor deposition on top of 3.5 μm of thermally grown SiO2. The SiNx thickness was chosen for optimal confinement of light at 1.55 μm, and low stress SiNx was used to avoid cracking. Typical losses in single-mode waveguides were measured to be 5 dB/cm. Amorphous WSi SNSPDs and contacts were patterned and protected by sputtered SiO2, and ridge waveguides were then etched into the SiNx using an SF6/C4F8 etch. After protecting the SNSPDs with an alkaline-resistant polymer coating, the suspended waveguide tapers were undercut with buffered HF and v-grooves were etched into the Si substrate using KOH.

Waveguide-coupled detectors were tested in a closed-cycle He-3 cryostat at 0.5 K. A single-mode laser with a tuning range of 1510 to 1620 nm was used to measure system detection efficiency (SDE), dark count rate (DCR), and spectral response. A SDE of ~2.5 % and DCR < 100cps was and observed with a detector bias current greater than 1.5 μA. The saturated internal efficiency indicates that nearly all the evanescently coupled light was detected in the SNSPD. The DCR with the input fiber coupled to the external laser and blanked was nearly indistinguishable, implying negligible background counts from the fiber couplers.The spectral response of a SNSPD coupled to the drop-port of a ring-resonator with a diameter of 100 μm indicates a typical linewidth of 100 pm, corresponding to total Q of ~16,000 and an intrinsic resonator quality factor of approximately 30,000.

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