Performance improvement of NbTiN superconducting nanowire single photon detectors by avalanche switching architecture

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Recent progress of the superconducting nanowire single photon detector (SSPD or SNSPD) has delivered excellent performance and impact on the QKD research field. Significant efforts are being made to achieve further improvement, and a primary concern at present is to resolve the trade-off between detection efficiency (DE), timing jitter, and response speed. For example, our standard SSPDs based on NbN or NbTiN nanowires have shown SDEs as high as ~80% at telecommunication wavelengths [1], but do not perfectly saturate in bias current dependency, implying that internal DE is not reached to 100%. Although the effective ways to achieve 100% internal DE are to create a narrower nanowire or to use a superconducting material with lower energy gap, these make the switching current (I_{sw}) of the nanowire smaller, degrading the timing jitter by reducing the signal-to-noise ratio (SNR) of the output. The superconducting nanowire avalanche photon detector (SNAP) is an alternative configuration that is able to resolve the trade-off [2]. Recently we have succeeded to develop fiber-coupled NbTiN-2SNAP devices with high DE, low system dark count rate (SDCR), and higher response speed than conventional SSPDs [3]. Here we introduce the demonstrated performances of our 2SNAP detectors.

We fabricated serially connected 2SNAP (SC-2SNAP) structure which is composed of several tens of parallel pairs of 60-nm-wide and 15-μm-long straight NbTiN nanowires connecting in series, covering the sensitive area of 15 × 15 μm^2. An optical cavity structure comprising quarter wavelength dielectric layers and Ag mirror was embedded on to the sensitive area to enhance absorptance of incident photons. Fabricated devices were mounted into compact packages which allow efficient optical coupling to a single mode optical fiber, and then installed into a Gifford–McMahon cryocooler system. Fig. 1 shows the system detection efficiency (SDE) and dark count rate (DCR) as a function of a bias current. The device showed a flat DE with an average value of 81.0% in the wide bias current range of 15-18.0 μA. The flat SDCR dependency in the bias current range of 15-17.5 μA was also shown and average value was 6.8 counts/s, which is considerably lower than the reported values for conventional SSPDs [1]. We also examined the timing jitter and obtained 68 ps full width of at half maximum (FWHM) timing jitter at the bias current of 17.5 μA

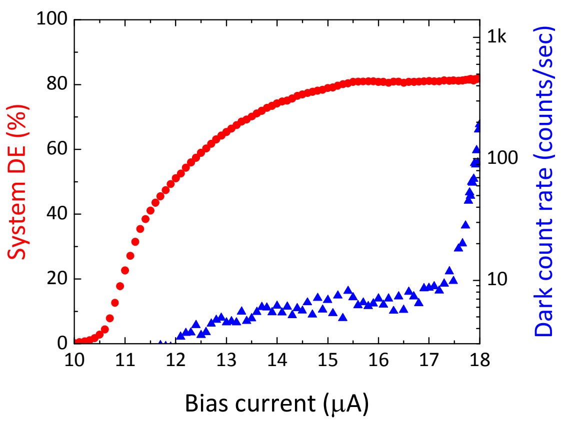

Fig. 1. System detection efficiency and system dark count rate as a function of bias current for SC-2SNAP.

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