Superconducting Cryogenic Coincidence Circuit with Signal Merger for High Repetition-Rate Two Photon Interference Based on Superconducting Nanostrip Single Photon Detector

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A superconducting nanostrip single photon detector (SNSPD) is an attractive detector for various advanced photon technologies such as quantum information and communications due to its high detection efficiency, low dark count rate, low timing jitter, and high counting rate [1], [2]. In quantum information and communication systems, Hong-Ou-Mandel (HOM) interferences are essential blocks, and SNSPDs are important devices for HOM interferences because the fidelity of the quantum state in HOM interference highly depends on the detection efficiency and timing jitter of photon detectors. HOM interference is also applied to sensing systems such as quantum optical coherence tomography [3], where the depth resolution depends on the repetition rate and the time window of coincidence detection. To improve the performance of such coincidence detection systems, coincidence detection with narrow time window and SNSPDs with reduced dead time are required.

In this work, we introduce the cryogenic signal processors based on single flux quantum (SFQ) circuits for coincidence detection systems with high repetition rate and narrow time window. The SFQ circuits are superconducting digital circuits with operating frequency at tens of GHz with low power consumption and low timing jitter due to high-speed switching time of Josephson junction (JJs) of a few ps. We have already demonstrated some SFQ-based post signal processors for SNSPDs such as multi-channel signal merger [4], coincidence circuit [5], and so on. We designed a coincidence circuit consisting of two 4-input SFQ signal mergers, a coincidence detection unit with multiple narrow time window options, and voltage drivers. The system employs two 4-pixel SNSPD arrays, each connected to one of the 4-input SFQ signal merger. Each combination of an SNSPD array and an SFQ signal merger functions as a single-channel photon detector with improved count rate capability as compared to conventional single SNSPD. The merged outputs from each SNSPD array are fed into the coincidence circuit, which has 3 different time windows, 30 ps, 100 ps, and 200 ps, and we can select one of them on demand in the experiments. The circuit operated correctly in liquid helium by the standalone test, and current sensitivity of all input ports was found to be sufficient to sense the output signals of NbTiN SNSPDs.

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