Multiplexed heralded single-photons toward a periodic and deterministic single-photone source

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Single- and multi-photon sources play essential roles in quantum information processing (QIP). Photon-pair generation by spontaneous parametric downconversion (SPDC) has been conventionally and widely used for creating two- and multi-particle entangled states and heralded single-photon states. However, probabilistic generation of the SPDC photon-pair state is a key obstacle to scaling up QIP systems beyond the proof-of-principle experiments. We report on our recent efforts toward a periodic and deterministic single-photone source by use of a temporal multiplexing technique [1-4] with a high-efficiency heralded single-photone source.

The basic idea of the temporal multiplexing scheme is shown in Fig. 1 (a). An optical pulse-train from a laser periodically pumps a $\chi^2$ nonlinear crystal, and generates photon pairs (i.e., signal and idler photons) in one or more time slots. Each signal photon is sent to a single-photone detector (SPD): a detection heralds in which time slot the corresponding idler photon is present. By using an adjustable storage cavity with a high-speed polarization switch, any of the time slots heralded to contain an idler photon can be multiplexed onto a single output time window. Thus, the single-photone probability during the output time window is increased according to the number of pump pulses (time slots) $N$ used for one cycle of the multiplexing. Moreover, if $N$ is large, the probability of generating unwanted multiple pairs in a given time slot can be made arbitrarily small, because the total pump energy through the multiplexing cycle is distributed over the $N$ time slots, and the ratio of the single- and multi-photone probabilities is as low as the one for a single (non-multiplexed) heralded single-photone source. In addition, the temporal multiplexing scheme can be used for generating multi-photone states by moving the nonlinear crystal inside the storage cavity [3]. Note that Migdall and co-workers [5] have proposed a similar technique based on “spatial” multiplexing.

Figure 1 (b) shows our experimental results in the single-photone probability versus $N$. We clearly observed the enhancement over the non-multiplexed source ($N = 1$): For a photon-pair generation probability per time slot $p = 0.35$, we observed a single-photone probability of 38.6% (see blue dots in Fig. 1 (b)), corresponding to a ~6 times enhancement from the non-multiplexed case. For $p = 0.07$, the multiplexed single-photone probability (see green squares in Fig. 1 (b)) is ~16 times larger than the non-multiplexed case. Moreover, measuring the second-order correlation function of the output photons, we observed that the ratio of single- and multi-photone probabilities is approximately independent of the temporal multiplexing. The enhancement in the single-photone probability and suppression of the multi-photone probability can be further improved incorporating recent state-of-the-art technologies.

![Fig. 1](image-url). (a) Simplified schematic diagram of our temporally multiplexed heralded single-photone source. PC: Pockels cell, SPD: Single-photone detector, PBS: Polarizing beam-splitter. (b) Observed multiplexed single-photone probability versus number of time slots $N$.

References