단광자 파속의 생성과 제어에 관한 연구

Temporal Shaping of a Heralded Single-Photon Wave Packet

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Quantum interference between independent single−photons, which is at the heart of physical implementations of photonic quantum information processing, is affected significantly by the shape of single−photon wave packet. Thus, it is of interest and importance to learn how to manipulate and to measure the shape of the single photon−wave packet.

In this paper, we report the temporal shaping of a heralded single−photon wave packet, conditionally prepared by detecting the idler trigger photon of the signal−idler photon pair born in the process of spontaneous parametric down−conversion (SPDC). Temporal shaping of the heralded single photon wave packet was accomplished by using chirp broadening and interference effects.

Consider the schematic of the experiment shown in Fig. 1. Collinearly propagating signal−idler photon pair are generated from type−I BBO crystal and they are splitted at the beamsplitter(BS). The idler photon is detected by a trigger detector. IF1 and IF2 are 80 nm FWHM interference filters centered at 816 nm. The signal photon passes through the interference filter IF2 and coupled into a 1602 m long single−mode fiber (SMF). And then the signal photon emerging from SMF is collimated and sent through a Michelson interferometer. We record the first−order interference due to the Michelson interferometer as well as the TCSPC measurement, synchronized to the trigger event, which records the temporal probability distribution of finding a single−photon.

Fig. 2(a) at left shows first−order interference of the signal photon. Note that the field autocorrelation by a Michelson interferometer only provides the power spectrum of the light source via the Wiener−Khintchine theorem, not the temporal profile of the pulse wave packet.

Fig. 2(b) ~ 2(e) at left shows the results of the TCSPC measurements, which reveal the wave packet profiles of the signal photon, for several different mirror positions of the Michelson

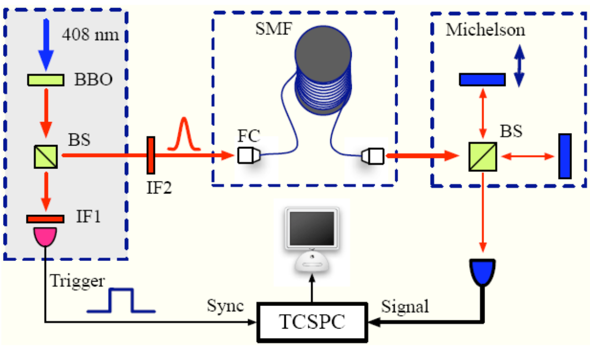

Fig 1 . Schematic of the experiment.

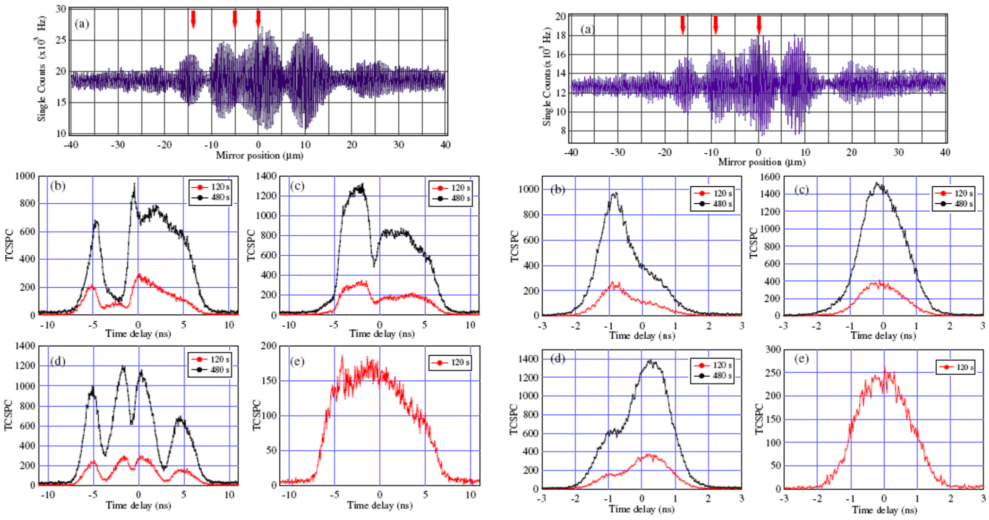

Fig 2 . Left: Experimental data. IF1 and IF2 are both 80 nm FWHM filters centered at 816 nm. (a) First-order interference fringe observed at the signal detector. Red arrows represent the mirror positions where the TCSPC measurements, which reveal the temporal shape of the single-photon wave packet, are taken. Mirror position are (b) 0 µm, (c) −5 µm, (d) −13.5 µm, and (e) −100 µm. Right: Experimental data. IF1 and IF2 are 10 nm and 80 nm FWHM filters, respectively. (a) First order interference fringe. TCSPC measurement are taken for mirror position, (b) 0 µm, (c) −9 µm, (d) −16 µm, and (e) −100 µm.

interferometer. When the Michelson interferometer is balanced within the coherence length, $\lambda^2/\Delta\lambda$, which is determined by the spectral bandwidth of the signal photon, temporal shaping of the single−photon wave packet occurs, see Fig. 2(b) ~ (d) at left. It is caused by interferometric suppression of specific spectral components in the chirp broadened single−photon wave packet. Since the effect of the Michelson interferometer can be seen as a sinusoidal spectral filter with a variable frequency, $2\pi/T$, where T is the delay between the paths, the wave packet shows more modulation as the Michelson interferometer gets more unbalanced(1). If the interferometer is made unbalanced more than the coherence length, $2\pi/T$, no interference occurs, see Fig. 2(e).

In addition, we also demonstrated nonlocal control of the temporal shaping of the heralded single−photon wave packet. To demonstrate this effect, we chose a 10 nm FWHM IF1 for the idler photon and 80 nm IF2 for the signal photon. It is clear that temporal shaping is almost disappeared due to narrow band filtering of the idler photon. See the Fig. 2 at right.

In conclusion, we have experimentally demonstrated temporal shaping of the heralded single-photon wave packet and nonlocal control of the temporal shaping by spectrally filtering the idler photon.

Reference

1. M. Bellini *et al.*, Phys. Rev. Lett. **90**, 043602 (2003).