Improving the Spectral Purity of Single Photons from a Silicon Ring Resonator with Pump Pulse Optimization

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Compact, high purity single photon source is a crucial tool for photonic quantum technologies. We can obtain spectrally-pure heralded single photons from a silicon microring resonator (MRR) via the spontaneous four-wave mixing (SFWM). However, the spectral purity P of photons generated from an MRR is limited to 0.92 [1]. To solve the issue, researchers [1] proposed to improve the spectral purity by the dual pulse pumping method, where interference between a temporally-overwrapping two pulses effectively manipulates the joint spectral amplitude (JSA). Here we propose a simpler scheme, where we can increase the spectral purity by solely manipulating the spectral phase distribution of a pump pulse.

The JSA of signal and idler photons generated from an MRR via SFWM can be obtained as $f(\omega_\mathrm{s},\omega_\mathrm{i}) = F_\mathrm{p}(\omega_\mathrm{s}+\omega_\mathrm{i})l_\mathrm{s}(\omega_\mathrm{s})l_\mathrm{i}(\omega_\mathrm{i})$, where $F_\mathrm{p}(\omega) = \int \mathrm{d}\omega_\mathrm{p}\, \alpha_\mathrm{p}(\omega_\mathrm{p})\alpha_\mathrm{p}(\omega-\omega_\mathrm{p})l_\mathrm{p}(\omega_\mathrm{p})l_\mathrm{p}(\omega-\omega_\mathrm{p})$. ω_p, ω_s and ω_i denote angular frequencies of the pump, signal and idler photons, respectively. $l_\mathrm{j}(\omega)$ (j = p, s, i) is the square root of the Lorentzian function including the Q value at resonance frequencies of MRR [2]. The pump pulse amplitude $\alpha_\mathrm{p}(\omega) = |\alpha_\mathrm{p}(\omega)|\mathrm{e}^{-i\Phi(\omega)}$, where $\phi(\omega) = \sum_{n=0}^{\infty}\frac{\phi_n(\omega-\omega_0)^n}{n!}$ is the spectral phase. When all the parameters ϕ_n are set to 0, *i.e.*, the pump is chirp free, we obtained a JSA shown in Fig. 1(a) having P of 0.92. Then we optimized the parameters ϕ_n to increase the purity. When $\phi_2 = -90$ ps^2, $\phi_3 = -5{,}700$ ps^3 and all the rest were 0, we obtained the JSA illustrated in Fig. 1(b) with $P = 0.95$, which exceeds the conventional bound. This is because the spectral chirp eliminates the Lorentzian side-lobe of $F_\mathrm{p}(\omega)$ originating from the resonator spectrum $l_\mathrm{p}(\omega)$, tailoring the JSA more center symmetric.

This work was supported by MEXT Q-LEAP Grant Number JPMXS0118067581.

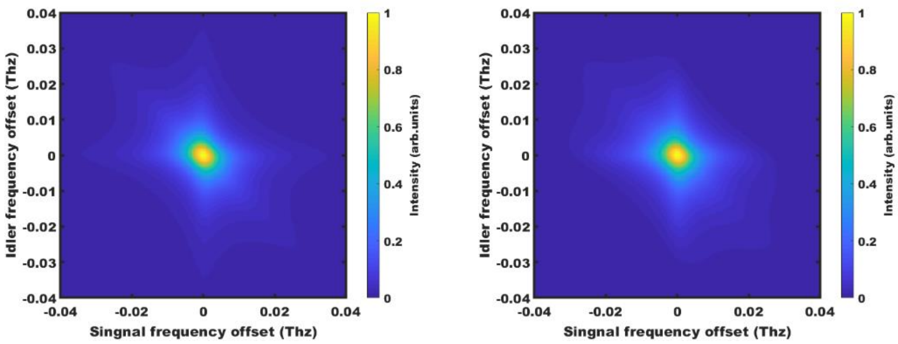

Figure 1. Calculated JSA of the photon pairs (a) without and (b) with the pump pulse optimization.

References:

[1] J. B. Christensen *et al.*, Opt. Lett. **43**, 859 (2018). [2] Z. Vernon *et al.*, Opt. Lett., **42**, 3638 (2017).