Quantum light generation and frequency conversion with integrated nanophotonics

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Quantum frequency conversion (QFC)[1] is an important resource for photonic quantum systems, for example, in creating telecommunications-band links for systems that naturally operate at other wavelengths and enabling interfaces between disparate physical systems. Experiments on high-dimensional entangled states based on frequency bin encoding[2] suggest that QFC can play an important role in such work as well. Recently, there have been advances in creating efficient frequency conversion technology based on scalable nanophotonics[3,4]. Here, we present two experiments that combine such nanophotonic QFC devices with nanophotonic quantum light sources (Fig. 1).

The first experiment (Fig. 1(a)) combines photon pair generation based on spontaneous-four-wave mixing (SFWM) in Si_3N_4 microring resonators with QFC based on four-wave mixing Bragg scattering (FWM-BS) in similar Si_3N_4 microrings. We first characterize quantum correlations between the signal and idler photons produced by the SFWM source. We find that the level of these correlations is unchanged after one of the photons is sent through the QFC device, which spectrally shifts its wavelength by a few nanometers with an on-chip efficiency of 25 %. Next, we turn the originally non-degenerate SFWM source (i.e., signal and idler photons at different frequencies) into an effectively degenerate source through QFC. By spectrally shifting the signal photon to a wavelength near that of the idler, we are able to perform Hong-Ou-Mandel experiments in which we observe quantum beats of single photons as the frequency of the converted signal is swept across that of the idler.

In a second experiment (Fig. 1(b)) we switch the source to a quantum dot single-photon source[5]. We compare the level of photon antibunching ($g^{(2)}(\tau)$) before and after QFC of the quantum dot single photons, and find that the light remains antibunched with $g^{(2)}(0) < 0.5$ throughout. Finally, we will discuss general noise and bandwidth considerations associated with our microring QFC devices, and how this influences their on-chip integration with other elements. We will also discuss how FWM-BS can be extended to enable telecom-band interfaces[3], as well other types of frequency-domain quantum state manipulation.

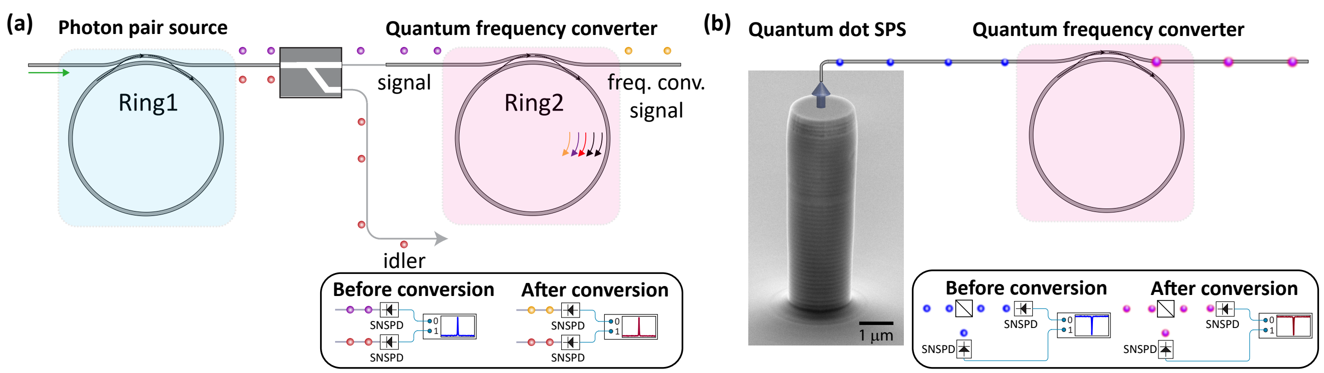

Figure 1: Quantum frequency conversion with integrated nanophotonics, using (a) microring photon pair sources and (b) quantum dot single-photon sources, together with a microring frequency converter.

References

[1] P. Kumar, Optics Letters **15**, 24, 1476-1478 (1990).
[2] M. Kues, et al, Nature **546**, 622-626 (2017).
[3] Q. Li, M. Davanco, and K. Srinivasan, Nat. Photonics **10**, 406-414 (2016).
[4] L. Fan, et al, Nat. Photonics **10**, 766-770 (2016).
[5] P. Senellart, G. Solomon, and A. White, Nat. Nanotechnology **12**, 1026-1039 (2017).