Chip-based visible-telecom photon pair sources using integrated microresonators

***Xiyuan Lu*[1,2], *Qing Li*[1,2], *Daron A. Westly*[1], *Gregory Moille*[1,2], *Anshuman Singh*[1,2], *Vikas Anant*[3], and *Kartik Srinivasan*[1]**

[1]*Center for Nanoscale Science and Technology, National Institute of Standards and Technology, Gaithersburg, MD, USA*
[2]*Maryland Nanocenter, University of Maryland, College Park, MD 20742, USA*
[3]*Photon Spot, Inc., Monrovia, CA 91016*

Integrated nanophotonic resonators are being intensely studied for their potential in generating quantum states of light. In the context of silicon nanophotonics, significant efforts are being devoted to creating telecommunications-band photon-pair sources based on spontaneous four-wave mixing [1]. These sources have been integrated with beamsplitters and phase shifters into a large-scale network [2], and the ability to generate not just a single idler and signal frequency, but rather a comb of frequencies, is being explored in the context of high-dimensional entanglement [3]. In general, however, the ability to use dispersion-engineering to create sources in which the signal and idler photons are widely separated in frequency has not been explored. Such sources, which have been developed in mm-scale crystalline resonators [4] and periodically-poled nonlinear crystals [5], can be valuable for quantum communication based on entanglement swapping [6]. In such an application, one photon from the pair source will be resonant with a quantum memory (at a visible wavelength, for example), while the other will be in the telecom band. Successive entanglement swapping operations can then remotely entangle the memories.

Here, we will report the development of a class of integrated, microresonator photon pair sources in which one photon is in the visible (between 630 nm - 810 nm), and the other is in the telecom [7]. The sources are based on cavity-enhanced spontaneous four-wave mixing in the Si_3N_4 platform (Fig. 1(a)-(b). Dispersion engineering is used to ensure that the relevant process is both frequency- and phase-matched, and access waveguides are engineered to enable efficient out-coupling of signal and idler photons that are separated in frequency by $>$ 250 THz. Photon pairs are generated with a coincidence-to-accidental ratio (CAR) up to (3800 $\pm$200), and the combination of CAR and pair detection rate competes favorably with existing macroscopic-scale technologies. We will discuss how these sources can be customized, through simple geometric modification and variation in the pump frequency, to address a variety of relevant quantum optical systems in the visible and short near-IR. Finally, we will discuss recent progress towards demonstrating time-bin entanglement and entanglement swapping.

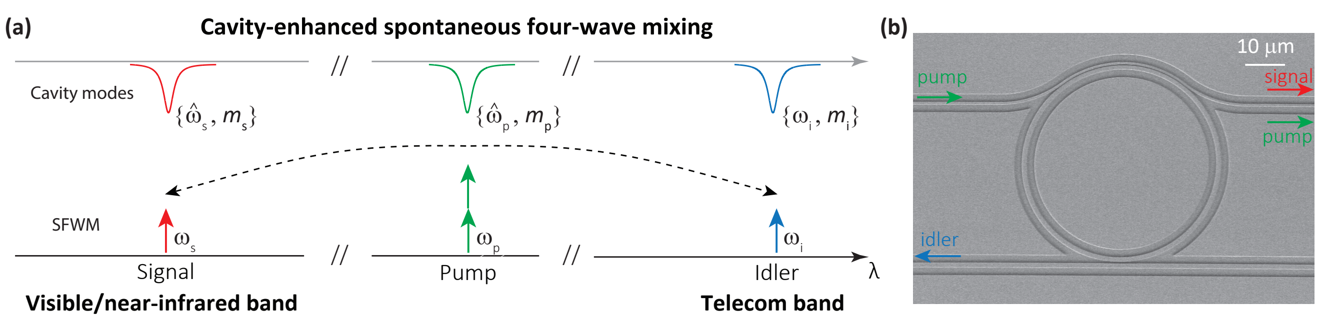

Figure 1: (a) Cavity-enhanced spontaneous four-wave mixing for generation of widely-separated photon pairs, with one photon in the visible and the other in the telecom. (b) Fabricated photon-pair generator, with the roles of the access waveguides noted.

References

[1] L. Caspani, et al, Light:Science and Applications **6**, e17100 (2017).
[2] J. Wang, et al, Science **360**, 285-291 (2018).
[3] M. Kues, et al, Nature **546**, 622-626 (2017).
[4] G. Schunk, et al, Optica **2**, 773-781 (2015).
[5] J. Fekete, et al, Phys. Rev. Lett **110**, 220502 (2013).
[6] M. Halder, et al, Nat. Physics **3**, 692-695 (2007).
[7] X. Lu, et al, arXiv:1805.04011 (2017).