Using four-wave mixing in silica waveguides to create photons on chip

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A necessary precondition of fully integrated quantum photonics is the generation of single photons on chip, either via heralded schemes or by integrating single emitters into a waveguided structure. Here we will discuss our techniques for the former.

While there are many possible materials for integration, we choose to work with silica-based glass for ease of coupling with fibre, increasing the flexibility of the platform. The waveguides on chip are defined by writing with a UV laser into a doped, photosenstive core layer, which also intrinsically provides the vertical confinement of the waveguide. Given that silica has zero intrinsic $\chi^{(2)}$, we use spontaneous four-wave mixing (SFWM) with a degenerate pump. To avoid noise from Raman scattering of the pump, the daughter photons must be kept away from the Raman band: either highly nondegenerate, or quite close to the pump (< 1 nm). We take both approaches.

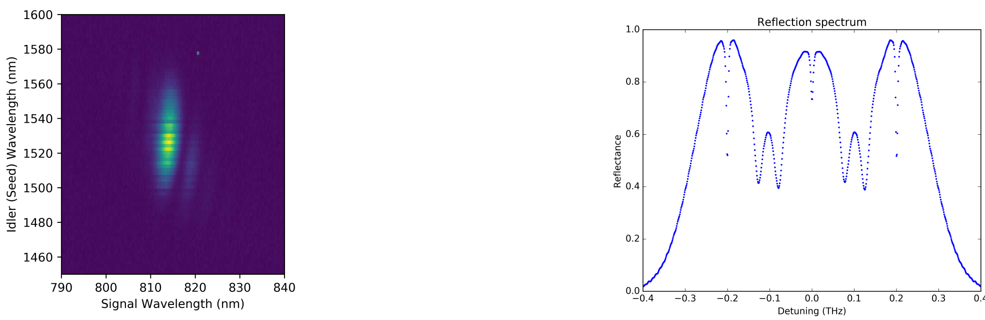

Figure 1: (Left) Measured seeded joint spectral intensity for the nondegenerate scheme. (Right) Modelled reflection spectrum for the narrowband scheme. The dips at 0 and ± 0.2 THz are the cavities of interest.

The nondegenerate case can be reached with high birefringence in the waveguide, here $(4.9 \pm 0.2) \times 10^{-4}$ [1], substantially improving state-of-the-art. This birefringence, with a suitable pump at 1060 nm, generates pairs of photons in spectrally uncorrelated modes near 1550 nm and 800 nm as shown in Fig. 1 (left)). Waveguide-to-fibre coupling efficiencies of 78–91 % are achieved for all fields, with the coupling most optimised for use with the 1550 nm photon as a heralded single photon.

The narrowband case, on the other hand, must be promoted with a cavity to attain reasonable brightness. We can write arbitrarily apodised Bragg gratings into our waveguides as we write them by interfering two UV beams and carefully controlling the phase relation between them with an EOM [2]. This allows us to define a single longitudinal cavity mode for each of the signal, idler, and pump: *only* these three cavity modes exist in the device and can be separately designed, as shown in Fig. 1 (right). This mitigates many problems with cavity-based schemes relying on broadband mirrors, *e.g.* allowing for spectrally uncorrelated daughter photons to be generated, as well as trivially providing some filtering of the pump.

We thus present two candidate technologies for on-chip photon creation, suitable for different schemes depending on the properties desired in a particular experiment.

References

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[2] C. Sima *et al.*, “Terahertz bandwidth photonic Hilbert transformers based on synthesized planar Bragg grating fabrication”, Opt. Lett. **38**, 3448 (2013)