Engineering waveguide arrays for high-purity matched four-wave mixing photon sources

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Abstract: We present recent developments in integrated four-wave mixing photon source arrays, produced via direct UV-writing in a silica-on-silicon substrate. These sources are of high purity and are mode-matched to optical fibre. Matching of the source arrays is demonstrated in initial results from quantum interference experiments, and efforts to further integrate these experiments are discussed.

Introduction

Significant advancements have recently been made in on-chip quantum optics experiments, highlighting the importance of integration in scaling to larger systems. Waveguide-integrated photon sources have been demonstrated in a variety of platforms, in the form of both single-photon emitters and photon-pair generation via non-linear processes. A key challenge in this area has been the difficulty of matching multiple sources without drastic reduction in count rates, particularly in an integrated format[1].

In this work we demonstrate that birefringent-matched four-wave-mixing (FWM) sources in UV-written silica-on-silicon waveguides possess sufficient uniformity for high quality quantum interference to be observed between photons emitted by independent guides in an array. This technology has previously been used in a range of two- and three-photon quantum circuits[2].

Fabrication

The UV-writing process utilized here involves a local refractive index increase induced in a photosensitive glass layer through absorption of a focused UV beam, translated across the substrate to inscribe a series of buried channel waveguides[3]. The silica core and cladding layers were fabricated on a thermally oxidised silicon substrate via Flame Hydrolysis Deposition (FHD), the former of these being doped with germanium and boron for photosensitivity and the latter with boron and phosphorus.

The birefringence of the resulting waveguides is dominated by the locked-in stress due to the different consolidation temperatures of these two FHD layers, which may be controlled by adjusting the dopant concentrations. This ability to tune the birefringence of the fabricated waveguides is invaluable since it allows the phase-matching to be tuned to place the signal and idler photons away from the Raman noise peak.

This approach produces waveguides which are highly uniform in both birefringence and effective index over chip scales, and may be fabricated reproducibly.

Characterisation

Characterisation of the source array was conducted by free-space launching into pairs of waveguides, via a free-space optical delay stage for one input, with an 80 MHz Ti-sapphire pump at 760 nm. The signal and idler outputs from each source were then separated and launched into separate fibres after filtering of the pump. The two signal photons were detected by Avalanche Photodetectors (APDs) and used to herald the idler photons, which were interfered at a 50-50 fibre beam splitter before being detected at two further APDs. The peak wavelength of the signal and idler photons, 670 nm and 820 nm respectively, were consistent with a waveguide birefringence of 1.2×10^{-4}.

Fig. 1a displays the coincidence count rates as a function of delay stage position for one pair of sources, both with and without minimal filtering. The Hong-Ou-Mandel (HOM) interference dip visibility is also plotted for four pairs of sources (Fig. 1b); these values demonstrate high quality non-classical interference, close to the calculated theoretical maximum for the system, for all four pairs of waveguides.

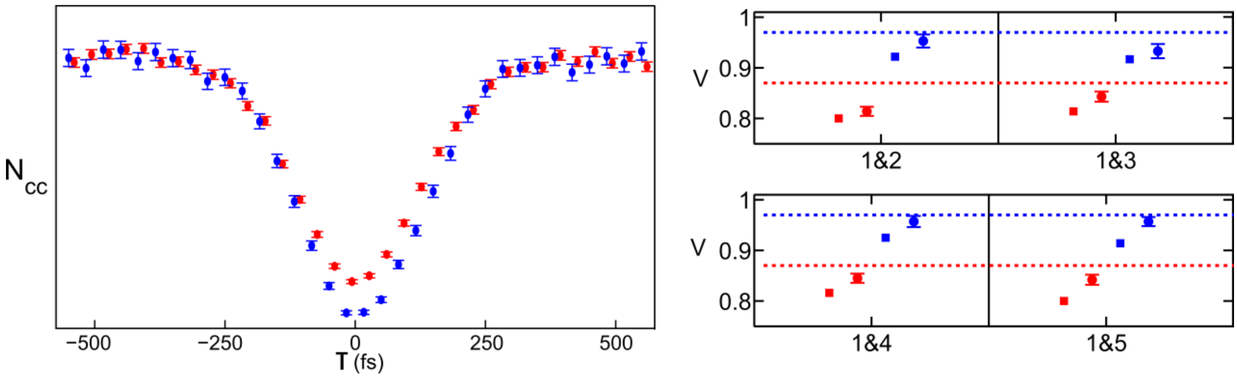

Fig. 1: a) Coincidence count rate as a function of delay for a representative source pair on the fabricated

Conclusion

We report the fabrication of matched UV-written waveguide arrays for FWM photon sources, and present non-classical interference between pairs of sources in a set of four. Results suggest that many on-chip sources of identical photons are possible in this platform with minimal additional development.

Further integration of these sources is also being explored; in particular the UV-written approach permits high-quality Bragg gratings to be incorporated readily, allowing for on-chip pump suppression. Additionally, a 1-N splitter at the input would reduce the number of free space launches, permitting scaling to larger numbers of sources.

References

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