Hybrid Integration for Single Photon Generation

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Abstract: A key resource for quantum optics experiments and applications are on-demand sources of single and multiple photon states at telecommunication wavelengths. We report a hybrid integrated source of heralded photons combining periodically poled lithium niobate waveguides, laser inscribed circuits and fibre Bragg gratings to demonstrate the spatial multiplexing of four identical photon pair sources. The achieved results reveal the large potential of such an approach for designing tools for advanced quantum applications.

Introduction

For over thirty years the role of single photons has evolved from a merely fundamental concept to a resource for quantum information science (QIS). Despite advances in genuine single photon sources [1], spontaneous parametric downconversion (SPDC) is the most common method for generating single and paired photons thanks to unrivalled simplicity and versatility. However, SPDC sources have a non-negligible probability to produce multiple pairs preventing an increase to the emission rate at will. Although some schemes exploit this feature [2], in most QIS experiments this multi-photon contribution results in reduced quantum state fidelities [3]. Temporal multiplexing schemes have been used to increase photon production rates by increasing the pump repetition rate [4]. A spatial multiplexing scheme can also be used to increase source brightness, while maintaining a fixed noise contribution [5]. This method uses multiple heralded single photons actively routed to a single output [6,7]. Integrated optics stands as an enabling technology for QIS experiments [8], where integrated waveguides in periodically poled lithium niobate (PPLN) [9] have proven to be a flexible platform for on-chip experiments [10,11]. However, PPLN is less suited to the implementation of complex linear components. The femtosecond laser direct-write (FLDW) technique permits the rapid prototyping of 3D waveguide circuits [12] in glass substrates including fibre Bragg gratings (FBG) and waveguide circuits [13]. Here, we combine the potential of linear FLDW laser written circuits and PPLN waveguides to collect and filter four heralded, spatially separated photons from a PPLN chip. Such a hybrid approach provides scalability and can immediately leverage any improvements in transmission, detection and photon production efficiencies.

Experiment

The experiment interfaces laser written waveguides, directly written in glass substrates with PPLN waveguide SPDC sources (See Fig. 1). The PPLN waveguides act as heralded single photon sources. In this process one photon of a downconverted pair heralds the existence of its complementary photon. The pump laser emits picosecond pulses at 710 nm. This laser is coupled into an optical fibre pigtailed to a FLDW 4-port beamsplitter in order to pump four identical PPLN waveguides. The nonlinear interaction produces 1310 nm (idler) and 1550 nm (signal) paired photons. Those pairs are then split deterministically using laser written wavelength demultiplexers (WDM) and subsequently coupled into single mode fiber in a V-groove array. Upon the detection of one out of four 1310 nm photons, the complementary 1550 nm photon is heralded and routed to a single output thanks to fast optical switches. The heralded single photon rate is recorded and the signal to noise is characterized by measuring the coincidence-to-accidental ratio (CAR), calculated by taking the ratio of coincident arrivals of signal and idler photons from the same pulse with those from subsequent pulses.

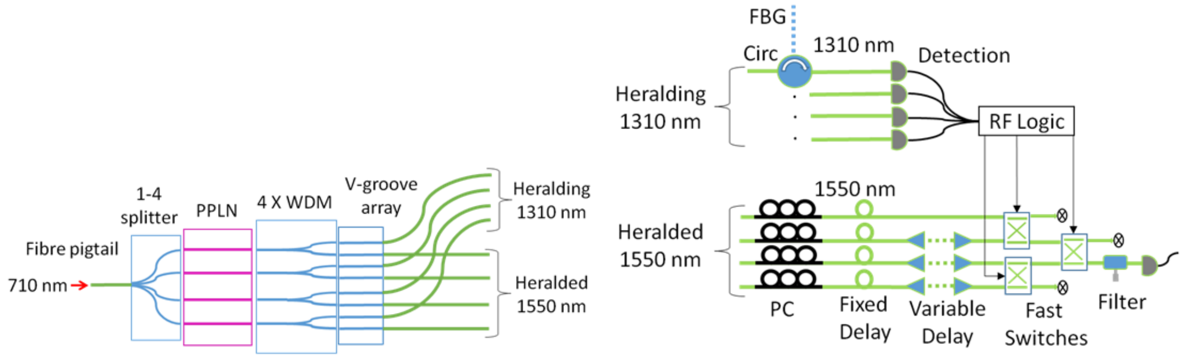

Fig.1: (left) A picosecond laser pumped array of 4 identical PPLN waveguides, where a pair of FLDW chips couple light in and out of the device. (right) The output of the WDMs is sent to a multiplexing setup. Four single photon channels at 1310 nm, which are filtered by FBG and circulators (Circ), herald the arrival of 1550 nm photons. Radio frequency (RF) electronics control the switches for routing the 1550 nm photons.

Results

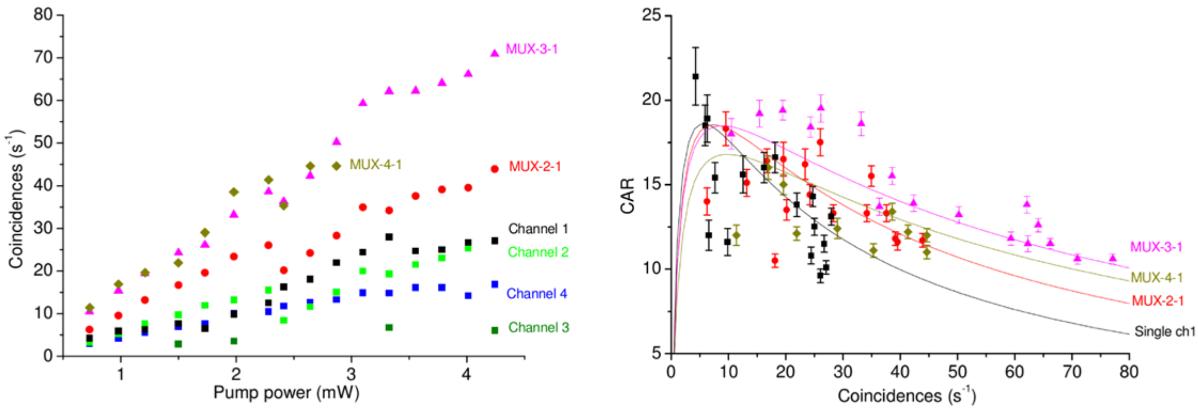

Fig.2: (left) Heralded photon rate vs. pump power for single channels and a 4-1 multiplexing scheme. (right) CAR vs. coincidences for multiplexing 2, 3 and 4 channels. Single channel 1 is shown for comparison.

Fig.2 clearly shows an increased photon rate, while maintaining a fixed signal-to-noise ratio through multiplexing. The overall results is in practice comparable to existing waveguide based photon sources due to high overall losses in the setup and one failing source (channel 3).

Conclusion

We have interfaced the largest number of SPDC sources on a single chip which is comparable to bulk optic demonstrations. This shows the practicality of hybrid integration for the preparation of single and multiple photon states. By increasing photon rates, while maintaining a fixed signal-to-noise ratio through multiplexing, we have demonstrated the scalability of our technique.

References

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