Interfacing solid-state single-photon sources and integrated photonics circuits: high rate three-photon coalescence.

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The development of optical quantum technologies relies on the use of many single photons to solve milestone problems spanning from quantum metrology, secure quantum communication and distributed quantum computing. This requires efficient sources producing highly indistinguishable single photons as well as photonic circuits showing high reconfigurability, phase stability and low losses. Integrated photonics circuits on glass have been demonstrated to be an excellent platform to tackle a vast variety of complex quantum operations such as Boson Sampling [1], quantum Fourier transforms [2], quantum random walks [3,4]. So far, these photonic chips have been operated with heralded single photon sources that show limited efficiency: because the probability of generating more than one heralded photon scales as the source brightness, the sources are typically operated with a brightness (i.e. probability to generate a photon-pair per pulse) around 1%. Alternatively, electrically-controlled semiconductor quantum dots coupled to microcavities have been shown recently to be excellent single photon sources, that deliver true single photon pulses with indistinguishability above 90% and brightness around 15% [5].

In this work we have combined for the first time these two highly promising platforms for scaling up optical quantum protocols. We have interfaced a solid-state single-photon source with an integrated photonic tritter in order to investigate the genuine quantum interference of three indistinguishable single photons. The quantum dot cavity device is resonantly excited under pulsed excitation (at a high repetition rate of 324 MHz) to generate a stream of single photons with $g^{(2)}(0)<5\%$ and indistinguishability >85% (between 80 ns delayed photons). We have developed a fast active demultiplexer to distribute three temporally distant single photons into three spatial fibre modes. The output of the time to spatial demultiplexer renders a three-single-photon generation rate of 3.9 kHz, three orders of magnitude higher than the same experiment performed with heralded single photon sources [6]. The three photons are injected in the reconfigurable photonic tritter where their coalescence is implemented. The output quantum state of light is collected in three fibres where pseudo-photon number resolving detection is performed with standard Silicon avalanche photodiodes with efficiency around 30% (see Fig. 1). The combined detection of three photon coincidences in the nine detectors (at a rate of threefold coincidences of 0.25 Hz) allows the final reconstruction and characterisation of the multi-photon coalescence state.

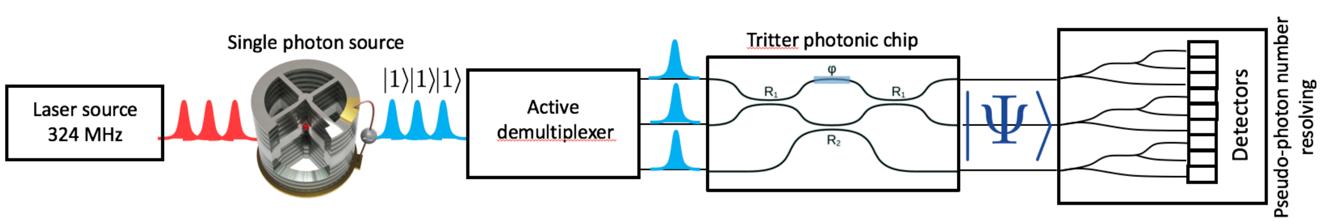

Figure 1: Schematic of the new optical platform combining solid-state single photon sources and glass photonic chips.

References

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