

Photon pair generation and manipulation in an integrated silicon chip

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Abstract: Quantum photonics is a promising technology for implementing quantum information tasks. We demonstrate integration of multiple photon pair sources together with a circuit enabling creation and manipulation of photon pairs in a monolithic silicon-on-insulator chip.

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1. Introduction

Quantum information enables fundamentally new ways for processing information [1]. Photonic quantum technologies are a promising road for implementing a quantum computer [2]. Those require single photon sources, linear optical circuits, single photon detectors and a way to reconfigure the circuit depending on the measurement. The silicon-on-insulator (SOI) platform offers compact circuits [3] and a high non linear coefficient suitable for photon pair generation [4], all working in the telecom band. We demonstrate here the integration of degenerate photon pair sources together with passive and active linear optical circuits all embedded in a monolithic SOI chip.

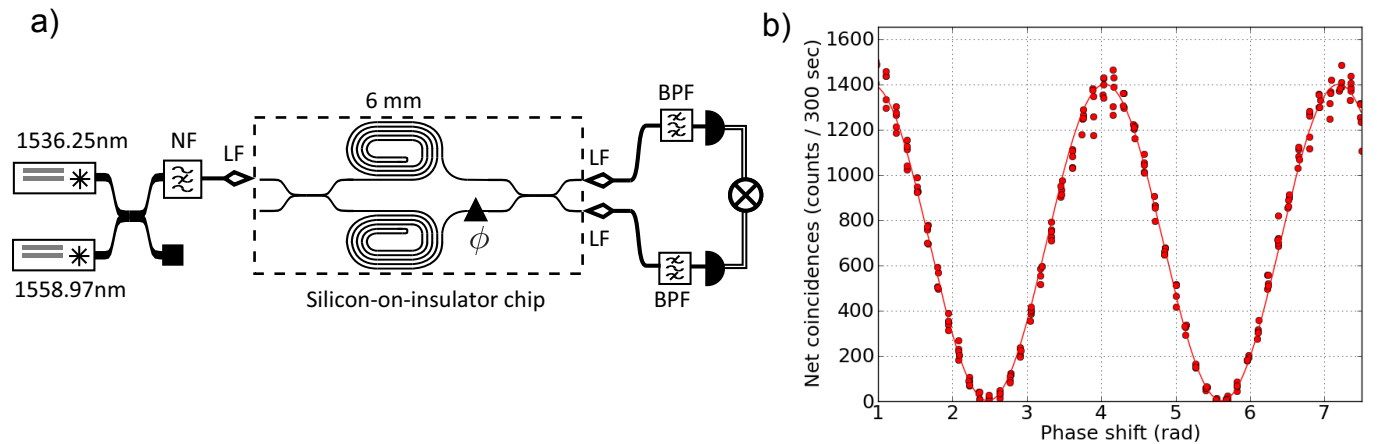


Fig. 1. (a) Schematic of the experimental setup. NF: notch filter; BPF: band pass filter; LF: lensed fibre. (b) Quantum interference fringe - number of coincidences as a function of the MZI phase ϕ

2. Device operation and results

The experimental setup works as shown on Figure 1a. Two lasers set up at $\lambda_1 = 1536.25\text{nm}$ and $\lambda_2 = 1558.97\text{nm}$ are combined on a multimode interference coupler, and filtered to remove the noise around $\lambda_s = 1547.70\text{nm}$. The two pumps are then injected in the chip using a lensed fibre. The first coupler splits the pump equally in both paths. Each arm is then composed of a 6mm long waveguide in which four wave mixing interaction permits conversion from one photon from each pump λ_1 and λ_2 in two degenerate photons around λ_s . To first order a photon pair is generated in state superposition of being in the top and the bottom arm of the interferometer. This $|20\rangle + |02\rangle$ state evolves through a relative phase shift to $|20\rangle + e^{i2\phi}|02\rangle$ and is then recombined on the last coupler of the interferometer. The output of the chips are then filtered to remove the pumps and the photons are measured using superconducting nanowire single photon detectors [5], and the coincidences between the two detectors are recorded using a time interval analyser. We measured a frequency doubled fringe with more than 99% visibility, signature of quantum interference (Fig. 1b). Setting the phase to $\pi/2$, the chip acts as a photon pair source. We performed a Hong-Ou-Mandel experiment, inserting a tunable delay after the chip and combining the two arms on an external beamsplitter. We obtained a dip visibility of $95\% \pm 4\%$. We also demonstrate phase memory effect [6] in the spontaneous four wave mixing process when operating the device backward - with the phase shifter before the long arms. In that configuration we measure the exact same fringes thanks to the phase transfer from the pump to the photon pairs.

This device is a promising integrated photon pair source and is a key step towards more complex architectures combining photon pair sources, linear optical quantum circuits and eventually single photon detectors.

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