Lithium niobate-on-insulator integrated photonics for linear optical quantum computing

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Linear optical quantum computing utilizes single photons or squeezed light and quantum interference to achieve an advantage in certain tasks such as boson sampling. Despite significant advances in integrated quantum photonics that can miniaturize table-top experiment to centimetre-scale chips, today's leading optical quantum computing experiments still use free-space and fibre optics [1, 2].

Lithium niobate-on-insulator (LNOI) is an emerging integrated photonics platform that has the potential of enabling a new generation of quantum photonic devices able towards demonstrating an on-chip quantum advantage. LNOI photons has a strong $\chi^{(2)}$ nonlinearity for efficient photon-pair or squeezed-state generation, high-speed electro-optic and thermo-optic phase control, low optical loss and a high index contrast for dense waveguide circuits [3]. While impressive experiments with LNOI have been performed, investigations into quantum computing applications remain limited.

Here, we report quantum interference between two nonlinear photon-pair sources in a programmable LNOI photonic circuit. We coherently pump two periodically poled LNOI waveguides to generate a two-photon entangled state and perform quantum interference in a Mach-Zehnder interferometer (MZI).

Our device is shown in Fig. 1a. By injecting a 781 nm wavelength laser into both spontaneous parametric down-conversion (SPDC) sources, we generate telecom-wavelength photons in the state $\frac{1}{\sqrt{2}}(|20\rangle + e^{2i\phi}|02\rangle)$, which is a coherent superposition of two photons in the upper and two photons in the lower waveguide [4]. The phase ϕ is controller with an on-chip thermo-optic phase shifter.

We manipulate this state with a programmable MZI to output either bunched or anti-bunched photons due to quantum interference. We measure quantum interference visibility of $95 \pm 1\%$, as shown in Fig. 1b, and perform Hong-Ou-Mandel (HOM) interference after the chip with $83.2 \pm 0.1\%$ visibility as shown in Fig. 1c.

Our results are a milestone in the development of LNOI quantum photonics, and the first step to scaling up towards dozens of sources and waveguides for the first demonstration of an on-chip quantum computation advantage with photonics.

References

[1] Zhong *et al.* Science **370** 1460 (2020)
[2] Madsen *et al.* Nature **606** 1476 (2022)
[3] Zhu *et al*. Adv. Opt. Photon. **13** (2021)
[4] Silverstone *et al.* Nat. Photon. **8** (2014)

Figures

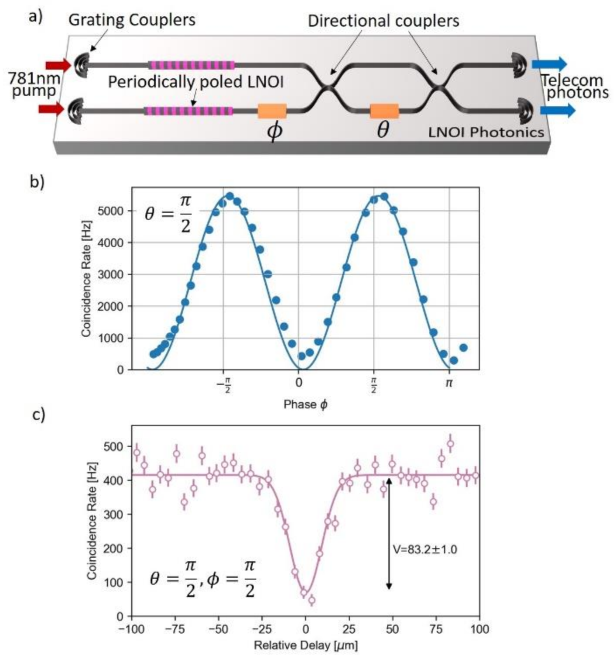

Figure 1: a) Schematic of our integrated LNOI quantum photonic circuits. b) Quantum interference between two LNOI SPDC sources. c) HOM interference with the generated photons