8×8 Programmable Si_3N_4 Photonic Processor for Linear Quantum Processing

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Universal linear optical networks made of on-chip tunable beam splitters and phase shifters form a very promising platform for quantum information processing (QIP). Thanks to their phase stability and reconfigurability, they are robust and enable a variety of quantum information and communication protocols such as quantum teleportation [1], quantum key distribution [2], photonic qubit gate protocols [3] and boson sampling [4]. Two known materials for on-chip platforms are silicon-on-insulator (SOI) and doped silica, where SOI allows for a high component density due to its high index contrast and silica has a low loss.

We introduce an 8×8 mode Blass matrix [5] as universal transformation circuit for linear-optical quantum information processing implemented on stoichiometric Si_3N_4 waveguides [6]. The Si_3N_4 platform offers the unique combination of high index contrast, ultralow straight-propagation loss and a spectrally wide transparency range. Fig. 1 shows a sketch of the 8×8 Blass matrix.

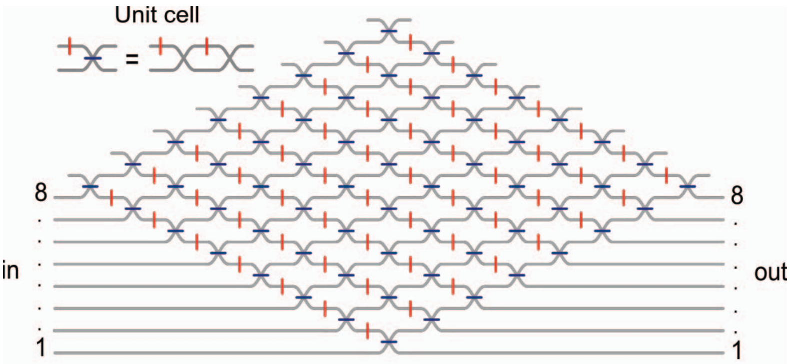

Fig. 1 The Blass matrix that shows the functional design of our photonic chip. Horizontal blue stripes are programmable beam splitters, vertical red stripes are phase modulators. The top left inset shows how the unit cell is constructed as a Mach-Zehnder interferometer.

In order to demonstrate that the photonic chip works as a linear-optical processor suited for general-purpose quantum information processing, we program on-chip quantum interference on several beam splitters within the Blass matrix and demonstrate a high visibility interference, obtaining an average fidelity of ~95%. To further demonstrate the flexibility and configurability of our processor we realized an 8-dimensional unitary transformation [8] with single photons in an 8 dimensional rail encoding.

Our findings demonstrate the suitability and reliability of a low-loss, integrated linear optical photonic processor based on Si_3N_4 waveguides. These results show the high potential of Si_3N_4 for the development of large universal linear optical quantum circuits, which is essential for the progress of quantum information processing.

References

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