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Integrated Quantum Photonics

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Of the various approaches to quantum computing [1], photons are particularly appealing for their low-noise properties and ease of manipulation at the single qubit level [2]. Encoding quantum information in photons is also an appealing approach to quantum communication, metrology (eg. [3]), measurement (eg. [4]) and other quantum technologies [5]. However, the implementation of optical quantum circuits with bulk optics has reached practical limits. We have developed an integrated waveguide approach to photonic quantum circuits for high performance, miniaturisation and scalability [6]. Here we report high-fidelity silica-on-silicon integrated optical realisations of key quantum photonic circuits, including two-photon quantum interference and a controlled-NOT logic gate [7]. We have demonstrated controlled manipulation of up to four photons on-chip, including high-fidelity single qubit operations, using a lithographically patterned resistive phase shifter [8]. We have used this architecture to implement a small-scale compiled version of Shor's quantum factoring algorithm [9] and demonstrated heralded generation of tuneable four photon entangled states from a six photon input [10]. We have combined waveguide photonic circuits with superconducting single photon detectors [11]. Finally, we describe complex quantum interference behaviour in multi-mode inter- ference devices with up to eight inputs and outputs [12], and quantumwalks of correlated particles in arrays of coupled waveguides [13].

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