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Photonic quantum technologies

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Of the approaches to quantum computing [1], photons are appealing for their low-noise properties and ease of manipulation [2], and relevance to other quantum technologies [3], including communication, metrology [4] and measurement [5]. We report an integrated waveguide approach to photonic quantum circuits for high performance, miniaturization and scalability [6–10]. We address the challenges of scaling up quantum circuits using new insights into how controlled operations can be efficiently realised [11], demonstrating Shor's algorithm with consecutive CNOT gates [12] and the iterative phase estimation algorithm [13]. We have shown how quantum circuits can be reconfigured, using thermo-optic phase shifters to realise a highly reconfigurable quantum circuit [14], and electro-optic phase shifters in lithium niobate to rapidly manipulate the path and polarisation of telecomm wavelength single photons [15]. We have addressed miniaturisation using multimode interference architectures to directly implement NxN Hadamard operations [16], and by using high refractive index contrast materials such as $\mathrm{SiO_xN_y}$, in which we have implemented quantum walks of correlated photons [17], and Si, in which we have demonstrated generation of orbital angular momentum states of light [18]. We have incorporated microfluidic channels for the delivery of samples to measure the concentration of a blood protein with entangled states of light [19]. We have begun to address the integration of superconducting single photon detectors [20] and diamond [21,22] and non-linear [23,24] single photon sources. Finally, we give an overview of recent work on fundamental aspects of quantum measurement, including a quantum version of Wheeler's delayed choice experiment [25].

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