Large-Scale Photonic Circuits for Quantum Information Processing

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Photonic integrated circuits (PICs) have become increasingly important in classical communications applications over the past decades, including as transmitters and receivers in long-haul, metro and datacenter interconnects. Many of the same attributes that make PICs attractive for these applications — compactness, high bandwidth, and the ability to control large numbers of optical modes with high phase stability — also make them appealing for quantum information processing. Here we review our recent progress in developing PICs for quantum information processing.

The first part of the talk will describe architectures for programmable PIC that can be programmed to implement arbitrary unitary linear-optics transformations. We recently applied these chips to applications ranging from deep neural networks[1] to quantum transport simulations[2], but this talk will focus on recent advances in entangled photon sources[3] and proposals for on-demand single photon sources[4], photon-photon nonlinear interactions, and neural neural network processors[5].

The second part of the talk will consider new PIC platforms that can be integrated directly with atom-like quantum memories. In particular, we will discuss PICs based on the AlGaN-sapphire material system that are transparent in the UV-VIS spectrum, for applications in multiplexed quantum repeaters. This PIC platform now allows quality factors in excess of 20,000 for wavelengths as short as 369nm[6] and the integration of diamond nitrogen vacancy color centers and superconducting single-photon resolving detectors[7]. Finally, we describe a blueprint for scalable cluster-state quantum computing that builds on large numbers of cavity-coupled diamond color centers networked by photonic switches and waveguides[8].

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5.	Steinbrecher, G. R., Olson, J. P., Englund, D. & Carolan, J. Quantum optical neural networks. arXiv [quant-ph] (2018).
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