Modular Linear Circuits for Integrated Quantum Optics

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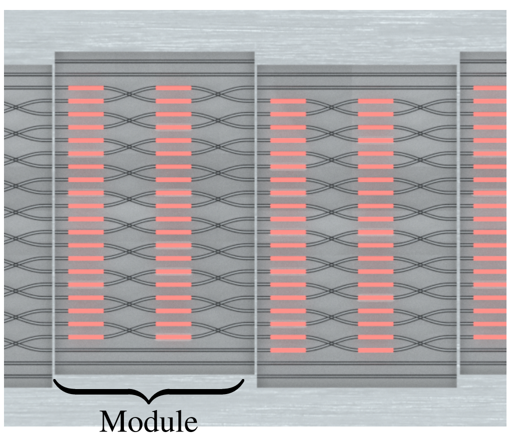
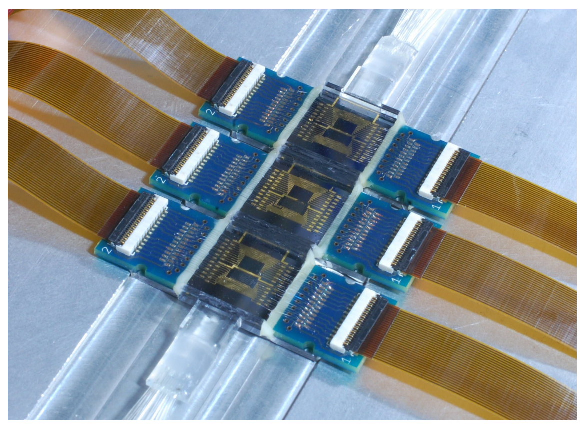
Quantum optics experiments are increasingly adopting an integrated format, and silica is an ideal material for this application, offering low propagation and fibre-coupling losses, indeed many key on-chip experiments have already been carried out using this material. Thus far such experiments have utilised bespoke, monolithic devices; here we propose an alternative approach in which a linear network is constructed from a set of identical reconfigurable modules, making more complex networks achievable. Such modules may be characterised individually, and the scheme permits the replacement of faulty or inferior elements.

Each of these modules is composed of an array of ten Mach-Zhender interferometers (MZIs) combined with forty thermo-optic phase shifters, permitting configuration of both amplitude and relative phase. Modules are cascaded to build up any arbitrary $N \times N$ unitary in an optimal way with at most N modules [1].

Modules are fabricated via direct UV writing into a photosensitive germanosilica layer in a planar silica-on-silicon substrate, produced via flame hydrolysis deposition (FHD). Waveguide dimensions are selected to provide mode-matching to optical fibre for improved coupling efficiency. Out-of-band first-order Bragg gratings are co-patterned with the waveguides in the network using a two-beam direct grating writing (DGW) approach [2] in order to further simplify the characterisation process, permitting losses to be measured precisely. The thermo-optic phase shifters are patterned via lift-off of an e-beam evaporated nichrome layer.



(a)



(b)

Figure 1: (a) Layout of a set of concatenated modular chips. (b) A linear optical network composed of three modular chips coupled together, with fibre V-groove assemblies at input and output.

The performance of our implementation was tested using a set of three modules coupled together, in a range of configurations. We report on proof-of-principle experiments making use of this novel architecture.

References

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[2] C. Sima, J. C. Gates, H. L. Rogers, P. L. Mennea, C. Holmes, M. N. Zervas, and P. G. R. Smith, "Ultra-wide detuning planar Bragg grating fabrication technique based on direct UV grating writing with electro-optic phase modulation," Optics Express **21**, 15747–15754 (2013)