Sci. Bull. (2015) 60(1):141
DOI 10.1007/s11434-014-0703-x

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Research Highlight

Quantum integrated circuit: classical characterization

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Published online: 5 January 2015

Quantum technologies promise a safer and faster life for us. One of the difficulties in developing quantum technologies is the scalability of quantum devices. Integrated quantum circuits based on waveguide networks fabricated by direct laser writing have become an attractive subject [1]. However, for the N-input and N-output ($N \times N$) integrated quantum circuit, the characterization of the operators becomes a hard problem when N is large. The measurement settings for the traditional quantum process tomography would exponentially increase with N.

In a recent work published by Heilmann et al. [2], they experimentally characterized the unitary operator of their homemade 8×8 waveguide network with a novel method which employs classical light only. In order to determine the unitary transformation matrix of the integrated circuit, one needs to obtain the full information of the moduli and phases of elements of the operator. In their method, the moduli components were obtained by sequentially illuminating each input port with laser light and measuring the intensity from all output channels, which is similar to the previous approach [3]. Inspired by Bowditch's work published in 1815 [4], the authors plotted Lissajous figures based on the intensity relations between input and output channels and the phase delay variation (commonly the ellipse). The phase elements can then be deduced from the shape, orientation, and rotation of the ellipse. Due to the fact that the plot of ellipse does not require highly precise phases delay, their method further reduces the experimental effort and enhances the accuracy of characterization compared with the previous approach [3]. In their experiment, the accuracy for all examined phase components can range from 0.14π down to 0.008π. The overall fidelity of their device can reach as high as 0.97. The authors proposed that their device could be used as a universal device to generate eight-order W-state, which improves the previous scheme [5]. By injecting a single photon in any of the input channels of the device, the output ports would represent an eight-order W-state.

The method used to characterize the operation of the integrated device requires only $2N - 1$ measurement settings for N channels, which is applicable to larger networks and the universal on-chip preparation of high-order W-state with the entanglement being robust against loss would find important application in quantum simulation and other on-chip quantum information processing.

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