Silicon quantum photonic device for multidimensional controlled unitaries

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Abstract: We present a fully reconfigurable silicon quantum photonic device capable of performing controlled four-dimensional unitary operations with 0.84 ± 0.02 fidelity. We report its characterisation by process tomography and deploy it to successfully perform a quantum model learning protocol.

Keywords: Process Tomography, Qudit Gates, Integrated Photonics, Model Learning

Qudits are quantum states with dimension higher than traditional qubits and offer certain advantages for quantum information processing. With their intrinsically higher information capacity, qudits have been used to obtain larger violation of local-realistic theories thus playing an important role in both quantum communication and quantum computing [1].

A fundamental prerequisite to enable qudits as carriers of quantum information in such applications is the demonstration of high-fidelity, arbitrary operations upon qudits. We do so introducing a silicon quantum photonic device capable of performing arbitrary unitary operations on a four-dimensional qudit (i.e. ququart) controlled by a qubit encoded in an ancillary register. We study the device performance by carrying out a selection of tomographic state reconstructions and find an average state fidelity of 0.95 ± 0.02. We demonstrate the first integrated quantum process tomography results for four dimensions and report an average process fidelity of 0.84 ± 0.02 from a range of processes uniformly sampled from the Hilbert space. Finally, we use this device as a quantum simulator to demonstrate a recently proposed protocol for quantum model learning [2].

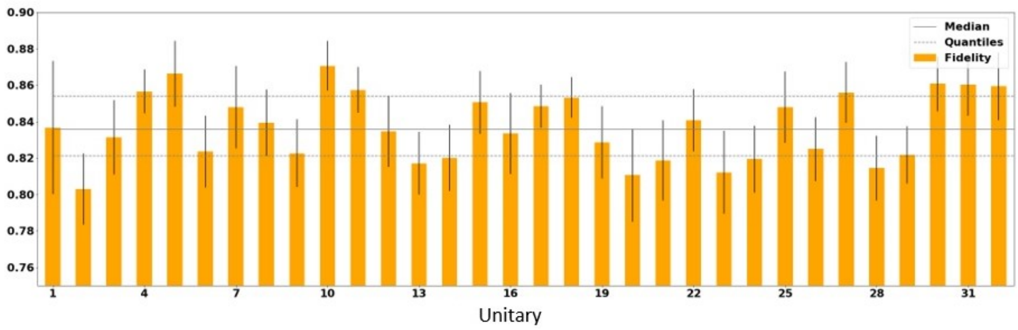

Fig. 1. Synoptic view of 32 Haar random unitary processes sampled from the Hilbert space shows an average process fidelity of 0.84 ± 0.02. Bar chart reports on the vertical axis the process fidelity measurements defined as $F_p = Tr(\chi_{tgt}\chi)$ where χ_{tgt} is the process matrix for the operation targeted whereas χ is the reconstructed process matrix.

References

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