ENERGY-EFFICIENT QUANTUM COMPUTING

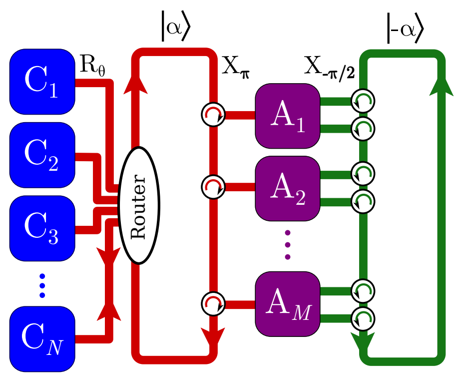
J. Ikonen,[1] J. Salmilehto,[2] and M. Möttönen[1]

[1]QCD Labs, COMP Centre of Excellence, Department of Applied Physics,
Aalto University, P.O. Box 13500, FI–00076 Aalto, Finland
[2]Department of Physics, Yale University, New Haven, Connecticut 06520, USA.
email: joni.2.ikonen@aalto.fi

In the near future, a major challenge in quantum computing is to scale up robust qubit prototypes to practical problem sizes and to implement comprehensive error correction for computational precision. However, extension of the main-stream experimental techniques [1] to a full-size solid-state quantum computer introduces practical challenges and scaling problems that are not faced in the present prototypes. One of the major issues is the management of harmful heat loads owing to conductance through cabling and dissipation at cryogenic components. This naturally raises the question that what are the fundamental limitations of energy consumption in scalable quantum computing.

In this work [2], we derive the greatest lower bound for the gate error induced by a single bosonic drive mode of given energy. This type of error, caused by quantum-mechanical uncertainties in the pulse, is inversely proportional to the pulse energy, and hence seems to pose a trade-off in the power management of the quantum computer. In addition to the lower bound itself, our method naturally finds the bosonic quantum states of the pulse that reach the bound. We explicitly show that single-qubit rotations are optimally realized by applying a certain amount of squeezing to coherent states.

The above-mentioned challenges further motivate the investigation of control methods alternative to the present standards, such as generating or redistributing the qubit control pulses at the chip level. Thus we propose a control protocol where multiple gates are generated with a single control pulse, and back-action-induced correlations between the pulse and computational qubits are removed using auxiliary qubits.



Whereas previous studies suggest that it is not possible to save energy by reusing control pulses without sacrificing the minimum gate fidelity [3], our method exhibits orders of magnitude smaller energy consumption with no drop in the average gate fidelity. Thus our work shows that precise, scalable control of quantum systems can, in principle, be implemented without the introduction of excessive heat or decoherence.

[1] J. Kelly *et al.*, Nature 519 (2015), 66–69.
[2] J. Ikonen, J. Salmilehto, and M. Möttönen, arXiv:1609.02732 (2016) [quant-ph].
[3] J. Gea-Banacloche and M. Ozawa, Phys. Rev. A 74 (2006) 060301.