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Trapped-Ion Entangling Gates Robust Against Qubit Frequency Errors

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Entangling operations are a necessary tool for large-scale quantum information processing, but experimental imperfections can prevent current schemes from reaching sufficient fidelities as the number of qubits is increased. Previous theoretical and experimental work has considered classes of errors including static offsets in the motional frequency, heating of the bus mode and timing errors in gate operation [1, 2], and shown analytically that these can be simultaneously minimised by a particular multi-toned modification to the Mølmer–Sørensen scheme.

We treat the hitherto neglected errors in qubit frequencies, which do not permit a closed-form analytic solution. We show numerically that simliar generalisations of the standard entangling gate can be made robust against noise and mis-sets of the frequencies of the individual qubits, including the case of separated carrier frequencies. We find numerically that a small-amplitude second tone can reduce the infidelity expectation by a factor of nearly four at the fault-tolerant limit, and additional tones can further improve this. This comes at the cost of a similar order increase in gate time, but significantly relaxes the degree of homogeneity required in the trapping field, making physically larger systems more practical.

[1] Webb, A. E., Webster, S. C., Collingbourne, S., Bretaud, D., Lawrence, A. M., Weidt, S., Mintert, F., and Hensinger, W. K. (2018). Physical Review Letters, 121(18), 180501.
[2] Shapira, Y., Shaniv, R., Manovitz, T., Akerman, N., and Ozeri, R. (2018). Physical Review Letters, 121(18), 180502.

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