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ABaQuS: A trapped-ion quantum computing system using $^{133}\mathrm{Ba}^{+}$ qubits

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Trapped atomic ions are one of the most promising quantum computing architectures. They exhibit all of the primitives necessary for building a quantum computer and have very few fundamental limitations to the achievable gate fidelities. While high-fidelity quantum logic has already been demonstrated on a small number of qubits, scaling up the system without compromising its performance remains challenging. Here we present the design and initial evaluation of a quantum system aimed at realising high-precision control over long chains of $^{133}\mathrm{Ba}^{+}$ ions.

Barium ions exhibit several features that are favourable for quantum computing experiments, including visible-light optical transitions and very long-lived metastable states. The $^{133}\mathrm{Ba}^{+}$ isotope is particularly interesting as it additionally offers a range of magnetically insensitive 'clock' qubit states in the ground level and in the metastable $D_{5/2}$ level, and optical 'clock' qubits spanning the $S_{1/2} - D_{5/2}$ manifolds [1]. Hence it opens a vast playground of novel qubit control schemes, including qubit hiding, partial projective measurements and mid-circuit measurements.

In our experiment we use a segmented monolithic 3D microfabricated trap [2] that provides a high degree of control of the trapping potential whilst maintaining a low heating rate. We show preliminary results on the trap characterisation performed with $^{138}\mathrm{Ba}^{+}$ ions.

The ground level qubit transition of $^{133}\mathrm{Ba}^{+}$ is driven by a two-photon Raman process using a 532 nm laser. We present the design and initial characterisation of our novel system for driving this 10 GHz transition with low phase and intensity noise. We further discuss the design of a laser-written waveguide device used for individual addressing of non-uniformly spaced ion crystals.

[1] J. E. Christensen, D. Hucul, W. C. Campbell, and E. R. Hudson. High-fidelity manipulation of a qubit enabled by a manufactured nucleus.npjQuantum Information, 6(1):35, 2020.
[2] P. See, G. Wilpers, P. Gill, and A. G. Sinclair. Fabrication of a monolithicarray of three dimensional si-based ion traps.Journal of Microelectrome-chanical Systems, 22(5):1180–1189, 2013.

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