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High fidelity microwave driven quantum logic for a scalable trapped ion quantum computing architecture

We report on a new experiment to demonstrate high-fidelity quantum logic operations, towards a scalable quantum computing architecture, based on designs put forth by Lekitsch et al.[1]. To realise the scalability conditions per reference [1], micro-fabricated, surface ion traps are required to create a modular, planar array on which quantum computation can be carried out. This approach requires the use of microwave fields and a magnetic field gradient for quantum state manipulation. The magnetic field gradient provides sufficient coupling through phonon modes in the ion trap to achieve multi-qubit gates [2]. A high two-qubit gate fidelity is required to make a quantum computer sufficiently fault tolerant to be practical and scalable. Gate fidelity can be improved by cooling the ion and minimising environmental noise which causes qubit decoherence [3]. Cryogenically cooling the ion traps to minimise anomalous heating and incorporating sympathetic cooling by a second ion species should improve gate fidelity [1,4].

We present experimental progress and plans. The experiment incorporates a micro-fabricated, surface ion trap and aims to demonstrate a two-qubit gate using a microwave field scheme mediated by a magnetic field gradient. A two qubit gate operation will be demonstrated by applying microwave fields to trapped Ytterbium, $^{171}\mathrm{Yb}^{+}$. A strong magnetic field gradient, with a simulated magnitude of $140\ \mathrm{Tm}^{-1}$, is created by permanent magnets mounted under the chip. The strong magnetic field gradient will allow high-speed quantum state manipulation to achieve a quantum gate fidelity above the fault tolerant threshold; a requirement to realise practical, scalable quantum computing [1]. The microwave fields are applied via in-vacuum antennae, which significantly improves interaction strength due to the high field density near the ion. The system incorporates atomic ovens for providing two atomic species. $^{171}\mathrm{Yb}^{+}$, will serve as the qubit via the hyperfine splitting of the electronic ground state. A Barium oven is incorporated to demonstrate sympathetically cooling $^{171}\mathrm{Yb}^{+}$ by laser cooling Barium, $^{138}\mathrm{Ba}^{+}$ in the trap. The system includes an in-vacuum heat exchanger connected to a pressurised Helium cryogenic system for cooling the chip below 50 K, to reduce anomalous heating and improve gate fidelity [3].

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