

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, $^{171}\text{Yb}^+$. A strong magnetic field gradient, with a simulated magnitude of 140 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. $^{171}\text{Yb}^+$, will serve as the qubit via the hyperfine splitting of the electronic ground state. A Barium oven is incorporated to demonstrate sympathetically cooling $^{171}\text{Yb}^+$ by laser cooling Barium, $^{138}\text{Ba}^+$ 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].

[1] B. Lekitsch, S. Weidt, A. G. Fowler, K. Mlmer, S. J. Devitt, C. Wunderlich, and W. K. Hensinger. Blueprint for a microwave trapped-ion quantum computer. *Nature*, (February):1 12 (2015)

[2] S. Weidt, J. Randall, S. C. Webster, K. Lake, A. E. Webb, I. Cohen, T. Navickas, B. Lekitsch, A. Retzker, and W. K. Hensinger. Trapped-Ion Quantum Logic with Global Radiation Fields. *Physical Review Letters*, 220501 (November) (2016)

[3] L. Deslauriers, S. Olmschenk, D. Stick, W. K. Hensinger, J. Sterk, and C. Monroe. Scaling and suppression of anomalous heating in ion traps. *Physical Review Letters*, 97(10):1 (2006)

[4] M. Guggemos, D. Heinrich, R. Blatt, and C. F. Roos. Sympathetic cooling and detection of a hot trapped ion by a cold one Sympathetic cooling and detection of a hot trapped ion by a cold one. *New Journal of Physics*, New J. Phys. 17 (2015)

Authors: Mr PEAKS, Mitchell (University of Sussex); Dr NAVICKAS, Tomas (University of Sussex); Dr PUDDY, Reuben (University of Sussex); Mr ROMASZKO, Zak (University of Sussex); Mr SIEGELE, Martin (University of Sussex); Dr STANDING, Eamon; Dr WEIDT, Sebastian (University of Sussex); Prof. HENSINGER, Winfried (University of Sussex)

Presenter: Mr PEAKS, Mitchell (University of Sussex)

Session Classification: Poster Session

Track Classification: Quantum Information & Computing