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Fast Coherent Transport in Cryogenic Ion Chip Trap

Ion trap quantum control is among the most advanced in quantum science. This finds application in pioneering work on quantum information processing and quantum simulation. One of the major challenges at present is to scale these systems up, which requires the ability to "wire up" a larger system of traps by moving quantum information around.

In our newly-realised cryogenic ion trap setup, we are addressing both these challenges. The 4 Kelvin cryostat, greatly reducing background gas collisions and electrode temperature, provides an excellent vacuum preserved in the presence of components which are not compatible with room-temperature vacuum systems.

We want to take advantage of this by placing CMOS switch electronics inside the vacuum system close to the ion trap chip itself. This should in turn allow us to realize a new scheme for quantum state control which involves switching the trapping potentials on nano-second timescales [1]. These timescales are much faster than the ions oscillation frequency, which sets the response time of the ion.

In this setup we have now performed quantum state control of single calcium ions and cooled the motion to the quantum ground state. Current experimental challenges include vibrations due to the pulse-tube head, for which I am investigating several mechanical solutions.

In order to perform quantum state control on radial modes of motion, we would like to actively stabilize the radio-frequency drive of the ion trap. I will present our approaches to doing this, including possible schemes and the current status of our implementation.

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[1] J. Alonso, F.M. Leupold, B.C. Keitch, J.P. Home, *Quantum control of the motional states of trapped ions through fast switching of trapping potentials*, New Journal of Physics **15 (1367-2630/13/023001)**, 25 (2013).

Summary

Results from a cryogenic ion trap experiment in which we have recently trapped calcium ions will be presented. We are working towards the use of this setup to investigate control of ions by switching the trap potentials much faster than the ions can respond. This opens up new directions in quantum control of trapped ions. I will present work towards this goal, focusing on my own recent work, e.g. vibration isolation and RF amplitude stabilization of the system.

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