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Quantum Control of Motional States in Mixed-Species Trapped Ion Crystals

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Motional modes of ions trapped in the same potential are often used to transfer information between ions, for example in quantum logic spectroscopy or Molmer-Sorensen gates. Good motional control is crucial for high-fidelity operations; as many modes as possible should be cooled to near the ground state. Unfortunately, in some crystals, due to geometrical constraints on the apparatus or low participation of the cooling ions in certain modes, it is difficult to perform rapid, efficient cooling of all motional modes.

Furthermore, each motional mode of a trapped-ion chain implements a harmonic oscillator, enabling the study of bosonic qubits on this platform. A significant barrier to this avenue of exploration is photon recoil; since both motional and atomic ion states are usually distinguished by state dependent fluorescence, it is difficult to non-destructively extract information about the state of motional modes.

To overcome both these issues, we have developed a technique, whereby oscillating potentials are applied to trap electrodes to directly, coherently, and rapidly parametrically couple two modes of motion. We use this coupling to demonstrate both cooling of difficult-to-cool modes, as well as non-destructive, repetitive readout of a single motional mode in a three-ion crystal in which the middle ion is a different species from the other two. In this presentation, I will describe these results, as well as the use of repetitive readout to stabilize the lowest two Fock states of a motional mode, and other related experiments.

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