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Quantum Logic Control of a Single Molecular Ion[1]

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An amazing level of quantum control is routinely reached in modern experiments with atoms, but similar control over molecules has been an elusive goal. A method based on quantum logic spectroscopy [1] can address this problem for a wide class of molecular ions [2,3]. We have now realized the basic elements of these proposals.

In our demonstration, we trap a calcium ion together with a calcium hydride ion (CaH^+) that is a convenient stand-in for more general molecular ions. We laser-cool the two-ion crystal to its motional ground state and then drive Raman-transitions in the molecular ion, where a transition in the molecule also deposits a single quantum of excitation in the motion of the ion pair (motional"sideband"). We can efficiently detect this single quantum of excitation with the calcium ion, which projects the molecule into the final state of the sideband transition, a known, pure quantum state.

The molecule can be coherently manipulated after the projection, and its resulting state read out by another quantum logic state detection [4,5] or alternatively, an entangled state between the logic ion and the molecule can be created [6]. All transitions we address in the molecule are either driven by a single, far off-resonant continuous-wave laser or by a far-off-resonant frequency comb. This makes our approach suitable for quantum control and precision measurement of a large class of molecular ions.

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