CSU PHYSICS COLLOQUIUM

Preparation and Coherent Manipulation of Pure Quantum States of a Single Molecular Ion

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Colorado State University
4:00 PM Monday, October 23, 2017
Refreshments at 3:45 PM
Location: 120 Engineering (Hammond Auditorium)

Abstract

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

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 cool the two-ion crystal to its motional ground state and then drive the motional sidebands of Raman transitions in the molecular ion. A transition of the molecule is indicated by a single quantum of excitation in the secular motion of the pair. We can efficiently detect this single quantum with the calcium ion, which projects the molecule into the final state of the attempted sideband transition, leaving the molecule in a known, pure quantum state.

The molecule can be coherently manipulated after the projection, and its final state read out by another quantum logic state detection [3]. We demonstrate this by driving Rabi oscillations between rotational states. 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 applicable to control and precision measurement of a large class of molecular ions.

[1] P.O. Schmidt, et al. Science **309**, 749 (2005)
[2] D. Leibfried, New J. Phys. **14**, 023029 (2012)
[3] C.-W. Chou, et al. Nature **545**, 203 (2017)

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Bio

Dietrich Leibfried grew up in south-western Germany and studied physics at the Ludwig-Maximilians-University in Munich. After a PhD thesis supervised by Theodor Hänsch at MPQ Garching, Germany he spent two exciting years as a postdoctoral guest researcher in David Wineland's Ion Storage Group at NIST in Boulder, CO. Around this time, the precise quantum-mechanical manipulation of trapped atomic ions became viable, making them a competitive approach towards quantum information processing. After three years as an assistant with Rainer Blatt at the University of Innsbruck, Leibfried permanently returned to the Ion Storage Group at NIST in 2001 to chase the dream of a large-scale quantum computer based on trapped ions. Despite steady progress, it is still a long way to this eventual goal. Lately, Leibfried became interested in how ideas from quantum information processing could be applied to apparently unrelated fields, with precision spectroscopy and quantum coherent preparation and manipulation of single trapped molecular ions being one example.