Ground State Cooling of Axial Motion for One Atom Strongly Coupled to an Optical Cavity

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We demonstrate localization to the ground state of axial motion for a single, trapped Cs atom strongly coupled to the field of a high finesse optical resonator. The axial atomic motion is cooled using coherent Raman transitions on the red vibrational sideband. An efficient state detection scheme enabled by strong coupling in cavity QED is used to record the Raman spectrum (see Fig. 1), from which the resulting state of atomic motion is inferred. We find that the lowest vibrational level of the axial potential with zero-point energy $\hbar\omega_a/2k_B = 13\ \mu K$ is occupied with probability $P_0 \simeq 0.95$.

The achievement of resolved Raman sideband cooling for trapped ions[1] and atoms in optical lattices[2] has made it possible in these systems to create quantum states of motion and to manipulate quantum information. For a single atom strongly coupled to a cavity field, this ability to access quantized center-of-mass motion enables diverse new protocols in cavity QED, including quantum state exchange between motion and light.[3]

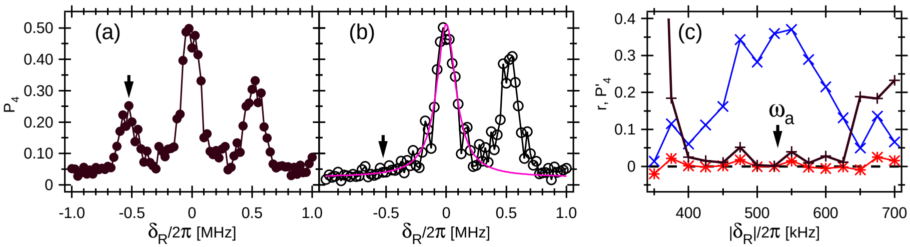

Figure 1: *Raman spectrum of an intracavity atom, with (a) 250 µs and (b) 5 ms of sideband cooling, the latter with a Lorentzian fitted to the carrier. (c) Red(∗) and blue(×) motional sidebands (same data as in panel b), as well as their ratio (+), after subtracting the Lorentzian contribution of the carrier. The suppression of the red sideband indicates that most of the atomic population is in the ground state of the trapping potential.*

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