COUPLING MACROSCOPIC QUARTZ RESONATORS TO NANOELECTRONICS

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The study of quantum behavior of motion has received a lot of attention during the last years. The motivation is three-folded. First, the observation of quantum effects in macroscopic mechanical systems will aid our understanding of the fundamentals of nearly macroscopic quantum effects. Second, this type of measurement needs extremely sensitive and low noise displacement sensing, enabling applications in other areas. Finally, the macroscopic degrees of freedom show promise for quantum computation applications. The observation of small mechanical oscillators at the quantum limit of their motion, where the phonon number n_m is zero, was reached some years ago [1–3].

Cavity optomechanics can be used to measure and control (back-action / sideband cooling) a near-ground state mechanical resonance through its coupling to an optical mode, as shown with micro mirrors up to 0.2 mg weight [4–6], cantilevers up to 0.5 mm long [7–9], or nitride membranes [10].

In our work we propose and demonstrate a new cavity optomechanical scheme which involves a genuinely macroscopic mechanical oscillator, five orders of magnitude more massive than earlier similar experiments [11], relatively near the ground state. As the mechanical system, we use a mm-sized piezoelectric quartz disk oscillator. Its motion is coupled to a charge qubit which translates the piezo-induced charge into an effective radiation-pressure interaction between the disk and a microwave cavity [12,13]. We measure the thermal motion of the lowest mechanical shear mode at 7 MHz down to 30 mK, corresponding to roughly 10^2 quanta in a 20 mg oscillator [14]. Furthermore, we observe back-action cooling of the motion by the qubit, demonstrating control of macroscopic motion by a single Cooper pair. We also predict that some realistic tuning to the design will allow the cooling and measurement of the mechanical resonator at the ground state, opening opportunities for macroscopic quantum experiments.

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