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Sideband Cooling Micromechanical Motion to the Quantum Ground State

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Accessing the full quantum nature of a macroscopic mechanical oscillator first requires elimination of its classical, thermal motion. The flourishing field of cavity optomechanics provides a nearly ideal architecture for both preparation and detection of mechanical motion at the quantum level. We realize a microwave cavity optomechanical system by coupling the motion of an aluminum membrane to the resonance frequency of a superconducting circuit [1]. By exciting the microwave circuit below its resonance frequency, we damp and cool the membrane motion with radiation pressure forces, analogous to laser cooling of the motion of trapped ions. The microwave excitation serves not only to cool, but also to monitor the displacement of the membrane. A nearly shot-noise limited, Josephson parametric amplifier is used to detect the mechanical sidebands of this microwave excitation and quantify the thermal motion as it is cooled with radiation pressure forces to its quantum ground state [2].

[1] Teufel, J. D. et al. *Circuit cavity electromechanics in the strong-coupling regime*, Nature 471, 204–208 (2011).
[2] Teufel, J. D. et al. *Sideband cooling micromechanical motion to the quantum ground state*, Nature 475, 359–363 (2011).