Strong Gate Coupling of High-Q Nanomechanical Resonators

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The detection of mechanical vibrations near the quantum limit is a formidable challenge since the displacement becomes vanishingly small when the number of phonon quanta tends towards zero. An interesting setup for on-chip nanomechanical resonators is that of coupling them to electrical microwave cavities for detection and manipulation. We have developed a fabrication method for achieving a large cavity coupling energy of up to $(2\pi)\,1$ MHz/nm for metallic beam resonators at tens of MHz.[1] We used focused ion beam (FIB) cutting to produce uniform slits down to 10 nm, separating patterned resonators from their gate electrodes, in suspended aluminum films. We measured the thermomechanical vibrations down to a temperature of 25 mK, and we obtained a low number of about twenty phonons at the equilibrium bath temperature. The mechanical properties of Al were excellent after FIB cutting and we recorded a quality factor of $Q \sim 3 \times 10^5$ for a 67 MHz resonator at a temperature of 25 mK. Between 0.2K and 2K we find that the dissipation is linearly proportional to the temperature.

[1]J. Sulkko, M.A. Sillanpää, P. Häkkinen L. Lechner, M. Helle, A. Fefferman, J. Parpia, P.J. Hakonen, Nano Letters **10**, 4884 (2010).