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Nanomechanical motion measured with an imprecision below the standard quantum limit[1]

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Observing quantum behavior of mechanical motion is challenging because it is difficult both to prepare pure quantum states of motion and to detect those states with high enough precision. We present displacement measurements of a nanomechanical oscillator with an imprecision below that at the standard quantum limit [1]. To achieve this, we couple the motion of the oscillator to the microwave field in a high-Q superconducting resonant circuit. The oscillator's displacement imprints a phase modulation on the microwave signal. We attain the low imprecision by reading out the modulation with a Josephson Parametric Amplifier, realizing a microwave interferometer that operates near the shot-noise limit. The apparent motion of the mechanical oscillator due the interferometer's noise is now substantially less than its zero-point motion, making future detection of quantum states feasible. In addition, the phase sensitivity of the demonstrated interferometer is 30 times higher than previous microwave interferometers, providing a critical piece of technology for many experiments investigating quantum information encoded in microwave fields.

[1] J. D. Teufel, T. Donner, M. A. Castellanos-Beltran, J. W. Harlow, K. W. Lehnert, Nature Nanotechnology, doi:10.1038/nnano.2009.343, (2009).

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