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Measurement and control of a mechanical oscillator at its thermal decoherence rate[1] DALZIEL WILSON, VIVISHEK SUDHIR, NICOLAS PIRO, RYAN SCHILLING, AMIR GHADIMI, TOBIAS KIPPENBERG, Swiss Federal Institute of Technology in Lausanne — In real-time (Markovian) quantum feedback protocols, the outcome of a continuous measurement is used to stabilize a desired quantum state. Extending such protocols to macroscopic systems is a significant challenge, as the measurement must in this case compete with rapid environmental decoherence. We report on the realization of an interferometric sensor that approaches the requirements of quantum feedback for a solid-state, 4.3 MHz nanomechanical oscillator: namely, the ability to resolve its zero-point motion in the timescale of its thermal decoherence. The sensor is based on near-field cavity-optomechanical coupling, and realizes a measurement of the oscillator's displacement with an imprecision 40 dB below that at the standard quantum limit, while maintaining an imprecision-backaction product within a factor of 5 of the Heisenberg uncertainty limit. As a demonstration of its utility, we use the measurement to feedback cool the oscillator to an phonon occupation of 5.4±0.7 (i.e, a ground state probablity of 16%). Our results establish a new benchmark for the performance of a linear position sensor, and signal the emergence of engineered mechanical oscillators as practical subjects for measurement-based quantum control.

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