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Optical levitation of quantum nano-mechanical resonators DARRICK CHANG, CINDY REGAL, SCOTT PAPP, DALZIEL WILSON, California Institute of Technology, JUN YE, JILA, NIST and University of Colorado, PETER ZOLLER, Institute for Theoretical Physics, University of Innsbruck, OSKAR PAINTER, JEFF KIMBLE, California Institute of Technology — There recently has been great interest in being able to observe quantum signatures in the motion of small mechanical systems. One major obstacle in many of the current approaches is the large coupling of these systems to a thermal environment, which tends to rapidly drive these systems back to a classical state. We propose to overcome this difficulty by levitating a nano-scale, dielectric mechanical resonator inside a high-finesse cavity via an optical dipole force, thus effectively removing any external thermal contact and creating a highly isolated system. The dipole force creates a mechanical potential for the center-of-mass motion and an effective "optical spring" for various internal degrees of freedom, whose strengths can be widely tuned simply by changing the optical field intensity. Using standard sideband cooling techniques, we show that ground-state cooling of these degrees of freedom is easily achievable under realistic conditions. Furthermore, we show how the tunability can be used to realize even more exotic signatures of quantum mechanical behavior, including quantum state transfer between two mechanical degrees of freedom and strong squeezing of mechanical motion.

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