



## Optical Tweezer Phonon Laser

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Optically levitated nanoparticles have recently emerged as a versatile platform for enabling next-generation sensing applications as well as for exploring fundamental physics. They are also very useful as testbeds for eventual chip-based applications. Experiments are approaching the quantum ground state of nanoparticle oscillation, and have realized applications such as thermometry, while theoretical modeling has produced precise agreement with experiment. In addition to the available linear vibrational mechanical degrees of freedom, spin, charge, and rotation have been added in various realizations of levitated optomechanics. In this work we introduce an important capability to the field of levitated optomechanics. We propose and develop a phonon laser based on the center-of-mass oscillation of a silica nanosphere levitated in an optical tweezer under vacuum. Our phonon laser is implemented via external feedback, thus allowing for optical creation and tuning of both mechanical gain and nonlinearity. We observe dynamics analogous to those familiar from the behavior of an optical laser: we record a threshold in the steady state phonon number as a function of gain, and the laser linewidth is observed to narrow across the threshold. Far above threshold, we measure a high degree of coherence indicated by an observation of the equal-time autocorrelation function of the mechanical amplitude [ $g^2(0) \sim 1$ ], and super-Poissonian but subthermal phonon statistics. All experimental data shows excellent agreement with a theory that includes spontaneous as well as stimulated emission of phonons.