State preparation and tomography of a nanomechanical resonator with fast light pulses

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Whereas continuous position measurements of a mechanical resonator are limited to the standard quantum limit (SQL), pulsed measurements can take 'snapshots' of the position with in principle unlimited precision. Beating the SQL with pulsed measurements requires resolving the position of the resonator with accuracy smaller than the zero-point fluctuations in a time much shorter than the oscillation period. This requires a large measurement bandwidth (optical cavity linewidth) while still maintaining a high ratio of the optomechanical coupling rate to the optical cavity linewidth. Here we report position measurements, with an accuracy of 16 times the mechanical ground state size, of a 3 MHz cryogenic nanomechanical resonator using nanosecond light pulses. We employ a sliced photonic crystal nanobeam in which subwavelength confinement leads to optomechanical single-photon cooperativities of 10^3 with an optical cavity linewidth of 20 GHz. We demonstrate tomography of conditional mechanical states, thermal squeezing and tracking of thermal dephasing. We discuss the outlook to use pulsed measurement protocols for quantum state preparation.

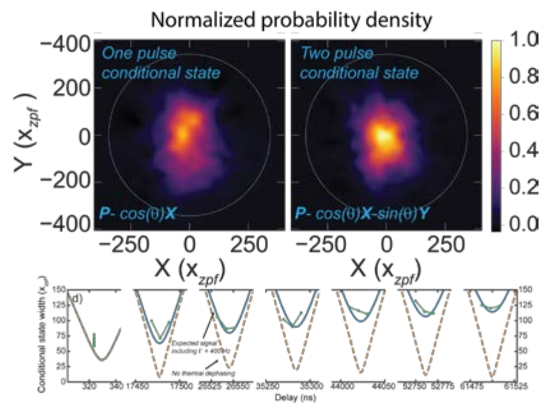

Figure 1. Top: reconstructed Wigner densities showing mechanical state preparation via measurement. The two pulse conditional state on the right (FWHM given by dashed green circle) shows cooling of the initial thermal distribution (FWHM given by dashed white circle). Bottom: thermal dephasing.

Keywords: Cavity Optomechanics, Quantum Tomography, Measurement Based State Preparation, Photonics

References

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