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Quantum aspects of cavity optomechanics with atomic ensembles and ensemble arrays

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While the motion of a many-atom ensemble of atoms interacting strongly with a single mode of an optical resonator can be devilishly complicated, under favorable conditions, the cavity can be made to interact with and to sense just one, or just a few, normal modes of the gaseous system. This leads to an atoms-based realization of cavity optomechanics, directly analogous to experiments in which one seeks to observe the motion of suspended mirrors, cantilevers, and membranes at the quantum limits of precision. I will discuss our progress toward demonstrating and understanding the distinctively quantum mechanical aspects of both the "opto" and "mechanical" portions of cavity optomechanical systems. Specifically, I will report on the observation of the ponderomotive squeezing of light by a mechanical oscillator, and of strong motional sideband asymmetry that demonstrates the quantization of collective atomic motion and quantifies the energy flux into the mechanical system due to quantum measurement backaction. I will conclude by describing our approach to realizing strong cavity coupling to a multi-mode mechanical system, specifically to an array of distinguishable mechanical oscillators.

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