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Quantum optomechanics in a superfluid-filled cavity[1]

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Coupling an optical cavity to a liquid can result in a range of phenomena that would not be readily accessible with solids. These phenomena may be related to the extreme compliance of a fluid's free surface, to the degrees of freedom that are unique to fluids (such as vortices), or to the fluid's various thermodynamic phases. Superfluid helium offers each of these, as well as other features that make it particularly well-suited to quantum optomechanics experiments: vanishing viscosity, negligible optical absorption, high thermal conductivity, and a liquid state that extends to $T = 0$ K. We have recently studied high-finesse optical cavities that are filled with superfluid helium and cooled to below 100 mK. The cavity mirrors serve to confine both light waves and the helium's density waves, resulting in optical modes that have near-perfect overlap with the acoustic modes. This maximizes the optomechanical coupling between the two and provides a highly efficient readout of the acoustic mode's fluctuations. We show that the Stokes and anti-Stokes light scattered by these fluctuations reveal features associated with quantum optomechanical effects - in particular the acoustic mode's zero-point motion, and the quantum back-action of the optical readout. These phenomena are fairly well-studied in solid-based optomechanical systems, but have not been observed previously in liquids.

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