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Hybrid atom-membrane optomechanics

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In optomechanics, laser light is used for cooling and control of the vibrations of micromechanical oscillators, with many similarities to the cooling and trapping of atoms. It has been proposed that laser light could also be used to couple the motion of atoms in a trap to the vibrations of a mechanical oscillator. In the resulting hybrid optomechanical system the atoms could be used to read out the oscillator, to engineer its dissipation, and ultimately to perform quantum information tasks. We have experimentally realized a hybrid optomechanical system by coupling ultracold atoms to a micromechanical membrane. The atoms are trapped in an optical lattice, formed by retro-reflection of a laser beam from the membrane surface. We observe both the effect of the membrane vibrations onto the atoms as well as the backaction of the atomic motion onto the membrane. By coupling the membrane to laser-cooled atoms, we engineer the dissipation rate of the membrane. This mechanism can be used to sympathetically cool the membrane with the atoms. The atom-membrane coupling strength can be enhanced by placing the membrane inside an optical cavity. Theoretical investigations show that this gives access to a regime of strong coupling, enabling ground-state cooling and quantum control of the membrane via the atoms.