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Interfacing ultracold atoms and mechanical oscillators on an atom chip

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Ultracold atoms can be trapped and coherently manipulated close to a chip surface using atom chip technology. This opens the exciting possibility of studying interactions between atoms and on-chip solid-state systems such as micro- and nanostructured mechanical oscillators. One goal is to form hybrid quantum systems, in which atoms are used to read out, cool, and coherently manipulate the oscillators' state. In our work, we investigate different coupling mechanisms between ultracold atoms and mechanical oscillators. In a first experiment, we use atom-surface forces to couple the vibrations of a mechanical cantilever to the motion of a Bose-Einstein condensate in a magnetic microtrap on an atom chip. The atoms are trapped at about one micrometer distance from the cantilever surface. We make use of the coupling to read out the cantilever vibrations with the atoms and observe resonant coupling to several well-resolved mechanical modes of the condensate. In a second experiment, we investigate coupling via a 1D optical lattice that is formed by a laser beam retroreflected from a SiN membrane oscillator. The optical lattice serves as a 'transfer rod' that couples vibrations of the membrane to the atoms and vice versa. We point out that the strong coupling regime can be reached in coupled atom-oscillator systems by placing both the atoms and the oscillator in a high-finesse optical cavity.