Quantum Optomechanics: exploring mechanical motion in the quantum regime

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The quantum optical control of solid-state mechanical devices, quantum optomechanics, has emerged as a new frontier of light-matter interactions. Devices currently under investigation cover a mass range of more than 17 orders of magnitude - from nanomechanical waveguides of some picograms to macroscopic, kilogram-weight mirrors of gravitational wave detectors. This development has been enabled by the insight that quantum optics provides a powerful toolbox to generate, manipulate and detect quantum states of mechanical motion, in particular by coupling the mechanics to an optical or microwave cavity field. Today, 10 years after the first demonstrations of laser cooling of micromechanical resonators, the quantum regime of nano- and micromechanical motion is firmly established.

This opens fascinating perspectives both for applications and for unique tests of the foundations of quantum physics. For example, the availability of quantum superposition states involving massive solid-state objects could enable a completely new class of experiments, in which the source mass character of the quantum system starts to play a role. This addresses directly one of the outstanding questions at the interface between quantum physics and gravity, namely “how does a quantum system gravitate?”