Nanomechanical membranes as transducers for classical and quantum signals

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A first generation of micro- and nanomechanical systems can now be coupled to modes of an electromagnetic field in a quantum-coherent manner [1,2,3], enabling, e. g., entanglement and interconversion between photons and phonons, and the preparation of mechanical devices in low-entropy quantum states. Using mechanical devices as a coherent transducer between different quantum systems—through appropriate functionalization—has thus become an intriguing, but realistic possibility. In the simplest case, these quantum systems can be different electromagnetic field modes, including microwave and optical fields [4].

Proof of principle transducers operating in a classical regime have recently been realized [5,6,7]. Our approach [6] is based on a high-Q silicon nitride membrane resonator, which is simultaneously coupled to a degenerate radio-frequency resonance circuit, and an optical readout mode. By detecting the phase fluctuations imprinted by the membrane on the optical mode with a quantum-noise limited imprecision, we can optically measure sub-nV signals induced in the RF circuit. The device resides in the strong coupling regime with electromechanical cooperativities exceeding 6000, enabling strong suppression of thermomechanical noise in the transduction cascade. An integrated version of such a device may find applications as a sensitive transducer also for classical fields, e.g. in NMR.

A key requirement for the prospect of using mechanical devices as quantum transducers in more complex hybrid systems—involving several electromagnetic modes or spin ensembles [4,8,9]—is the weakest possible coupling of the mechanical mode to a hot thermal bath. I will discuss our progress in the development of such very high-Q mechanical oscillators [10].

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