Micromechanical Resonators with High-Reflectivity Mirrors for Experiments in Quantum Opto-Mechanics

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Abstract:
We have fabricated high-\(Q\) high-reflectivity micromechanical resonators having resonant frequencies up to 2 MHz and reflectivity > 99.99%. These devices will allow the resonator’s mechanical motion to be coupled to the mode of an optical cavity for enhanced radiation-pressure back-action cooling of the mechanical motion, and other quantum opto-mechanical studies.

Summary of Research:
High-\(Q\) high-reflectivity micromechanical resonators open up a new regime of opto-mechanical coupling, in which the concepts of quantum optics are utilized to prepare and control mechanical quantum states (quantum-opto-mechanics). The main idea is to use radiation-pressure interaction in a high-finesse cavity, where the mechanical oscillator is used as an end-mirror. This allows, for example, to laser-cool its motion close, in principle, to the quantum ground state. (For typical oscillation frequencies of 1 MHz this is on the order of 100 \(\mu\)K). We have demonstrated radiation-pressure back-action cooling of such devices [1] and have recently combined it with cryogenic techniques [2]. Entering the quantum regime of such optomechanical devices will require high reflectivity (optical finesse > 10,000), resonance frequencies above the optical shot noise (typically > 1 MHz) and weak coupling to the environment, i.e. large mechanical quality factors.

Our latest structures were produced at CNF. They are hybrid systems combining high-reflectivity with high mechanical quality factors. 2 \(\mu\)m of low-stress silicon nitride are deposited on a standard Si-wafer via low-pressure chemical vapor deposition. A high-reflectivity (R > 99.99%) Bragg-mirror made of alternating layers of Ta₂O₅ and SiO₂ is deposited by an outside vendor using ion beam sputtering. Subsequently, small mirror-pads are defined by photo-lithography and etched in inductively-coupled plasma (ICP). Finally the oscillators are formed using reactive-ion etch (RIE) and freed from the Si substrate by etching with XeF₂. Typical dimensions of our beams are around 100 \(\mu\)m \(\times\) 50 \(\mu\)m and fundamental oscillation frequencies range from hundreds of kHz up to 2 MHz. The fabrication process produces no detectable degradation of the mirror reflectivity. Testing of these structures is underway.

References:
Figure 1: An array of micromechanical resonators with high-reflectivity mirror pads.

Figure 2: Close-up of resonators with mirror pads.