LENS-QSTAR Seminar
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Ultralow-noise electro-optomechanical transduction cascade based on a nanomechanical membrane resonator

Electromechanical and optomechanical systems share the underlying physical processes, but the techniques and technologies for perfecting them are rather distinct. Nonetheless, both platforms, each in its own right, have progressed at an extremely rapid pace over the last years, and brought about unprecedented opportunities in sensing of force and displacement, and the manipulation and detection of electromagenetic and/or mechanical quantum states (1). Recently, a new research frontier has emerged, dedicated to the combination of electro- and optomechanical systems (2-4). The benefits of such integrated devices could be manifold, and reach from the (near) noiseless transduction of weak electronic signals into the optical domain over ultraefficient electrooptic modulators to a fully quantum-coherent conversion cascade of microwave to optical photons (and back), with possible intermediate storage in phononic modes. We have developed and investigated a proof-of-principle implementation of such an electro-optomechanical transducer (5). It is based on an ultrahigh-Q silicon nitride membrane resonator (6), which is simultaneously coupled to a degenerate radio-frequency (RF) 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 miniscule voltage signals induced in the RF circuit. Among other analyses, we quantify the noise added in all stages of the transduction cascade. We find that the membrane thermal noise, and the optical readout noise, both add as little as 60 pV/Hz 1/2 , while the main noise contribution is due the RF circuit itself, which generates ~800 pV/Hz 1/2 of Johnson noise. Further improvements of this platform are readily achievable, through more compact integration, improved membrane resonators (e.g. by suppression of phonon tunnelling loss (7)), and RF circuits
with lower loss and/or temperature. Looking further ahead, the investigation of hybrid interference effects—such as opto/electromechanically induced transparency (OMIT) (8)

and the intimately related mechanically dark modes (9)—appear as an exciting route for further research, in particular with the perspective of quantum state conversion and storage.

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