Quantum mechanical interface for opto-electronics

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A nanomechanical oscillator can serve as a universal coupling device interfacing atoms, optical photons and electrical circuits. Nanomechanical objects such as mirrors and membranes can efficiently couple to light and at the same time can serve as a capacitive element of a LC circuit. These functionalities allow creating a quantum interface between atoms, optical photons and electronics. A way to entangle atomic spin-polarized ensembles with nanomechanical oscillators placed in a high-Q optical cavity has been proposed [1]. Furthermore, the mechanical motion of a nano-membrane can be strongly coupled to the charge-flux degrees of freedom of a LC circuit if the membrane is electrically coupled to the capacitor of the circuit [2]. Theoretical analysis suggests that optical cooling of the resonant mode of the LC by several orders of magnitude via such an interface is possible. This membrane-mediated interaction between the cavity photons and the electrical circuit could open up a wide variety of new applications in metrology and quantum information science.

We experimentally investigate a dielectric SiN membrane and a semiconductor membrane made of GaAs as potential elements for the opto-electronical interface. All experiments have been conducted at room temperature in a vacuum chamber under 10^{-7} Torr pressure. Q-factors exceeding $2*10^6$ of the SiN membrane with 1 mm^2 crossection and the thickness of 50nm at eigen-frequencies in the MHz range have been measured. In a separate experiment Q-factors up to $0.4*10^6$ have been measured for a GaAs membrane with the thickness of 150nm, the crossection of $1.3*1.9mm^2$ and eigen-frequencies in the 25-100kHz range [3]. Using a low finesse cavity we have demonstrated optical cooling of several vibrational modes of this membrane by coupling it to light with the energy above the band gap. The cooling mechanism is presently under investigation.

1. Establishing Einstein-Podolsky-Rosen channels between nanomechanics and atomic ensembles. K. Hammerer, M. Aspelmeyer, E.S. Polzik, P. Zoller. Phys. Rev. Lett. 102, 020501 (2009).
2. J. Taylor, A. Sørensen, C. Marcus, E.S. Polzik. Paper in preparation.
3. Cavity optomechanics with GaAs membrane. K. Usami, B. Melholt Nielsen, A. Naesby, T. Bagci, J. Liu, S. Stobbe, P. Lodahl, and E. S. Polzik. Poster at this conference. Paper in preparation.