Cooling a mechanical resonator via coupling to a tunable double quantum dot

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We study the cooling of a mechanical resonator (MR) that is capacitively coupled to a double quantum dot (DQD). The MR is cooled by the dynamical back-action induced by the capacitive coupling between the DQD and the MR. The transition between the two dots of the DQD is excited by an a.c. field and afterwards a tunneling event results in the decay of the excited state of the DQD. An important advantage of this system is that both the energy level splitting and the decay rate of the DQD can be well tuned by varying the gate voltage. We find that the steady average occupancy, below unity, of the MR can be achieved by changing both the decay rate of the excited state and the red-detuning between the transition frequency of the DQD and the microwave frequency, in analogy to the laser sideband cooling of an atom or trapped ion in atomic physics. Our results show that the cooling of the MR to the ground state is experimentally implementable.

I. Introduction

Applications of quantum mechanical resonator (MR):

- mass detection;
- high-precision displacement measurement;
- testing transition between classical and quantum behaviors;

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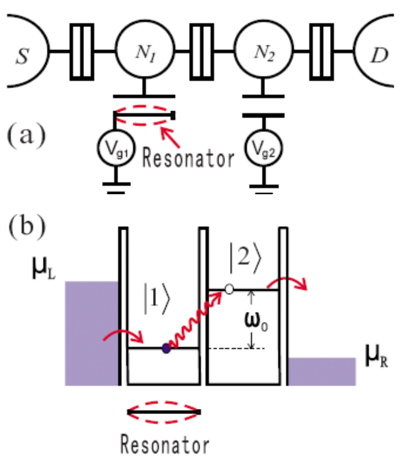
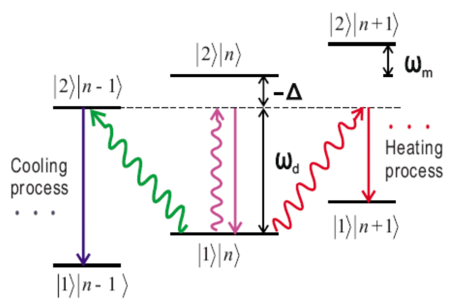
II. Cooling a MR via a double quantum dot



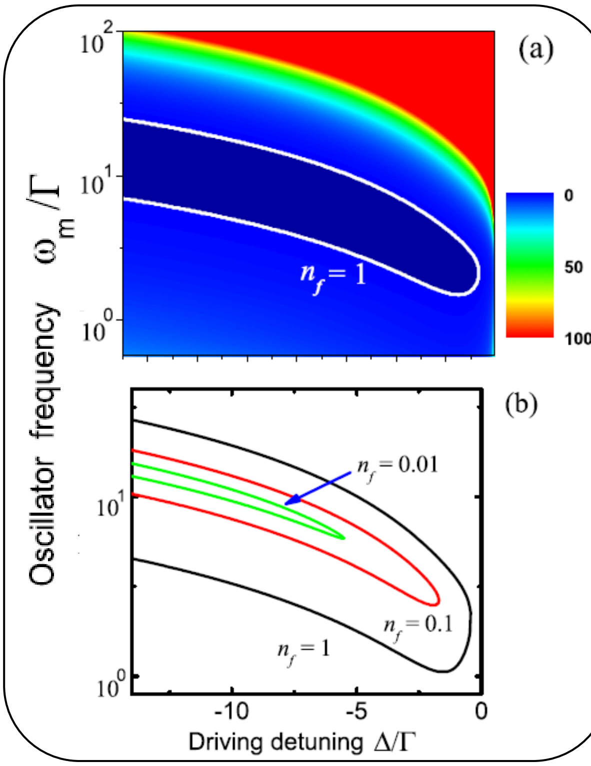
III. Cooling mechanism



State of the MR: $|n\rangle, \quad n = 0,1,2,....$

State of the double quantum dot: $|1\rangle, |2\rangle$

IV. Results: average phonon number in MR



V. Conclusions

In summary, we have studied the cooling of a MR by electron statically coupling it to a semiconductor DQD. We show that when the two-level system (DQD) is driven by a microwave field in red-detuning, the MR can be cooled, in analogy to the laser sideband-cooling of atoms or trapped ions in atomic physics. Our results show that the ground-state cooling of the MR can be achieved both by detuning the transition frequency of the DQD from the microwave frequency and by changing the decay rate of the DQD.

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