MAR08-2007-002169

Abstract for an Invited Paper
for the MAR08 Meeting of
the American Physical Society

Cavity Assisted Sideband Cooling of Mechanical Motion

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This talk will provide a pedagogical introduction to the theoretical ideas that form the basis for cooling a mechanical cantilever using light-induced forces. During recent years, these concepts have been realized in a series of experiments by various groups, that have demonstrated impressive progress in cooling. Several of them will be discussed in the following talks of this session. Ultimately, this line of research may lead to the quantum-mechanical ground state of the center-of-mass motion of objects composed of many billions of atoms. A common ingredient is the use of an optical cavity to resonantly enhance the radiation pressure force affecting the motion of the cantilever. I will start by reviewing the classical description of how a time-retarded force leads to enhanced friction and thus cooling. Then I will present a fully quantum-mechanical description, that takes into account the opposing effect of the photon shot noise [F. Marquardt, J. P. Chen, A. A. Clerk and S. M. Girvin, Phys. Rev. Lett. 99, 093902 (2007); see also I. Wilson-Rae, N. Nooshi, W. Zwerger and T. J. Kippenberg, Phys. Rev. Lett. 99, 093901 (2007)]. This theory yields a quantum-limit for the reachable photon number that can be made arbitrarily small, provided a high-finesse cavity is combined with a high-frequency mirror (the "resolved sideband limit," analogous to ion cooling). Various different ways of experimentally measuring the photon number will be mentioned. Finally, I will briefly give an outlook regarding the opportunities for quantum-coherent experiments that will open up once the ground state has been reached. This talk primarily reports joint work with A. Clerk, J. P. Chen, and S. Girvin.