Mirror-mediated cooling of atoms, molecules and particles

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Single mirrors, both micro-fabricated and macroscopic, offer a variety of geometries for the manipulation of atoms and molecules. We describe here a new mechanism based upon the retarded interaction of an illuminated particle with its own reflection.

Mirror-mediated cooling [1,2] is in essence a prototype of both the cavity-mediated cooling of atoms [3] and the cavity-cooling of interferometers [4]. It offers a new paradigm, by reducing the cavity to a single round-trip that can no longer be regarded as nearly closed or quasi-Markovian. A classical analysis is easily cast in three dimensions as an extension of optical binding [5,6,7], revealing new transverse cooling mechanisms and allowing the plain plane prototype to be extended to complex shapes and geometries including fibres, external resonators and amplifiers. Simple geometrical optics analysis gives a powerful insight, while a transfer matrix method allows a smooth progression from mirror-mediated to cavity-mediated mechanisms and Doppler cooling.

The weak basic phenomenon of mirror-mediated cooling may be enhanced by including geometric or material resonances, such as etalons, plasmon resonances, waveguides, narrowband filters, photonic crystals and whispering-gallery resonators, within the feedback path [8], to enhance the retardation upon which the effect depends. Separating the cooled particle from the resonator brings great experimental flexibility, including the ability to replicate the geometry in microfabricated arrays.

Similar resonances offer a means of enhancing dipole traps formed by the foci of steeply curved mirrors, while the complex ray paths and polarizing properties of such mirrors suggest their potential, together with planar permanent magnets, for tiny, replicable magneto-optical traps. We shall give a brief report of recent theoretical and experimental progress [9].

[1]A. Xuereb, P. Horak, T. Freegarde, Phys. Rev. A **80**, 013836 (2009)
[2]A. Xuereb *et al.*, Phys. Rev. A **79**, 053810 (2009)
[3]P. Horak *et al.*, Phys. Rev. Lett. **79**, 4974 (1997)
[4]T. J. Kippenberg, K. J. Vahala, Opt. Express, **15**, 17172 (2007)
[5]F. Depasse, J.-M. Vigoureux, J. Phys. D **27**, 914 (1994)
[6]P. C. Chaumet, M. Nieto-Vesperinas, Phys. Rev. B **64**, 035422 (2001)
[7]N. K. Metzger, E. M. Wright, W. Sibbett, K. Dholakia, Opt. Express **14**, 3677 (2006)
[8]A. Xuereb, T. Freegarde, P. Horak, P. Domokos, `arXiv:1002.0463` (submitted)
[9]H. Ohadi, M. Himsworth, A. Xuereb, T. Freegarde, Opt. Express **17**, 23003 (2009)