Cooling atoms, particles and polarisable objects using dissipative dipole forces

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Optical cooling methods are generally applicable to a very restricted range of species. As a means of overcoming this problem, we explore the effect of the retarded interaction of any polarisable particle (an atom, a molecule or even a micromirror) with itself, similarly to cavity-mediated cooling[1]. We use the transfer matrix method[2], extended to allow us to handle moving scatterers, to explore the most general configuration of a mobile particle interacting with any 1D combination of fixed optical elements. Remarkably, this model allows a solution in closed form for the force acting on the particle, without any *a priori* restriction on the nature of the particle[3].

Mirror-mediated cooling[4] is a powerful extension of optomechanical schemes that can be used to cool an atom using a single plane mirror, but requires a large separation between the atom and the mirror in order to be effective. If the mirror is replaced with a cavity, *outside* of which the atom sits, we show that the cavity acts to 'fold', or multiply, the optical path length, and therefore enhance the friction force acting on the atom, by several orders of magnitude. Crucially, this mechanism can also be applied to the cooling of micromirrors on cantilevers, Figure 1, whereby the efficiency of the optomechanical cooling schemes currently in use can be increased by $\sim 10^4$ simply by adding a second fixed mirror—a significant advance on the current state of the art.

The use of optical resonances on templated surfaces[5], rather than resonances in a cavity, will potentially allow the creation of integrated 2D arrays of micromirrors each coupled to a resonant element that requires no alignment, and each cooled using this 'external cavity cooling' mechanism. This opens up the possibility of investigations into the interactions between light and mesoscopic objects at an unprecedented scale.

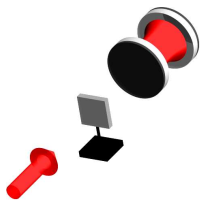

Figure 1: *Coupling light interacting with a cantilever to a cavity enhances the optomechanical friction force by several orders of magnitude.*

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