Light-mediated Particle Interactions in a Laser Trap

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Optical manipulation of small objects has been the focus of attention for over three decades and has brought about a revolution in our techical capabilities and in our understanding of the electromagnetic forces acting on different materials ranging from atoms, to dielectric and conductive particles all the way to biological samples. The implications of these developments are so far-ranging that even now we do not foresee their full capabilities.

At first, much of the attention was focussed on the direct forces that are exerted directly on the object by the laser beam used for its control. Recent developments in trapping multiple objects and downscaling the trap's size (and the objects' size as well) open up new questions as to the mutual interactions which take place among the trapped elements. Indeed, when one single coherent beam is used for holding together the sample, the light scattered by each element contributes to the global scattered field which influences all particles. Experimental evidence has already shown that when a sufficiently large number of objects is trapped, the trapping field cannot be considered independently of the scattered components and that the trap is the result of the global superposition of all fields.

We will discuss different aspects of the interaction of multiple particles trapped by a common coherent field. Pairs of spheres [1, 2] and multiplets [3, 4] are known to bind together maintaining preferential distances dictated by the interaction between the scattered and the trapping field. Multiple spheres form structures which depend on the symmetries imposed on the problem.

A such one-dimensional arrangement can be obtained either through the interference of two beams [2] or through a strongly elliptical trap. For this trap geometry the effects of fluctuations are strongly modified in the two directions (parallel and perpendicular to the trapping field). In addition, in the elliptical trap configuration the interaction strength is not constant and can thereby influence the trapping characteristics.

In a two-dimensional arrangements where preferential sites are imposed by the trapping beam [2] the particles mostly sit at the pre-chosen positions but present residual fluctuation-induced motion which is reminiscent of transport problemes. If instead the trap is smooth, states may be found where the particles move quite freely, followed, as the trap power is increased, by "viscous" motion as in a fluid, and terminating in "rigid" structures.

Additional optical interactions may also be induced by cell surfaces, whereby the effectiveness of these contributions depends on the size of the particles, the light polarisation, and in general by the systems parameters. Size considerations will be discussed for downscaling to very small objects.

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