Advanced Studies in Optical Binding

K. Dholakia[1,2], **N. K. Metzger**[1], **and E. M. Wright**[2,1]

[1]University of St Andrews, UK
[2]The University of Arizona, USA

Optical forces arise due to the light matter interaction. These forces have had impact right from the single atom level through Bose-Einstein condensates up to biological cells and colloidal matter. Light-matter interactions may be used to dictate the organization and manipulation of colloidal and biological matter at the microscopic level. An inhomogeneous optical field permits dielectric spheres of higher refractive index than their surrounding medium to be trapped in three dimensions in the field maxima primarily through the dipole interaction [1]. This allows physicists, chemists and biologists to explore a range of fundamental phenomena. From a physics perspective this includes thermally activated escape from a potential well, studies of optical angular momentum, stochastic resonance and various studies of colloidal behaviour in external potentials. From a biological perspective optical trapping has revolutionised our understanding of molecular motors.

Non-zero order light patterns and various families of propagating light fields are of significant interest across numerous branches of the sciences. If one goes beyond a standard Gaussian beam one may look at examples such as Hermite-Gaussian, Laguerre-Gaussian and Bessel light modes. These latter two modes possess cylindrical symmetry and have been of interest for studies of optical angular momentum, optical vortices, micromanipulation and for novel beam characteristics (e.g., studies of the Poynting vector and their reconstruction). Other extended two and three dimensional light patterns too have become of widespread interest: in the realm of optical micromanipulation they may create extended potential energy landscapes that may allow novel studies of extended colloidal systems and interactions therein.

Deformation of the light pattern by the very interaction of the particle with the imposed light field is a relevant issue for three dimensional structures which might be created using these techniques. The light matter interaction may lead to "optical binding". Such "optical binding" is radically different from conventional predefined trapping alluded to above: Here the very interaction between an object and its nearest neighbors creates a self consistent and homogeneous solution that allows an optical geometry to, in principle, create a large scale colloidal array. This topic has come again to the fore: work over a decade ago shows this effect in studies of Burns, Golovechenko and Fournier [2]. The St Andrews group have looked at new forms of optical binding in both counter-propagating and vertical geometries [3]. The key is that the interparticle spacing here is, unlike the earlier form of optical binding, of the order of microns and indeed the stronger interaction between the particles is key to creating the new forms of bound matter currently under study in our group. Interesting behaviour such as bistability may be observed.

In this talk I will discuss recent work on optical trapping in extended light patterns and primarily concentrate on the latest data in the area of optical binding which is proving a rich and surprising area in this field.

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