Theory and Modeling of Optical Forces within a Collection of Mie Scatterers

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Optical binding and trapping have been experimentally verified on dielectric particles by various groups [1–4, to name only a few]. The corresponding theoretical analysis, however, still needs to be developed beyond the simple approximations of Rayleigh scattering or couple of Mie particles. In this work, we present an exact method to compute the optical forces within a system of multiple Mie particles. For the sake of simplicity, the particles are taken to be lossless dielectric cylinders, which is not a severe limitation per se since apart from the depolarization effects, most of the phenomena observed in two-dimensions can be generalized to three-dimensions.

The optical forces are computed from the Maxwell stress tensor, which therefore requires the knowledge of the scattered field from the collection of particles. The latter is computed from the Mie theory for cylinders and the Foldy-Lax multiple scattering equations, which take into account all the interactions between the particles. Hence, apart from the assumption of real permittivity, the method does not make any approximation on the size of the particles or their number in the collection.

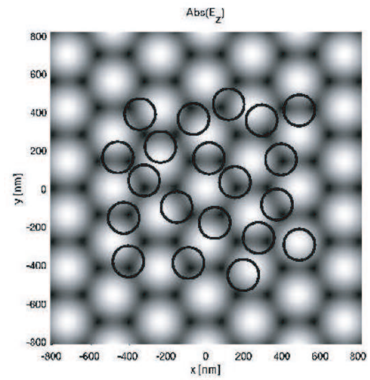

Figure 1: Initial positions of 20 particles in an interference field.

In order to conform to the experimental setup, the system of particles is excited by three incident beams, forming an hexagonal interference pattern. For the sake of illustration, we present results for a collection of 20 particles initially randomly positioned in the interference field, like shown in Fig. 1. The forces on each particle is computed and their positions are updated accordingly. At the next time step, the forces are computed anew with the new positions, and the process is reiterated until convergence has been obtained, shown in Fig. 2. It can be seen that for the particle size considered, a gradient force is exerted on the particle which tends to align them with the high eld intensity regions. However, binding forces between the particles tend to disrupt this regular pattern and it is seen that the nal positions of some particles (typically toward the edge of the collection) is shifted from the expected positions. We believe that it is the rst time that this phenomenon, known in experimental situations, is shown by an analytical modeling.

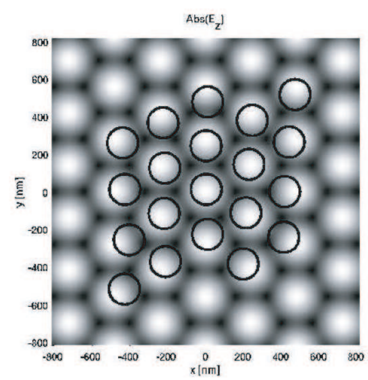

Figure 2: Final positions of 20 particles due to optical forces.

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