Optical forces in complex media

Juan Jose Saenz∗\textsuperscript{1}

\textsuperscript{1}Donostia International Physics Center - DIPC (SPAIN) – Spain

Abstract

Appropriate combinations of laser beams can be used to trap and manipulate small particles with "optical tweezers" as well as to induce significant "optical binding" forces between particles. Here we review some basic concepts related to the optical forces on small (sub-wavelength) particles, focusing on the interplay between scattering asymmetry and momentum transfer. These forces are, in general, non-conservative (curl forces) which lead to a number of intriguing predictions regarding the dynamics of nanoparticles in complex media. As a recent example, we will discuss the self-organized collective behavior of gold nanoparticles moving in aqueous solution under a non-conservative optical vortex lattice. As we will see, above a critical field intensity and concentration, the interplay between optical forces, thermal fluctuations and hydrodynamic pairing leads to a spontaneous transition towards synchronised motion exhibiting a rich assortment of collective dynamics.

Optical forces between small particles are usually strongly anisotropic depending on the interference landscape of the external fields. This is in contrast with the familiar isotropic van der Waals and, in general, Casimir-Lifshitz interactions between neutral bodies arising from random electromagnetic waves generated by equilibrium quantum and thermal fluctuations. We recently showed that artificially created random fluctuating laser fields could be used to induce and control isotropic dispersion forces between small colloidal particles. Interestingly, when the light frequency of a quasi-monochromatic isotropic random field is tuned to an absorption line (at the so-called Fröhlich resonance) we will see that the attractive force between two identical molecules or resonant nanoparticles follows a gravity-like inverse square distance law. Our results generalize Lorentz’s (and Spitzer-Gamow’s "Mock Gravity") electromagnetic version of the remarkable Fatio-LeSage’s corpuscular theory of gravity introduced as early as in 1690.

∗Speaker