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Theory of light scattering at nanoparticles and optical forces between small particles

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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 (subwavelength) 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. 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. As we will see, artificially created random fluctuating light fields can be used to induce and control dispersion forces between small colloidal particles. Interestingly, for relatively high refractive index semiconductor nanoparticles, the interactions can be tuned from attractive to strongly repulsive when the frequency of the external fluctuating field is tuned near the first magnetic Mie-resonance. Interactions induced by randomly fluctuating light fields open a path towards the control of translational invariant interactions with tuneable strength and range in colloidal systems.