The mechanical effects of light on a micron-sized ellipsoidal polystyrene particle

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Abstract

Since the early works by Ashkin [1], it has been known that micrometer-sized dielectric spheres can be levitated by a simple laser beam, due to radiation pressure forces. Parallel to levitation, small particles can be made to rotate through the action of optical torques: in experiments, rotation has been demonstrated with chiral particles [2], also with birefringent and/or absorbing particles through angular momentum transfer from the laser beam [3,4]. In this communication, we address the case of ellipsoidal particles, which are not chiral, absorbing or birefringent (or negligibly so), and report on their dynamical states under laser illumination. We describe single particle optical levitation which we performed with a series of such ellipsoids. According to laser beam diameter and ellipsoid axes lengths, we observed a variety of dynamical behaviours, ranging from simple static equilibriums, through periodic oscillations, up to irregular (chaotic) motions. In our setup, we use a vertical moderately focused laser beam (wavelength: 514 nm, beam waist ≈ 1.25 µm and M^2≈2). The ellipsoidal particles, about 20 µm along their long axis, are obtained by mechanical stretching of polystyrene spheres. Samples for experimenting are diluted water suspensions of such particles, contained in a horizontal glass cell (1 mm in thickness). A typical experiment starts with capturing one particle from the suspension. The laser beam then drives particle levitation. The ascension ends when the particle gets in contact to the cell ceiling. At this stage the upward motion is stopped but not the angular motion: in many examples, the particle still continuously oscillates around the beam axis, and sometimes very complex behaviors (including tumbling) are observed. We observe the particle motion from the top, with a home made microscope. The particle oscillations are characterized by monitoring the on-axis transmitted laser light: we simply record the laser intensity through a pinhole centered on the bare beam symmetry axis, downstream of the levitated particle. The motion depends on different parameters. For example small aspect ratio ellipsoids levitate like a sphere without any dance motion, whereas higher aspect ratio ellipsoids were observed to show different types of oscillation. The location of the particle in the beam significantly affects the motion. When trapped close to beam waist position, ellipsoids align their long axis along the beam axis direction. Conversely when the ellipsoid is above or below beam waist, it generally tends to equilibrate horizontally, i.e long axis perpendicular to the beam axis.

References:

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