Effective generation of pitch degree of rotational motion using Dual Trap in optical tweezers

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Any rigid body can have three degrees of rotational freedom, which in the nomenclature of the airline are yaw, pitch and roll. Among these, the yaw degree of rotational motion has been extensively studied in the optical tweezers community. We have generated the pitch degree of rotational motion by using two trapping beams placed next to each other into which the particle is simultaneously trapped and then moving the focus of one of the trapping beams deeper. We have successfully generated this pitch motion for extended objects and even spherical birefringent microparticles.

Introduction

Optical tweezers are very useful for micromanipulation, numerous problems are being addressed by the rotational optical tweezers with applications in disciplines of physics [1] and biology [2]. It can not only be used to move and apply forces on particles along the three translational degrees (X, Y, Z) of freedom but also rotate particles (Yaw, Roll, Pitch). Generation of the pitch and the roll degrees of freedom has so far remained elusive in spherical particles. We have successfully generated this pitch motion for extended objects and even spherical birefringent microparticles.

Methodology and results

The pitch motion of elongated/asymmetric particles is relatively simple to observe with video microscopy as opposed to spherical particles due to their asymmetry as shown in fig: 2. The spherical birefringent particles leave the total intensity of the scattered light unaltered while performing pitch motion. As the birefringent particles show an asymmetry of the scattered light in the cross-section visible under cross polarizers [3] the pitch motion can be detected. The idea is to trap the particle using two traps and generate pitch motion by manipulating one of them pivoting the other. We have generated a controlled pitch motion of an elongated asymmetric particle and extended the same technique to spherical birefringent particles as shown in fig 1.

![Fig1](image.png)

Fig1. Schematics of the trapped elongated (i) spherical (ii) particle when L1 (focused laser on left) is (a) at the reference plane, (b) below the reference plane and (c) above the reference plane.

The spherical birefringent particles picks up an asymmetry in the cross-section without affecting the total intensity of the backscattered light conforming the pitch motion as shown in fig: 3. However, the pitch motion of the asymmetric particle generated employing the aforementioned technique can be detected by capturing images in chronological order as shown in fig: 2.
Fig 2. Snapshot of a 5-micron wide irregular particle undergoing pitch motion by controlled defocusing of laser(L1) on one end (left) and pivoting the other laser(L2) on opposite end(right). Both the lasers are focussed on same plane to grip the particle when (a) the distance moved by the focus of L1 (D) is zero. (b), (c), (d), (e), (f) are the images captured while defocusing and the focus of L1 is at a distance 0.5 μm, 1 μm, 1.5 μm, 2 μm and 2.5 μm below the reference plane respectively. (g), (h), (i), (j), (k) are the images captured while refocusing and the focus of L1 is at a distance 2 μm, 1.5 μm, 1 μm, 0.5 μm and 0 μm respectively.

Fig 3. (a),(b)Figure depicting pitch motion of the spherical birefringent particle. (c) The overall intensity remains same for the particle when it executes pitch motion, but then there will be an asymmetry developed in the cross-section of the particle visible under cross polarizers.

References