RADIATION FORCES ON ELLIPSOIDS DUE TO A FOCUSED GAUSSIAN BEAM

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KEY WORDS: radiation forces, ellipsoid, geometrical optics

1. INTRODUCTION.

In calculating radiation forces in an optical trap, particles are typically modeled using a sphere but actual specimens have various sizes and shapes that range from spherical to elongated forms. The behavior of an ellipsoid in an optical trap was found to depend on the particle aspect ratios [1]. In this work, we calculate the radiation forces due to a focused Gaussian beam for ellipsoidal particles in the geometrical optics for the case of (1) particles with different shapes (2) particles with different volumes and (3) an expanding particle.

2. RESULTS

Fig. 1a shows that for moderately elongated particles ($k_{xz} < 2$), the force curves are similar to a reference sphere. For more elongated particles ($k_{xz} \geq 2$), the axial forces increase and the curves lose their bimodality, suggesting that an elongation in the optical axis makes trapping harder.

The stiffness of the optical trap is reduced as the ellipsoidal particle volume increase. Figure 1b shows that for larger particles, the peaks of the force curves are farther from each other and the downward slope between the two peaks is also less steep. Figure 1c shows the force curves for an ellipsoid that is expanding uniformly in all directions, effectively changing the index of refraction. As the particle expands, the magnitude of the forces decrease giving rise to negative axial forces which lead to trapping. At around 150% volume expansion, the force curve becomes symmetric and at ~175% expansion, the sign of the forces reverses such that the particle is always pushed in the direction of the particle displacement.

![Figure 1](image.png)

Figure 1: Force versus displacement curves for (a) ellipsoidal particles with the same volume but different aspect ratios (i.e. different shapes), (b) ellipsoidal particles with the same aspect ratio but different volumes (i.e. different sizes), and (c) an expanding ellipsoidal particle.

References: