Radiation Force on Sphere in Ray Optics Regime

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Abstract

The analytic expressions of radiation force on sphere in loosely focused Gaussian beam are derived in suitable form for applications by photon stream method in ray optics regime. For perfect reflecting sphere, analytic solution of scattering force and simplified expression of gradient force are obtained. Computation results presented are consistence with previous theoretical studies and reported experimental results.

1. Introduction

The theoretical model for radiation force has been developed two different ways: Electromagnetic wave approach was developed to calculate radiation force for object smaller than wavelength of illuminated light by many authors. However, this approach is very complicated theoretically and difficult to apply to non-spherical object and non-Gaussian beam profile. Ray optics approach was studied by Ashkin. The ray optics approach is applicable to object larger than wavelength of illuminated light and simple to apply to arbitrary shape of object and non-Gaussian beam profile. Actually, most applications of radiation force are in ray optics regime, such as optical levitation and optical chromatography. Therefore the ray optics approach was studied in this paper by photon stream method.

2. Results

Using photon stream method, the scattering and gradient forces are calculated in Fig. 1 and 2. The calculation conditions are

$P=50mW$	$\lambda=0.488\mu m$	$\omega_0=3\mu m$
$r_p=2\mu m$	$n_o=1.33$	$n_s=1.59$

where P is power of light, λ is wavelength of light, ω_0 is minimum beam waist, r_p is sphere radius, n_o is the index of refraction of medium, n_s is index of refraction of sphere.

For perfect reflecting sphere, the analytic solution of scattering force and simplified expression of gradient force are derived and calculated with sphere having high index of refraction in Fig. 3 and 4.

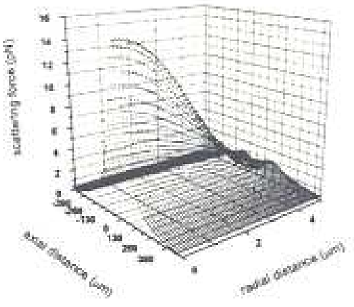

Fig. 1. Scattering force

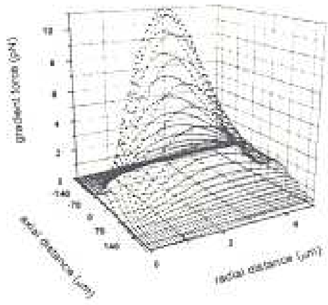

Fig. 2. Gradient force

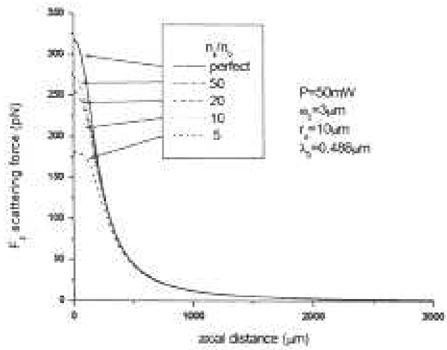

Fig. 3. Scattering force of perfect reflecting sphere

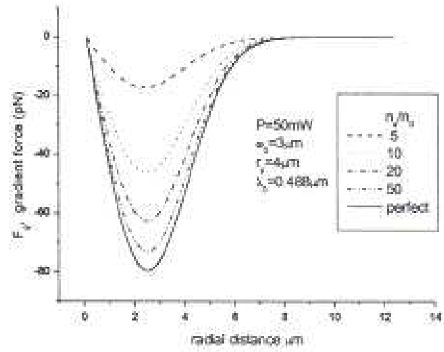

Fig. 4. Gradient force of perfect reflecting sphere

3. Conclusion

In this paper, the analytic expressions of gradient and scattering force equations for non-absorbing sphere in loosely focused Gaussian beam are derived from photon stream method in ray optics regime. And, for perfect reflecting sphere, the analytic solution for scattering force equation and simplified expression for gradient force are obtained. The calculated results are consistence with experimental observation reported in the literature and previous theoretical studies.

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