Partially Coherent Forces on Submicrometer Magnetodielectric Particles

Juan Miguel Auñón and Manuel Nieto Vesperinas

Instituto de Ciencia de Materiales de Madrid,
Consejo Superior de Investigaciones Científicas.
Campus de Cantoblanco, Madrid, 28049, Spain
jmaunon@icmm.csic.es

In this work we investigate the photonic forces from three-dimensional electromagnetic field emitted by a three-dimensional fluctuating homogeneous and isotropic source. This primary source will induce electric, and in this case also magnetic, dipoles in the particle. These induced dipoles will also be considered as a secondary source which will interact with the primary source, originating a new force on themselves [1].

In order to see the effects on a magnetodielectric particle we consider a semiconductor particle, with a real refraction index such as Silicon. In this type of particles, in the range of the near infrared, the total cross section can be determined uniquely by the two first electric, and magnetic, Mie coefficients, thus, the total force can be calculated using the dipolar approximation instead of the Maxwell's stress tensor .

In the attached figure we show the force from the primary (first row) and the secondary (second row) sources. The electric, magnetic and electric-magnetic interference forces are shown for a zero coherence length of the source. In near-field, the behavior and the change of the sign in this force is due to that of the polarizability of the particle considered (see the plots inset). We can easily see that, whereas the force from the primary source is constant for any distance from the source larger than 2.5 times the wavelength, the force from the above mentioned induced secondary source oscillates and tends to zero with increasing distance due to the homogeneous waves. In the near-field, the total force (the sum of all the components) will be governed by the secondary source, nevertheless, as we go away from the plane of the source, the homogeneous waves of the field emitted by the primary source will predominate. In this regard, it is worth remarking that in Fig. 1(c) we see a zone where the force will be negative and constant for any distance. The magnitude of this last force is one order lower than that from the primary source; thus it does not dominate; however, manipulating the properties of the electromagnetic field we could have a tractor force [4]

In summary, we have shown, that the mechanical action on a magnetodielectric particle from the electromagnetic field emitted by a primary source cannot be totally determined unless one takes into account the induced dipole as a *new source*. This effect is extremely important at distances shorter than the wavelength.

References

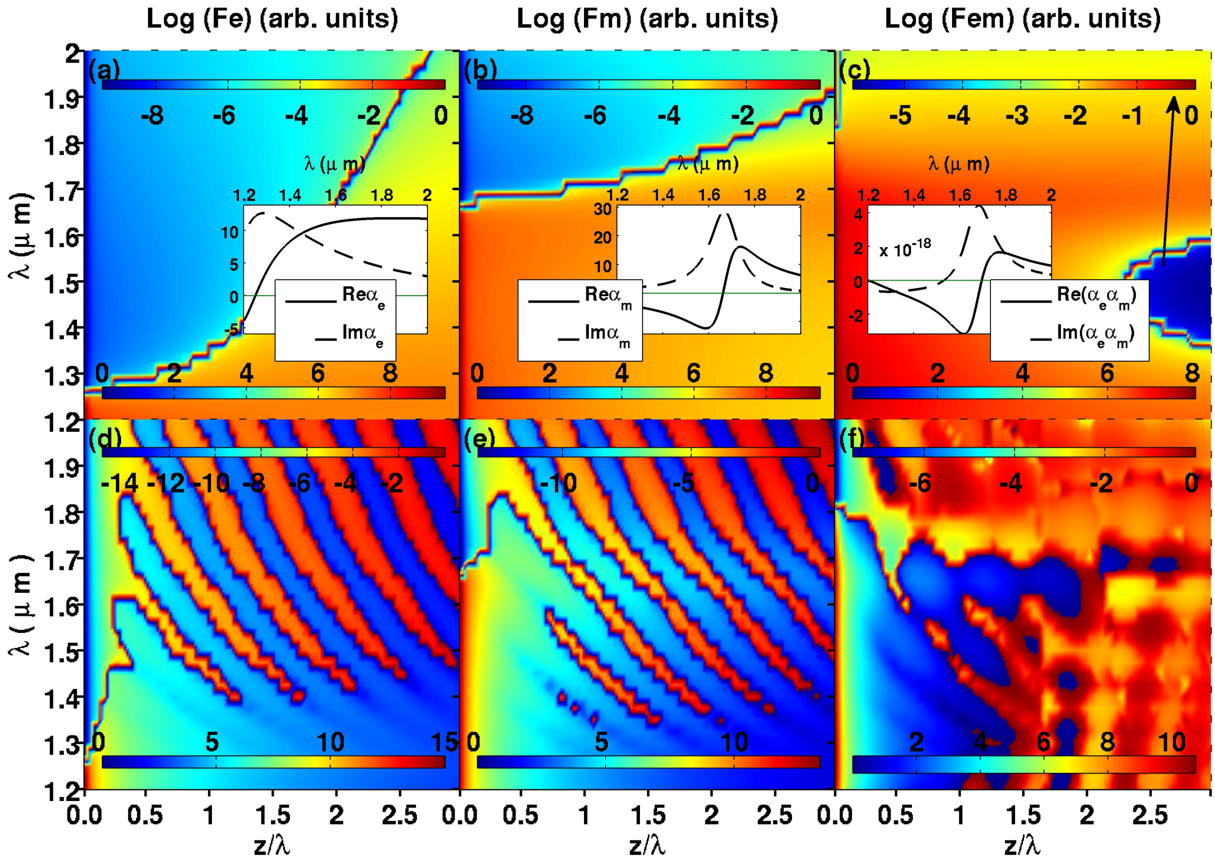
[1] J.M. Auñón and M. Nieto-Vesperinas (to be published).

[2] A. García-Etxarri *et al*. "Strong magnetic response of submicron Silicon particles in the infrared". Optics Express, **19**, 4815 (2011)

[3] M. Nieto-Vesperinas *et al*. "Angle-suppressed scattering and optical forces on submicrometer dielectric particles". Journal of the Optical Society of America A, **28**, 54 (2011)

[4] A. Novitsky *et al*. "Single Gradientless Light Beam Drags Particles as Tractor Beams". Physical Review Letters, **107**, 203601 (2011)

Figures



First row: Electric, magnetic and interaction forces from the primary source normalized to the spectrum of the force. The insets show the behavior of the polarizability (normalized to the radius³) in the range of wavelengths considered (adapted from [3])
Second row: The same as the first one for the secondary source (the induced dipoles)