I am looking for a postdoc!!

Instituto de Ciencia de Materiales de Madrid

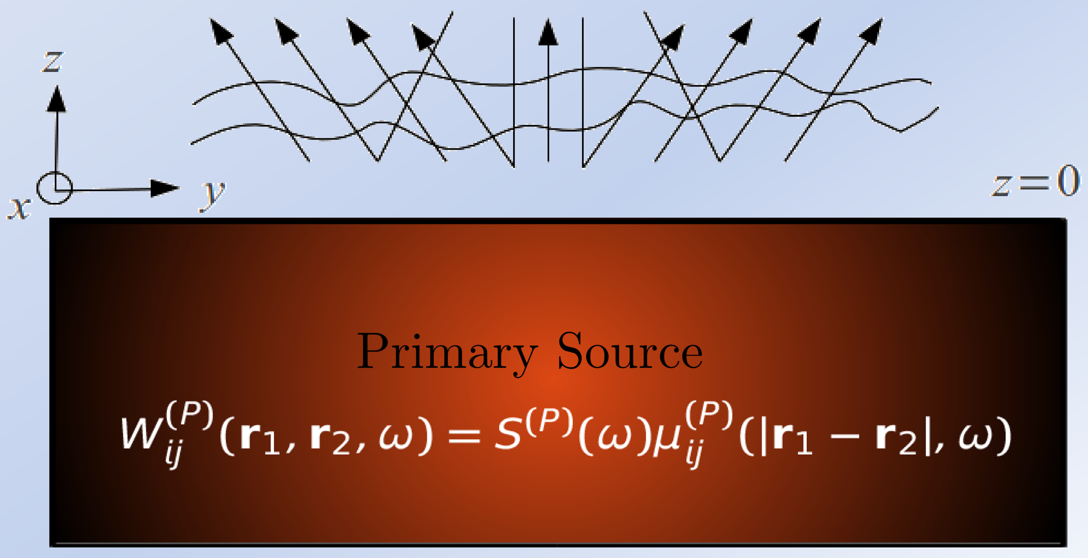
ICMM CSIC Consejo Superior de Investigaciones Científicas

New Van der Waals and Casimir forces: Partially Coherent Forces on Submicrometer Magnetodielectric Particles

Juan Miguel Auñón[1] and Manuel Nieto-Vesperinas[2]
Instituto de Ciencia de Materiales de Madrid (CSIC)
Cantoblanco, Madrid 28049
[1]jmaunon@icmm.csic.es, [2]mnieto@icmm.csic.es

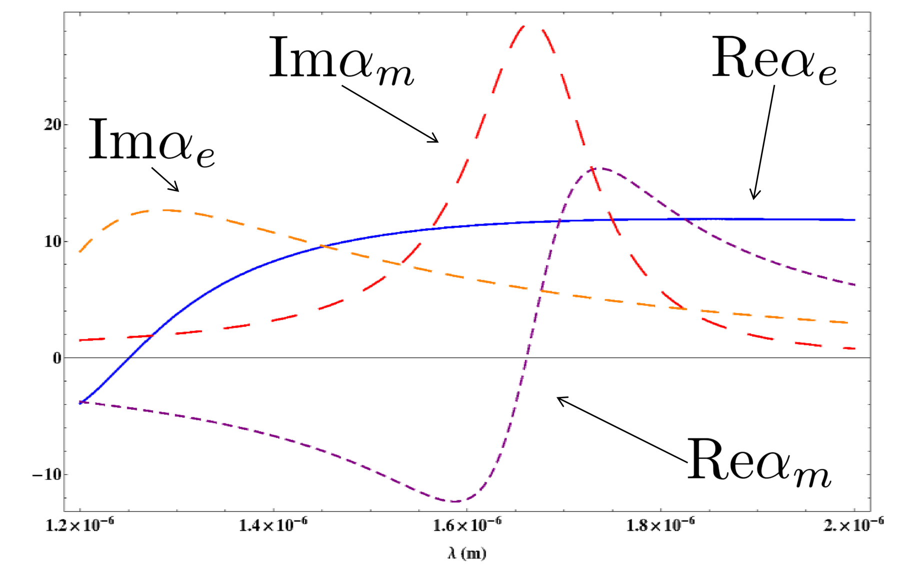
Abstract

In this work we study the different forces on a magnetodielectric particle when a electromagnetic partially coherent field impinges into the particle. The field emerges from a three-dimensional source and will excite electric and magnetic dipoles which will act as a secondary source. The induced dipoles will play a role similar to the induced vacuum fluctuations in Van der Waals (VdW) and Casimir-Polder (C-P) configurations. This secondary source will interact with the primary source originating a new a non-despreciable force, at least, in the near-field range. We also address important relations when Kerker's conditions are fulfilled.



$W_{ij}^{(P)}(\mathbf{r}_1,\mathbf{r}_2,\omega)=S^{(P)}(\omega)\,e^{(-(|\mathbf{r}_1-\mathbf{r}_2|)^2/2\sigma^2)}\delta_{ij}/(2\pi)^{3/2}\sigma^3$

$\sigma\rightarrow$ coherence length of the source $\quad \sigma=0\rightarrow\delta-$correlated source



M. Nieto-Vesperinas, et al. J. Opt. Soc. Am. A 28, 54 (2011).

Vacuum energy

$\hbar\omega[\frac{1}{2}+1/(\exp(\hbar\omega/kT)-1)]\approx\frac{1}{2}\hbar\omega$

$$F_i^e(\mathbf{r}) = \frac{\varepsilon_0\varepsilon_1}{2}\Re\{\langle\alpha_e E_j^*(\mathbf{r})\,\partial_i E_j(\mathbf{r})\rangle\}$$

$$F_i^m(\mathbf{r}) = \frac{\mu_0\mu_1}{2}\Re\{\langle\alpha_m H_j^*(\mathbf{r})\,\partial_i H_j(\mathbf{r})\rangle\}$$

$$F_i^{e-m}(\mathbf{r}) = -\varepsilon_0\varepsilon_1\frac{Zk_0^4}{12\pi}\Re\{(\alpha_e^*\alpha_m)\langle\mathbf{E}^*\times\mathbf{H}\rangle_i\}$$

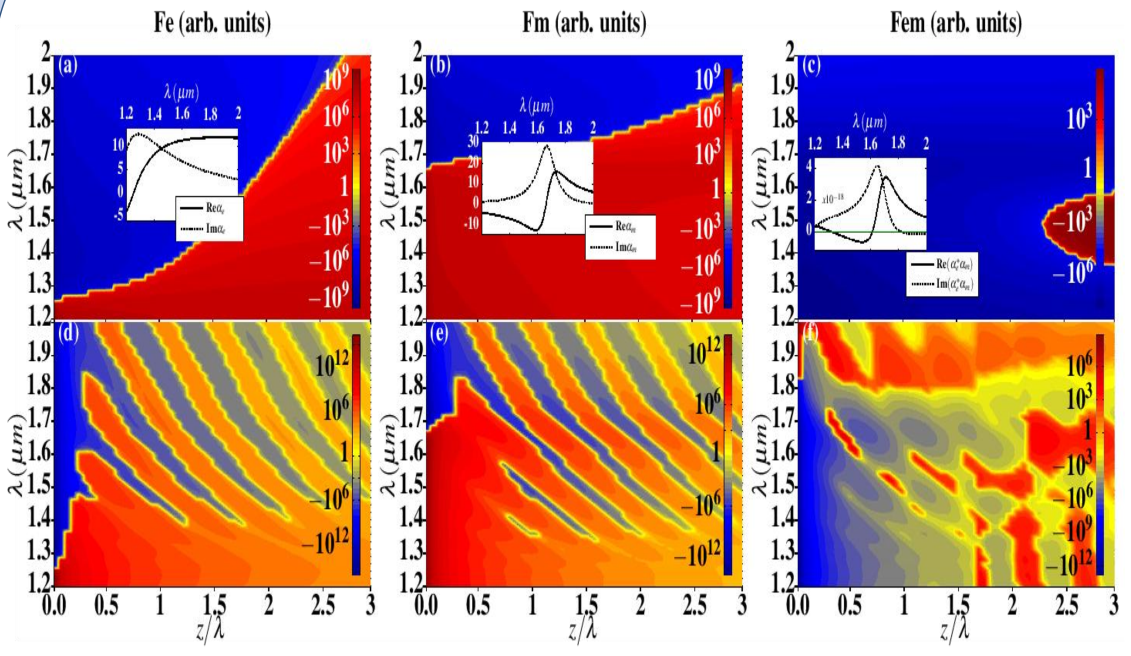
$$E_i(\mathbf{r}_0,\omega)=E_i^{inc}(\mathbf{r}_0,\omega)+E_i^p(\mathbf{r}_0,\omega)+E_i^m(\mathbf{r}_0,\omega)$$

Primary Source

$$E_i^{inc}(\mathbf{r}_0)=\mu_0\mu_2\omega^2\int_V G_{ij}^{EP}(\mathbf{r}_0,\mathbf{r}',\omega)\,P_j(\mathbf{r}',\omega)\,d^3r'$$

	$z<\lambda$	$z>\lambda$
Kerker 1 $\mathrm{Re}\alpha_e=\mathrm{Re}\alpha_m$	$F^e(\mathbf{r}_0,\omega)=F^m(\mathbf{r}_0,\omega)$	$F^e(\mathbf{r}_0,\omega)=F^m(\mathbf{r}_0,\omega)$
Kerker 2 $\mathrm{Re}\alpha_e=-\mathrm{Re}\alpha_m$	$F^e(\mathbf{r}_0,\omega)=-F^m(\mathbf{r}_0,\omega)$	$F^e(\mathbf{r}_0,\omega)=F^m(\mathbf{r}_0,\omega)$

Fig. 1



Logarithmic of the electric (first column), magnetic (second column) and interaction force (third column) for the primary source (first row) and for the induced dipoles (second row) versus the distance from the source.
Blue areas indicate a negative force and red areas a repulsive force

Secondary Source

$$E_i^p(\mathbf{r}) = \mu_0\mu_2\omega^2 G_{ij}^{Ep}(\mathbf{r},\mathbf{r}_0,\omega)\,p_j(\mathbf{r}_0,\omega)$$

$$E_i^m(\mathbf{r})=\frac{Z_0 i\omega}{c}G_{ij}^{Hm\leftrightarrow}(\mathbf{r},\mathbf{r}_0,\omega)\,m_j(\omega)$$

Fig. 2

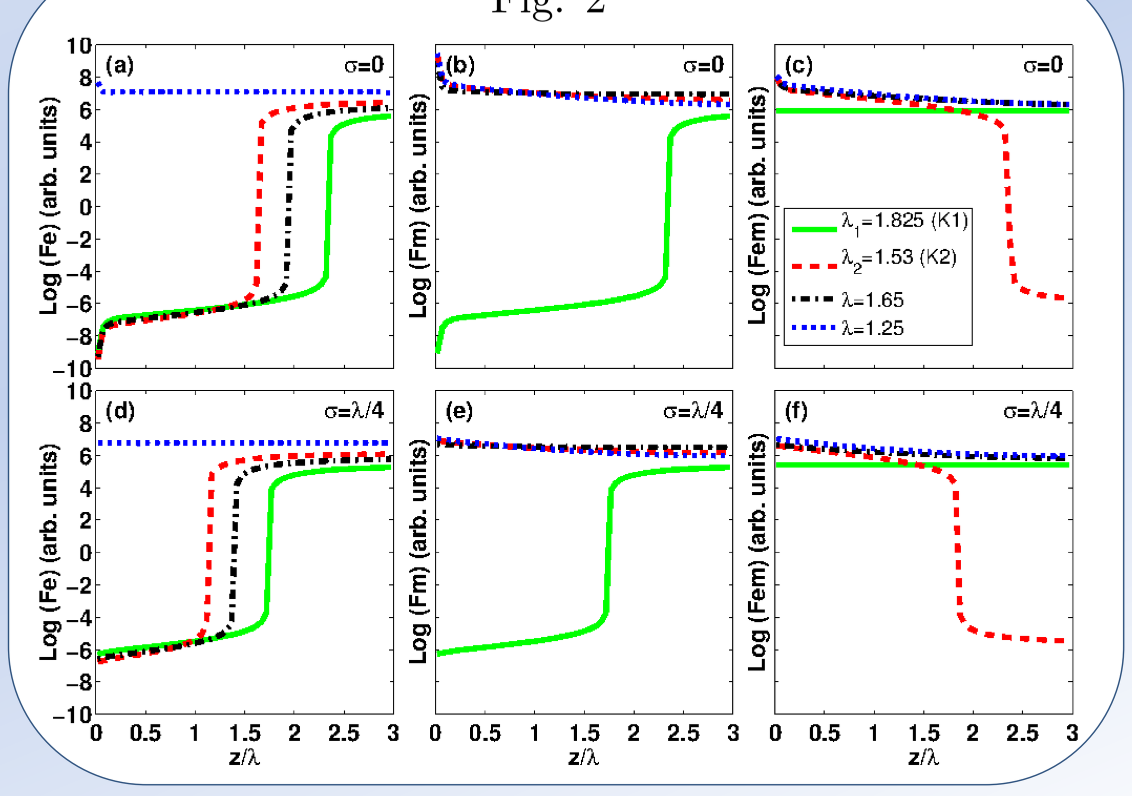


Fig. 3

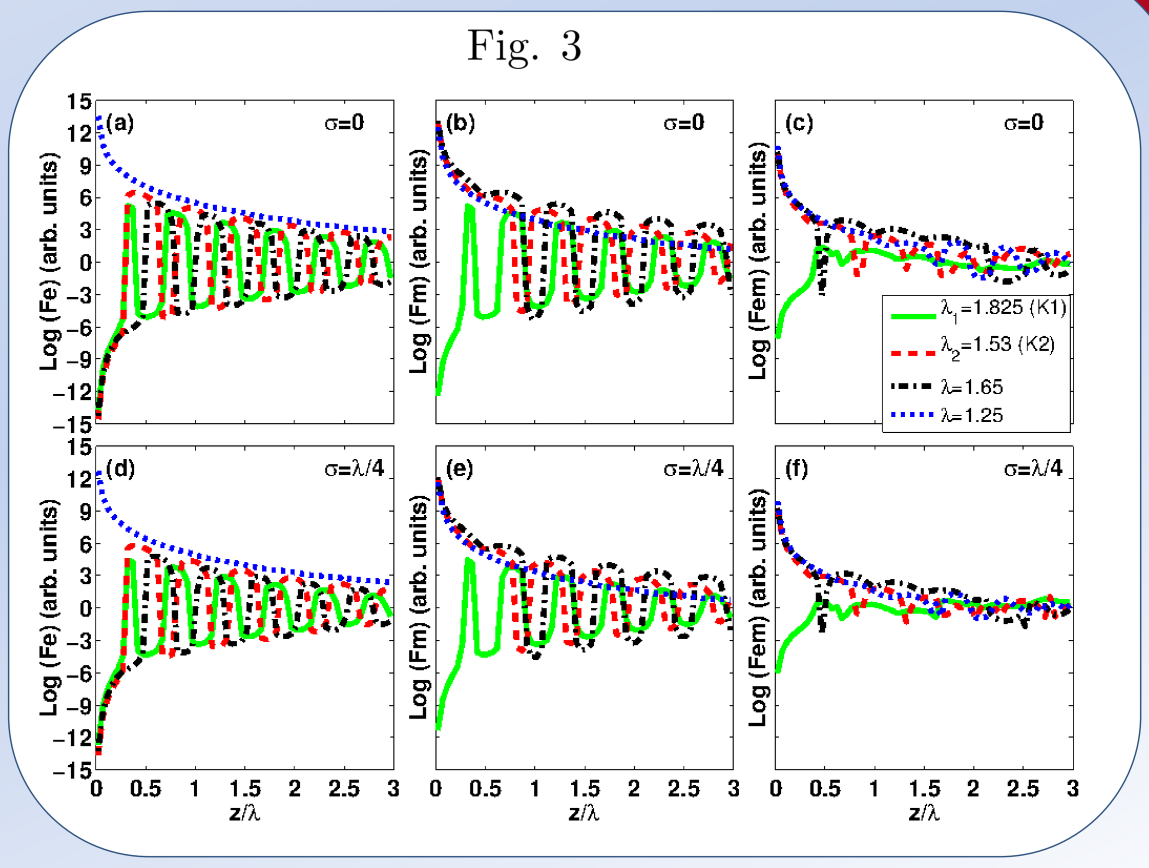
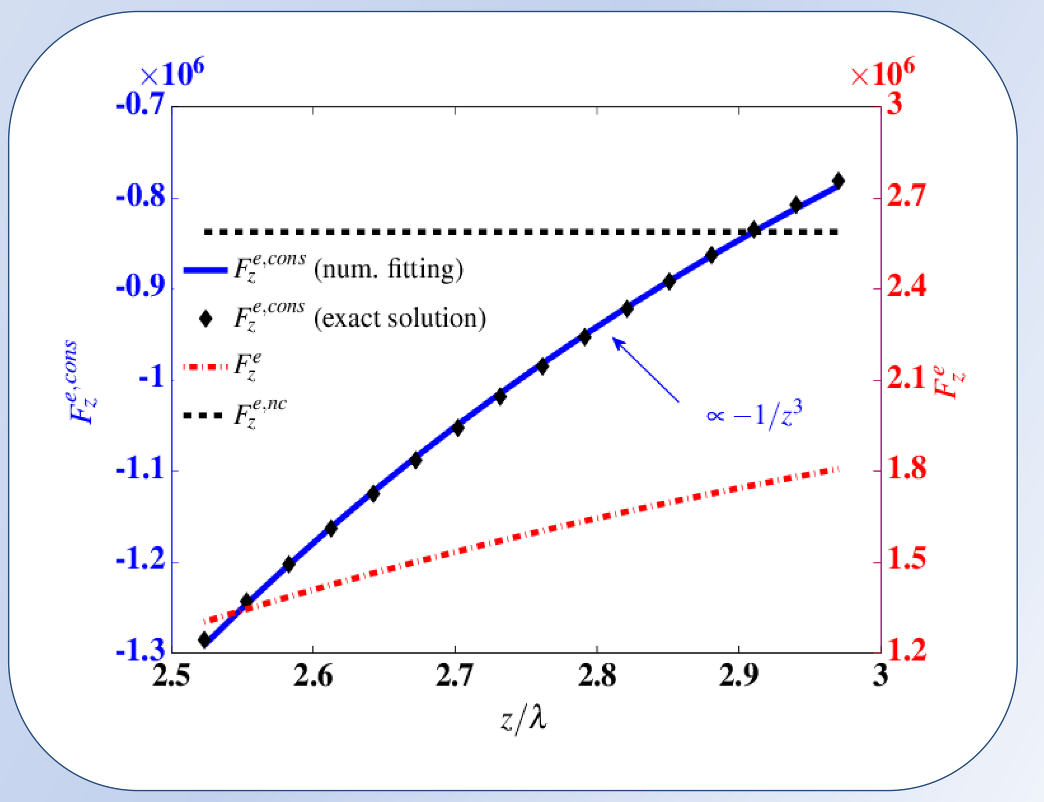


Fig. 1 shows the logarithmic of these forces. In Fig. 1 (a-b) appears a natural line which separates the conservative and non-conservative components of the forces.

We can see in Fig.2 (a-b) important relations between the electric and magnetic force (see also the table) when we are in the Kerker's conditions.

On the other hand, in Fig. 3 we can see how this force predominates for distances shorter than the wavelength, however it decreases fastly and the first one will be the main force.



At far-field, the quasiastatic approximation is not valid. The above figure shows the conservative electric force (left axis) and non-conserative force (right axis). We can see how the force cannot be described by a conservative force losing the asymptotic power law $-1/z^3$

In summary, 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 dipoles as a new source. **This new force is analogous to the VdW and C-P forces due to these dipoles are induced in a regime where the temperature does not play any role.**

References: J. M. Auñón, C. W. Qiu, and M. Nieto-Vesperinas, "Tailoring photonic forces on a magnetodielectric nanoparticle with a fluctuating optical source," Phys. Rev. A 88, 043817(2013).