An analysis of magnetic materials through an extension of the discrete dipole approximation

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Recent advances in nanotechnology and nanoscience involving materials with magnetic properties (magneto-optical materials) [1,2,3,4] as well as those with unconventional optical properties (metamaterials) [5,6] have been performed, awakening a growing interest in this matter. The possibility of modeling the properties of such materials, and even design them in a customized way, is highly appreciated and currently constitutes a hot point. Furthermore, comparison and further agreement between experimental results and some theoretical framework is a constant requirement by researchers in those fields. In particular, the presence of a relative magnetic permeability μ_r different from 1 (even negative or tensorial) requires the revision and upgrading of the commonly available electromagnetic numerical methods [7,8].

In this sense, our Group has been working, during the last years, in the generalization of some widely used numerical methods, such as the extinction theorem [9]. Other approaches include Mie theory applied to materials with arbitrary optical constants ε and μ [10,11] and the discrete dipole approximation (DDA by its acronym in English) [12,13,14,15]. In this work we focus on the second: an extension of the DDA to the case of bianisotropic materials (both ε and μ tensorial magnitudes) [16]. The use of commercial software, like COMSOL, FDTD or DDSCAT (based on DDA), is helping as well to understand the required new point of view.

In this research we present an overview of the formalism of this extension together with some early results showing the potential of this new tool, and also verifying its reliability. At present, extinction, absorption and scattering cross-sections can be readily obtained, including scattering patterns at any given plane, and dipole moment distributions (3D) for **p** and **m** (electric and magnetic). Polarimetric calculations can also be accomplished for any given incident wave polarization. Also, inhomogeneities can be taken into account, providing a good position to study systems involving more than one material, like nanoshells [17].

To check the reliability of the code, we have performed some calculations on systems at reach for conventional methods. Two examples are displayed in the next figures. Figure 1 shows the well-known zero-backscattering feature of a small particle ($R \approx 0.01\lambda$) satisfying Kerker's condition ($\varepsilon=\mu$) [18]. Figure 2 shows the extinction efficiency of both a gold sphere of radius R=20 nm, and a sphere with a dielectric ($\varepsilon=2$) core (inclusion) of radius R=12 nm and a metallic (gold) shell, for an external radius R=20 nm. Comparison between our code [16] and the well-proved DDSCAT code from B. T. Draine [14,15] is also presented.

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Figures

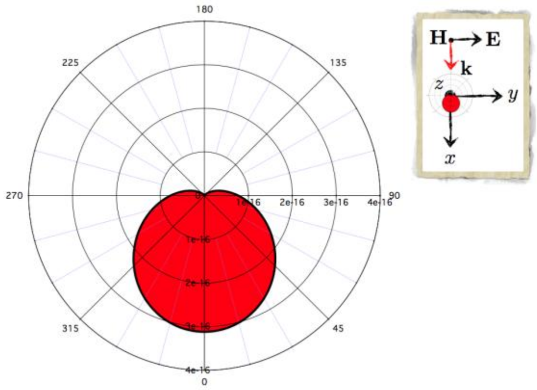

Figure 1: Scattering pattern of a sphere of radius R≈0.01λ satisfying Kerker's condition (ε=μ=2). The scattering plane coincides with the incident plane, with the incident wave being P-polarized.

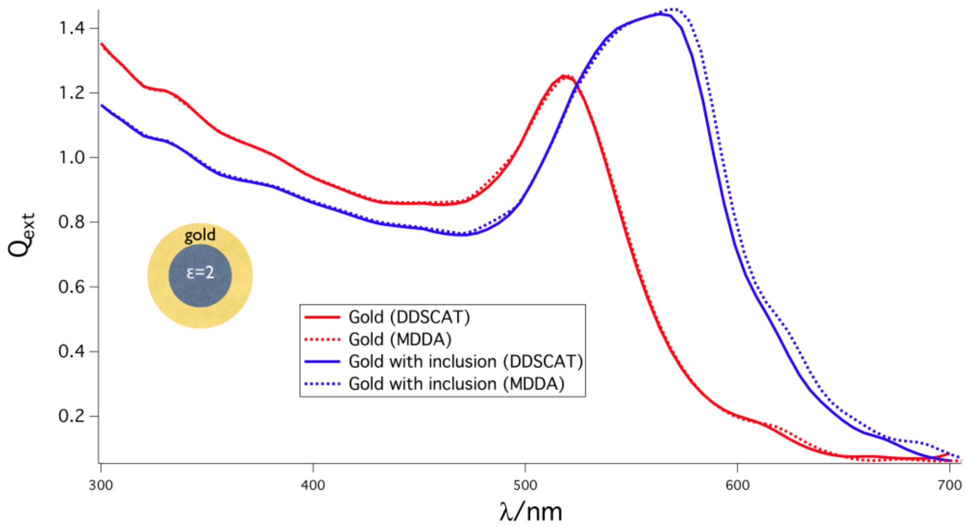

Figure 2: extinction efficiency of both a gold sphere of radius R=20 nm, and a sphere with a dielectric (ε=2) core (inclusion) of radius R=12 nm and a metallic (gold) shell, for an external radius R=20 nm. Comparison between our code and the well-established DDSCAT code is also provided.