Magneto-optical effects in nano-disks as a perturbation of the optical response

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Electromagnetic scattering from nanometer-scale particles is currently a topic of considerable interest, which is being investigated both theoretically and experimentally for the purpose of understanding the underlying physics and to study novel near- and far-field optical and magneto-optical effects [1–5]. To address fundamental issues of magneto-optical scattering from nanometer-scale magnetic structures, we have investigated the optical and magneto-optical responses of nano-scale ferromagnetic (cobalt) disks arrays by means of self-consistent numerical simulations, using an extension of the discrete dipole approximation [6]. We also implemented an approach to the problem by modeling the nanoscale-disk with an array of radiating dipoles interacting as if they were belonging to an infinite film. This infinite layer (IL) approach neglects the effects of the lateral confinement on the induced dipoles distribution and it is used as a reference for the full calculations. Specifically, we studied the case of 5 nm thick cobalt disks in the diameter range from 200 to 1000 nm, illuminated under normal incidence with a wavelength of λ = 632.8 nm. We furthermore assumed the magnetization to lie in the plane of the disk and being oriented perpendicular to the electric field of the incoming electromagnetic wave, i.e. the transverse magneto-optical Kerr effect (T-MOKE) configuration. The induced polarization pattern and the near- and far-field optical and magneto-optical responses have been calculated, finding clear nano-scale confinement effects as one reduces the diameter of the disks (see Fig. 1). However, we also observe that the rather weak magneto-optical response essentially mimics the optical response, and we demonstrate that it can be calculated as a perturbation of the latter with a high degree of accuracy. This strong similarity between the optical and magneto-optical nano-scale confinement effects also results in the fact that the normalized magneto-optically induced far-field light intensity change, which is the quantity measured in experiments, is only weakly affected even in the case of sub-wavelength sized disks (see comparison with results from our IL approach in Fig. 2).

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References

[1] M. Grimsditch and P. Vavassori, J. Phys.: Condens. Matter **16**, R275 (2004).
[2] J. B. González-Díaz, J. M. García-Martín, A. García-Martín, D. Navas, A. Asenjo, M. Vázquez, M. Hernández-Vélez and G. Armelles, Applied Physics Letters **94**, 263101 (2009).
[3] M. I. Stockman, Physics Today **64**, 39 (2011).
[4] V. Bonanni, S. Bonetti, T. Pakizeh, Z. Pirzadeh, J. Chen, J. Nogués, P. Vavassori, R. Hillenbrand, J. Åkerman and A. Dmitriev, Nano Letters (2011), 10.1021/nl2028443.
[5] R. Alcaraz de la Osa, J. M. Saiz, F. Moreno, P. Vavassori and A. Berger, submitted to Phys. Rev. B.
[6] R. Alcaraz de la Osa, P. Albella, J. M. Saiz, F. González and F. Moreno, Opt. Express **18**, 23865 (2010).

Figures

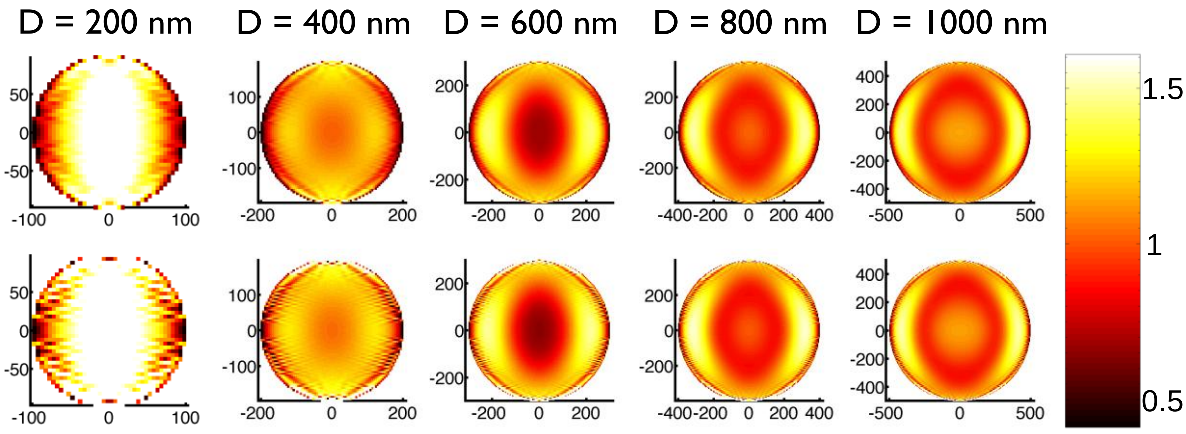

Figure 1: Absolute value of the primary optical (upper panel) and the magneto-optical (lower panel) components of the induced dipole moment for several disk diameters D normalized to an equivalent infinite layer (IL) calculation.

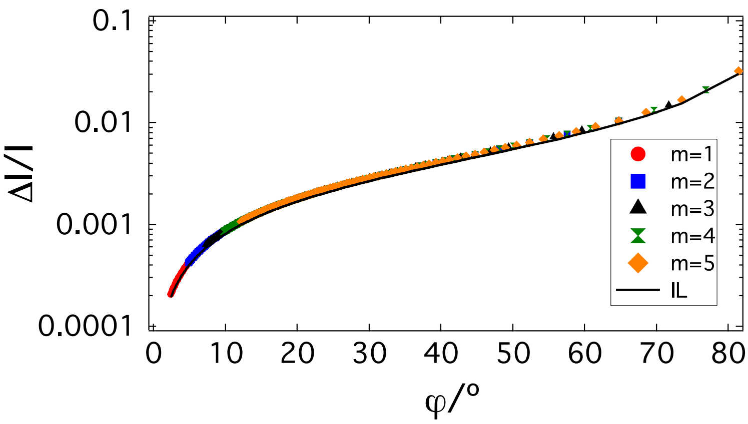

Figure 2: Normalized magneto-optical intensity change signal ΔI/I vs. diffraction angle φ for several horizontal diffraction orders m: D=200nm with λ=632.8nm.