

Plasmonic phase tuning of magneto-optics in ferromagnetic nanostructures

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Abstract

Electromagnetic scattering from metallic nanometer-scale particles is currently a topic of huge interest. The vast majority of these studies is performed on noble-metal nanostructures and is focused on the effects on the scattered field due to the nano-confinement of electric fields caused by the excitation of localized plasmon resonances in single nanoparticles. In the last years the research efforts moved on magnetoplasmonic nanostructures, viz., nanostructures that combine magnetic and plasmonic functionalities [1]. These systems could be the building block of a new class of magnetically controllable optical nanodevices for future biotechnological and optoelectronic applications.

Very recently it was shown how the concerted action of localized plasmon resonances in single nanoparticles and magnetization can be exploited to actively manipulate the reflected light's polarization (i.e., to induce and control Kerr rotation/ellipticity reversal) of pure ferromagnetic nanostructures beyond what is offered by intrinsic material properties [2], even if plasma oscillations in ferromagnetic materials typically exhibit a stronger damping than in noble metals [3]. While most of the investigations carried out before were focused on the achievement of substantial enhancement of magneto-optical Kerr effect here we study the polarizability of nanoferrimagnets to understand the role of the phase of localized plasmon resonances on their magneto-optical activity. We demonstrate that these systems can be described as two orthogonal damped oscillators coupled by the spin-orbit interaction, as shown in Fig. 1. We prove that only the spin-orbit induced transverse plasmon plays an active role on the magneto-optical properties by controlling the relative amplitude and phase lag between the two oscillators [4]. A formalism to compute the polarizability, as well as the far-field magneto-optical spectra, of large magnetic ellipsoidal nanoelements, i.e., exceeding the Rayleigh limit (electrostatic regime) is presented [5]. This approach can be applied to real samples of optically non-interacting flat disks with circular and elliptical sections, and size up to a few hundred nanometers. We find a surprisingly excellent quantitative agreement between calculated and experimental magneto-optical spectra both for circular and elliptical nanodisks, as shown in Fig. 2. In spite of its approximations and simplicity, the formalism developed captures the essential physics of the interplay between magneto-optical activity and localized plasmon resonances in ferromagnetic nanostructures.

References

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Figures

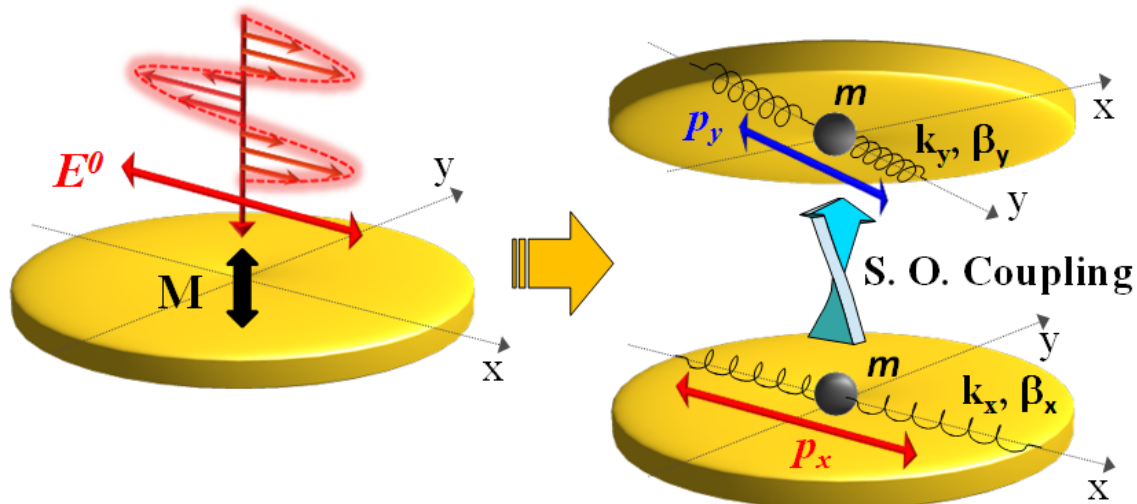


Figure 1. A ferromagnetic disk modeled with two orthogonal damped harmonic oscillators coupled by the spin-orbit (SO) interaction; m represents the mass of the conduction electrons; the spring constants k_x and k_y originate from the electromagnetic restoring forces due to the displacements of the conduction electrons; β_x and β_y are the damping constants.

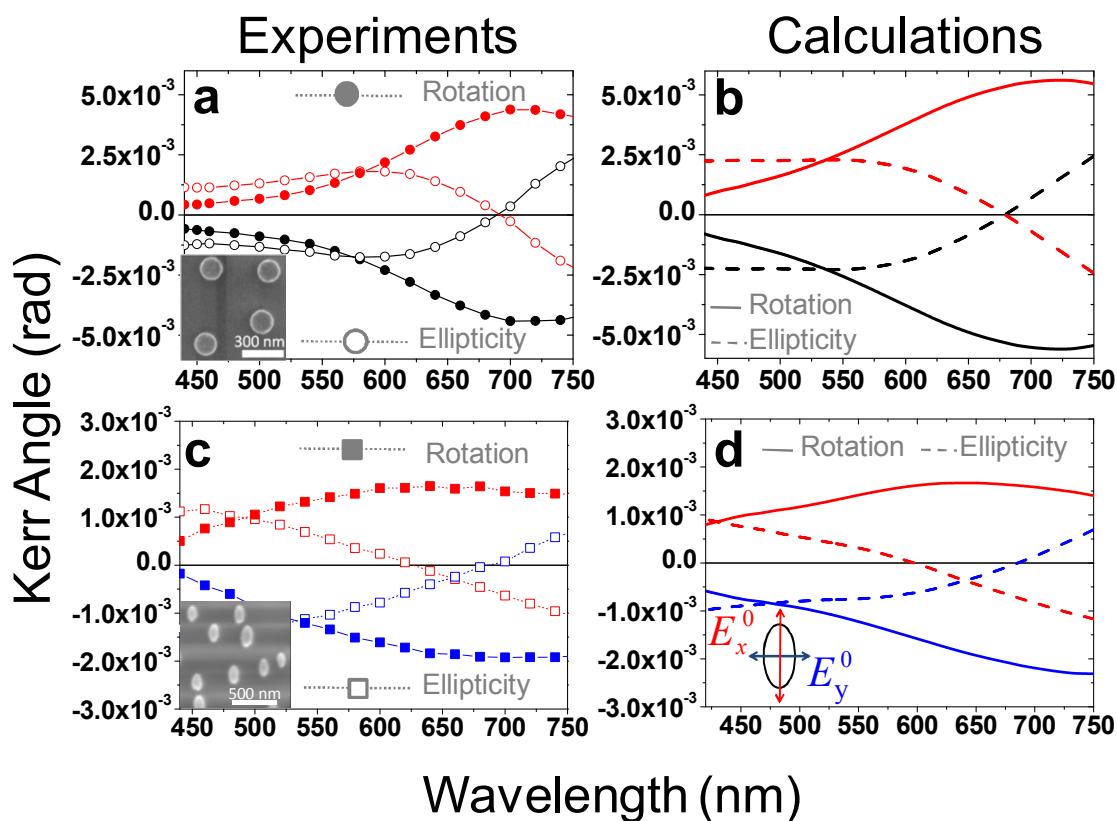


Figure 2. Experimental magneto-optical spectra for Ni disks with diameter of 160 nm (a) and elliptical disks with in-plane dimensions of 180 nm and 100 nm. The thickness is 30 nm in both cases. Calculated spectra for circular (b) and elliptical (d) disks. Insets: Scanning Electron Microscopy images of a portion of the samples.