Shaping Magneto-Optical Spectra with Plasmonic Resonances

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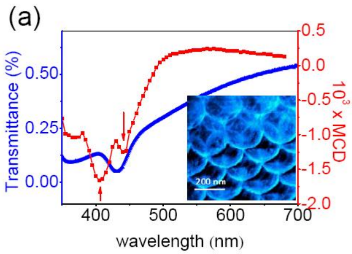
The magneto-optical activity results from the interaction of polarized light with magnetized media. This is revealed by an induced rotation and ellipticity of the polarization as the light is transmitted or reflected from a medium in the presence of a magnetic field and/or magnetization. Thus, the interaction of light with magnetic materials provides a way to manipulate the polarization of light and to exploit this phenomenology for characterization as well as applications. Indeed, the cross link between light and magnetism affords the basis for potentially novel devices in data control of optical communications, optical storage data and sensing. This has, in turn, spurred the research on new materials exhibiting large magneto-optical responses at the operating wavelengths, in particular in the visible. The strategies towards magneto-optical enhancement are essentially based on the dramatic intensification of the lightmatter interaction when media are nanostructured intentionally to couple predominantly with photons of certain wavelengths.

In previous works, we have demonstrated the efficiency of coupling magneto-optics to photonic bandedge effects in magnetophotonic crystals [1, 2], where at frequencies close to the band edges the group velocity of light is dramatically slowed down and, therefore, photons of those wavelengths couple very intensively with the medium. Exploiting this mechanism, we have achieved enhanced magneto-optical responses at near-band edge wavelengths in three-dimensional magneto-photonic crystals (3D-MPCs) (see Figure 1a). Here we envisage an alternative strategy to boost magneto-optic signals by coupling to plasmonic resonances. Thus, the incorporation of magnetic nanoparticles into plasmonic structures provides an alternative pathway to modulate the magneto-optical spectra and enhance the response at specific wavelengths. In this case, we have exploited the huge increase of the electromagnetic energy density associated with plasmons that are excited in extremely confined regions around metal/dielectric interfaces. With this in mind, we have coated corrugated gold/dielectric interfaces with magnetic (nickel and iron oxide) nanoparticles [3]. We have found that the magneto-optical spectra at visible wavelengths are strongly modified when the magnetic nanoparticles are incorporated into plasmonic structures formed either by Au voids or Au nanodisk arrays. In particular, we find that the magnetooptical activity is enhanced by up to around one order of magnitude (Figure 1b) for wavelengths that are correlated to the excitation of either propagating or localized surface plasmons. In addition, we demonstrate that this strong magneto-optical activity is not merely the result of the reflectance modification associated to diagonal terms of the permittivity tensor, but to an intrinsic huge enhancement of the optical activity related to the off-diagonal permittivity coefficients.

Our results demonstrate the potential of exploiting light polarization in plasmonic and photonic structures as a powerful strategy to customize the magneto-optical spectral response of magnetic materials and to obtain optimized materials for applications such as sensing or optical communications.



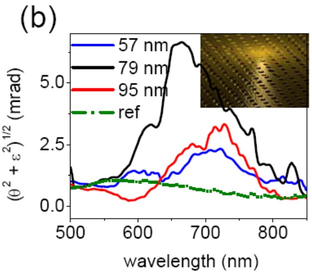


Figure 1: (a) Spectral response of the optical transmission (blue) and the magnetic circular dichroism (red) of a direct opal infiltrated with $MnFe_2O_4$ of nanoparticles (see a SEM image in the inset). (b) Magneto-optical spectra (θ = rotation, ε = ellipticity) of iron oxide nanoparticles deposited on nanodisks arrays with diameter *d* = 57, 79 and 95 nm and on a flat surface. The inset shows a SEM picture of one of the nanodisk arrays.

References

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