Optimizing light harvesting for high magneto-optical performance in metal and metal-dielectric magnetoplasmonic nanodiscs

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Magnetic Nanostructures and MagnetoPlasmonics
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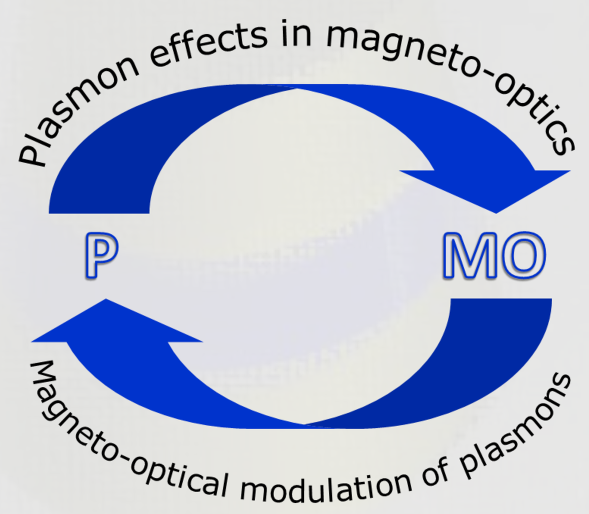
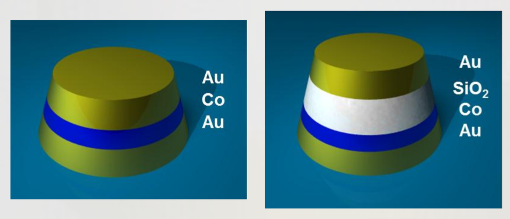
Magnetoplasmonics

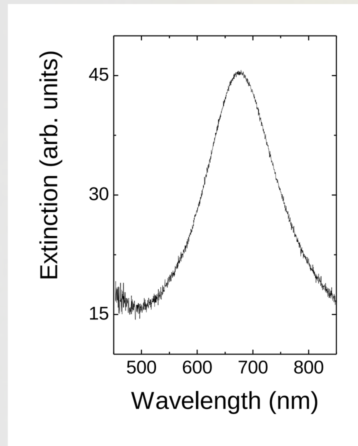
Magnetoplasmonics deals with the study of materials and/or phenomena involving both plasmonic and magneto-optical (MO) properties. A two-way path connects both properties: the MO response of the system can be modified by the presence of plasmon resonances and the plasmons properties can be modulated by means of an applied magnetic field. Here we focus on the first path, in particular on the **MO activity enhancement in nanodiscs** due to the excitation of localized surface plasmons (LSP).



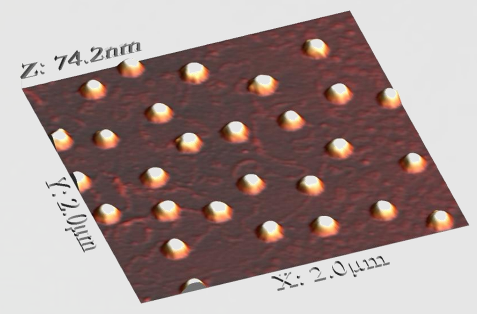
Magnetoplasmonic nanodiscs



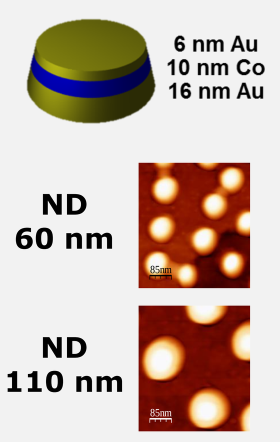
Composed of plasmonic material (Au here) and MO material (Co here). They can contain other passive materials (SiO_2 here).



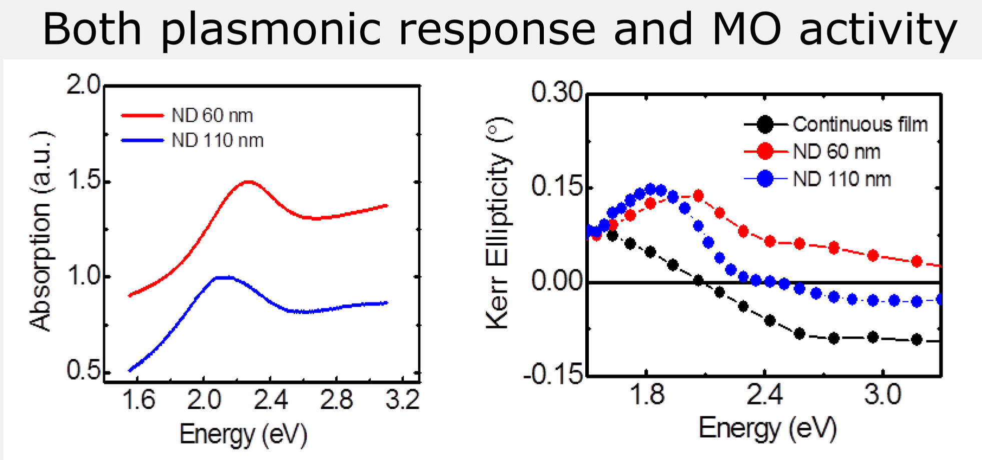
Fabricated by colloidal lithography and evaporation, which allows to obtain extended and uniform areas of randomly distributed nanodiscs. The discs show well-defined LSP resonances, slightly broadened due to the presence of Co.



MO enhancement in Au/Co/Au nanodiscs

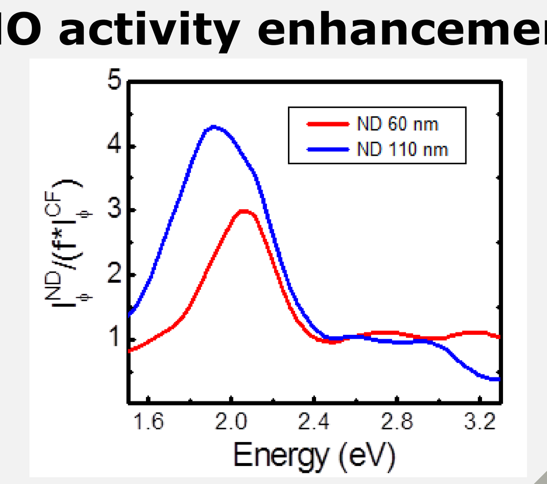


Both plasmonic response and MO activity



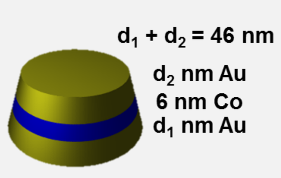
The excitation of the LSP increases the electromagnetic (EM) field in the disc, and therefore in the Co layer. The MO response of the system is enhanced in the corresponding spectral region.

MO activity enhancement

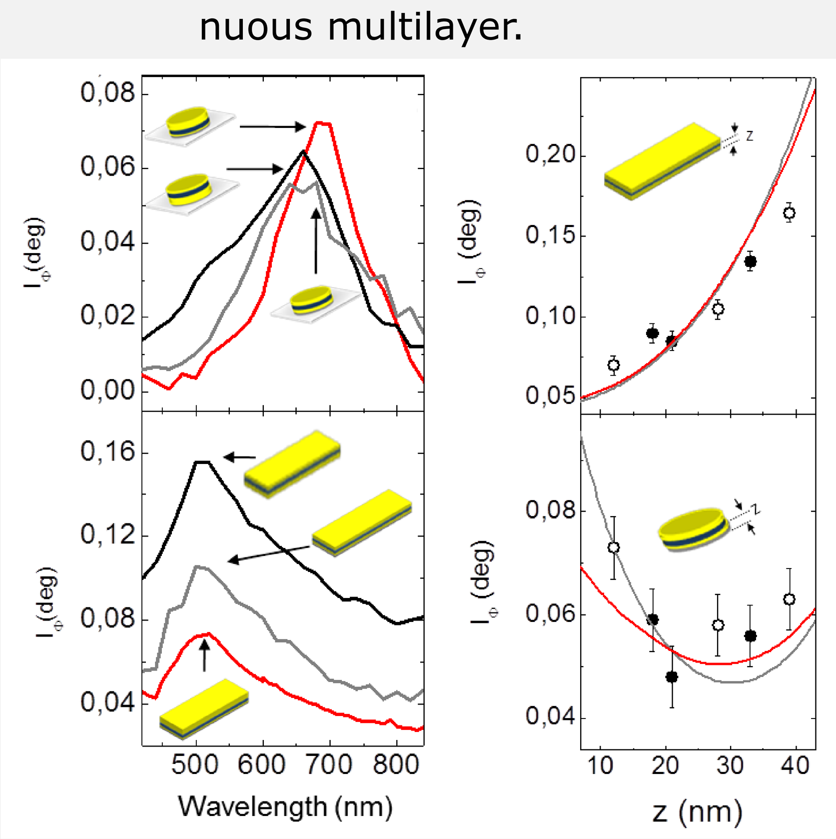


J. B. González-Díaz *et al.*, Small **4**, 202 (2008);
G. Armelles *et al.*, J. Opt. A: Pure Appl. Opt. **11**, 114023 (2009)

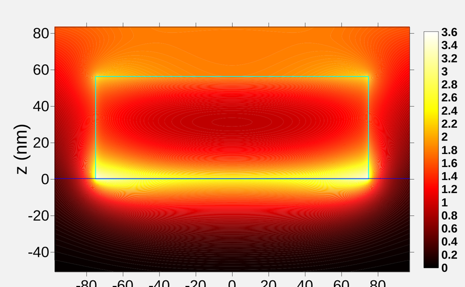
EM distribution inside nanodiscs



The MO activity depends on the position of the Co layer inside the nanodiscs. This dependence differs from that of a continuous multilayer.



Non-uniform electromagnetic field distribution inside a Au nanodisc



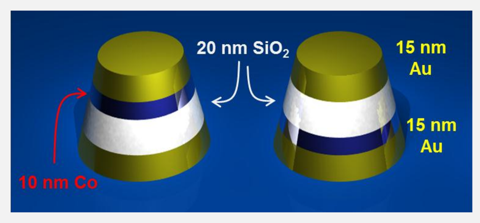
The MO activity of the nanodiscs is proportional to the EM field distribution inside the Co layer:

$$I_\phi \propto \iint_{S(\varepsilon_{MO}\neq 0)} |\varepsilon_{MO}(x,y)| E_z(x,y) E_p(x,y)\,dxdy$$

The evolution of the MO activity allows to determine the distribution of the EM field.

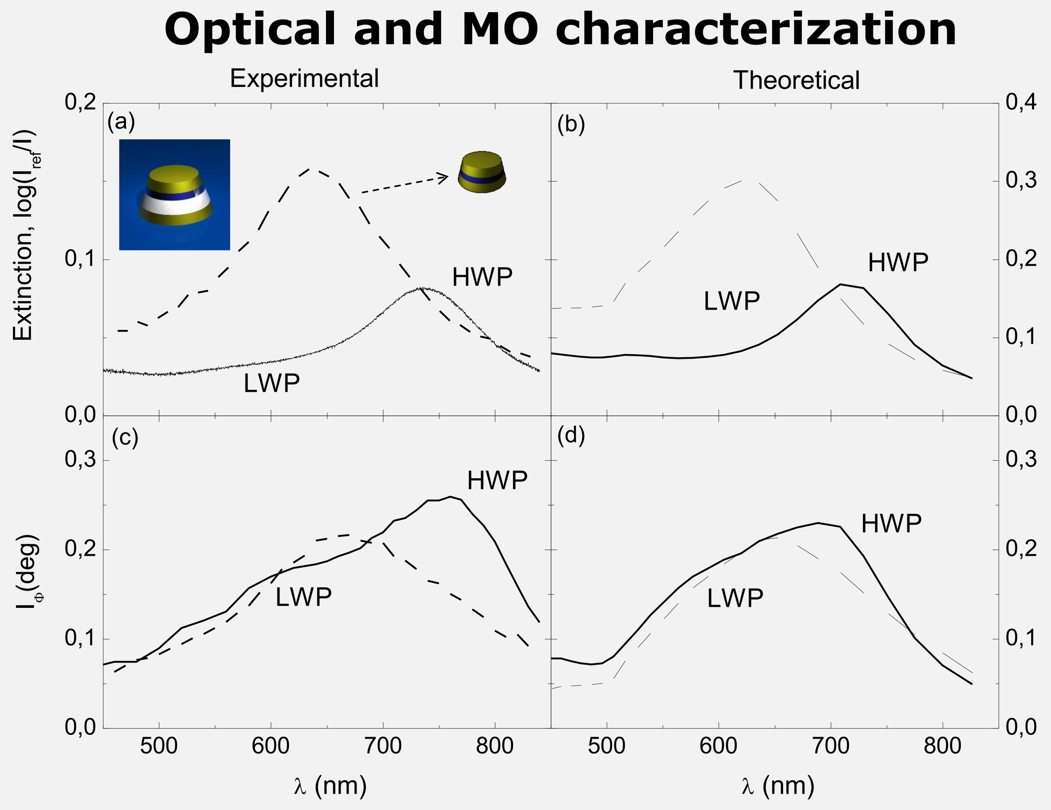
D. Meneses-Rodríguez *et al.*, Small **7**, 3317 (2011)

High MO activity and low absorption

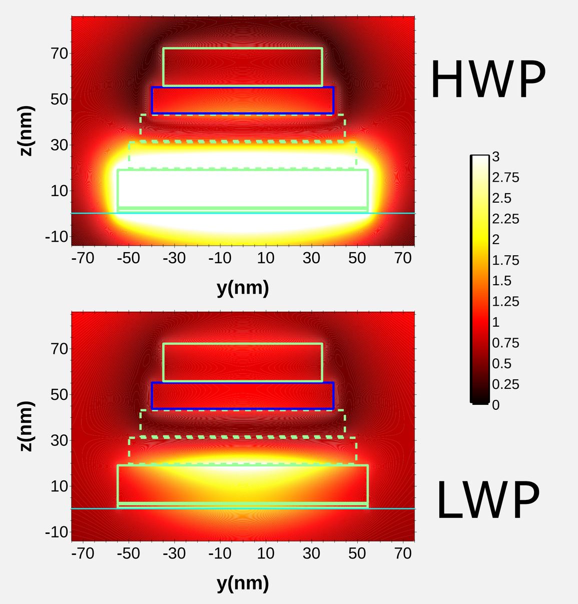


The insertion of a dielectric layer in the metal nanodisc gives rise to multiple mode resonances: a peak appears in the high wavelength region (HWP) and another peak in the low wavelength region (LWP).

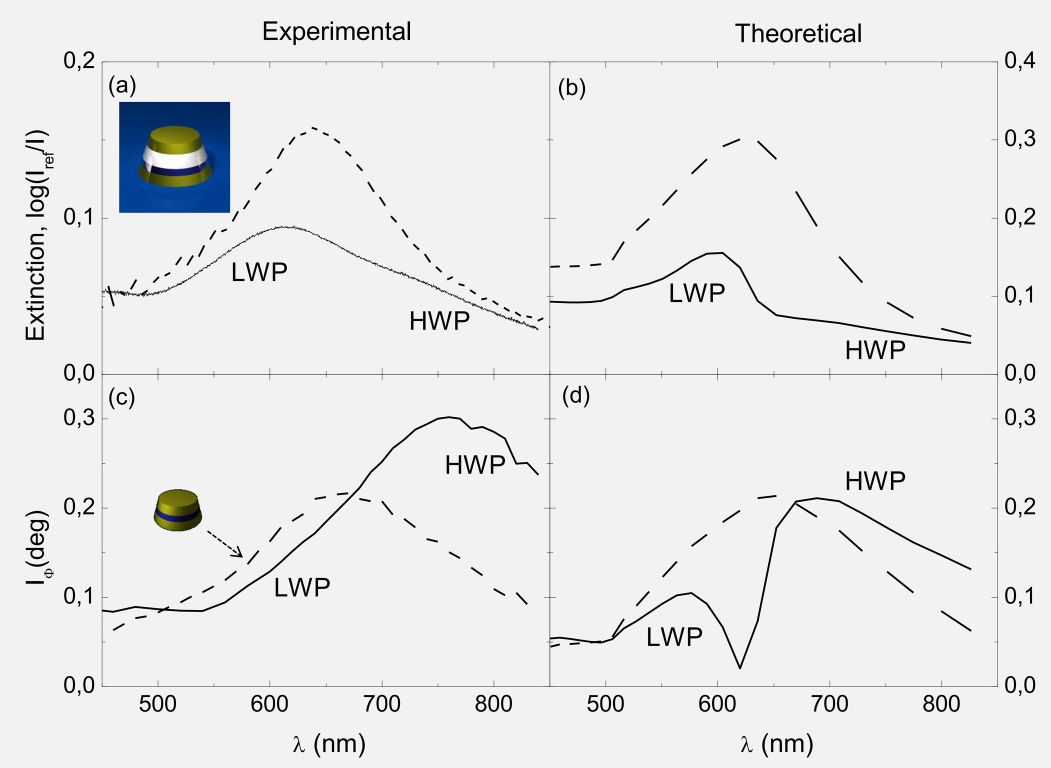
Optical and MO characterization

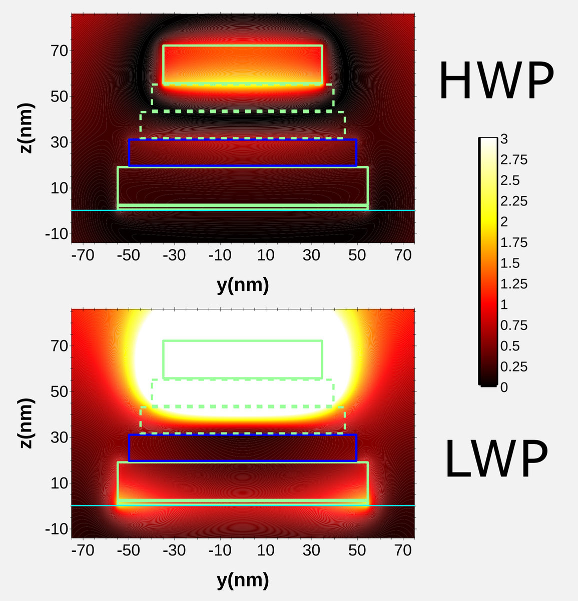


EM field distribution



This configuration shows large MO activity linked with high absorption.



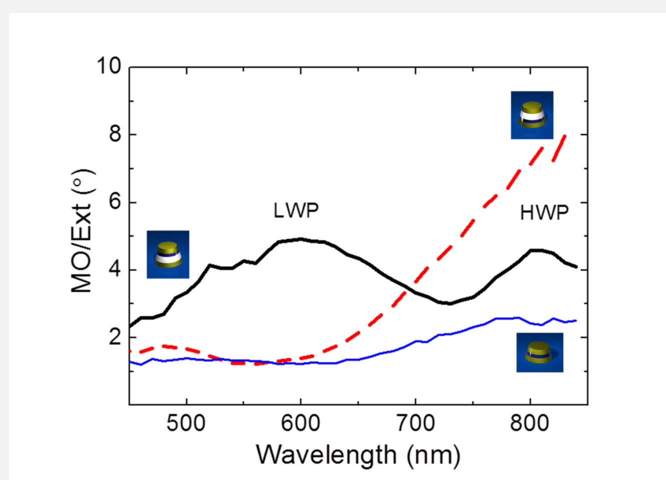


Here, large MO activity occurs with low absorption.

The EM field in the whole structure governs the extinction response of the system. The MO activity is determined by the field in the Co layer. Both quantities can be decoupled in these kind of nanostructures.

Figure of merit:
MO activity/optical extinction

For transmission related applications, both MO activity and absorption are relevant. In metal/dielectric nanodiscs, an adequate design can provide resonances with a very good figure of merit.



J. C. Banthí *et al.*, Adv. Mater. **24**, OP36 (2012)

Conclusions

- The increase in electromagnetic field associated with localized surface plasmon excitation results in an enhancement of the magneto-optical activity in magnetoplasmonic nanodiscs.
- The monitorization of the magneto-optical activity as a function of the Co layer position allows to probe the electromagnetic field distribution inside the nanodiscs.
- A smart design of the internal architecture of the nanodiscs allows to obtain configurations with maximum electromagnetic field at the magneto-optically active layers and minimum in the other, optically lossy ones. This gives rise to specific resonances with high magneto-optical activity and low optical absorption.

Acknowledgements

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