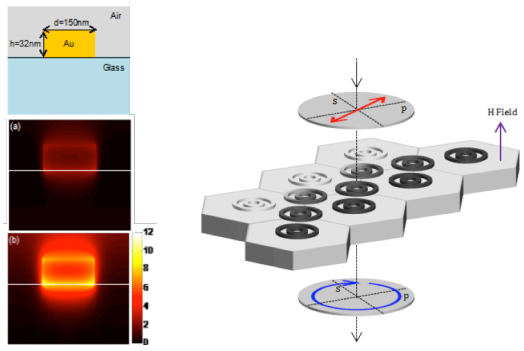
SUMMER INTERNSHIPS 2017

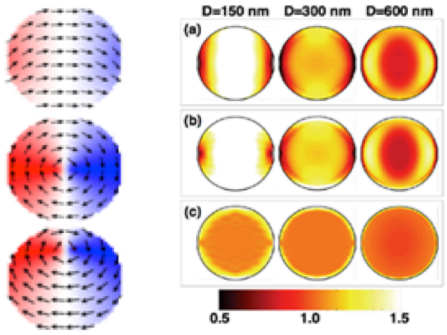
TITLE: Nanostructured magnetic materials for the manipulation of light propagation and polarization

DESCRIPTION (Objectives, tasks, materials, equipment):

In the last decade, thank to a strong development of nanotechnology, there has been an increased interest in the study of the optical properties of metallic nanostructures and nanoparticles and their ability to control and manipulate light. In particular, it was found that tailor designed nanostructured materials offers the possibility to dynamically control propagation, localization, and polarization of light at the nanoscale, beyond the intrinsic properties of the constituent material. A current focal point of research is, thereby, the development of novel nanostructured composite materials (metamaterials) with "designed" and tunable optical properties. These novel materials exploit the capability of metallic nanoparticles to confine the electromagnetic (EM) field beyond the diffraction limit when properly excited by the electromagnetic field of a light beam impinging on them (plasmon resonance, i.e. oscillations of charged free electrons inside the material). This property offers a way to beat the light diffraction limit and enable a path towards subwavelength optics to be used to develop nano-photonics devices, which can be used, for instance, to transport information at the nanoscale limit or for novel high-tech optical devices (flat lenses and or polarizers). Equivalently interesting, is the strong dependence of this EM field confinement effect on the environment that offers a clear pathway to the development of ultrasensitive (at the single molecule level) sensors for environmental and biological applications.



Left panel: simulations of the radiation field enhancement in a metallic nanostructure due to the excitation of localized Plasmon resonance (compare images b) and c). Right panel: meta-material made of ferromagnetic metallic nanostructures (concentric nano-rings) periodically arranged on transparent substrate for controlling light polarization.



Left panel: simulation results showing micromagnetic configurations in a cylindrical ferromagnetic nano-dot. Right panel: their effect on the calculated dielectric polarizability of the nanostructure.

Particularly interesting are composite metamaterials made of ferromagnetic nanoelements because they combine the plasmonic behavior described above with intertwined optical and magnetic properties, namely they display a magneto-optical (MO) activity. Thereby, the use of MO-active nanostructures can open up the pathway to design new types of nano-photonic devices and biosensors with enhanced performances, which can be remotely controlled by external magnetic fields.

The goal of the present internship project is the investigation and control, in the visible and low-infrared spectral regions, of the mutual relations between magnetism and optical properties of selected composite metamaterials made of ferromagnetic and multilayered noble-metal/magnetic nano-structures of integrated in a transparent substrate and even embedded in flexible and stretchable transparent membranes.

To this purpose, advanced optical modelling tools based on classical electromagnetic theory, will be used to explore (understand and design) optical and magneto-optical behaviours of nano-structured metamaterials supporting plasmonic resonances. In addition the project aims at incorporating micromagnetic simulations into the optical modelling to deal with the local effects that a non-uniform magnetization state are expected to have on the optical and magneto-optical properties of nano-scale objects.

During the project, the student will have the opportunity to participate in the measurements to verify the predictions of modelling efforts using our optical spectrometer and magneto-optical spectrometer. The acquired data will be compared with the results obtained using the modelling approaches mentioned above. To do so, programming of data analysis and data fitting software will be used.

References and reading list:

- G. R. Fowles, Introduction to Modern Optics (Dover Publications, INC., New York)
- S. Enoch & N. Bonod, Plasmonics (Springer-Verlag, Berlin)
- M. J. Freiser, IEEE Trans. Magn. 4, 152 (1968)
- V. Bonanni et al., Nano Letters 11, 5333 (2011)
- R. Alcaraz de la Osa et al., Phys. Rev. B 85, 064414 (2012)
- N. Maccaferri et al., Opt. Express 21, 9875 (2013)
- N. Maccaferri et al., Phys. Rev. Lett. 111, 167401 (2013)
- K. Lodewsky et al., Nano Letters 14, 7207 (2014)
- M. J. Donahue & D. G. Porter NIST IR 6376 (Gaithersburg, MD) (1999) http://math.nist.gov/oommf

SUPERVISOR: Dr. Paolo Vavassori

SHORT DESCRIPTION OF THE GROUP:

The Nanomagnetism Group at CIC nanoGUNE is conducting world-class basic and applied research in the field of magnetism in nano-scale structures. The Group staff has a longstanding expertise and proven track record in fundamental and applied aspects of nano-magnetism, and specifically in the use of magneto-optical methods. The main scientific topics pursued by the Nanomagnetism Group are:

- understanding magnetism and magnetic phenomena on very small length and very fast time scales in systems with competing interactions by means of experiments and theory

- development of advanced methodologies and tooling for magnetic materials characterization at the nanometer-length scale and the picosecond-timescale (especially magneto-optics)

- design, fabrication and characterization of novel nanometer-scale magnetic structures, meta-magnetic materials, thin films and multilayers

- novel concepts for applied magnetic nano-scale materials

More info: http://www.nanogune.eu/en/research/nanomagnetism

TIMETABLE: to be determined; an early start of the internship (beginning of June) would be preferred.

COMMENTS: Internship duration from 1.5 to 2 months (to be discussed).
Applicants should send an email to jm.pitarke@nanogune.eu including their academic record.
More info: http://www.nanogune.eu/summer-internship
Deadline for applications: 5 February 2017

SUITABLE FOR physicists, materials scientists, engineers