MAP-fis Essay Proposal, 2016-2017

(*please write in English*)

Supervisor

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Title

Ultrafast Dynamics in Nanostructured Magnetoplasmonic Materials

Area

(*Materials, Optics, Condensed Matter Theory, High Energy Theory, ...*);

Nanotechnology; Magnetoplasmonics; Ultrafast Optics and Photonics

Summary of Proposal

Understanding and controlling the interaction between light and matter is of fundamental importance to a wide range fields in science and technology. When we consider the effect of light on metals, we usually use them as mirrors. However, there is a fascinating light-matter interaction involving metals - the surface plasmon-polariton - that enables us to use metals as much more than just mirrors. Surface plasmon-polaritons (SPs) are electromagnetic waves coupled to the collective oscillations of the surface free charges in an interface between two media with permittivities of opposite sign, typically a dielectric and a metal [1], and can exist on a wide variety of metallic structures, such as single surfaces, thin films, nanoparticles, cylinders, etc.

Currently, technology provides a simple yet compelling way to not only tune the resonance frequencies of the system, but also the strength of the interaction with radiation, via the exploitation of near-field coupling between neighboring units. A step forward in the development of plasmonics that would allow the realization of fundamental components in nanophotonic chips, such as modulators, switches or active multiplexors and couplers, is to find ways of controlling SP properties by using external agents, such as temperature [2], voltage [3] or incident photons [4]. For this purpose, an innovative approach is the incorporation of a ferromagnetic material into the plasmonic structure, thus creating a magnetoplasmonic system [5].

Magnetoplasmonic systems, where magnetic and plasmonic properties are interconnected, allow for the plasmonic properties to be tunable upon the application of a magnetic field (active plasmonics) [6], or the MO effects to be largely increased by plasmon resonance excitation, as a consequence of the enhancement of the electromagnetic field in the MO active component of the structure [7]. In our research we will model, fabricate and study systems composed of both noble and ferromagnetic

metals (magnetoplasmonic systems). Noble metals have intense and narrow plasmon resonances but lack magneto-optical (MO) activity. On the other hand, ferromagnetic metals are MO active but their plasmon resonances are weak and broad. We will combine both kinds of materials in smart structures intended to obtain systems that simultaneously exhibit plasmon resonances and MO activity such as Au/Co/Au [5,6], Ag/Co/Ag [8] and Au/Fe/Au [9] heterostructures. We propose a complete study related with the optimization of the resonance effect with the sample morphology such as size, layer thicknesses, roughness and microstructure.

Once this fundamental work is concluded, our goals will be focused on the possibility to prepare magnetoplasmonic systems for potential technological applications in fields such as data transport and processing. However, we should initially face important and unresolved problems, which are related with how fast these processes are and how they can be controlled. In order to answer any of these questions, we will perform a systematic study of fundamental processes in magnetoplasmonic systems such as temporal spectral responses, magneto-optical activity, dynamics of excitations and interdependence between magnetic and plasmonic properties. This study will be carried out with our recently built ultrafast laser spectroscopy system, which allows us to access real-time physical processes on the femtosecond time-scale (1 fs =10^{-15} s). The recent advances on the development of our system allow us to attain unprecedented temporal resolutions of approximately 8 fs [10], which is expected to be the same order of magnitude than the spectral plasmon relaxation processes. With this new and unique system, we hope that unexplored and novel phenomena in the field of magnetoplasmonics will be unveiled.

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References

(*to allow students a first look at the topic*)

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