Taking magneto-optics to the nanoscale: development of a tip-enhanced magneto-optic microscope

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Magneto-optics - In recent years, light has been proposed as a highly versatile and powerful tool for probing and manipulating magnetic order through magneto-optical mechanisms. At low beam power, this interaction leads to the alteration of the light scattered by a magnetic sample by changing its polarization and/or energy which makes it possible to study the static and dynamic magnetic properties of these systems. One can cite the archetypal magneto-optical Kerr effect (MOKE) [1], which probes magnetic orders, or inelastic Brillion light scattering (BLS), which gives direct access to the dispersion law of magnetic excitations [2]. These methods have demonstrated strong advantages such as non-invasiveness, versatility and direct imaging capability [3,4]. Unfortunately, the optical nature of these approaches comes with intrinsic limitations in terms of signal and resolution.

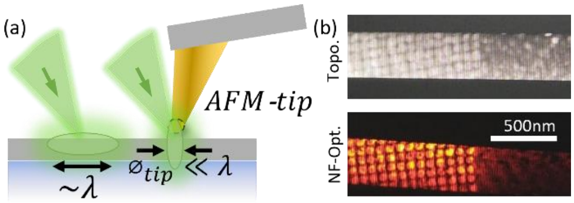

***Figure 1:** (a) Far-field and near-field optical response of a thin film under a λ~532nm light beam. (b) First topographic and near-field optical image obtained @ the LSPM of 100 nm width nano-discs.*

Tip-enhancement - To push magneto-optics to the nanoscale, we propose to take advantage of the plasmonic properties of metallic nano-objects. It consists in the collective resonant excitations of the electron cloud of a metallic nano-object induced by an incident light beam [5] which drastically amplifies the local electrical field, and so the local optical signal, in its very close vicinity [6]. By focusing the light beam to the space between a sample and a scanning AFM tip, it is then possible to produce an image of its optical response with a nanometer resolution (tens of nanometers depending on the tip apex as shown Figure 1-a). Imagery using this, so-called, tip-enhancement has already been used to probe the optical properties in a wide range of systems [7] (see Figure 1-b).

General objective - The goal of thesis is to develop a completely new type of tip-enhanced scanning microscope sensitive to the local magneto-optic properties of magnetic systems in thin film at the nanoscale: Magneto-Optical Kerr effect (MOKE, to image the static organization of the magnetization) and Brillouin light scattering (BLS, to probe the magnetization dynamics in the GHz-subTHz range). The development of this table-top experiment is based on the combination and the synchronization of an atomic force microscope (AFM) and a Brillouin light scattering spectroscope (BLS). This unique approach will offer new insight in the field of magnetic systems by probing the local spin dynamics such as the organization of SWs in nano-objects (patterned films, magnetic textures), the imaging of the antiferromagnetic order or even the local coupling between magnetic and structural orders. Finally, this technique is compatible with a large sample environment allowing, in the long term, the local study of the SW response to external stimuli (applied field, RF excitations).

Implementation of the thesis - The thesis as well the development of the setup will be achieved at the LSPM. All the experimental aspects of this thesis project are founded by the ANR-JCJC Ti-Bistro and the PEPR-SPIN (~550 k€ of equipment) and preliminary results obtained on the individual parts of this setup: optical near field imaging (as shown Figure 1-b), and far field BLS. In parallel to the progressive optimization, assembly and synchronization of the different parts constituting this setup, intermediate experimental, theoretical and numerical studies involving interesting physics of both magnetic dynamics at the nano-scale and nano-magneto-optics will be achieved.

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