Physical properties of laser-produced nanostructures

PhD-thesis at the IMMM CNRS 6283 Le Mans, France in a collaboration with Duisburg-Essen Univ. (Germany)

Directed by : Vasily Temnov and Gwenaelle Vaudel (Le Mans, France)
Co-directed by : Michael Farle and Anna Semisalova (Duisburg, Germany)

Institut des Molécules et Matériaux du Mans, UMR CNRS 6283, Le Mans Université, Le Mans, France
vasily.temnov@univ-lemans.fr

Femtosecond laser interactions with magnetic materials result in an immense variety of physical phenomena from different area of physics: nonlinear optics, magnetism, spintronics, acoustics, physics of shock waves and/or laser-induced phase transitions. In this thesis we want to understand how different elementary excitations (electrons, phonons, magnons etc.) induced in nanostructured ferromagnetic thin films and their interactions with light can be probed with acousto-magneto-optical experiments [1-2]. For this purpose, the PhD student will have to characterize novel, unique and periodic nanostructures (metasurfaces/diffraction gratings) produced by ps or fs-laser interactions with ferromagnetic thin films. One of the objectives will be to (resonantly) enhance the interaction strength between the magnetic, optical and acoustic excitations. Several spectroscopic techniques (FMR, ultrafast magnonics and magneto-optics) will be used.

The fabrication process of deterministic topological magnetic nanostructures in Fig. (a-b) demonstrate the capability of extreme nonlinear acoustics to tailor the pathways of destructive single-shot femtosecond or picosecond laser-induced interactions evolving through solid-liquid-solid phase transitions (c). More complex structures, such as functional acousto-magneto-optical diffraction gratings (d) can be then produced by projection of periodic phase mask on a surface of ferromagnetic nickel thin film. The purpose of this PhD-thesis would be to investigate physical properties of such magnetic nanostructures using advanced methods of time-resolved optical pump-probe spectroscopy (Le Mans) and experimental nanomagnetism (Duisburg), design and fabricate new structures etc. The PhD student will be trained to develop his own conceptually-driven research program starting from physical questions and potential applications, stimulated by continuous interactions with professor-level researchers abroad and accompanied by a series of collaborative research stays. The current chain of laser-nanofabrication includes leading researchers from NanoGUNE St. Sebastian and Ecole Polytechnique Palaiseau. Physical properties will be jointly addressed by focused spectroscopic efforts using state-of-the-art experimental facilities at the IMMM Le Mans and Univ. Duisburg-Essen (Duisburg).

The working language for this PhD will be English; the starting date is October 1st 2021. The PhD student will be based mainly at Le Mans university but with regular stays at Duisburg and perhaps at other partner laboratories. A cotutelle between France and Germany will be administratively organized.

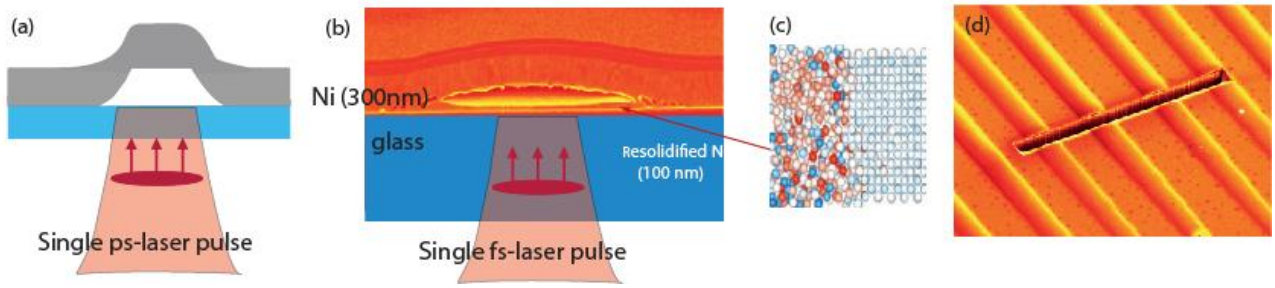

Figure: Single focused picosecond (a) or femtosecond (b) laser pulses create different structures in magnetic thin films potentially containing novel states of materials - amorphous metals (c) and can create arbitrary shaped 2D –landscapes, for example deformable acousto-magneto-optical diffraction gratings (d) [3].

References

[1] V.V. Temnov et al., *Nature Phot.*6: 728, 2012; *Nature Comm.*4: 1468, 2013.

[2] J. Janusonis et al., *Phys.Rev. B* 94: 024415, 2016; C. Chang et al., *Phys. Rev. B* 95: 060409, 2017.

[3] V.V. Temnov et al., *Nanoletters* 20, 7912 (2020).