Spatially resolved investigation of all optical magnetization switching in TbFe alloys.

M. Mawass[1], A. Arora[1,5], O. Sandig[3], C. Luo[2], A.A. Ünal[1,4], F. Radu[1], S. Valencia[1] and F. Kronast[1]
1. Department Materials for Green Spintronics, Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany; 2. Department of Physics, University of Regensburg, Regensburg, Germany; 3. Institut für Experimentalphysik, Freie Universität Berlin, Berlin, Germany; 4. Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Berlin, Germany; 5. Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany

High storage density magnetic devices rely on the precise, reliable and ultra-fast switching times of the magnetic states. Optical control of magnetization using femtosecond laser without applying any external magnetic field offers the advantage of switching magnetic states at ultrashort time scales, which has attracted a significant attention. Recently, it has been reported and demonstrated the, *so-called*, all-optical helicity-dependent switching (AO-HDS) in which a circularly polarized femtosecond laser pulse switches the magnetization of a ferromagnetic thin film as function of laser helicity [1]. Afterward, in more recent studies, it has been reported that AO-HDS is a general phenomenon existing in magnetic materials ranging from rare earth – transition metals ferrimagnetic (e.g. alloys, multilayers and hetero-structures system) to even ferromagnetic thin films. Among numerous studies in the literature which are discussing the microscopic origin of AO-HDS in ferromagnets or ferrimagnetic alloys, the most renowned concepts are momentum transfer via Inverse Faraday Effect (IFE) [1-3] and the concept of preferential thermal demagnetization for one magnetization direction by heating close to Tc (Curie temperature) in the presence of magnetic circular dichroism (MCD)[4-6]. In this study, we investigate all-optical magnetic switching using a stationary femtosecond laser spot (3–5 µm) in TbFe alloys via photoemission electron microscopy (PEEM) and x-ray magnetic circular dichroism (XMCD) with a spatial resolution of approximately 30 nm. We spatially characterize the effect of laser heating and local temperature profile created across the laser spot on AO-HDS in TbFe thin films. We find that AO-HDS occurs only in a ‘ring’ shaped region surrounding the thermally demagnetized region formed by the laser spot and the formation of switched domains relies further on thermally induced domain wall motion. Our temperature dependent measurements highlight the importance of attaining Tc, local temperature and temperature gradients for helicity-dependent switching. In addition, by investigating a series of samples with different Tb concentrations and film thicknesses, we demonstrate that the switching direction for a given laser helicity, inverts at a threshold film thickness [7]. We show that our results can be explained in the presence of one orientation MCD. Magnetic domains are heated preferentially and consequently, demagnetized in the region close to Tc, leading to an asymmetrical response with respect to the incoming laser helicity. These new findings shed light on a robust and reliable switching process, which paves the way for further understanding of the AO-HDS and its microscopic origin.

[1] Stanciu, C. D. *et al.* All-optical magnetic recording with circularly polarized light. *Phys. Rev. Lett.* 99, 1–4 (2007). [2] Kimel, A. V. *et al.* Ultrafast non-thermal control of magnetization by instantaneous photomagnetic pulses. *Nature* 435, 655–657 (2005). [3] Kirilyuk, A. *et al.* Ultrafast optical manipulation of magnetic order. *Rev. Mod. Phys.* 82, 2731–2784 (2010). [4] Cornelissen, T. D., Córdoba, R. & Koopmans, B. Microscopic model for all optical switching in ferromagnets. *Appl. Phys. Lett.* 108 (2016). [5] Khorsand, A. R. et al. Role of magnetic circular dichroism in all-optical magnetic recording. *Phys. Rev. Lett.* 108, 1–5 (2012). [6] Ellis, M. O. A., Fullerton, E. E. & Chantrell, R. W. All-optical switching in granular ferromagnets caused by magnetic circular dichroism. *Sci. Rep.* 6, 30522 (2016). [7] Arora, A. *et al.* Spatially resolved investigation of all optical magnetization switching in TbFe alloys *Sci. Rep.* 7: 9456 (2016).

 978-1-5386-6425-4/18/$31.00 ©2018 IEEE