MA 41: Focus: All-optical magnetic switching

Organizers: M. Aeschlimann (U. Kaiserslautern), M. Albrecht (U. Augsburg)

Since the discovery of all-optical switching (AOS) in ferrimagnetic rare-earth transition metal (RE-TM) alloy films the question arose if a manipulation of magnetic order by light without applying magnetic fields is specific for 3d-4f systems or a more general phenomena. After years of research, all-optical magnetic switching was indeed observed in various other systems, including multilayer structures, synthetic ferrimagnetic heterostructures and even in ferromagnetic Co/Pt layered films. These very recent new findings open up a broad range of additional exciting applications based on AOS, but also restart the discussions about the fundamental physics involved in AOS. This focus session shall give an overview of novel experimental and theoretical developments in this exciting research field.

Time: Thursday 9:30–12:30 Location: H 1012

Invited Talk MA 41.1 Thu 9:30 H 1012

Optically-induced magnetisation switching: Experiments and models — •Hans Christian Schneider — Physics Department, University of Kaiserslautern, Germany

This talk will present a general overview of optically induced magnetic switching in multi-sublattice magnets. Apart from reviewing experimental results, it will try to set the stage for the following talks by giving an introduction to the different mechanisms that contribute to optically induced magnetization dynamics in general. The different models that are nowadays applied to explain magnetization dynamics (or its crucial mechanism) during optical switching will be reviewed with a particular focus on the angular-momentum balance, and an attempt will be made to identify the remaining "mysteries" connected with all-optical switching. For the inverse Faraday effect the basic concepts that have been originally developed for semiconductors will be compared with more recent theoretical approaches.

Finally, we characterize conditions for heat-induced magnetic switching, and discuss its physical mechanism in a generic two-sublattice toy model, which includes dynamical exchange and electron-phonon scattering in the band picture.

Invited Talk MA 41.2 Thu 10:15 H 1012

All optical control of magnetic thin films and nanostructures — •Eric Fullerton — University of California San Diego, La Jolla, CA 92093-0401 USA

The possibilities of manipulating magnetization without applied magnetic fields have attracted growing attention over the last fifteen years with implications for future magnetic information memory and storage technologies. I will discuss recent experiments on the optical manipulation of the magnetization of engineered materials and devices using 100-fs to 10-ns optical pulses. We demonstrate that all optical switching can be observed in a broad range of materials and not limited to selected rare-earth transition-metal alloy films as had been previously observed. We observe all optical switching in a variety of engineered materials, including ferrimagnetic alloys, multilayers, heterostructures and rare-earth-free Co-Ir-based synthetic ferrimagnets [1] and most recently observe optical control of ferromagnetic films and nanostructures [2]. The latter discovery could potentially enable breakthroughs for numerous applications since it exploits materials that are currently used in magnetic data storage, memories and logic technologies. This work is supported, in part, by the ONR MURI program and is in collaboration with M. Gottwald, R. Medapalli, C.-H. Lambert, R. Tolley, V. Uhlir, and Y. Fainman at UCSD, S. Alebrand, D. Steil, M. Cinchetti and M. Aeschlimann at University of Kaiserslautern, M. Hehn, D. Lacour and S. Mangin at Université de Lorraine and Y. Takahashi and K. Hono at NIMS in Japan. [1]. Mangin et al., Nature Materials 13, 286, (2014). [2]. Lambert et al., Science 345, 1337 (2014).

15. min. break

Invited Talk MA 41.3 Thu 11:00 H 1012

All-optical switching: a challenge for its theoretical description — •Ulrich Nowak[1], Sönke Wienholdt[1], Steffen Sievering[1], Denise Hinzke[1], Karel Carva[2], and Peter Oppeneer[2] — [1]Fachbereich Physik, Universität Konstanz, D-78457 Konstanz — [2]Department of Physics, Uppsala University, SE-751 20 Uppsala

The term all-optical switching (AOS) refers to the fact that some magnetic materials can be switched solely by the effect of an ultrafast laser pulse, without any applied magnetic field. First, this effect was shown for ferrimagnets [1-3] but later also for layered, synthetic ferrimagnets [4] and recently even for ferromagnets [6]. Two different kinds of AOS have to be distinguished, namely helicity dependent AOS [1,4,5], where the new magnetic orientation is defined by the helicity of the laser light, and thermally driven swiching with linearly polarized light which cannot define the new orientation but always switches the initial state to the reversed one. In this talk an overview over the current status of the understanding and the remaining open questions is given.

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[1] K. Vahaplar et al. Phys. Rev. Lett. **103**, 117201 (2009) [2] I. Radu et al., Nature **472**, 205 (2011) [3] S. Wienholdt et al., Phys. Rev. B, **88**, 020406(R) (2013) [4] S. Mangin et al., Nature Mater. **13**, 286 (2014) [5] C.-H. Lambert et al., Science **345**, 1337 (2014)

Invited Talk MA 41.4 Thu 11:30 H 1012

All-optical helicity-dependent magnetic switching in Tb-Fe — •Rudolf Bratschitsch — Physikalisches Institut, Westfälische Wilhelms-Universität Münster

Ferrimagnets such as GdFeCo can be switched all-optically by circularly polarized femtosecond laser pulses, opening the door to ultrafast magnetic data storage. We reveal all-optical switching (AOS) in the ferrimagnet Tb-Fe [1]. We demonstrate that AOS also occurs in a tailored artificial zero moment magnet consisting of two TbFe layers, which exhibit no AOS as single layers [2]. Finally, we show that expensive and bulky laser amplifier systems are not necessary to induce AOS and present AOS with a laser oscillator [3].

[1] A. Hassdenteufel et al., Adv. Mat. 25, 3122 (2013)
[2] C. Schubert et al., Appl. Phys. Lett. 104, 082406 (2014)
[3] A. Hassdenteufel et al., Opt. Expr. 22, 10017 (2014)

Invited Talk MA 41.5 Thu 12:00 H 1012

Ultrafast magnetization dynamics of thin films showing helicity dependent magnetization switching — •Grégory Malinowski — Institut Jean Lamour, Département P2M Université de Lorraine - CNRS UMR 7198 Boulevard des Aiguillettes, BP 239 54506 VANDOEUVRE LES NANCY Cedex (France)

The interplay of light and magnetism has been a topic of interest since the original observations of Faraday and Kerr where magnetic materials affect the light polarization. While these effects have historically been exploited to use light as a probe of magnetic materials there is increasing research on using polarized light to alter or manipulate magnetism. For instance deterministic magnetic switching without any applied magnetic fields using laser pulses of the circular polarized light has been observed for specific ferrimagnetic materials [1,2]. More recently, optical control of ferromagnetic materials ranging from magnetic thin films to multilayers and even granular films have been shown to present helicity dependent magnetization reversal [3,4]. In this presentation, we will focus on ultrafast magnetization dynamics of thin films multilayers and alloys showing helicity dependent all-optical switching. [1] C.D. Stanciu et al., Physical Review Letters 99(4), 047601 (2007). [2] S. Alebrand et al., Applied Physics Letters 101(16), 162408 (2012). [3] S. Manginet al., Nat Mat ,3864 (2013). [4] C. Lambert et al., Science 345, 1337 (2014)