Catching the moment – magnetization dynamics studied with X-ray Photoemission Electron Microscopy

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Abstract Time resolved Photoemission Electron Microscopy (PEEM) using a stroboscopic pump probe mode in combination with X-ray magnetic circular dichroism (XMCD) has proven to be a versatile tool to access the magnetization dynamics in microstructures and thin films. Here, PEEM studies of the dynamics of $Co/SmFeO_3$ and of GdFeCo will be presented.

Introduction

Ultrafast control of the magnetization of thin films using femtosecond laser pulses has attracted remarkable interest in the last fifteen years. Beginning with the report of an unexpected ultrafast demagnetization in a nickel thin film in 1996 [1], the research on ultrafast magnetization dynamics quickly developed. While the proper microscopic description of ultrafast demagnetization is still intensely debated, novel laser-induced magnetic phenomena have been discovered during these years in a large variety of materials ranging from ferromagnets (FMs) to antiferromagnets (AFMs) and from metals to insulators [2]. Using synchrotron-based X-ray techniques, the different elements composing a heterostructure can be selectively investigated due to the element specificity and sensitivity to different magnetic order, e.g. ferromagnetic and antiferromagnetic, provided by widely tunable polarized X-rays and allowing investigations in a wide range of materials and experimental conditions. Here we present the application of Photoemission Electron Microscopy (PEEM) for the study of laser-induced magnetization dynamics.

At the Surface/Interface: Microscopy (SIM) beamline of the Swiss Light Source (SLS) at the Paul Scherrer Institut (PSI) a femtosecond (fs) laser is used as the pump-pulse (Femtosource Scientific XL 500, 500 nJ per pulse, 50 fs pulsewidth, 800 nm wavelength, 5.2 MHz repetition rate) [3]. Here, the laser is used to directly excite the measured sample area, in contrary to other setups where

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it is used to close a circuit by a photodiode to create for example a magnetic field pulse or a current pulse. The technique and its potential will be presented by two examples. The first one is about fast heating through a spin reorientation phase transition and the second about the investigation of all-optical switching.Dynamics of laser-induced spin reorientation in Co/$SmFeO_3$ heterostructure

Dynamics of laser-induced spin reorientation in Co/$SmFeO_3$ heterostructure

Ultrafast control of a ferromagnet (FM) via exchange coupling with an antiferromagnet (AFM) is demonstrated in a Co/$SmFeO_3$ heterostructure [4]. Employing time-resolved photoemission electron microscopy combined with x-ray magnetic circular dichroism, a sub-100-ps change of the Co spins orientation by up to 10º driven by the ultrafast heating of the $SmFeO_3$ orthoferrite substrate through its spin reorientation phase transition is revealed. Numerical modeling of the ultrafast-laser-induced heat profile in the heterostructure, and the subsequent coupled spins dynamics and equilibration of the spin systems suggest that the localized laser-induced spin reorientation is hindered compared with the static case. Moreover, numerical simulations show that a relatively small Co/$SmFeO_3$ exchange interaction could be sufficient to induce a complete and fast spin reorientation transition (SRT).

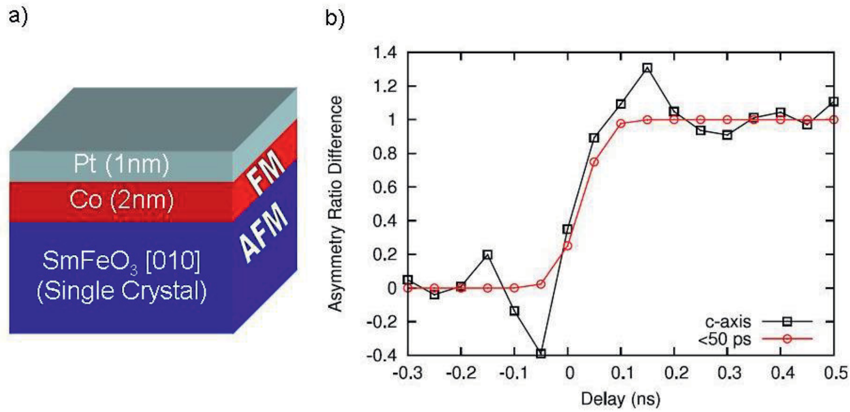

Fig. 1. a) sketch of the sample heterostructure. b) Time dependence of the XMCD signal after heating with a 50fs laser pulse. Black squares are the measurements and red circles simulations which give an upper limit of the time needed of the orientation change, which is given by the time resolution of the experiment.

All-optical magnetization switching in GdFeCo based ferrimagnetic alloys

Recently it was discovered that an ultrafast laser pulse alone, without any magnetic field, is enough to deterministically reverse the magnetization: the magnetization reversal in a GdFeCo ferrimagnet can be triggered solely by a single, linearly polarized laser pulse [5, 6]. Here, we investigate the influence of the magnetization compensation point on the all-optical magnetization switching in GdFeCo samples. Switching is possible below and above the magnetization compensation temperature T_M but in its immediate vicinity.

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