Soft X-ray microscopy of fast spin dynamics in nanoscale magnetic structures

Peter Fischer
LBNL/CXRO, 1 Cyclotron Road Berkeley, CA 94720 U.S.A.

email: PJFischer@lbl.gov

The scientific desire and technological demand to manipulate spins on the nanoscale can only be met by advanced analytical tools. The ultimate goal for modern magnetic microscopies is to combine spatial resolution in the nanometer regime, a time resolution on a ps to fs scale and elemental specificity which allows to study novel multicomponent and multifunctional magnetic nanostructures and their ultrafast spin dynamics down to fundamental magnetic length and time scales. Magnetic soft X-ray microscopy combines X-ray magnetic circular dichroism (X-MCD) as element specific magnetic contrast mechanism with high spatial and temporal resolution. Fresnel zone plates used as X-ray optical elements provide a spatial resolution down to currently better than 12nm [1] thus approaching fundamental magnetic length scales such as the grain size [2] and magnetic exchange lengths. The stochastic character of nanoscale magnetism, e.g. in magnetization reversal phenomena or in the depinning process of domain walls in nanowires can be addressed by analyzing repeated images recorded under applied magnetic fields [3] or short current pulses [4]. Utilizing the inherent time structure of current synchrotron sources fast magnetization dynamics with 70ps time resolution, limited by the lengths of the electron bunches, can be performed within a stroboscopic pump-probe scheme. I will review recent achievements with magnetic soft X-ray microscopy with focus on current induced wall [5] and vortex dynamics in ferromagnetic elements [6]. Future directions in soft x-ray microscopy will push the spatial resolution below 10nm by improved optics and with the advent of fsec high brilliant X-ray sources, snapshot imaging of fsec spin dynamics seems to come within reach.

The collaboration with M.-Y. Im (CXRO), G. Meier, L. Bocklage, M. Bolte, R. Eiselt, (U Hamburg), S. Kasai, K. Yamada, K. Kobayashi, T. Ono (U Kyoto), Y. Nakatani (U Chofu), H. Kohno (U Osaka), A. Thiaville (U Paris-Sud) is greatly appreciated. This work is supported by the Director, Office of Science, Office of Basic Energy Sciences, Materials Sciences and Engineering Division, of the U.S. Department of Energy.

[1] W. Chao et al. Optics Express (2009) in print
[2] M.-Y. Im, et al, Advanced Materials 20 1750 (2008)
[3] M.-Y. Im, et al., Phys Rev Lett 102 147204 (2009)
[4] G. Meier et al., Phys. Rev. Lett. 98, 187202 (2007)
[5] L. Bocklage, et al., Phys Rev B 78 180405(R) (2008)
[6] S. Kasai, et al., Phys Rev Lett 101, 237203 (2008)