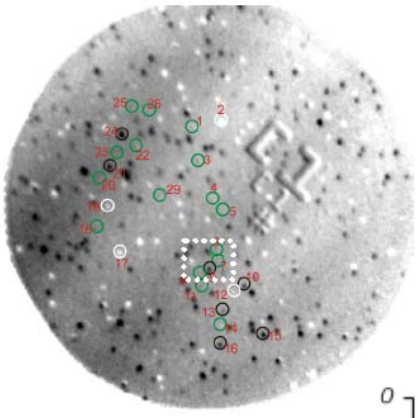
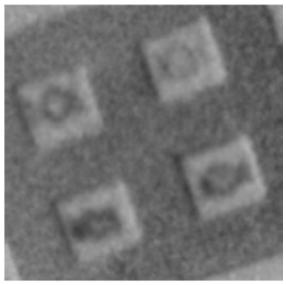
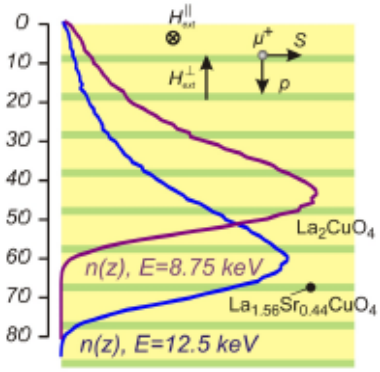
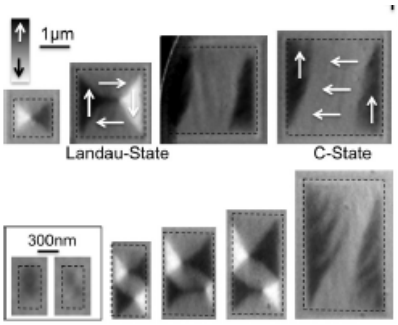








SLS Symposium on

Nanomagnetism and Spin Dynamics

Tuesday, July 5, 2011

10:00 to 12:15, WBGB/019

10:00 Laser induced magnetization dynamics studied by PEEM
Loïc Le Guyader, S.E. Moussaoui, A. Kleibert and F. Nolting

10:30 Magnetism in the 2D Limit and Interface Superconductivity in Metal-Insulator $La_{2-x}Sr_xCuO_4$ Superlattices
A. Suter, E. Morenzoni, T. Prokscha, H. Luetkens, B.M. Wojek, G. Logvenov, A. Gozar and I. Božović

11:00 Coffee

11:15 Control of spin configuration in half-metallic $La_{0:7}Sr_{0:3}MnO_3$ nano-structures
J. Rhensius, C. A. F. Vaz, H. S. Körner, L.J. Heyderman and M. Kläui

11:45 Studying the magnetization curves of individual nanoparticles at finite temperatures
A. Kleibert, A. Balan, J. Bansmann, A. Fraile Rodríguez and F. Nolting

Laser induced magnetization dynamics studied by PEEM

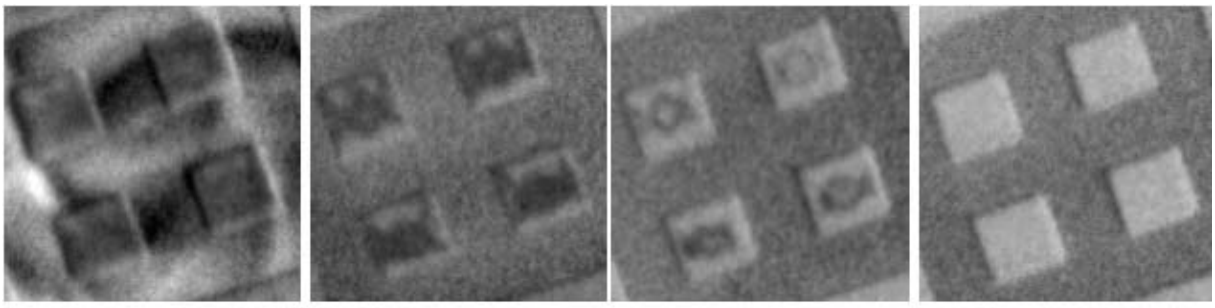
Loïc Le Guyader, Souliman El Moussaoui, Armin Kleibert, and Frithjof Nolting

Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen, Switzerland

ABSTRACT

The interaction of femtosecond laser pulsed with magnetic domains is an intriguing way to manipulate the spins at the nanoscale going beyond the manipulation using Oersted-fields. To get insights into this area which pushes the frontiers of science forward, experimental techniques allowing the access of short time scales together with a high spatial resolution are required. A photoemission electron microscope (PEEM) in combination with X-ray magnetic circular dichroism (XMCD) and a femtosecond pulsed laser allows the determination of element specific moments with 100 nm spatial and 50 ps temporal resolution. For the timeresolution the pulsed nature of the X-rays produced by the synchrotron sources is employed.

After presenting this technique and our implementation in detail, I will show two examples which will emphasize strength and weakness of the approach. In the first example, I will show that in Co/SmFeO3 heterostructure it is possible to excite with a laser pulse the spin reorientation phase transition in the orthoferrite single crystal substrate. The later induces a change of the Co spin orientation within 50~ps. In the second example, the interaction of structured GdFeCo ferrimagnetic alloys with femtosecond laser pulses is studied and the latest time resolved measurements will be shown.



Magnetism in the 2D Limit and Interface Superconductivity in Metal-Insulator $La_{2-x}Sr_xCuO_4$ Superlattices

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The real ground state of a spin-$1/2$, 2D Heisenberg antiferromagnet on a square lattice (2DHAF) is still a matter of debate. A model system which is believed to be close to the 2DHAF is La_2CuO_4 (LCO) which orders in bulk at $T_N \simeq 315$ K, caused by the residual out-of-plane interactions in the system. In order to approach the real 2D limit, we investigated superlattices (SLs), synthesized digitally by molecular beam epitaxy, with alternating thicknesses of LCO and non-superconducting metallic $La_{1.55}Sr_{0.45}CuO_4$ (LSCO). Counting in $1/2$-unit-cell (UC) increments, each of which contains a single CuO_2 plane, the investigated SLs have the repeat structure [3LSCO+6LCO], [3LSCO+9LCO], and [3LSCO+12LCO], respectively.

We show, by means of low-energy muon spin rotation measurements, that few-unit-cells thick LCO layers are antiferromagnetically ordered (AF LRO). Below a thickness of about 5 CuO_2 layers the long-range ordered state breaks down, and a magnetic state appears with enhanced quantum fluctuations and a reduced spin stiffness. Figure 1 shows the situation for [3LSCO+12LCO] with the μ^+ stopping profile, and the measured zero field precession signal which shows AF LRO. At the same time superconductivity is found in all these SLs with T_C's $\simeq 25$ K. The magnetic state can exist in close proximity (few Å) to superconducting layers, without transmitting supercurrents.

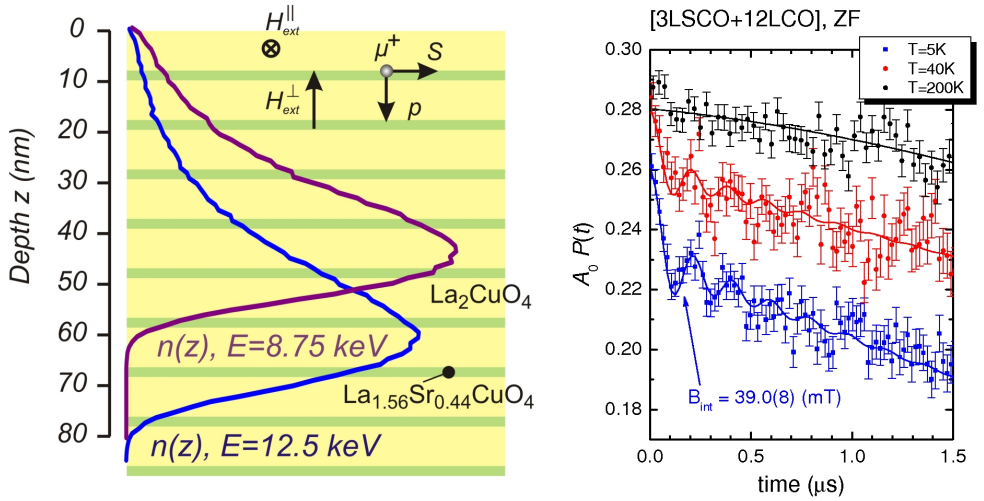

Figure 1: Left: μ^+ stopping distribution, $n(z)$, for the [3LSCO+12LCO] superlattice. The yellow stripes represent the LCO, the green ones the LSCO. Right: Zero field precession signals of the [3LSCO+12LCO] superlattice, showing that 5 CuO_2 layers order antiferromagnetically.

Control of spin configuration in half-metallic $La_{0.7}Sr_{0.3}MnO_3$ nano-structures

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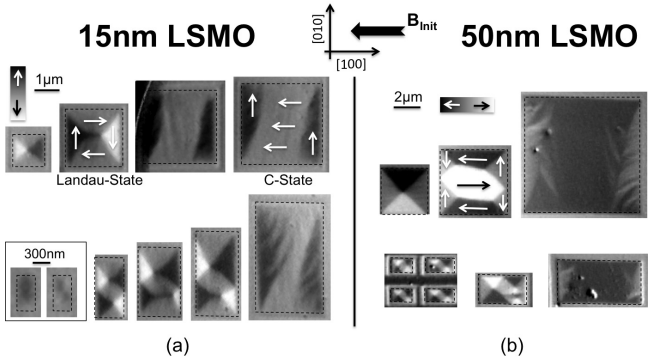
We investigate the interplay between the governing magnetic energy terms in patterned half-metallic $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) elements by direct high-resolution x-ray magnetic microscopy as a function of temperature and geometrical parameters. Half-metals gained our interest due to their unique electronic behavior, rendering the electrons at the Fermi energy nearly 100% spin polarized [1], and their Curie temperatures above room temperature [2]. We show that the magnetic configuration evolves from multidomain to flux-closure states (favoured by shape anisotropy) with decreasing element size, with a thickness-dependent crossover at the micrometer scale. The flux-closure states are stable against thermal excitations up to near the Curie temperature. Our results demonstrate control of the spin state in LSMO elements by judicious choice of the geometry, which is key for spintronics applications requiring high spin-polarizations and robust magnetic states. The figure shows the



evolution of the magnetic state as a function of element size shows a transition from a multidomain state to simpler, shape anisotropy-dominated, magnetic states with decreasing lateral dimension. The larger elements have a domain configuration similar to a high moment C-state, but with domains not uniformly magnetized (with ripple contrast) separated by irregular domains walls, which we associate with local pinning of the magnetization that may help stabilize these high magnetic moment configurations. For lateral dimensions below about 2 μm and 4 μm for the 15 nm (a) and 50 nm (b) thick LSMO films, respectively, the magnetic states fall into well-defined shape anisotropy-dominated flux closure states, with uniformly magnetized domains and sharp domain walls.

References

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[2] G. H. Jonker and J. H. van Santen, *Physica* **16**, 337 (1950).

Studying the magnetization curves of individual nanoparticles at finite temperatures

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Magnetic nanoparticles show a variety of novel magnetic phenomena when compared to the respective bulk materials, mostly due to the effect of the surface and interface on the magnetic interactions and to critical magnetic length scales such as domain wall width and exchange length [1]. One important question is related to magnetic switching processes in nanoparticles. It is generally assumed that at T = 0 K the magnetic reversal occurs as a coherent rotation of the atomic spins. However, at finite temperatures thermal excitations may disturb the ferromagnetic spin order and thus lead to complex reversal modes [2]. These modes are not only relevant for the quasi-static properties of the particles, but also determine their dynamical response to external stimuli.

We have used photoemission electron microscopy (PEEM) together with x-ray magnetic circular dichroism (XMCD) to detect the magnetization curves of individual Fe nanoparticles at room temperature, cf. Fig. 1. By varying the particle size we observe the transition from superparamagnetic fluctuations to stable ferromagnetic order at a particle size of about 12 nm. Applying a magnetic field allows us to record magnetization curves of the particles in both, the superparamagnetic and the ferromagnetic state, as well as in the transition regime. We compare these data with the predictions of conventional macro spin theory and discuss the role of thermal excitations and non-collinear spin structures on the magnetization reversal.

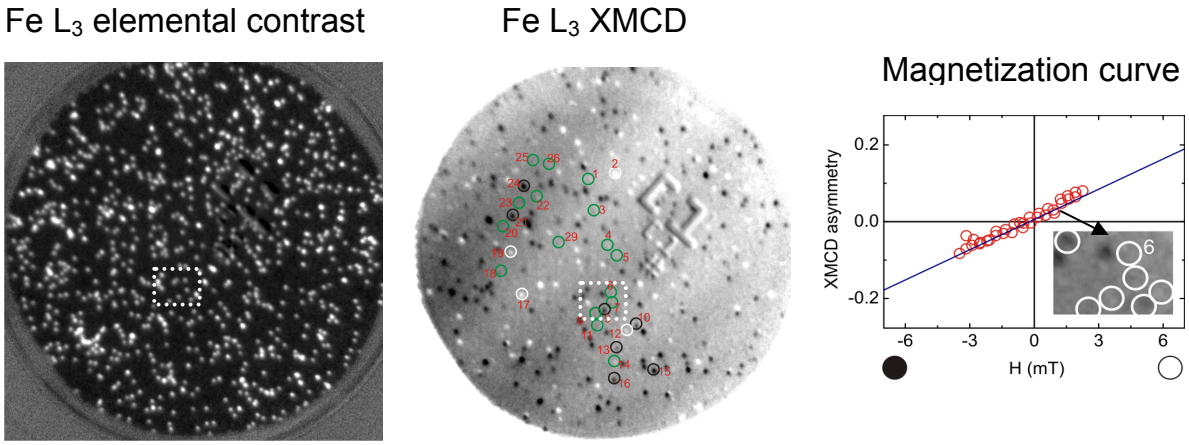

Figure 1: PEEM elemental contrast (left) and XMCD contrast (middle) from individual Fe nanoparticles. A distribution of the magnetic orientations of the individual particles in the ensemble is observed, as characterized by their different XMCD gray scale levels. Applying a magnetic field allows to record magnetization curves of individual nanoparticles (right). The given curve belongs to the particle labeled as number 6 in the highlighted rectangular area in the left and middle panel.

References:

[1] A. Fraile-Rodriguez *et al.*, Phys. Rev. Lett. **104**, 127201 (2010).
[2] S. Krause *et al.*, Phys. Rev. Lett. **103**, 127202 (2009).