# 100ps Time-Resolved Magnetic X-ray Microscopy – Techniques and Applications

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Fast magnetization dynamics of ferromagnetic elements on short length scales is currently attracting substantial scientific interests for both technological and fundamental reasons. Measurements with a time resolution of 70-100 ps combined with a lateral resolution of 20-40 nm were performed using two different sample geometries (magnetic 'in-plane' excitation by a microcoil and 'out-of-plane' excitation by a stripline) at two different microscopes: a full-field soft X-ray microscope (XM-1, ALS beamline 6.1.2) and a scanning transmission X-ray microscope (STXM, ALS beamline 11.0.2). The scanning microscope equipped with a fast avalanche photo diode (APD) detector allowed us to speed up time-dependent measurements by about a factor of 10.

Spin precession [1] and gyrotropic vortex motion [2,3] in micron-sized ferromagnetic patterns have been studied. Complementary to the time-domain 'pump-and-probe' measurements a frequency-domain 'sine excitation' technique [2] was implemented into X-ray microscopy. In this way, the dynamics of specific eigenmodes of ferromagnetic patterns could be imaged. A novel highly non-linear effect has been found in micron-sized magnetic Landau structures for the first time [3]: a clear change of the sense of rotation of the magnetic vortex is observed by increasing the amplitude of an exciting alternating magnetic field over a well pronounced threshold level (about 2 mT in the present experiments). This unambiguously leads to the conclusion that the direction of magnetization of the magnetic vortex core could be repeatable switched by 180°, allowing a deliberate and reproducible switching of the vortex core and consequently of the chirality (handedness) of the vortex structure. A model for this surprising effect is given based on transitions from deterministic to chaotic behaviour of magnetic vortex structures.

In contrast to static experiments, where vortex core switching only occurs with external magnetic fields of about 100 mT or higher, the novel dynamic vortex core switching needs only a few mT. This might open paths for new technological applications.

[1] H. Stoll et al., *High-Resolution Imaging of Fast Magnetization Dynamics in Magnetic Nanostructures,* Appl. Phys. Lett. **84**, 3328, 2004
[2] A. Puzic et al., *Spatially resolved ferromagnetic resonance: Imaging of ferromagnetic eigenmodes,* J. Appl. Phys., in press
[3] B. Van Waeyenberge et al., *Vortex Core Switching Observed in Excited Ferromagnetic Micron-Sized Thin Film Elements,* in preparation