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Domain-wall oscillations studied by time-resolved soft X-ray microscopy

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Fast magnetization dynamics in the micro- and nanometer regime are an interesting field of research. On these length scales magnetic structures can be designed to contain a single vortex or a single domain wall. Both size and speed of these patterns are of great interest in todays research for prospective non-volatile data storage devices [1]. Especially the possibility to move domain-walls by spin-polarized current gained a lot of interest. [2].

Magnetic configurations can be imaged by soft X-ray magnetic microscopy with a spatial resolution down to 15 nm.[3] By a stroboscopic pump and probe measurement scheme a temporal resolution below 100 ps is achieved. This provides the opportunity to directly image changes in magnetic domains and domain-wall motion.

We image oscillations of a single domain wall in a confining potential in time steps of 200 ps by time resolved X-ray microscopy at the full-field soft X-ray transmission microscope at the Advanced Light Source in Berkeley (beamline 6.1.2) [4]. Domain walls are prepared in permalloy nanostructures with a restoring potential. The oscillation of a 180° domain wall is triggered by nanosecond current pulses. The spin-polarized current and the accompanying Oersted field can contribute to the motion of the wall. By analysis of the distinct domain-wall dynamics the dominant contribution is determined. In our geometry the motion of the wall is determined by the Oersted field although the spin-polarized current directly flows through the ferromagnetic structure.

An analytical model of a rigid particle precisely describes the domain-wall motion.[5] Oscillations are studied for different pulse length and amplitudes. From the observed oscillations we extract the driving force, the confining potential, and the domain-wall mass. Nonharmonic terms determine the motion of the wall. The influence of the nonharmonic potential is studied by looking at various phase spaces of the domain-wall motion.

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[1] D. A. Allwood, et. al., Science **296**, 2003 (2002).
[2] M. Hayashi, et al., Science **320**, 209 (2008).
[3] W. Chao, et al., Nature **435**, 1210 (2005).
[4] L. Bocklage, et al., Phys. Rev. B **78**, 180405(R) (2008).
[5] B: Krüger, et al., Phys. Rev. B. **75**, 054421 (2007).

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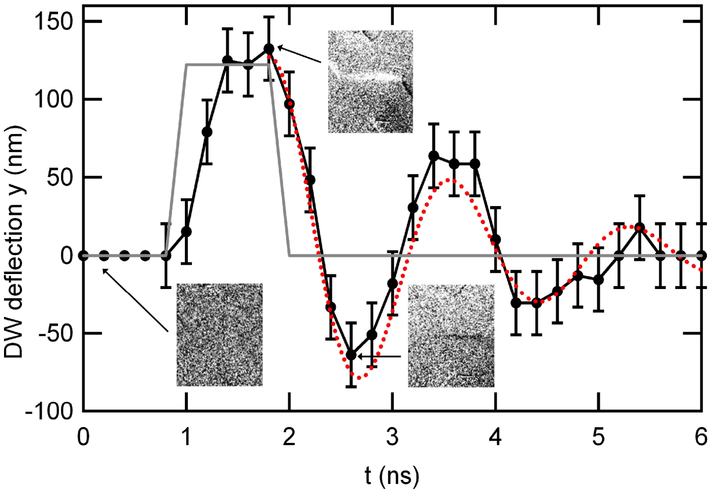

Fig. 1: Time evolution of the vertical deflection of the DW due to a 1.1 ns long current pulse (closed circles). The black line is a guide to the eye. The grey curve depicts the current pulse. The dotted red curve is a fit to a free damped harmonic oscillation. The images show differential X-ray images of the deflection of the domain wall at 200 ps, 1800 ps, and 2600 ps delay time.

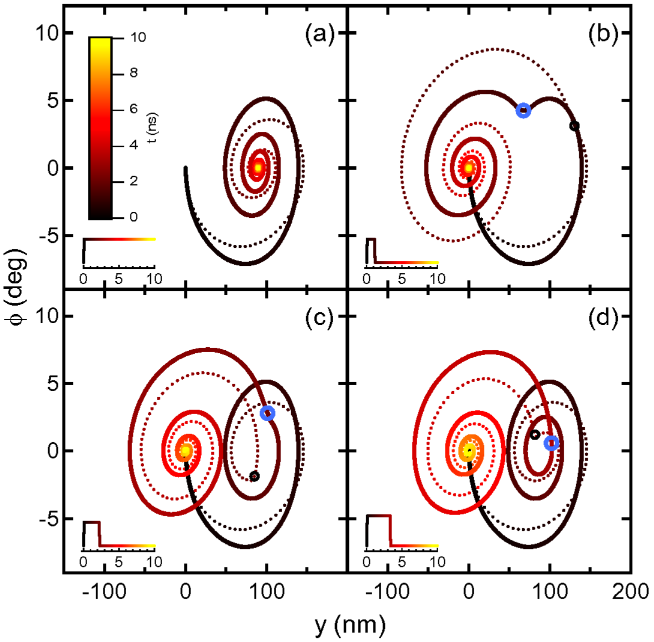

Fig. 2: Trajectories in the phase space of position y and out-of-plain angle for a step like field (a) and field pulses of 1.1 ns (b), 2.2 ns (c), and 3.3 ns (d). Trajectories for the harmonic and nonharmonic potential are the dotted and solid lines, respectivley.

The circles depict the time when the magnetic field has decreased to half of the amplitude for the harmonic (black) and nonharmonic potential (blue). The insets depict the pulse profile for the first 10 ns.