Static and dynamic properties of magnetic domain walls

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Domain walls in small elements exhibit complex spin arrangements that strongly deviate from the wall types commonly encountered in magnetic thin film systems or bulk ferromagnets. They can be modified by changing the geometry of the element [1], and they can be moved by injecting electrical current pulses. We image the static properties of domain walls by spin-polarized scanning electron microscopy [2], thereby determining their internal structure with 10-nm resolution. The dynamic properties are explored by time-resolved magneto-optical Kerr microscopy, which has limited spatial yet high temporal resolution. When propagated by magnetic field, domain walls go through a sequence of entirely different behavior depending on the field strength: Steady-state motion at low fields is followed by turbulent, chaotic motion at high field, the so-called Walker breakdown. In a study combining experiment and micromagnetic simulations, we investigated vortex walls in permalloy wires with widths ranging from 300 to 900 nm. In wide wires, we find the dynamics of vortex walls to depart significantly from the current description that a domain wall is a compact entity moving along the wire [3]. Instead, the wall is composed of several substructures evolving in different dynamic regimes with very different velocities. Wire edges crucially affect this dynamics and can be influenced by a variation of growth parameters. Possibilities how to overcome the limits imposed by the Walker breakdown will be discussed. Wall motion by spin current follows different laws. We find persistent, static modifications of the wall structure upon propagation: Vortex walls transform to transverse configurations upon subsequent pulse injections [4]. This change is directly correlated with the decay of the wall velocity. Transverse walls, on the other hand, keep their transverse character. In magnetic bilayer wires, however, a new effect occurs: The direction of the spin current sets the polarity of the transverse wall [5]. Such effects become important when one tries to exploit domain walls for use in spin-based devices.

References:

[1] P.-O. Jubert, R. Allenspach, and A. Bischof, Phys. Rev. B 69, 220410(R) (2004).
[2] R. Allenspach, IBM J. Res. Develop. 44, 553 (2000).
[3] C. Zinoni, A. Vanhaverbeke, P. Eib, G. Salis, and R. Allenspach, Phys. Rev. Lett. 107, 207204 (2011).
[4] M. Kläui, P.-O. Jubert, R. Allenspach, A. Bischof, J.A.C. Bland, G. Faini, U. Rüdiger, C.A.F. Vaz, L. Vila, and C. Vouille, Phys. Rev. Lett. 95, 026601 (2005).
[5] A. Vanhaverbeke, A. Bischof, and R. Allenspach, Phys. Rev. Lett. 101, 107202 (2008).