BOUNDARY CONDITIONS IN PRECESSIONAL MOTION

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The development of modern recording devices leads to a drastic reduction in size of the magnetic structures which store the information. Thus, the influence of the boundaries on the switching behaviour of the magnetic bits increases. On the other hand, the increasing data rate requires to take the precessional motion of the magnetization into account. In order to understand switching of the magnetization in a microstructures, we need to investigate the basic linear excitations and their dependence on the boundaries.
In 1958 C. Kittel [1] considered the propagation of spin excitations in a linear spin chain with finite length and proposed two limiting scenarios: in the short wavelength limit the excitation is dominated by the exchange interaction, resulting in an antinode at the ends of the chain. In the long wavelength limit, instead, the amplitude of the motion of the end spins is greatly reduced, so that the ends behave as they were fixed (Kittel pinning). Whether these boundary conditions are realized in practice and which one determines the actual spin dynamics in finite size elements are
difficult questions to answer. We present a recent experiment [2] that provides images of the reflection of a spin excitation at the boundary of a micrometer-sized disk. The special symmetry of the problem allows for an analytical solution of the Landau-Lifshitz equation governing the precessional motion. This solution includes exact boundary conditions which reproduces the experimentally observed behaviour of the excitation near boudaries and recognize Kittel pinning as the main mechanism determining the spin dynamics in this elementary mesoscopic ferromagnet.
The question of the boundary conditions is a central one in precessional dynamics. If exchange can be neglected, the boundary conditions are those of magnetostatics. Notice that pinning at boundaries means that the uniform precessional mode is forbidden, so that spatial non-uniformities during the motion are unavoidable. In general, the boundary conditions for magnetostatics do not require exact pinning, and the degree of freedom at boundaries depends both on the magnetic state inside the sample and the magnetic field outside it. The complications increase further when the exchange field starts to become relevant (which is the case of nanoscale magnetic elements or of higher modes in micron-scale elements and magnetic anisotropies play a role. Then, the boundary conditions depend on the length scale of the excitation. Thus, requiring pinning of the magnetization vector or setting its normal derivative at surfaces to zero is only a practical way to to reduce the amount of simulation work involved the actual motion could be subjet to more complicated boundary conditions. It will be one major task of future experiments with high spatial resolution, e.g. at advanced X-ray sources, to determine accurately the motion of spins close to boundaries, where, to our opinion, the main physics resides.

[1] C. Kittel, Phys. Rev. **110,** 1295 (1958). See also P. Pincus, Phys. Rev. **118**, 658 (1960)
[2] Y. Acremann et al., Science **290**, 492 (2000); Y. Acremann, Diss. ETH Nr 14389, 2001.