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Domain wall motion on ferromagnetic nanotubes

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Abstract. The dynamical regimes of the motion of domain walls in magnetic nanotubes are studied. We have found that vortex domain wall dynamics in magnetic nanotubes present qualitative changes when dipole fields are properly included in the calculations. The phenomenology we found after the application of an external field leads us to conclude that dipole effects are not easily described by simpler anisotropy-like models. We demonstrate that dipolar effects changes qualitatively the mobility of a vortex wall and that the initial chirality plays a crucial role in the wall dynamics near the Walker breakdown.

In this work we address the issue of domain wall motion on magnetic nanotubes. Such systems have been the target of extensive studies since they were synthesized some years ago [1]. Among the most relevant results concerning the properties of nanotubes we remark those that either by energetic arguments or computer simulations have provided a basic picture of the reversal process [2,3]. In this work we provide a simple view of the dynamics that follows closely the basic theory of domain wall motion. By a suitable adaptation of the collective coordinate approach to magnetization dynamics we predict that a qualitative modification of the domain wall motion characteristics is obtained when proper care is taken of the magnetic dipolar field effects. We have demonstrate that in magnetic nanotubes the Walker breakdown, that is, the threshold from the low field steady motion to a high field precessional motion depends on the initial chirality of the vortex wall. We adopt a specific model for the wall by consider a modification of a recently proposed model [2] for a static vortex wall without radial component. The applied field induces a radial component on the magnetization, which we write $M_\rho = M_s \sin\Theta(z) \sin p$, as illustrated in Fig. 1. Clearly, the ground state is achieved with p=0 or $p=\pi$ as we can see from Fig. 2. For small values of the applied field, the radial component of the magnetization is small and near the equilibrium value (p=0), whereas for values near the Walker critical field, the magnetization reaches the critical value $p=\pi/2$. Note that the energy maxima in Fig. 2 are slightly different, which makes the wall dynamics dependent of the initial chirality of the wall, as we can see from Fig. 3 where the dash lines are calculated starting with a counterclockwise vortex wall (p=0) and the full lines are constructed starting from a clockwise vortex wall ($p=\pi$).

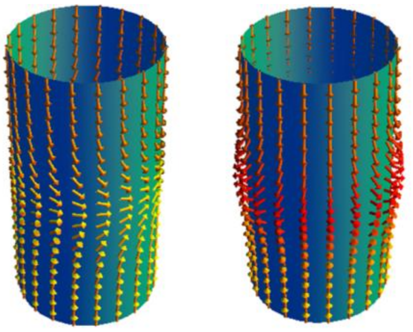

Figure 1: Vortex domain wall magnetization for two values of the angle *p*. The left figure (p=0) correspond to a static vortex wall. The figure at right illustrates the case with $p=\pi/2$ which maximizes the radial magnetization.

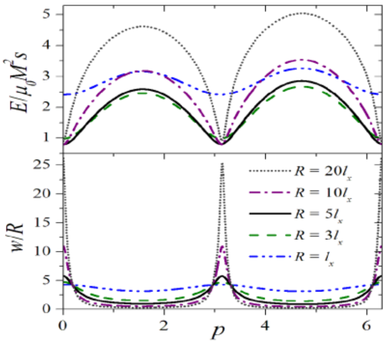

Figure 2: The upper panel illustrates the total energy as a function of the angle *p*. The lower panel illustrates the behavior of the domain wall width as a function of *p*, and different values of the tube radius, measured in units of the exchange length.

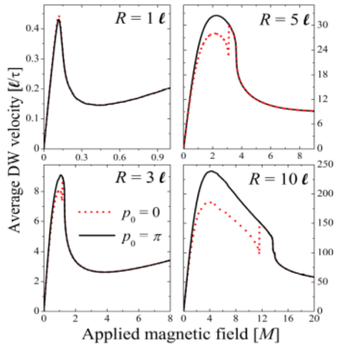

Figure 3: Applied field dependence of the average domain wall velocity for magnetic nanotubes. This kind of Walker breakdown is consequence of the non-rigidity of the vortex DW, while the two paths depend on the initial chirality of the vortex wall.

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