Interactions between a magnetic skyrmion and anisotropy walls

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The magnetic skyrmion is a topologically protected spin texture. We have previously reported the simulation results for the motion of skyrmions in magnetic nanowires patterned by the magnetic anisotropy undulation [1, 2]. Our study was focused on the forces induced by the anisotropy gradient and the anisotropy walls. In this study, we simulate the motion of skyrmions interacting with the anisotropy walls more precisely, and give an analytical explanation to the obtained results.

The micromagnetic simulator MuMax3 has been used for calculating the skyrmion motion in the nanowire with the anisotropy gradient. The force by anisotropy gradient is determined in terms of skyrmion's velocity. In Fig. 1, we show schematically the gradient force F_g and the (Magnus) gyrocoupling force $\mathbf{G}\times\mathbf{v}$ [3]. The repulsive forces from the walls are in balance with these 2 forces. We have found that the reactions from the wall for both F_g and $\mathbf{G}\times\mathbf{v}$ depend only on the distance from the wall X besides the skyrmion's radius and shape and the functions are identical. it can be described in terms of a potential.

We set the anisotropies K_+ and K_- for the bottom and top of the wall. The total potential can be written as

$$U(X) = E_{\mathrm{ani}}\left(\frac{K_+ + K_-}{2}\right) - (K_- - K_+)v(X), \qquad (1)$$

where $U(0) = E_{\mathrm{ani}}((K_+ + K_-)/2)$ and $U(\pm\infty) = E_{\mathrm{ani}}(K_\pm)$ and the force is given by $-\mathrm{grad}_X U(X)$. In Fig. 2, we show the simulation and analytical results of F_{wall}. F_{wall} has a maximum at $X = R$ and a finite value at $X = 0$.

This research and development work was supported by the ULVAC. Inc., and the MIC.

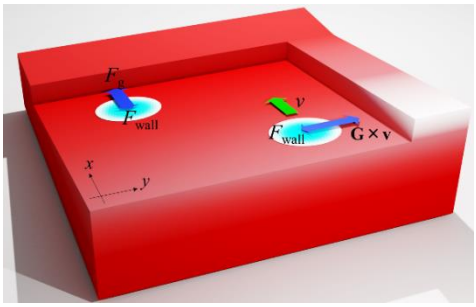

Fig. 1 The schematics of the nanowires patterned by anisotropy walls with the skyrmions.

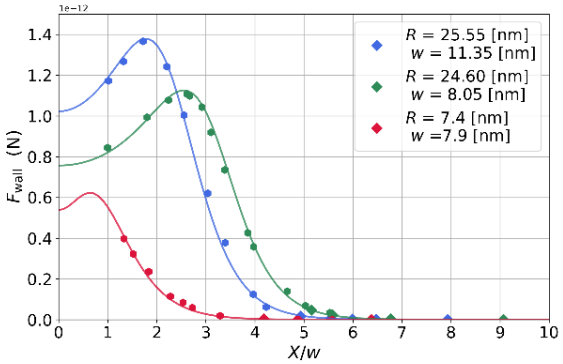

Fig. 2 The simulation (dots) and analytical results (solid lines) of 3 different skyrmions. X, R, and w are the distance between the center of skyrmion and the anisotropy wall, skyrmion radius, and w is the domain wall width, respectively.

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[2] C. Liu *et al.*, JSAP spring Meeting (2019), Tokyo, [3] A.A. Thiele, Phys. Rev. Lett. **30**, 230 (1973)