Statistical Control of Vortex Chirality in Ferromagnetic Rings with Nanoelements

Uladzislau Makartsou,[1] Mathieu Moalic,[1] Mateusz Zelent,[1] Maciej Krawczyk,[1] and Michal Mruczkiewicz[1,2]

[1] *Institute of Spintronics and Quantum Information, Faculty of Physics, Adam Mickiewicz University, Uniwersytetu Poznańskiego 2, 61-614 Poznań, Poland*

[2] *Institute of Electrical Engineering, Slovak Academy of Sciences, Dubravska cesta 9, SK-841-04 Bratislava, Slovakia*

Chirality control in ferromagnetic nanorings (NR) typically requires breaking the ring symmetry [1], which affects domain wall motion under an external magnetic field. Our approach instead uses a single-domain ferromagnetic nanoelement (NE) with strong shape anisotropy inside the nanoring to control vortex chirality via its magnetization state. In our study we use MuMax3 [2]. Using magnetic parameters of Fe from [3], we added 20 nm magnetic grains in the NR via Voronoi tessellation to show that our results are robust even for imperfect materials. Grain's are obtained from a normal distribution of M_s with mean 1600 kA/m and standard deviation σ of 5% = 32 kA/m. In our study, we ran 600 simulations for a single NR, 51.8% resulted in a Clockwise (CW) state and 48.2% resulted in a Counterclockwise (CCW) state. With NE, we have almost complete control over VS chirality at remanence based on NE magnetization orientation. For parallel magnetization of NE with B_ext, 99.0% of simulations show CCW configuration, and for opposite magnetization, 98.5% show CW configuration.

In summary, we have shown that adding a small FEN inside a FER can systematically control the vortex chirality. By altering the magnetization orientation in FEN, the symmetry of HTH DWs can be changed during remagnetization and determine the ring's magnetization chirality. This approach has potential applications in magnetic memories and spin wave control for stochastic computing in ring-based systems

References:

[1] E. Saitoh, M. Kawabata, K. Harii et al., "Manipulation of vortex circula- tion in decentered ferromagnetic nanorings," Journal of Applied Physics, vol. 95, p. 1986, 1 2004.

[2] A. Vansteenkiste, J. Leliaert, M. Dvornik et al., "The design and verifi- cation of mumax3," AIP Advances, vol. 4, p. 107133, 10 2014.

[3] T. Miyawaki, K. Toyoda, M. Kohda, A. Fujita, and J. Nitta, "Magnetic interaction of submicron-sized ferromagnetic rings in one-dimensional array," Applied Physics Letters, vol. 89, 2006.

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