O-II-6

Reversal dynamics of single vortex core driven by azimuthal spin-wave-mode excitations in soft magnetic disk

Myoung-Woo Yoo*, and Sang-Koog Kim†

National Creative Research Initiative Center for Spin Dynamics and Spin-Wave Devices, and Research Institute of Advanced Materials, Department of Materials Science and Engineering, Seoul National University, Seoul 151-744, Republic of Korea

† Corresponding author: sangkoog@snu.ac.kr

1. Introduction

Vortex-state nano magnets, owing to the binary representation of their out-of-plane vortex-core magnetizations in soft magnetic dots as well as their high thermal stability, have been considered potential candidates for information storage media [1]. Although ultrafast, low-power-driven core switching by azimuthal spin-wave modes has been experimentally demonstrated [2], quantitative interpretations and deeper understanding remain elusive, particularly when compared with the case of well-known gyration-mode-assisted vortex-core reversals. Here, on the basis of micromagnetic numerical simulation results, we tackle the underlying dynamics of azimuthal spin-wave-mode-assisted core reversal.

2. Simulation Method

We conducted micromagnetic simulations on a Permalloy disk of 300 nm diameter and 20 nm thickness [3]. To selectively excite the right-handed or left-handed rotational mode of the azimuthal mode, we used, respectively, clockwise or counter-clockwise circular-rotating fields of the relevant eigenfrequency [4]. The field amplitudes H_0 used were within the H_0 = 120 – 155 Oe and 60 – 180 Oe ranges for the right- and left-handed rotational modes, respectively.

3. Results and Conclusion

The simulation results showed that the excited azimuthal modes cause vortex-core gyrations whose frequencies are close to the eigenfrequencies of the azimuthal modes, which are an order of magnitude greater than that of the gyration mode [5]. Due to such high-frequency core gyrations, the switching times are within the 0.5 – 1.5 ns range, which corresponding to an order of magnitude faster than gyration-mode-driven core reversals. The core-reversal mechanism is the same as that of the vortex-antivortex/vortex-pair-mediated reversal, while maintaining the $m_{z,dip}$ = -1 criterion [6]. For a given disk, the $v_{\max}$ are ~380 and ~820 m/s for the m = -1 and +1 modes, respectively, though v_{cri} is known to be ~330 m/s in gyration-mode-assisted core-switching [7]. This difference originates from the difference in $h_{z,\min}$ between the gyration-mode- and azimuthal-mode-driven reversal mechanisms for the general criterion of $m_{z,dip}$ = -1. In our calculations, hz,min was estimated to be ~6 kOe and ~10 kOe for the m = -1 and +1 mode excitations, respectively. We found close correlations between the maximum core velocities ($v_{\max}$) and minimum gyrofields ($h_{z,\min}$), as well as the critical mz dip required for core reversals. This work provides for further understanding of the azimuthal-mode-assisted core-reversal mechanism and offers a means of practical implementation of vortex-core reversals in information storage devices.

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea funded by the Ministry of Science, ICT & Future Planning (grant no. 2013003460).

4. Reference

[1] B. Van Waeyenberge et al., Nature (London) 444, 461 (2006); S.-K. Kim et al., Appl. Phys. Lett. 92, 022509 (2008).

[2] M. Kammerer et al., Nat. Commn. 2:279 doi: 10.1038/ncomms1277 (2011).

[3] See http://math.nist.gov/oommf.

[4] K. Y. Guslienko et al., Phys. Rev. Lett. 101, 247203 (2008).

[5] K. Y. Guslienko et al., J. Appl. Phys. 91, 8037 (2002).

[6] M.-W. Yoo et al., Phys. Rev. B, 82,174437 (2010).

[7] K.-S. Lee et al., Phys. Rev. Lett., 101, 267206 (2008).