Vortex dynamics of coupled circular-shape tri-layer magnetic nanodisks

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1. Introduction

Coupled vortex dynamics as well as single vortex dynamics have been intensively studied owing to fundamental interest of magnetic coupling and the possibility of implementing vortices in information-storage [1], magnonic crystals (MC) [2], processing devices[3], and spin torque oscillators (STOs) [4]. In this later case spin-valve structure or magnetic tunnelling junctions MTJs is usually used, Synchronization between different STOs by means of coupling between vortex oscillators would be one of the most efficient ways to increase emitted power; which implies a deep understanding of the dynamic coupling between vortices.

2. Simulations

To study the coupling effect between vortices in vertical scheme a layered magnetic nanopillars consisting of ferromagnetic (F) and nonmagnetic (N) layers is modeled using OOMMF [5], we conduct the micromagnetic simulations for a circular Py dot having the thickness of 20 nm and the diameter of 180nm. The physical parameters of the individual cells of xy directions 2.5×2.5 nm^2, and different cell size is used for z direction 2.5-20 nm used; were: the exchange stiffness constant A = 1.3×10^{-11} (J/m), the saturation magnetization M_s = 830×10^3 A/m, and the Gilbert damping constant of $\alpha = 0.01$.

To excite spin Eigen-modes, a Gaussian pulse field is applied to the vortex-state tri-layer dots along the x-direction. In order to get the eigenmodes frequencies a Fourier transform of the time evolution of magnetization is applied and simulated Fourier power spectra is obtained where peaks present the eigenmodes frequencies.

3. Result and Conclusion

We explored the coupling effects on vertically coupled vortex-pair where we demonstrate by the micromagnetic simulations that the spinwaves frequency dependence on coupling is substantially different from the lateral coupled vortices case. We find that, the dipolar coupling between the vortex-pair mainly ruled by the relative chirality configuration, leading to a reduction of the out-of-phase coupled azimuthal modes frequencies and increase the in-phase coupled azimuthal mode frequencies, for the parallel and antiparallel chirality configurations respectively.

As to the parallel chirality case the coupling between chiralities induce additional splitting of the azimuthal modes as well as the coupled gyrotropic mode, that depend on the coupling strength between the ferromagnetic layers. Coupling additionally transforms modes profile for the out-of-phase mode and decrease their frequencies meanwhile increases the frequencies of the in-phase modes. An interesting result of our study is that the lowest coupled azimuthal mode splitting that differs from the gyrotropic dependence with the spacer thickness (coupling) and from the lateral coupling case.

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4. Reference

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