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Refractive Index and Snell's Law for Dipole-Exchange Spin-Waves in a Confined Planar Structure

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1. Introduction

Dipole-exchange spin waves (DESWs) in magnetically ordered materials of restricted geometries including one-dimensional (1D) multilayer, 2D patterned rectangular-, circular-, and stripe-shaped magnetic elements have attracted increasing interest in the areas of nanomagnetism and magnetization (dynamics [1]. Owing to advances in the fundamental understanding of excited DESW modes in micron or nano-sized magnetic thin films [2], it is likely to explore a new class of logic devices [3] along with other integrated electronic circuits [4] based on DESWs. An understanding of the macroscopic wave properties of DESWs in magnetic waveguides of lateral confinements is thus a prerequisite for making such DESW's devices technologically applicable.

In wave optics, macroscopic wave properties on refraction and reflection behaviors have been described simply by the well-known Snell's law and refractive indices of constituent optical media, since the macroscopic behaviors result from microscopic interactions between the optical waves and charged particles in media. Analogously, the macroscopic behaviors of DESWs can be expounded in a similar way, and Snell's law for DESWs could be expressed by DESW's refractive indices through constituent magnetic material parameters.

2. Results and discussion

Snell's law of reflection and refraction for DESWs in laterally restricted geometry of magnetic thin films, along with and explicit form of the refractive index are analytically derived from a microscopic approach using both the dispersion relations of two constituent magnetic media and aspecific boundary condition at their interface. The analytical derivation sare confirmed by micromagnetic numericalcal calculations conducted on, notonly the macroscopic refraction and reflection behaviors of DESWs, but also their total reflection at aspecific interface between Permalloy (Py: $Ni_{80}Fe_{20}$) and Yttrium iron garnet (YIG: $Y_3Fe_5O_{12}$). Snell's law of DESWs presented will not only provide the analytic constraints of spin wave modes at the interface between different magnetic media, but also much quantitative information on their macroscopic behaviors of reflection and refraction[5,6].

3. Conclusion

We explicitly derived refractive index and Snell's law of reflection and refraction for dipole-exchange spin waves in a geometrically confined planer structure composed of different magnetic media. The macroscopic wave properties of reflection and refraction for DESWs are analytically described and interpreted in terms of a dimensionless parameter, the refractive index of a given magnetic medium and the corresponding Snell's law. The analytical calculations are verified by micromagnetic numerical calculations of a total refection as well as the reflection and refractive behaviors of DESWs at a specific interface between Py and YIG.

This work was supported by Creative Research Initiatives (ReC-SDSW) of MEST/KOSEF.

4. Reference

[1] B. Hillebrands and K. Ounadjela (Eds.), Spin Dynamics in Confined Magnetic Structures, Vol. 83 of Topics in Applied Physics (Springer, Berlin, 2002).

[2] C. Bayer, J. Jorzick, B. Hillebrands, S. O. Demokritov, R. Kouba, R. Bozinoski, A. N. Slavin, K. Y. Guslienko, D. V. Berkov, N. L. Gorn, M. P. Kostyle, Phys. Rev. B **72**, 064427 (2005).

[3] R. Hertel, W. Wulfhekel, and J. Kirschner, Phys. Rev. Lett. **93**, 257202 (2004); S. Choi, K.-S. Lee, K. Y. Guslienko, and S.-K. Kim, Phys. Rev. Lett. **98**, 087205(2007).

[4] S. Kaka, M. R. Pufall, W. H. Rippard, T. J. Silva, S. E. Russek, and J. A. Katine, Nature **437**, 389 (2005).

[5] S. Choi, S.-K.Kim, V. E. Demidov, S. O. Demokritov, Appl. Phys. Lett. **90**, 083114 (2007).

[6] S. -K. Kim, S. Choi, K.-S. Lee, D.-S. Han, D.-E. Jung, and Y.-S. Choi, Appl. Phys. Lett. **92**, 212501 (2008).