Magnonic Band Structures in Two-dimensional Magnonic Crystals of Square-shape Antidot Array

Dong-Soo Han*, Ki-Suk Lee and Sang-Koog Kim†
Research Center for Spin Dynamics & Spin-Wave Devices, Nanospinics Laboratory, and Research Institute of Advanced Materials, Department of Materials Science and Engineering, Seoul National University, Seoul 151-744, Republic of Korea

1. Introduction

Magnonic crystals (MCs) and their band structures have attracted a great deal of interest owing to their potential applications to new types of information signal carriers. Towards the realization of such a magnonic device, not only reliable control of propagating spin waves along well-behaved waveguides[1,2] but the waveguide miniaturization[3] down to less than micrometer size are necessary. In our previous report[4,5], we proposed semi-one dimensional planar-patterned MC waveguides which can be used as an efficient spin-wave filter[5]. In such planar-patterned MCs, there are two different (high and low) bandgaps and the width and position of the bandgaps are found to vary with a periodicity $P=P_1+P_2$, P_1/P and its repeating number$N$[5], where P_1(P_2) corresponds to the segment length of the 30 (24)-nm-wide strip. The lower bandgap opening originates from "diagonal" coupling between the two identical modes having opposite propagation vectors and the higher bandgap originates from "off-diagonal" coupling between the initially propagating mode and newly excited higher modes by two dimensional scattering of spin waves at periodic edge-steps[4]. In order to understand the exact origin of such 2D scattering of spin waves in width modulated MCs, a study on 2D MCs of a square shaped antidot array is prerequisite. Here we report on spin-wave modes in such 2D MCs of a square shaped antidot array, for example.

2. Simulation Method

In this study, we chose an approach of micromagnetic numerical calculation[6] for a model system which consists of a 10 nm-thick Permalloy (Py) film and 4-nm-square-shaped antidot array of square lattice arrangement and 12 nm inter-distance between square antidots, as shown in Fig. 1. The material parameters used for Py are as follows: the saturation magnetization M_s=860×10^3 A/m, the exchange stiffness A_{ex}=1.3×10^{11} J/m, and the Gilbert damping constant α=0.01.

3. Results and discussion

To comprehensively understand complex band structures in the 2D MCs, we observed the dispersion curves of spin waves along the specific wave vectors of k=[100], [010], and [110]. In the result, due to the directionally different magnetic environment,different band structures along each of the different k-directions and corresponding bandgaps were found. All the band gaps occur at the Brillouin Zone (BZ) boundaries for all the k-directions. This is different from the result that the higher bandgap was observed far away from the BZ boundaries in the planar-patterned MCs[4].This can be understood in the sense that newly excited spin waves by 2D scattering at square-antidots are fully divided into two wave-vector components, k_x and k_y, thus there is only a "diagonal" coupling between the identical modes at the BZ boundaries[4]. This result may offer deeper understanding of the 2D scattering of spin waves observed in width modulated MCs.

This work was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (No. 20100000706)

4. Reference

[1] K.-S. Lee and S.-K. Kim, J. Appl. Phys. **104**, 053909 (2008).
[2] R. Hertel et al., Phys. Rev. Lett. **93**, 257202 (2004).
[3] M. P. Kostylev et al., Appl. Phys. Lett. **87**, 153501 (2005); T. Schneider et al., Appl. Phys. Lett. **92**, 022505 (2008).
[4] K.-S. Lee et al., Phys. Rev. Lett. **102**, 127202 (2009)
[5] S.-K. Kim et al. Appl. Phy. Lett. **95**, 082507 (2009)
[6] See http://math.nist.gov/oommf.

†To whom all correspondence should be addressed: sangkoog@snu.ac.kr

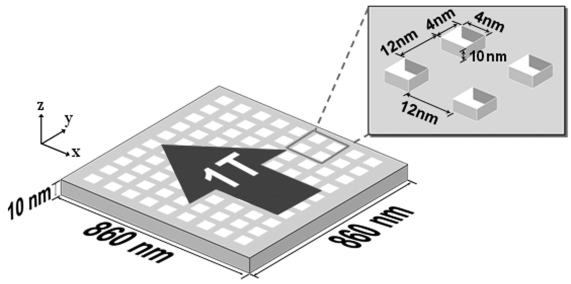

Fig. 1. Model geometry for a 2D MC of square-shaped antidots in a Py film. The initial magnetizations point in the －x direction, as indicated by the purple arrow, by application of the 1T magnetic field. The inset displays the dimensions of the unit period.