Snell's law for isotropically propagating spin wave

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Control of spin wave (SW) propagation is one of crucial tasks in magnonics [1]. As one of the important properties of the propagation, refraction of magnetostatic surface spin wave (MSSW) has been investigated [2]. However, MSSW has anisotropic dispersion relation and it should be taken into count the angle dependent wave vector of SW. Such anisotropic Snell's law requires complex calculation and it is not easy to apply techniques grown in optics. Regarding the dispersion relation of SW considering exchange interaction and dipole-dipole interaction [3],

$$\omega^2 = (\omega_H + \alpha\omega_M k^2)\left[\omega_H + \alpha\omega_M k^2 + \omega_M\left(1 - \frac{1-e^{-kd}}{kd}\right)\right] \qquad (1)$$

SWs propagating in-plane with out-of-plane magnetization propagate isotropically. Furthermore, Eq.1 describes the dispersion relation of magnetostatic forward volume wave (MSFVW) when$\alpha\omega_M k^2 = 0$ is assumed. In this study, we investigated Snell's law for both MSFVW and isotropically propagating dipole-exchange SW.

The micromagnetic simulation is performed utilizing mumax3[4]. To suppress the SW attenuation, we use material parameters of yttrium iron garnet (YIG), which is a well-known material having low damping. In the simulation, samples are shaped as Fig.1. The black and white areas are respectively the thicker and thinner regions. And the thickness step, the boundary between two regions, is tilted with the angle θ_1. The rf magnetic field is applied at the antenna. MSFVW is excited in the thicker(800 nm) region, passes through the thickness step and propagates in the thinner(400 nm) region. The incident wave is refracted by following Snell's law $\frac{sin\theta_1}{sin\theta_2} = \frac{k_2}{k_1}$. The wave number is independent of the direction of propagation due to the isotropic dispersion property. For MSFVW, a wavenumber is varied in order to keep kd constant when it passes through a thickness step. Hence, the Snell's law for MSFVW is independent of frequency (Fig.2).

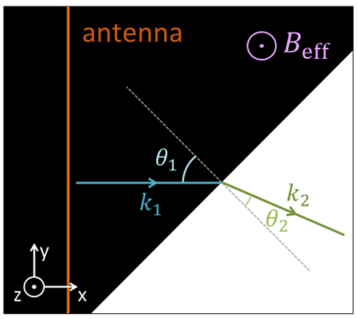

Figure1

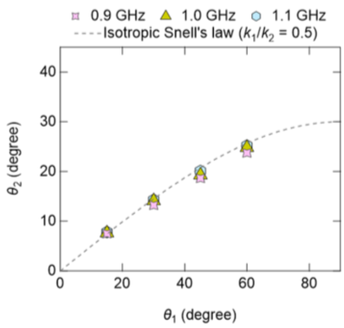

Figure2

Figure 1: Simulation setup
Figure 2: Refraction angle versus incident angle of MSFVW

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