Computer Simulation Of Spin Wave In Frequency Domain

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Abstract

Spin waves (magnons) are collective magnetic excitations. The Landau-Lifshitz-Gilbert (LLG) equation is used to describe the motion of magnetic moments in micromagnetics, and spin waves can be simulated by solving the LLG equation in time domain. Here, we transform the LLG equation to a frequent domain form under linear approximation. We combine the two form of LLG equation: solving the equation in time domain to obtain the steady state of magnetic texture while solving the equation in frequency domain to simulate the spin waves above the obtained magnetic texture. Our simulations elucidate that using the new form we can obtain the right results while spend less time. Micromagnetic simulation is performed by COMSOL.

LLG equation

$$\frac{\partial \boldsymbol{m}}{\partial t} = -\gamma \boldsymbol{m} \times \boldsymbol{H}_{eff} + \alpha \boldsymbol{m} \times \frac{\partial \boldsymbol{m}}{\partial t}$$

$$\boldsymbol{H}_{eff} = \boxed{A\nabla^2 \boldsymbol{m}} + \boxed{K(\boldsymbol{m}\cdot\boldsymbol{e}_a)\,\boldsymbol{e}_a} - \boxed{D\nabla \times \boldsymbol{m}}$$

Exchange interaction
Anisotropy
Dzyaloshinskii-Moriya interaction (DMI)

Linear approximation

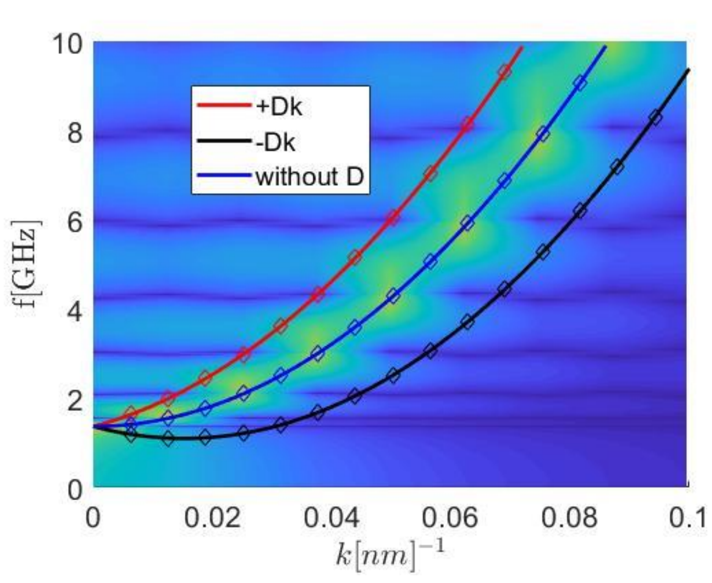
$$\begin{aligned}\frac{\partial \delta \boldsymbol{m}}{\partial t} = &-\gamma \boldsymbol{m}_0 \times \left[A\nabla^2 \delta\boldsymbol{m} + \boldsymbol{h} - D\nabla \times \delta\boldsymbol{m} + K(\delta\boldsymbol{m}\cdot\boldsymbol{e}_a)\,\boldsymbol{e}_a\right] \\ &-\gamma \delta\boldsymbol{m} \times \left[A\nabla^2 \boldsymbol{m}_0 + \boldsymbol{H} - D\nabla \times \boldsymbol{m}_0 + K(\boldsymbol{m}_0\cdot\boldsymbol{e}_a)\,\boldsymbol{e}_a\right] \\ &+\alpha \boldsymbol{m}_0 \times \frac{\partial \delta\boldsymbol{m}}{\partial t}\end{aligned}$$

m_0 means themagnetic texture, δm means small oscillation

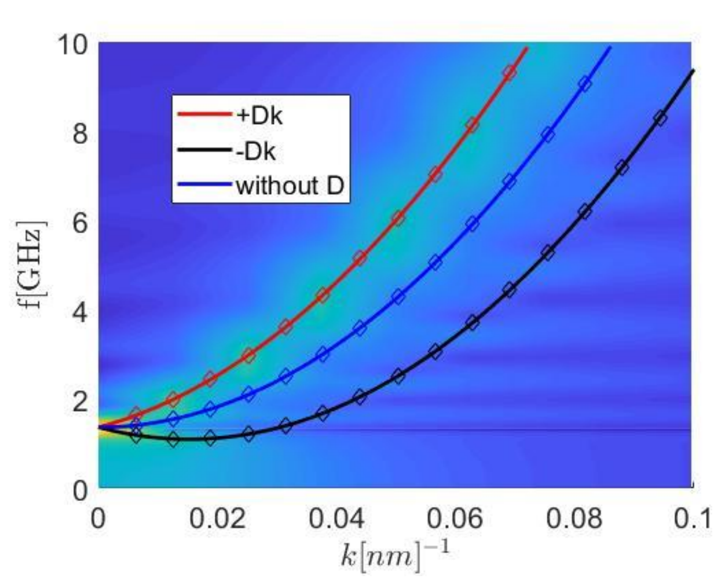
Frequency domain transform

$$\delta\boldsymbol{m}(\boldsymbol{r},t) = \delta\boldsymbol{m}(\boldsymbol{r})e^{-i\omega t}$$

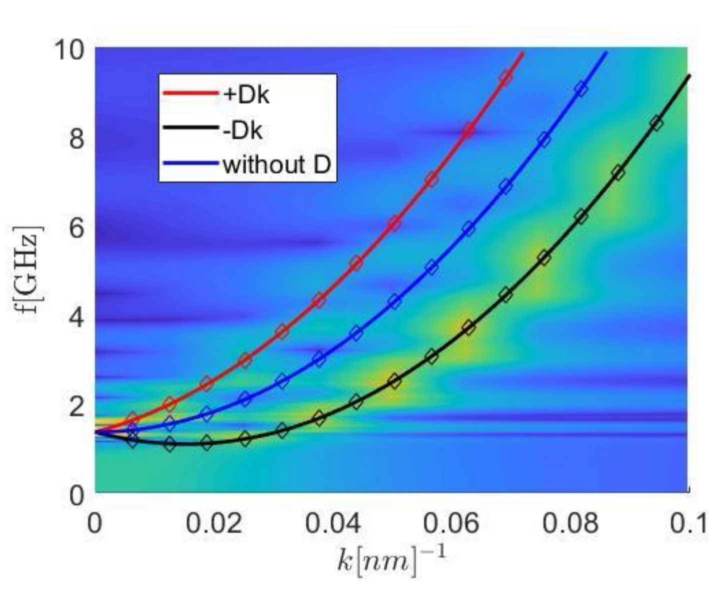
1-D model



(a).without DMI



(b).with k>0



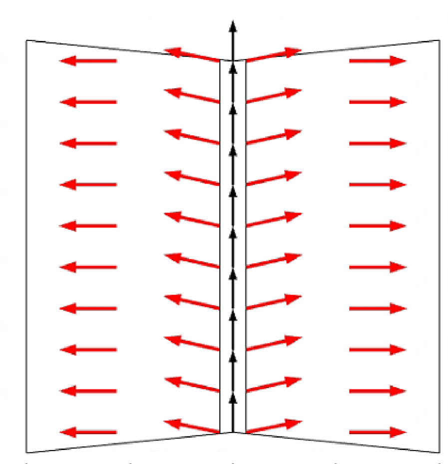
(c).with k<0

$$\omega_0 = \gamma\left(Ak^2 + Dk + K\right)$$

the dispersion relation of one-dimensional spin wave

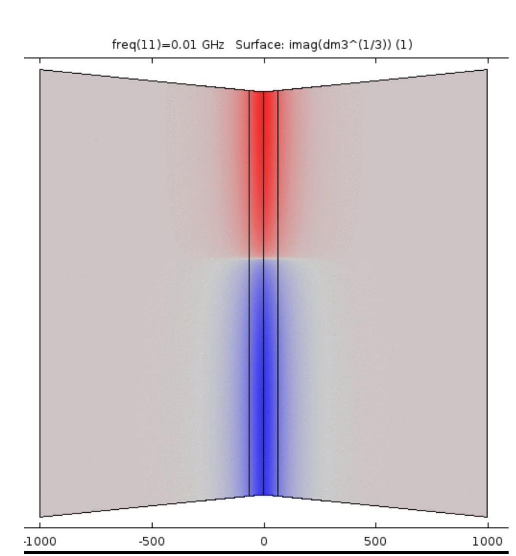
k>0 means the spin wave propagating towards the positive x-direction.

2-D model with domain wall

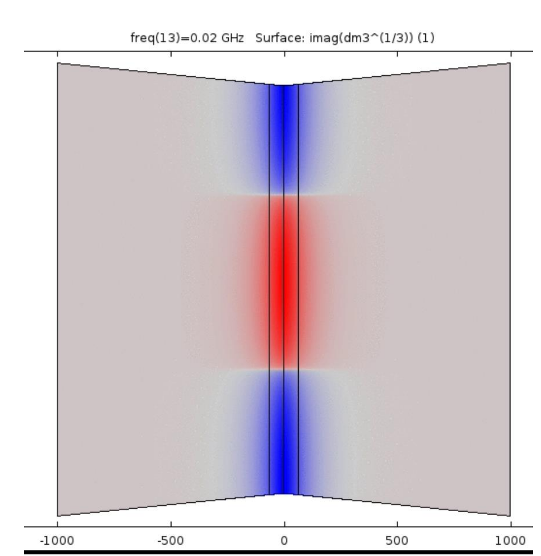


The sketch of magnetic texture

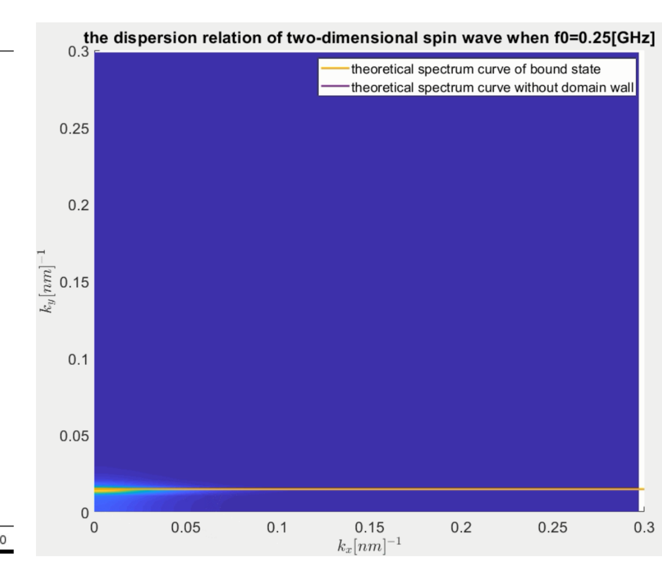
We calculate the spin wave propagation above the magnet texture like left. The dispersion relation of it match the theoretical curve very well.



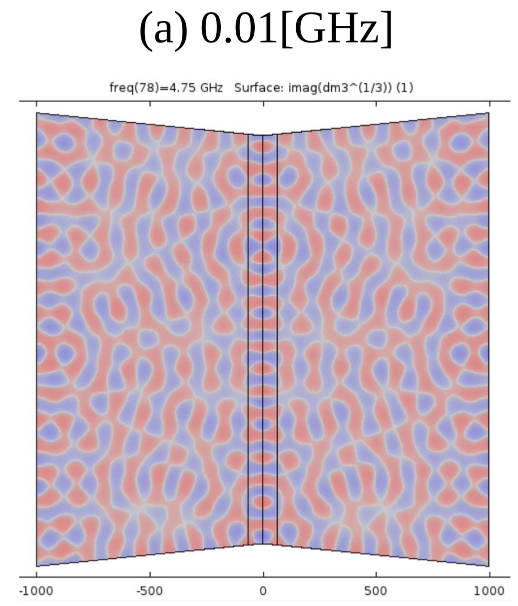
(a) 0.01[GHz]



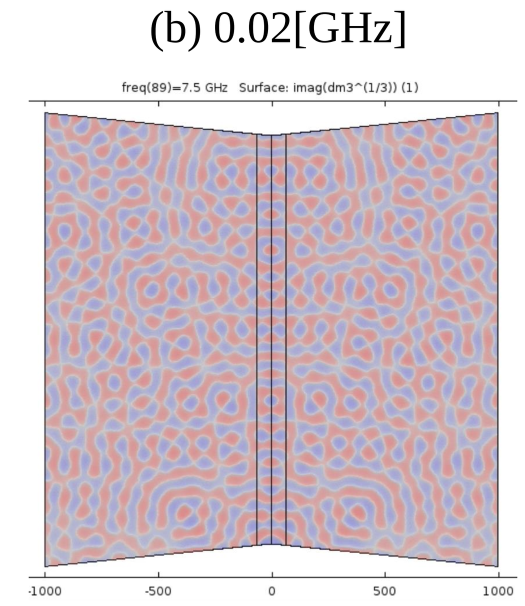
(b) 0.02[GHz]



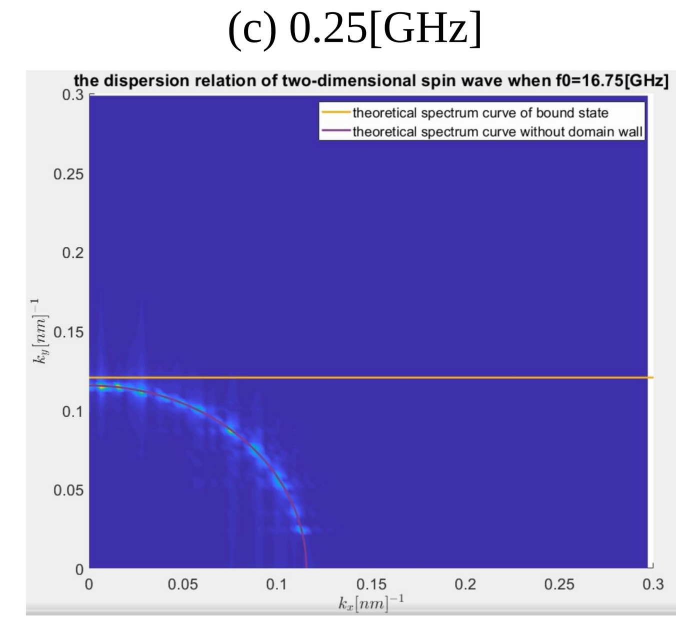
(c) 0.25[GHz]



(d) 4.75[GHz]



(e) 7.5[GHz]



(f) 16.75[GHz]

Bound state(a,b,c)   Bulk state(d,e,f)

Reference

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