Coupling between surface acoustic waves and spin waves in planar nanostructures

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Magnetoelastic interactions have received considerable attention in recent years due to the potential for mutual compensation of drawbacks and sharing of benefits between the magnonic and phononic platforms. However, the effective coupling between SAWs and spin waves (SWs) requires the absence of spatial averaging, which needs for wave vector matching and agreement of the profiles in out-of-plane direction, and is highly anisotopic[1], i.e. depends on both the direction of the applied magnetic field and the polarization of the surface acoustic wave (SAW).

This coupling becomes more intricate in nanostructured materials. In this work, we extend our previous research[2] to investigate the effects of patterning on magnetoelastic interactions using finite element method software. We explore the magnetoelastic dispersion relations for an array of thin strips with varying magnetic properties, but identical elastic characteristics.

The study focuses on SAWs and SWs propagating along the periodicity direction, leading to the folding of the magnetoelastic dispersion relation into the first Brillouin zone. An in-plane magnetic field is applied at a 45° angle to the wave vector, facilitating the interaction between Rayleigh SAWs and SWs. Our key findings are: (i) higher dispersion branches of SAWs are exclusively due to magnetoelastic interactions, and (ii) the partial confinement of SWs within the strips and the resulting nonuniform phase shifts influence their coupling with freely propagating SAWs. Since the pattering of the magnetic layer modifies the shape anisotropy and the associated magneto-rotation coupling[3], we also discuss its constitution and anisotropy with respect to conventional magnetoelastic coupling.

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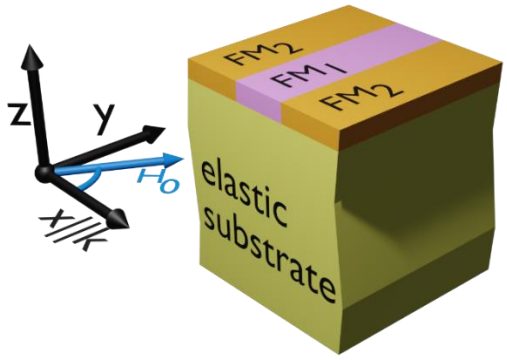

Fig.1. The unit cell of considered system. External magnetic field H_0 is applied at oblige angle to the wave vector k (for SAWs and SWs). $FM_{1,2}$ – ferromagnet with different magnetic properties.

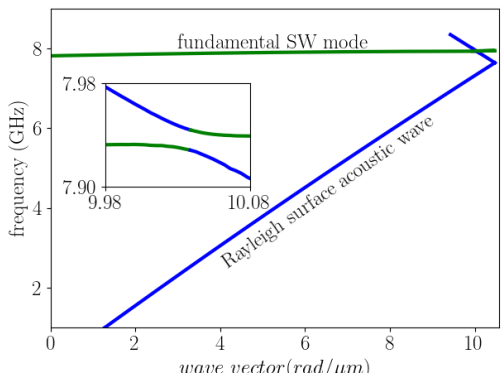

Fig. 2. Rayleigh SAW dispersion relation with the fundamental mode for spin waves.

[1] Dreher et al., *Surface acoustic wave driven ferromagnetic resonance in nickel thin films: Theory and experiment*, Phys. Rev. B **86**, 134415 (2012)
[2] Babu et al., *The Interaction between Surface Acoustic Waves and Spin Waves: The Role of Anisotropy and Spatial Profiles of the Modes*, Nano Lett. **21**, 2, 946–951 (2021)
[3] Xu et al., *Nonreciprocal surface acoustic wave propagation via magneto-rotation coupling*, Sci. Adv. **6**, eabb1724 (2020)