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Optimizing acoustic wave – spin wave resonant coupling in the magphonic crystal

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We have investigated co-directional and contra-directional couplings between spin wave and acoustic wave in one-dimensional periodic structure (magphonic crystal). The system consists of two ferromagnetic layers alternating in space. We have taken into consideration materials prominent in magnonics: YIG, CoFeB, permalloy, and cobalt. The coupled mode theory (CMT) formalism have been successfully implemented for the first time to describe magnetoelastic interaction as a periodic perturbation in the magphonic crystal. We have shown, that CMT analysis of magnetoelastic coupling allows to effectively design a spin wave-acoustic wave transducer based on a magphonic crystal. Analitycal results have been compared with frequency-domain and time-domain numerical simulations.

We have demonstrated how the energy is spatially exchanged between spin wave and acoustic wave in the optimized magphonic crystal if the resonance condition is satisfied. In the case of contra-directional coupling, i.e. when spin wave and acoustic wave have opposite signs of the group velocities, we have observed phenomenon similar to the Bragg reflection at the frequency in the stop band However, if the wave that incides to the structure is purely elastic, the reflected wave is purely magnetic. What is more, the reflected spin wave has much shorter wavelength compared to the acoustic wave. On the other hand, in the co-directional coupling, i.e. when spin wave and acoustic wave have the same signs of the group velocities, we have observed complete conversion of energy from spin wave to acoustic wave periodically in space. Since the exchange length is in the micrometer and sub-micrometer scale, such conversion should be experimentally achievable. Moreover, we propose thin film – substrate systems optimized for the experimental investigation of the linear coupling between surface spin waves and surface acoustic waves.

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References
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