Magneto-acoustic metamaterials: From bulk to surface acoustic waves

(complete result)

Y. Au, O. S. Latcham, A. V. Shytov, and V. V. Kruglyak
University of Exeter, United Kingdom

Owing to magneto-elastic coupling, acoustic waves may be scattered resonantly by magnetic elements [1]. The scattering may be further enhanced via the Borrmann effect (Fig. 1) when the elements form a periodic array [2]. Here, we report on the use of finite-element modelling to explore how the findings above map onto surface acoustic waves (SAW) [3]. Specifically, we consider single- and double-layer Ni stripe arrays patterned on top of a $LiNbO_3$ substrate that carries Love SAWs. We observe enhancement of the coupling for single-layer stripes, but only for Gilbert damping below its realistic value. For double-layered stripes, a weak yet clear and distinct signature of Bragg reflection is identified far away from the acoustic band edge, even for a realistic damping value. Double-layered stripes also offer better magnetic tunability when their magnetic period is different from the periodicity of elastic properties of the structure because of staggered magnetization patterns. The results pave the way for the design of magneto-acoustic metamaterials with an enhanced coupling between propagating SAWs and local magnetic resonances. Such metamaterials may lead to development of reconfigurable SAW-based data circuits and unconventional computing approaches, such as artificial neural networks and reservoir and in-memory computing.

The research is funded by the EPSRC of the UK (Projects EP/L019876/1 and EP/636 T016574/1).

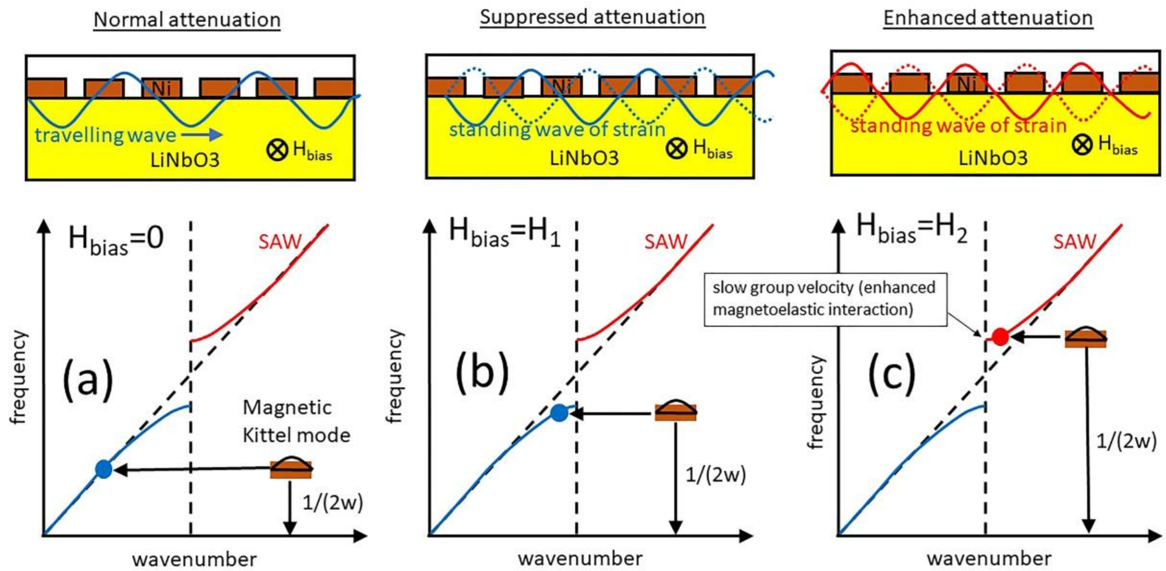

Fig. 1. Borrman's effect in the magneto-acoustic system. (a) Array of Ni stripes (of width w) leads to an acoustic band gap in the spectrum of SAWs in $LiNbO_3$. For $H_{bias} = 0$, the stripes' magnetic mode couples to SAWs with frequencies in the allowed band. (b) Raising H_{bias} to H_1 moves the SAW-magnetic mode hybridisation to the lower edge of the acoustic band gap. A standing SAW forms in the array with the maxima of the strain located in the gap between the Ni stripes. This leads to suppression of interaction between the SAW and the magnetic mode (suppressed magnetic attenuation of SAWs). (c) Further increase of H_{bias} to H_2 relocates the hybridisation point to the upper acoustic band edge. The standing SAW' strain maxima are inside the Ni stripes, leading to the enhancement of interaction between the SAW and the magnetic mode (enhanced magnetic attenuation of SAWs).

[1] O. S. Latcham, et al, Appl. Phys. Lett. **115**, 082403 (2019); *ibid*. **116**, 209902 (2020).
[2] O. S. Latcham, et al, Appl. Phys. Lett. **117**, 102402 (2020).
[3] Y. Au, O. S. Latcham, A. V. Shytov, and V. V. Kruglyak, *Resonant scattering of surface acoustic waves by arrays of magnetic stripes*, J. Appl. Phys. **134**, 000000 (2023).