Magnetoeleastic waves in nanoscale waveguides and piezoelectric/magnetostrictive bilayer transducers

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In recent years, spintronics for logic operations made significant advances by demonstrating nanoscale logic devices such as majority gates [1] and directional couplers [2] as well as demonstrations of logic circuits based on these devices [3,4]. One main challenge is the CMOS-integratable and efficient coupling between the magnetic and electric domain. A potential transducer that can solve this problem is based on piezoelectric/magnetostrictive bilayers [5,6]. When a voltage is applied, the piezoelectric induces strain in the device which then couples with the magnetization via the magnetoelastic coupling. In this approach, a voltage is applied instead of a current which is expected to strongly reduce the Joule dissipation as compared to current based transducer concepts such as inductive antennas. In this work, we theoretically analyze the fundamental coupling between the elastic and magnetic domain inside the transducer and unravel the dimensional and material influences on the transducer efficiency.

The magnetoelectric transducer generates both dynamic strain as well as dynamic magnetization. As a result, the waveguide connected to the transducer is excited both via the elastic as well as magnetic domain. The elastic excitation results in elastic waves whereas the magnetic excitation results in ferromagnetic resonance or spin waves inside the waveguide. When the waveguide has magnetostrictive properties, both wave types can interact with each and form additional magnetoelastic waves [7]. Moreover, at nanoscale dimensions, the waves are confined which results in multiple modes, all with different dispersion relations and mode profiles. From symmetry considerations and the fundamental coupling relations, it can be shown that not all quantized elastic modes interact with the quantized spin wave modes. In addition, it is shown that mode profiles of both the elastic as well as the spin waves are very weakly affected by the magnetoelastic coupling. These results are essential when designing next generation spintronic logic devices for both the transducer and waveguide side.

This work has been partially funded by the European Union’s Horizon 2020 research and innovation programme within the FET-OPEN project CHIRON under grant agreement No. 801055. F.V. acknowledges financial support from the Research Foundation - Flanders (FWO) through grant No. 1S05719N.

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