Orbital currents generated by surface acoustic waves in FM/NM bilayers

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Surface acoustic waves (SAWs) can be coupled efficiently to magnetostrictive ferromagnetic materials (FM) and are known to drive large angle magnetization precession [1,2]. The resulting magnetization oscillation may pump spin and orbital currents into adjacent nonmagnetic (NM) materials, which eventually can be converted into detectable charge currents from inverse spin and orbit Hall effects. However, pumping mechanisms can have diverse origins such as spin or orbital pumping, magnetorotation, and phonon angular momentum transfer—all of them with different symmetries with respect to the angle between SAW and magnetization. Typically, the detection of spin currents is done through inverse spin Hall effect (ISHE) in large spin orbit coupling (SOC) materials such as Pt, Ta and W. Nevertheless, these materials can be toxic, hard to find and are associated with environmentally harmful techniques. More recently, the orbital angular momentum has taken protagonism as it is predicted to have a comparable or even larger effect than its spin counterpart and may occur in cleaner and less expensive materials.

Here, we explore different pumping mechanisms in bilayer systems made of FM/NM through acoustically driven magnetization waves. The studied hybrid devices consist of a piezoelectric substrate where Interdigital Transducers (IDTs) are placed facing each other to generate and detect SAWs transmission. The FM/NM bilayers are deposited in different structures in the acoustic path in between facing IDTs (see Figure 1 (d)) and both transversal or longitudinal voltages can be detected in presence of SAW. We compare nickel and cobalt as FM and chromium and aluminium as NM.

We demonstrate that SAW may induce orbital currents that are detected in the NM layer. Figure below shows a large inverse orbital Hall effect in the chromium compared with a tiny effect in aluminium. We study further amplitude asymmetries as a function of the angle between SAW and magnetization to quantify both the orbital pumping from FM and the orbital Hall conductivity in the NM metals.

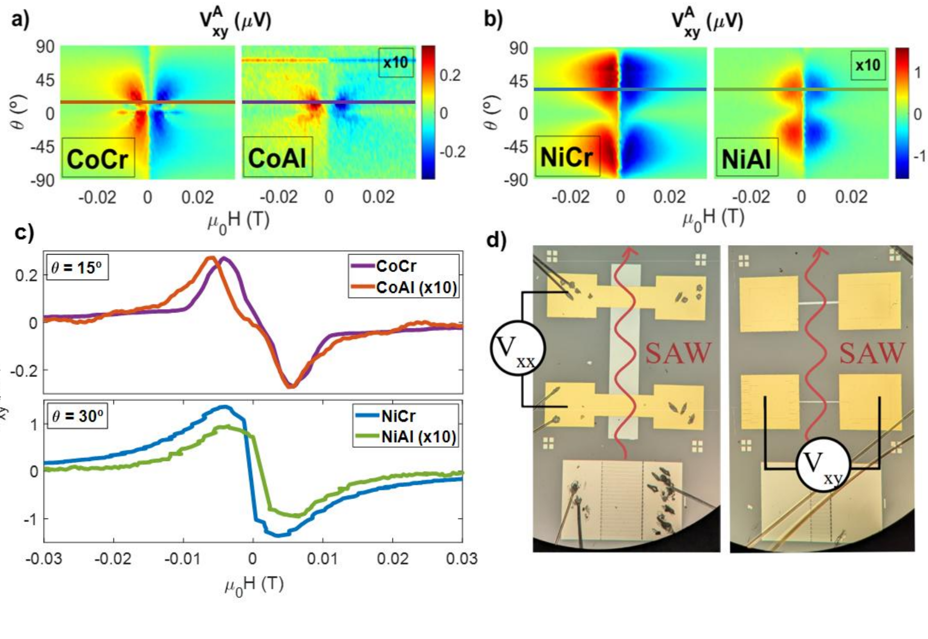

Figure. Measures of the angular dependence of the antisymmetric part of the transversal voltage (V_{xy}^A) for **a)** Cobalt/Chromium, Cobalt/ Aluminium and **b)** Nickel/Chromium, Nickel/ Aluminium bilayers in the presence of 1.3 GHz SAWs. **c)** Measures of the field dependence of the V_{xy}^A for the Cobalt bilayers at θ=15º and the Nickel bilayers at θ=30º. **d)** Experimental set-up for longitudinal (V_{xx}) and transversal (V_{xy}) voltage detection.

References

[1] B. Casals et al., Phys. Rev. Lett. **124**, 137202, (2020)

[2] M. Rovirola et al., Phys. Rev. Research **6**, 023285 (2024)