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Magneto-acoustics non-linearities without threshold

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Magnon-phonon coupling arising from magneto-striction in ferromagnetic materials enables dynamical magnetization driving by coherent phonons, namely acoustic (strain) waves, opening novel opportunities for the development of magnonics. At low strain amplitude (10^{-5}) ferromagnetic resonance induced by surface acoustic waves (SAW) is obtained. At the resonance, when the SAW frequency and precession frequency match, increasing the acoustic amplitude leads to SAW-induced magnetization switching [1]. In an intermediate regime, we investigate the onset of nonlinearities that appear in SAW-driven magnetization dynamics.

Using a time- and spatially-resolved magneto-optical Kerr setup with laser detection synchronized to SAW rf bursts [2], we evidence non-linear effects in the magnetization dynamics of the ferromagnetic semiconductor (Ga,Mn)As. They appear as a doubling of the precession frequency in the time domain ($f=2f_{SAW}$), and of the wavevector in the space domain ($k=2\,k_{SAW}$), in the absence of non-linear acoustic effects and without power threshold. The dependence of the magnetic dynamical signal on the strain amplitude reveals two regimes. In the low-strain regime the f (2f) component has a linear (quadratic) behavior with the SAW amplitude. We show that this regime is well accounted for by an all-analytical perturbative model of two coupled parametric oscillators [3] with SAW-dependent frequency and damping while the intrinsic magnetic non-linearities of the Landau-Lifschitz-Gilbert equation can be neglected. With increasing SAW amplitude, the f-component becomes sublinear and the peak of the SAW-induced ferromagnetic resonance curve shifts to lower magnetic field, which is the signature of the rising importance of intrinsic magnetic nonlinearities as shown by numerical simulations taking into account non-linearities of magnetic origin.

[1] P Kuszewski, I S Camara, N Biarrotte *et al.*, J. Phys.: Condens. Matter 30, 244003 (2018)
[2] P. Kuszewski, J.-Y. Duquesne, L. Becerra *et. al.*, Phys. Rev. Appl. 10, 034036 (2018).
[3] M. Kraimia, P. Kuszewski, J.-Y. Duquesne *et al.*, Phys. Rev. B 101, 144425 (2020).

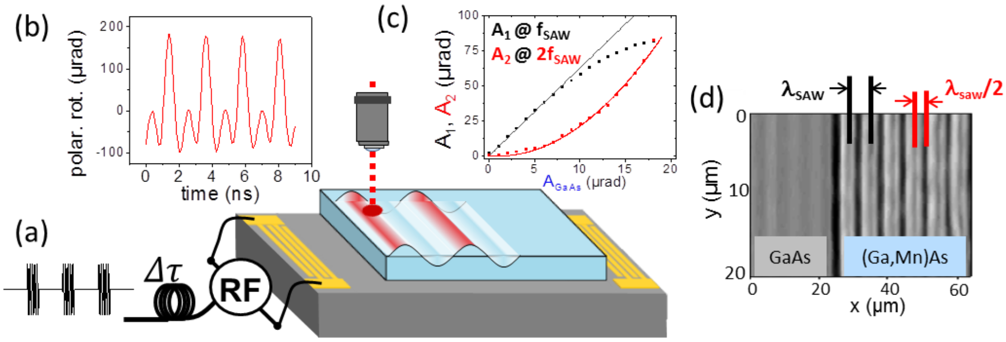

Figure 1 : (a) Experimental scheme; (b) time-resolved magnetization dynamics showing frequency doubling; (c) SAW amplitude dependence of the f_{SAW} and $2f_{SAW}$ components (d) spatially-resolved magnetization dynamics showing wavevector doubling.