Magneto-acoustics non-linearities without threshold

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Magnon-phonon coupling arising from magnetostriction 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 \cite{1}. In an intermediate regime, we investigate the onset of non-linearities 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 \cite{2}, we evidence non-linear effects in the magnetization dynamics of the ferromagnetic semiconductor \((\text{Ga,Mn})\text{As}\). They appear as a doubling of the precession frequency in the time domain ($f=2f_{\text{SAW}}$), and of the wavevector in the space domain ($k=2k_{\text{SAW}}$), 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 \cite{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 non-linearities as shown by numerical simulations taking into account non-linearities of magnetic origin.

\cite{1} P Kuszewski, I S Camara, N Biarrotte \textit{et al.}, J. Phys.: Condens. Matter 30, 244003 (2018)

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