Modelling of magnetization oscillations’ excitation by surface acoustic waves in metal films

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The work is devoted to model the nonlinear and parametric interactions between surface acoustic waves and magnetic oscillations in thin metal films. We consider elastic strains excitation on the surface of metal film induced by a femtosecond laser light. We highlight the observation of magnetostatic surface spin waves and elastically driven magnetization precession excitation.

We consider a periodic grating formed by interference of two femtosecond laser pulses on the film surface. Due to the thermal gradient that is due to the gratting, we generate elastic strains [1]. A DC magnetic field is applied in the plane of the film. We calculate the expressions of the magnetoelastic interaction’s energy density and of the deformation tensor’s components which are responsible of the magnetoelastic interaction. The magnetization dynamics are forced (via inverse magnetostriction) by two surface-confined elastic waves: Rayleigh Surface Acoustic Wave (SAW) and Surface Skimming Longitudinal Wave (SSLW) [1]. The excitation of FMR harmonics and frequency-mixing by elastic waves were calculated within the framework of a theoretical model taking into account the Landau-Lifshits-Gilbert (LLG) equation, boundary conditions for the magneto-elastic stresses and the elastic displacements’ equations. The alternating magnetoelastic field is determined by SAW and SSLW strain components. The equations for the magnetic oscillations were derived by first and second order perturbation theory.

The parametric interaction of the elastic waves with a magnetic oscillator leads to frequency-mixing: SAW+SAW, SAW+SSLW and SSLW+SSLW. We observe a correlation between the amplitude of the magnetic oscillations and the in-plane orientation of the internal magnetic field. We investigate the influence of the delay when the field orientation change from parallel to perpendicular regards to the interference stripes. We also consider the numerical solutions of LLG equation to obtain the dispersion curves for magnetostatic surface spin waves. We demonstrated that SAW and SSLW can excite spin waves. Influence of the heat flow in the grating to magnetoelastic dynamics is also considered. We compare our theoretical results with the experimental ones obtained in [1].

Funding through Nouvelle équipe, nouvelle thématique ”Ultrafast acoustics in hybrid magnetic nanostructures”, Strategie internationale NNN-Telecom and the Acoustic HUB de la Region Pays de La Loire, Alexander von Humboldt Stiftung, ANR-DFG “PPMI-NANO”, PRC CNRS-RFBR ”Acousto-magneto-plasmonics” (grants numbers 17-02-01138, 17-57-150001) is greatfully acknowledged.

[1] C.L. Chang et al., Phys. Rev. B **95**, 060409(R) (2017).