Micromagnetic simulation of inertial spin waves in ferromagnetic nanodots

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The study of ultra-fast magnetization processes is a central issue in spin dynamics for its potential application to future generations of nanomagnetic and spintronic devices[1]. In the last decades, after the pioneering experiment[2] revealing subpicosecond spin dynamics, the investigation of ultra-fast magnetization processes has increasingly attracted the attention of many research groups stimulating the production of considerable research. The advent of intense high-frequency magnetic field sources has recently allowed for the direct detection of non-thermal, ultrafast magnetization processes in the terahertz range, which made it possible to demonstrate the spin nutation in ferromagnets[3] experimentally and thereby confirm the presence of inertial effects in magnetization dynamics theoretically predicted several years ago[4].

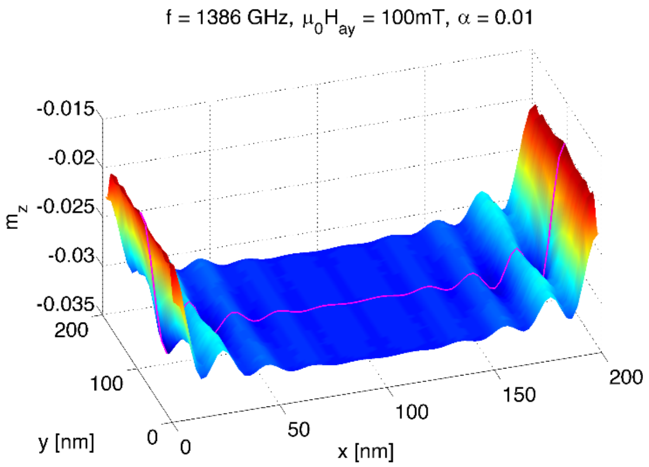

Figure 1: Snapshot of steady-state out-of-plane ac magnetization response (normalized by saturation magnetization) at driving frequency f = 1386 GHz. The color code represents the value of out-of-plane magnetization at each spatial location, ranging from minimum (blue) to maximum (red).

From the theoretical point of view, inertial magnetization dynamics can be modeled by augmenting the classical Landau-Lifshitz-Gilbert (LLG) precessional dynamics with a torque term taking into account angular momentum relaxation[3,4] proportional to the second time-derivative of magnetization. Such a torque transforms the classical LLG equation into a wave-like equation with hyperbolic mathematical nature, meaning that inertia leads to wave propagation phenomena with finite speed. In particular, when magnetic systems of nano- and micro-scale are considered, the issue of the emergence of inertial spin waves oscillating at terahertz frequency arises.

In this paper, by combining analytical theory and full micromagnetic simulations of inertial LLG (iLLG) dynamics, we demonstrate[5] the possibility to excite ultra-short inertial spin waves (see Fig. 1) that propagate with finite speed in a confined ferromagnetic nanodot. The nanodot is driven by the action of terahertz fields with amplitude similar to those achievable with state-of-the art terahertz experimental setups.

References

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