Micromagnetically integrated numerical model of spin pumping based on spin diffusion

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The interaction between localized and mobile spins in magnetic materials has long been understood. It has been modeled in various forms (e.g. [2]) and is successfully used to model and design spintronic devices. In those cases, the interest lies in the effect that a spin current (usually originating from a charge current) has on the dynamics (i.e., precession) of local magnetization. But the reverse is also true: The precession of magnetization has an effect on spin current, in that it can be the origin of it. The term *spin pumping* means the outflow of spins from a magnetic material with precessing magnetization into a nonmagnetic material. This effect has been proven in numerous experiments.

There currently exists no generalized numerical implementation of spin pumping. The often used Buettiker-style formulation (see, e.g. [3]) is limited to homogeneous precession and therefore unsuitable to support micromagnetic computations for magnonics. This limits exploring the effects of spin pumping in magnonic systems (where it is used as a detection method as well as being responsible for parasitic relaxation effects) to experiments.

Based on the spin drift-diffusion model [4], we created a generalized numerical model for spin pumping that also includes the spin torque originating from spin pumping [1]. Thus also the changes in precession speed and apparent damping can be properly computed. Figure 1 shows the damping of a propagating magnon by spin torque.

The method has already been published and is currently in use within our group to explore spin current signal from magnonic devices.

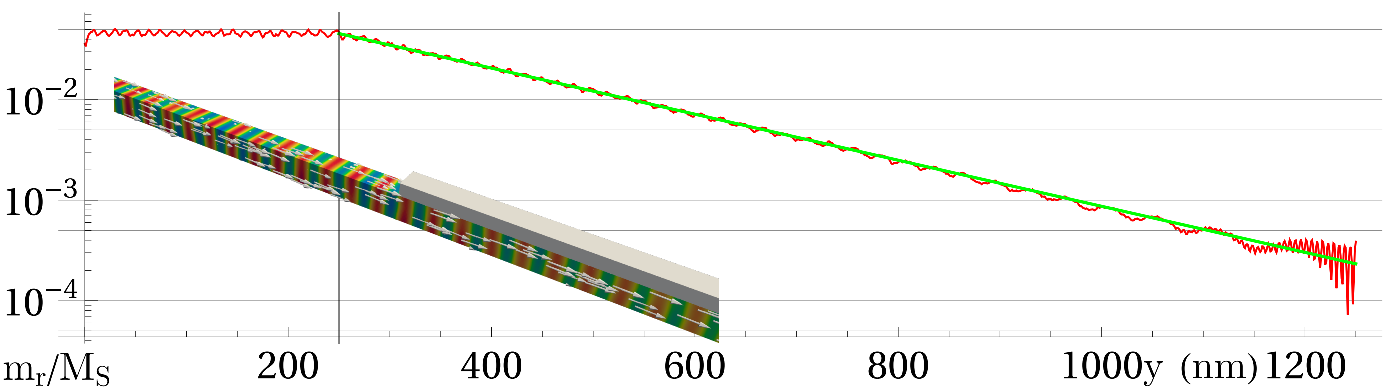

Figure 1: Amplitude of a magnon in a waveguide. After 250 nm, the waveguide is covered by a spin sink. The amplitude gets reduced by spin torque after that point until the magnon is almost completely subdued.

References

[1] M. Gattringer, et al.: Micromagnetically integrated numerical model of spin pumping based on spin diffusion. Physical Review B, 106, 024417 (2022).

[2] S. Zhang and Z. Li: Roles of Nonequilibrium Conduction Electrons on the Magnetization Dynamics of Ferromagnets. Physical Review Letters, 93, 127204 (2004).

[3] P. Omelchenko, E. Girt, and B. Heinrich: Test of spin pumping into proximity-polarized Pt by in-phase and out-of-phase pumping in Py/Pt/Py. Physical Review B, 100, 144418 (2019).

[4] S. Zhang, P.M. Levy, and A. Fert: Mechanisms of Spin-Polarized Current-Driven Magnetization Switching. Physical Review Letters, 88, 236601 (2002).