Inversion of the Spin-torque Effect by Resonant Magnon Scattering in Nanoscale Magnets

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Magnetic damping is a key metric for many spintronic applications. We present the experimental study and theoretical model of a damping mechanism that can dominate the magnetic energy dissipation in nanomagnets. This mechanism arises due to magnon spectrum quantization caused by the geometric confinement [1,2]. The dissipation becomes resonantly enhanced near magnetic field values corresponding to the degenerate three-magnon [1,3] process and dominates the magnetization dynamics even at low excitation levels (Fig. 1).

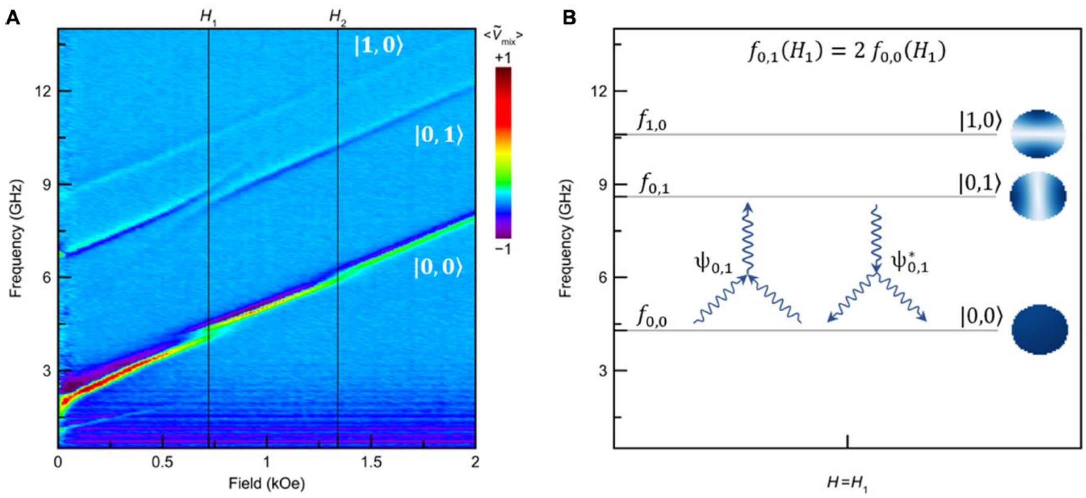

Figure 1: (A) Spin-torque ferromagnetic resonance on a 60 nm MTJ nanopillar with out-of-plane magnetic anisotropy. The spectrum reveals three discrete spin wave modes localized in the nano-size free layer of the MTJ. At the characteristic fields of the three-magnon scattering, the spin wave spectra show anomalies (splitting, broadening, apparent anti-crossing). (B) Sketch of the three-magnon scattering: at the first characteristic field, two quanta (magnons) of the lowest-energy spin wave mode merge into one magnon of the next higher-energy mode. The lateral profile of the spin wave amplitudes is shown. Source: modified from Ref. [1] (see *).

The observed magnon scattering redefines the response of a nanomagnet to spin-torques. It inverts the effect of the spin-torque on magnetic damping and turns an anti-damping spin-torque into a torque that enhances magnetic dissipation. The discovery of this counterintuitive effect advances our understanding of spin dynamics in nanomagnets and has far-reaching implications for spin-torque oscillators [4], spin-torque memory, and other emergent spintronics technologies [5]. The ability to control and tune magnetic dissipation is a key concept of emergent spintronic technologies. Therein, magnon scattering processes play a major role [6,7], and hold the promise for manipulating magnetic states on the quantum level. Controlling these processes [8], while being imperative for spintronic applications [1], has remained difficult to achieve.

We develop an approach for toggling magnon processes by a nanoscale dipole switch. We demonstrate an experimental proof-of-concept in magnetic tunnel junction nanodevices, consisting of a free layer and a synthetic antiferromagnet. By triggering the spin-flop transition in the synthetic antiferromagnet and utilizing its dipole field, we controllably tune the strength of the magnon interaction by at least one order of magnitude, resulting in two distinct dissipative states. The results open up an avenue for controlling magnon processes by external stimuli at the nanoscale and show prospects for spin-torque applications and hybrid quantum information technologies.

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