Nonlinear magnetization dynamics for sensitive magnetometry

Nonlinear large angle magnetization dynamics is an essential ingredient in understanding the switching characteristics of both memory and logic devices. When the angle of spin precession is large enough, generation of high-harmonics by a nonlinear process may take place in a so-called parametric process.

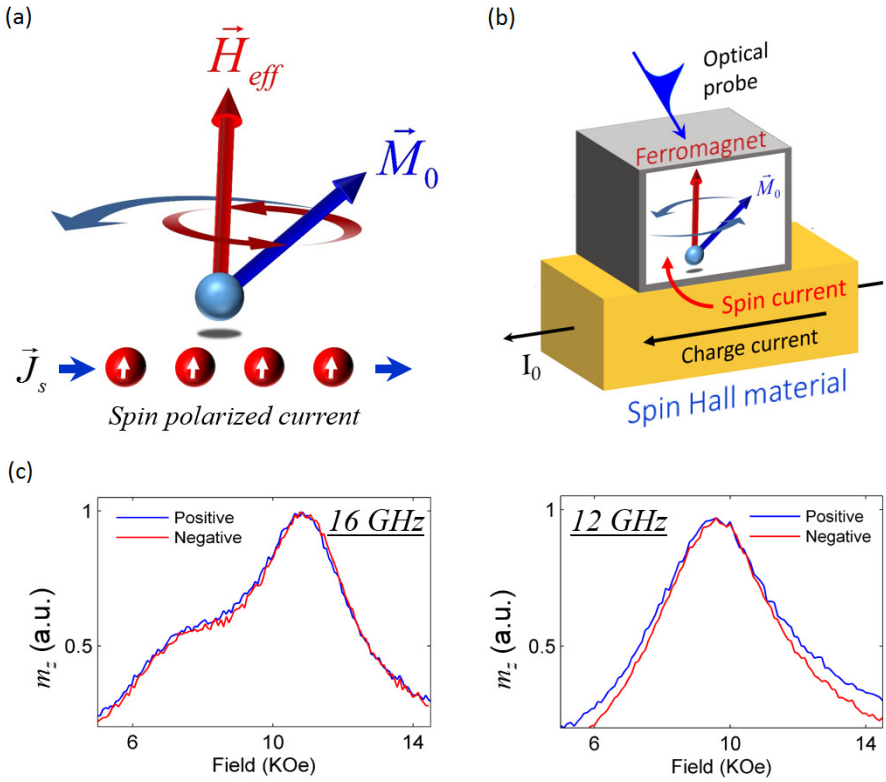
In several recent works, the generation of high harmonics was studied in thin ferromagnetic films and was shown to result in a very high conversion efficiency. In these works, however, the role of the anisotropy field was not considered.

In our work on this topic, my colleagues and I showed that the high conversion efficiency originates from the form of the magnetic potential barrier which becomes very shallow for specific, well-defined, conditions of externally applied magnetic field. Under these conditions, the spins are unconstrained and are allowed to change their orientation "freely" as though they are in free space. The reason for the behavior is that the effective field which the spins precess about is not restricted to a specific direction but rather reorients about the spins as they precess. As a result, large angle spin precessions take place which in turn generate the higher harmonics.

The importance of this effect is that it allows to increase the sensitivity to measurement of additional torques that might exist, such as those that originate from proximate spin currents, for example.

This is the principle behind the work that was presented in [PRL 116, 047204].

Indeed, recently my colleagues and I demonstrated the increase in sensitivity by injecting spin currents into a ferromagnetic structure using the spin Hall effect (unpublished result, see figure).



Enhanced sensitivity for measurement of proximate spin currents. (a) Measurement concept. (b) Experimental realization. Spin current is generated in Pt film by the spin Hall effect and injected into a Co|Ni|Co trilayer. (c) Measured resonance linewidth in the trilayer for 16 GHz (left) and 12 GHz (right) for positive and negative current polarity in the Pt. The torque generated by the spin current is sensed only when the potential barrier is shallow (12 GHz).