Spin pumping effect proven for the first time

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German physicists led by Prof. Dr. Hartmut Zabel have demonstrated the spin pumping effect in magnetic layers for the first time experimentally. The behaviour of the spin pumping had previously only been predicted theoretically. The research team at the Ruhr-University Bochum has now succeeded in measuring the effect using ultrafast X-ray scattering with picosecond resolution. Through their rotation of the magnetic moments, the so-called magnetic precession, single electrons can mutually influence each other's rotation (spin) through a non-magnetic intermediate layer. This is a crucial insight for future generations of magnetic sensors in hard disk read heads and other data storage. The researchers reported on their findings in *Applied Physics Letters*.

Magnetic spinning tops are different

Once put into motion and left to itself, a spinning top will slow down after a few rotations and eventually come to a halt. Friction losses deprive it of energy, until it finally stops spinning. Also, two spinning tops put at a certain distance to avoid touching show by and large the same behaviour. "In particular, we do not expect that one spinning top can affect the rotation of the other", said Prof. Hartmut Zabel. Whether both tops rotate in the same or in the opposite direction, should have no impact on the number of rotations before they come to a stop. "But that's precisely what happens with magnetic spinning tops", as Bochum's research group confirmed in its experiments.

Magnetic rotation in the gigahertz range

Once triggered, the magnetic moments rotate in a crystal lattice until their rotation energy is exhausted through excitation of lattice vibrations and spin waves. Spin waves are excitations of the magnetic moments in a crystal, which propagate in form of waves. The research team separated two ultra-thin magnetic layers with a layer of copper. The copper layer was made thick enough that the two ferromagnetic layers can have no influence on each other - at least no static influence. However, once one of the two ferromagnetic layers is stimulated to a very fast precession in the gigahertz range, the damping of the precession depends of the orientation of the second magnetic layer. If both layers have the same orientation, then the damping is lower. If both are oriented in opposite directions, then the damping is higher.

Dynamic interaction

Up to now, it had not been possible to research the effect described as "spin-pumping" experimentally. The scientists have now been able to demonstrate the effect in the ALICE test chamber built by RUB physicists in Berlin. The precession of the magnetic moments in a ferromagnetic layer is "pumped" through the non-magnetic intermediate copper layer and absorbed by the second ferromagnetic layer. In other words, ferromagnetic layers, which do not interact with each other statically because the intermediate layer is too thick, are still able to "affect" each other dynamically through pumping and diffusion of spins from one layer to another.

A typical "spin valve" in data storage

The sequence of layers selected in the experiment is that of a typical spin valve. These are nano-magnetic layer structures which are used as magnetic sensors in the read heads of hard disks and which encode the logical bits "0" and "1" in non-volatile magnetic data storage. The speed at which data can be read and written, depends crucially on the precession of the magnetic moments and their damping. "Therefore, the finding that the damping of the magnetic precession is influenced by spin pumping through non-magnetic intermediate layers is not only of fundamental but also of practical interest for industrial applications" said Professor Zabel.

More information: R. Salikhov, R. Abrudan, F. Brüssing, St. Buschhorn, M. Ewerlin, D. Mishra, F. Radu, I. A. Garifullin, and H. Zabel, "Precessional Dynamics and Damping in Co/Cu/Py Spin Valves", *Applied Physics Letters* Vol. 99, 092509 (2011), DOI: 10.1063/1.3633115

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