A direct view on spin-waves

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Spin-waves are promising candidates for future information processing schemes as there is almost no frictional heating in magnetic transport. Information encoding, however, is only possible in spin-wave packets. A group of CUI researchers has succeeded in creating and capturing such defined wave-packets in slow-motion videos. The team describes its experimental set-up for uncovering the ultrafast processes in the interdisciplinary journal *Scientific Reports*. In addition, the experiment generated a wave-motion which approaches the excitation region from a distance rather than emerging out of it. The motion contradicts human intuition similar to a "moonwalk".

"A recent great vision is to use spin-waves for information transfer and processing," says Dr. Philipp Wessels from the Center for Optical Quantum Technologies (ZOQ) of Universität Hamburg. The advantage of magnetic transfer to conventional electronics is that there is almost no frictional heat load. Currently, the heat load imposes serious limitations in building smaller and faster circuits for computer processors and mobile phones. Due to the coupling of the magnetic moments, spin-waves move nearly frictionless. But only spatially and temporally confined spin-waves in form of spin-wave packets may encode information. Wessels: "Our set-up is able to directly launch such wave-packets and enables a full characterization of all dynamical parameters."

The measurements done by the scientists of the CUI groups headed by Prof. Markus Drescher (Universität Hamburg) and Dr. Guido Meier (Max Planck Institute for Structure and Dynamics of Matter) show the emergence of a spin-wave: Thereby the scientists tilt the magnetic moments of the atoms in the sample with a very short and intense magnetic field pulse. The tilted "compass needles" then start precessing and this motion is transferred to the neighboring elementary magnets. Thus a magnetic Mexican wave spreads and a spin-wave packet is born. The motion of the magnetic moments is captured by the pump-probe technique using femtosecond laser pulses.

A video directly shows how the Mexican wave spreads: The tilt of the magnetic elements (Mz) is presented with respect to space (x and y) and time. After excitation in the source region (x ≈ 5 µm) the magnetic moments start precessing and subsequently the oscillation is transferred to the right. The depicted sequence originally lasts for 1.5 nanoseconds and was captured using 300 femtosecond short laser pulses; the ultra-slow-motion movie features 200 billion frames per second. Due to the high spatial resolution of 500 nanometers also very small structures can be observed with the instrument.

Additional information: Didactic videos on forward and backward volumes

The videos demonstrate how the wave packets propagates from the source to the right in both cases. In the above version the wave front moves with the wave package, in the second version it moves towards the package.

More information: Philipp Wessels et al. Direct observation of isolated Damon-Eshbach and backward volume spin-wave packets in ferromagnetic microstripes, *Scientific Reports* (2016). DOI: 10.1038/srep22117

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