Ultrafast tracking of electron spins

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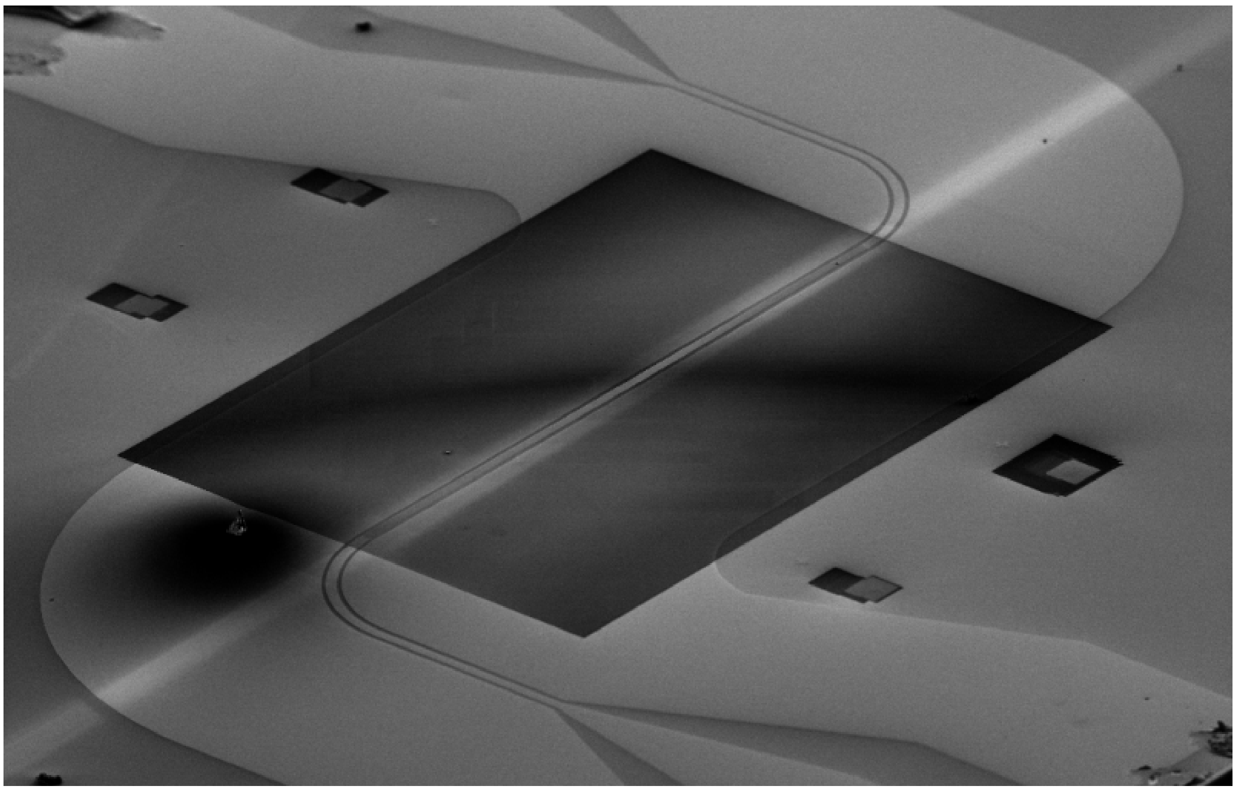

A microscope image of the magnetic sample, showing the bright track of the X-ray beam. Credit: Lars Bocklage/DESY

Our present digital information processing and storage is based on two properties of the electron. The first is its charge, which is used in electronic circuits to process information. The second is its spin, which represents the information stored on a magnetic hard disk. Recent research attempts to make use of the charge and the spin of the electron simultaneously. This approach could enhance functionality, capacitance, energy consumption and speed of today's information technology.

Researchers from DESY, from the Max-Planck-Institute for Structure and Dynamics of Matter, and from the University of Hamburg have now made a big step towards tracking the spin at very high frequencies that are technologically important. The team used the extremely brilliant X-rays generated at DESY's PETRA III facility, to read out a nuclear sensor placed in the investigated magnetic material. In this way they could determine the motion of the, as the researchers report in the journal *Physical Review Letters*.

"The actual orbit of the spin is important as it determines many of the spin related effects that are under research now and proposed for new functional devices", explains main author Lars Bocklage from DESY, who is also a member of the Hamburg Centre for Ultrafast Imaging (CUI). "Especially for data processing and mobile communication high frequencies are of importance. But even the fastest microscopy techniques available to determine spin motions reach their limit when it comes to the Gigahertz regime used in the present experiment." A Gigahertz corresponds to a billion cycles per second.

The trick in the new work is the use of a certain isotope of iron that contains one neutron more than the most prevalent iron isotope in nature. It can absorb X-rays of a specific energy, but reemits the X-ray after a very short time. This technique is called nuclear resonant scattering. The team around Bocklage found out in which way the X-ray emission is influenced by the motion of the spin. "This way the spin leaves a fingerprint in the photons emitted from the iron isotope, and the orbit of the spin can be identified," explains Bocklage.

The system that was investigated is a 13 nanometres (millionths of a millimetre) thin ferromagnetic film of nickel and iron, an alloy called

Permalloy. The material was excited with an external magnetic high-frequency field that initiates a precession of the spins. This means the spin axes reel like a child's top that has been nudged sideways. The exact motion of the spin was not known up to now. The investigations show that the shape and the amplitude can be precisely determined.

"The spins perform an elliptical motion in the thin film which has many implications for the research fields of spintronics, spincaloritronics, and magnonics as well as for the theoretical models that describe spin related effects," reports Bocklage. "With the given nuclear scattering technique and the findings on the spin motion, systems can be tuned to optimize the orbit of the spin and with it the functionality of future spin-based devices."

More information: "Spin Precession Mapping at Ferromagnetic Resonance via Nuclear Resonant Scattering of Synchrotron Radiation"; *Physical Review Letters*, 2015; DOI: 10.1103/PhysRevLett.114.147601

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