Antiferromagnets are suitable for transporting spin waves over long distances, study finds

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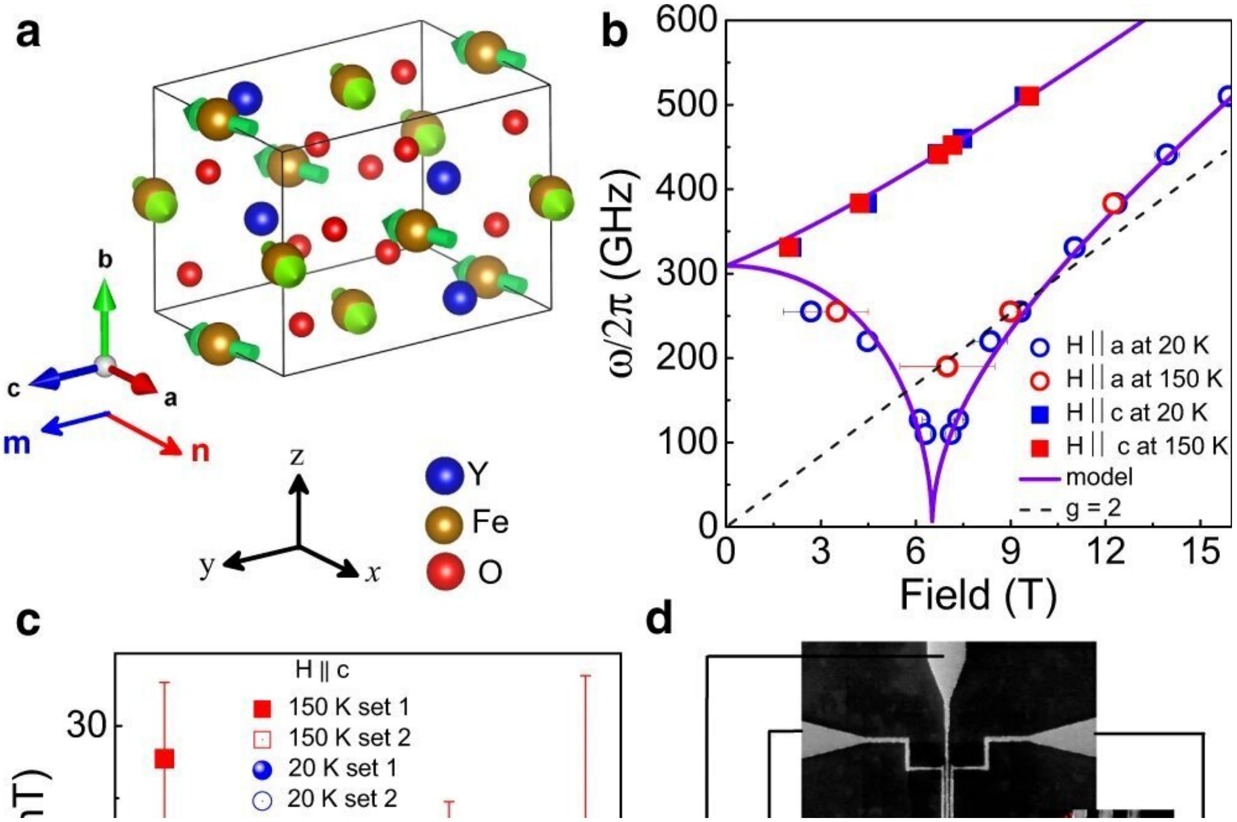

Crystal structure, magnetic resonance and the device. a Crystal structures of YFeO3[010], where the nearest neighbour Fe-ions are coupled antiferromagnetically along the easy-axis ([100] a-axis) and the moments are slightly canted along the c-axis which yield a net weak magnetization directed parallel to the c-axis. The arrows in the structure indicate the direction of spins of the Fe ions. b Resonance frequency as a function of magnetic field along a-axis (open symbol) and c-axis (closed symbol) for two different temperatures, 20

K in blue and 150 K in red. The model parameters for the fits are μ_0H_E=635T, μ_0H_a=0.19T, μ_0H_b=0.7 and μ_0H_{DMI}=12T. The g = 2 line shows the frequency of a potential spurious paramagnetic resonance. c Linewidth as a function of frequency for the configuration of H along c-axis at 20 K and 150 K. The open and closed symbols correspond to data taken separately, after removal and reintroduction of the sample, to test reproducibility. The solid solid and dashed lines are the theoretical fitting using the model from Fink, which yields damping coefficients of 3.5 ± 0.4 × 10−6 and 3.4 ± 0.3 × 10^{-6} for the two sets of data at 20 K and 6.2 ± 0.3 × 10^{-6} and 4.6 ± 0.5 × 10^{-6} for 150 K. The extracted parameters from (b), μ_0H_E, μ_0H_a, μ_0H_b and μ_0H_{DMI} are used in this model. d SEM image of a typical device, where the charge current is driven along the middle wire and the non-local voltages are measured in both wires to the left and right of it. We associate orthogonal coordinates with the crystallographic axes: $x \parallel a$, $y \parallel c$, $z \parallel b$. Credit: *Nature Communications* (2022). DOI: 10.1038/s41467-022-33520-5

Smaller, faster, more powerful: The demands on microelectronic devices are high and are constantly increasing. However, if chips, processors and the like are based on electricity, there are limits to miniaturization. Physicists are therefore working on alternative ways of transporting information, such as quantized spin waves, also called magnons, for example.

The advantage would be that they have very little energy loss and can therefore spread over long distances. However, spin waves do not form in just any material, they need certain properties to do so. Hematite, for example, the main component of rust, offers these properties.

New material class for spin wave transport

In an EU project together with the Université Paris-Saclay, Shanghai University and Université Grenoble Alpes, physicists at Johannes

Gutenberg University Mainz (JGU) have now been able to develop a completely new class of materials for transporting spin waves: antiferromagnets with tilted magnetic moments.

"These materials have the potential to increase computing speed significantly compared to existing devices and at the same time greatly reduce waste heat," said Felix Fuhrmann of Mainz University. In the antiferromagnets, the spin waves and thus the information stored in them can be transported over long distances—a distance of around 500 nanometers is possible.

It may not sound like much, but transistors in chips today are usually only about seven nanometers in size, so the range of the spin waves is significantly greater than the distance required. "The transport of information over long distances is crucial for an application in microelectronic devices. With the antiferromagnets, we have found a material class that offers this important property and thus opens up a large pool of materials that can be used for devices," said Fuhrmann.

An external magnetic field as enabler

The scientists examined the canted antiferromagnet yttrium iron oxide, $YFeO_3$. Since its crystal structure differs fundamentally from that of the established hematite, the researchers initially asked themselves whether spin waves can still form and propagate—and found out that they definitely can.

A little trick makes it possible: the physicists apply an external magnetic field to the material. "Magnons are a collective excitation of the magnetic moments in a magnetically ordered crystal. They can therefore be manipulated by magnetic fields, as we were able to successfully demonstrate," said Fuhrmann.

The research was recently published in *Nature Communications*.

More information: Shubhankar Das et al, Anisotropic long-range spin transport in canted antiferromagnetic orthoferrite $YFeO_3$, *Nature Communications* (2022). DOI: 10.1038/s41467-022-33520-5

Provided by Universitaet Mainz

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