QUANTUM PHYSICS

Researchers want to use antiferromagnet as magnetic storage

Antiferromagnetic materials could store data in an energy-saving and stable manner – but reading them out has been impossible so far. Researchers have found an easy way.

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Unlike a magnet, antiferromagnetic materials do not exhibit a magnetic field macroscopically.

Externally, antiferromagnetic materials [https://de.wikipedia.org/wiki/Antiferromagnetismus] do not exhibit a magnetic field after being exposed to another field. At the atomic level, however, the situation is different: The individual atoms have a magnetic spin, but it is oppositely aligned in neighboring atoms. Macroscopically, the effects cancel each other out, but they can lead to unexpected material properties. One trigger is quantum metrics, which describes the distance between adjacent wave functions [https://www.science.org/doi/10.1126/science.adf1506] . Researchers at Nanyang Technological University in Singapore succeeded for the first time in reading out quantum metrics [https://phys.org/news/2023-08-antiferromagnets-memory.html] .

For their experiments, the researchers needed a special material to rule out other influences such as Berry curvature [https://en.wikipedia.org/wiki/Berry_connection_and_curvature] . A crystal of manganese, bismuth and tellurium ($MnBi_2Te_4$) proved promising. The material consists of even, staggered layers. Within one layer, the spin of the manganese atoms is the same, with two superimposed ones opposite. Thus, only crystals with an even-numbered number of layers are antiferromagnetic.

Quantum metrics, as already indicated above, describes the ratio of the orientation of the spins of the individual planes. It indicates whether the magnetic spin of layer n, to put it simply, points upwards, that of layer n+1 points downwards – or vice versa. The spin can be set via an externally applied magnetic field, but a change requires a flux density of several Tesla.

Spins deflect electrons

For their experiments, the researchers prepared crystals with a thickness of only four layers on a silicon wafer. They contacted the crystals and allowed an alternating current to flow. Their expectation: If the crystal is antiferromagnetically polarized, a new alternating voltage should be measurable transversely to the direction of flow of the applied current.

As expected, measurements showed a new AC voltage component with twice the frequency of the applied current. Similar to a diode, it does not behave linearly – this is often observed in quantum effects. The new alternating voltage increases disproportionately strongly compared to the measurement signal. Their sign depends on the quantum metric, i.e. the orientation of the spin of the individual layers. It occurs both in the direction of the applied field and transversely to it and is strongly pronounced compared to similar nonlinear effects.

Antiferromagnets like it cold

However, there are still a few challenges to be overcome before antiferromagnetic materials can be used in practice. The largest is that the materials are only antiferromagnetic below the so-called Néel temperature. If it gets too warm, they become paramagnetic, and the spins of the atoms align themselves arbitrarily.

The Néel temperature is material-dependent, the $MnBi_2Te_4$ used lost its antiferromagnetic properties at 20 Kelvin. The researchers carried out the measurements at 1.8 Kelvin, just above absolute zero. At least this material is not suitable for a practical application as storage – but it provides new insights into quantum mechanical effects that were previously only suspected.

The researchers have published their findings in the journal Nature [https://www.nature.com/articles/s41586-023-06363-3] , and a preprint (PDF) [https://arxiv.org/pdf/2306.09285.pdf] can be found at Arxiv. ■

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