Spin wave detective story redux: Researchers find more surprising behavior in a 2-D magnet

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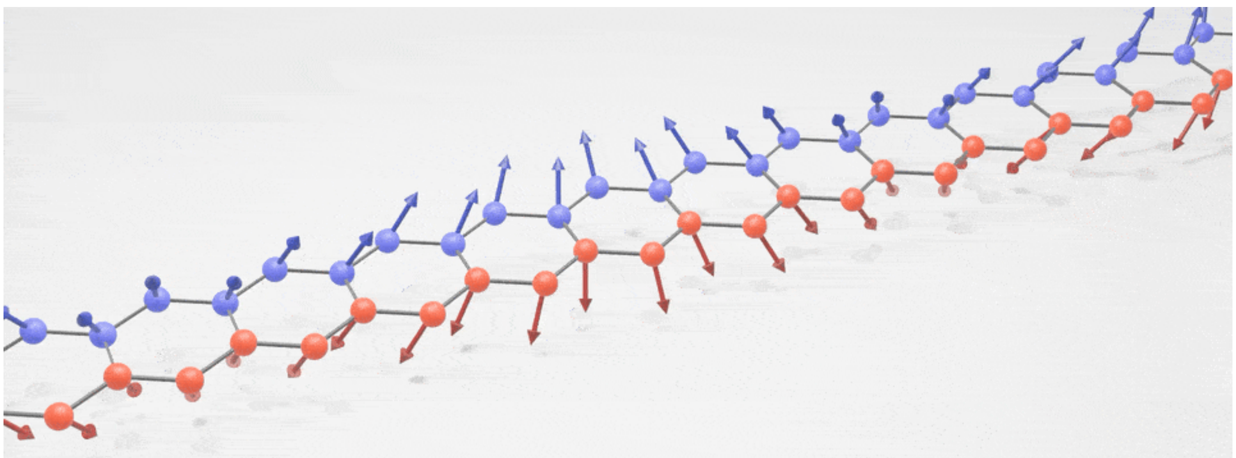

Vibrations in a lattice: This is an illustration of quantized lattice vibrations in a material, where the word 'quantized' is used to mean that only certain frequencies of vibrations are allowed. In this animation, you can see how this vibration propagates through the structure of a one-dimensional (1-D) chain of atoms, with some atoms getting closer to each other, then farther away, as the material vibrates. Credit: Sean Kelley/NIST

A few months ago, a team of scientists from the National Institute of Standards and Technology (NIST) reported something surprising about a 2-D magnetic material: Behavior that had long been presumed to be due to vibrations in the lattice—the internal structure of the atoms in the material itself—is actually due to a wave of spin oscillations.

This week, the same group describes another surprise finding in a different 2-D magnetic material: Behavior presumed to be due to a wave of spin oscillations is actually due to vibrations in the lattice.

The work, published in *Nature Communications*, is further evidence that the NIST team's unique experimental capabilities play a pivotal role as an investigative tool for scientists studying these 2-D magnets.

Waves of spin oscillations involve changes to a quantum property of atoms called spin; the feature that makes magnets magnetic. If you think of each atom as being a compass, then spin is (metaphorically) the needle of the compass. In this metaphor, however, the spin can point both north (up) and south (down). In some materials, spin can "flip" from one metaphorical direction to another.

The experiment employed Raman spectroscopy, a technique that probes a sample with laser light and then measures how that light is scattered by the sample. This can reveal information about a 2-D material such as its structure, defects, doping, number of layers and coupling between the layers, and more. The custom-engineered Raman system at NIST adds the ability to simultaneously track the scattered light as a function of both temperature and magnetic field.

Manipulating the temperature and magnetic field while measuring the Raman signal allows scientists to identify whether they are observing lattice vibrations or spin waves. Furthermore, in this new paper researchers report that they can track spins within a single layer as the spins "flip" to a new direction.

Scientists know that the behavior they found is intrinsic to the material itself because Raman spectroscopy allows them to investigate the 2-D material noninvasively, without the addition of electronic contacts that could influence the results.

"Our data show clear features that identify a magnetic phase transition in the material using light as a probe," Hight Walker said. "Layer by layer, we observe spins changing their direction."

The Importance of 2-D Magnets

Some materials are composed of layers that interact very weakly, which allows scientists to pull apart or isolate individual layers and access atomically thin (on the order of a few nanometers) 2-D sheets. For example, graphene was the first 2-D material isolated from graphite by using an adhesive surface to peel off a single layer one atom thick.

These materials are called 2-D because, while they can be relatively wide—on the scale of micrometers—they are also extremely thin—as thin as a single atom or 100,000 times smaller than a human hair. That property allows for more customizability than 3-D materials. Dramatic differences can be seen between one and even as few as two layers of the same material.

But until recently, no one thought layered materials could be magnetic when you reduce their size down to the 2-D limit. Then, just a couple of years ago, it was discovered that some of them could, in fact, keep their magnetic behavior in a single layer, and 2-D magnets became a hot topic of research.

The NIST-led work, done in collaboration with scientists from The Ohio State University, Towson University, Penn State University, the University of Arkansas, and the National Institute of Materials Science in Japan, involves a 2-D material called chromium triiodide (CrI3), which has promising properties that could someday be manipulated to make devices useful for quantum computing.

The more that scientists learn about these 2-D materials, the closer they are to realizing potential applications, especially in next generation electronics and even quantum information.

More information: Amber McCreary et al. Distinct magneto-Raman signatures of spin-flip phase transitions in CrI3, *Nature Communications* (2020). DOI: 10.1038/s41467-020-17320-3

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