X-ray holograms reveal secret magnetism（图）

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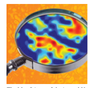
[摘要] May 2, 2007，The May 2 issue of the journal Nature reveals how collaboration between scientists in the United States and the United Kingdom has led to a major breakthrough in the understanding of antiferromagnets, which could help spur their exploitation for information technology or other products.

[关键词] antiferromagnets;X-ray



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The May 2 issue of the journal Nature reveals how collaboration between scientists in the United States and the United Kingdom has led to a major breakthrough in the understanding of antiferromagnets, which could help spur their exploitation for information technology or other products.

Scientists at the Center for Nanoscale Materials at Argonne National Laboratory, the London Centre for Nanotechnology and the University of Chicago have exploited a technique called X

-ray photon correlation spectroscopy to see the internal workings of antiferromagnets, such as the metal chromium, for the very first time.

“The strong connections between the University of Chicago and Argonne National Laboratory helped coalesce the right people at the right facility to be able to image this hidden order and describe both its classical and quantum behavior,” said Thomas Rosenbaum, a co

-author of the article and the John T. Wilson Distinguished Service Professor in Physics at Chicago.

Unlike conventional magnets, antiferromagnets are materials that exhibit “secret” magnetism that is not detectable at the classical—

or macroscopic—

level. Instead, their magnetism is confined to very small regions where atoms behave as tiny magnets by spontaneously aligning themselves oppositely to adjacent atoms, thus neutralizing the overall magnetism of the material.

“People have been familiar with ferromagnets for hundreds of years and they are being used in everything from driving electrical motors to storing the information in hard disk drives,” said Gabriel Aeppli, Director of the London Centre for Nanotechnology. “But we haven’t been able to make the same strides forward with antiferromagnets because, until relatively recently, we couldn’t look inside them to see how they

The magnetic characteristics of ferromagnets have been studied by scientists since Greek antiquity, enabling them to build up a detailed picture of the regions, or “magnetic domains,” into which they are divided. However, antiferromagnets remained a mystery because their internal structure is far too fine to be measured using visual inspection techniques.

The internal order of antiferromagnets is on the same scale as the wavelength of X-rays, below 10 nanometers. X-

rays have now been used to produce a “speckle” pattern that is actually a hologram, or more loosely speaking, a fingerprint of a particular magnetic domain configuration.

“Since the discovery of X-

rays over 100 years ago, it has been the dream of scientists and engineers to use them to make holographic images of moving objects, like magnetic domains, at the nanoscale,” said Eric D. Isaacs, Director of the Center for Nanoscale Materials. “This has only become possible in the last few years with the availability of coherent X

-

ray sources, such as the Advanced Photon Source, and the future looks even brighter with the development over the next few years of fully coherent X

-ray sources called free electron lasers.”

In addition to producing the first holograms of an antiferromagnet, the research revealed that the holograms actually evolve with time, even down to the lowest temperatures. This research implies that the antiferromagnet is never truly at rest, and the responsibility for this most likely lies with quantum mechanics, the laws of physics that govern the atomic and subatomic worlds.

Quantum mechanics imposes uncertainties not only on conventional particles such as electrons and atoms, but also on objects such as magnetic domain wallsÑthe boundaries between two adjacent regions with different magnetic orientation. The new experiments thus help to open the prospect of exploiting antiferromagnets in emerging technologies such as quantum computing.

“The key finding of our research provides information on the stability of domain walls in antiferromagnets,” said Oleg Shpyrko, lead author on the publication and researcher at the Center for Nanoscale Materials. “Understanding this is the first step towards engineering antiferromagnets into useful nanoscale devices that exploit it.”

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