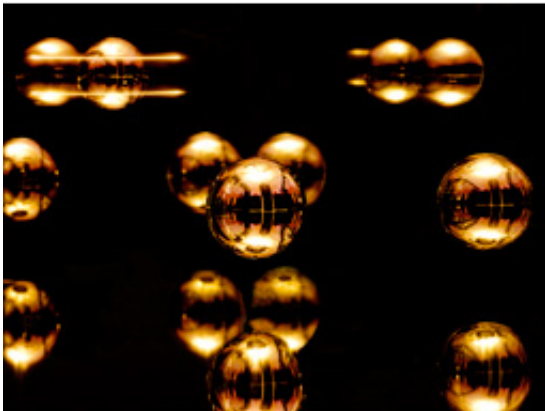


Smallest atomic displacements ever observed

September 1 2011



Femtосcale atomic displacements in crystals play a big role in the electronic properties of exotic multiferroics materials, generating a mutual interaction between magnetic and ferroelectric macroscopic properties, of potential interest in the domain of advanced magnetic material for electronics. These materials combine both the crystallographic and magnetic symmetries to produce oriented displacements of atomic positions, as pictorially represented in the art image, leading to a control of electric polarization by a magnetic field and viceversa. (Credit: Ghiandoni/Paolasini)

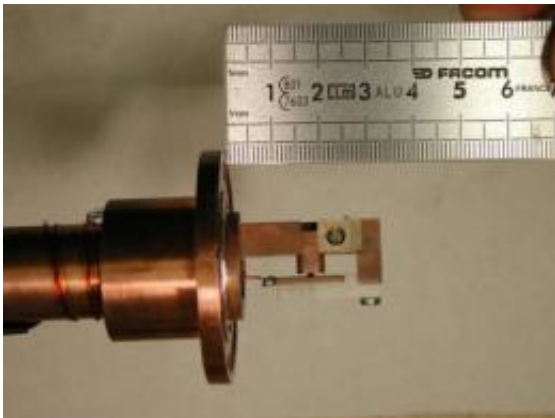


This photo shows the experimental set-up at ESRF beamline ID20, with the cryostat of a large superconducting magnet in the upper part. The experiment took place in the gray disk-shaped chamber between the two blue split-coils of the magnet. The polarized X-ray beam is led to the experiment in the long steel tube from the right. The detector arm to the left can rotate about the cryostat and may be tilted up and down. It detects scattered X-rays, and in the circular chamber at its end is an analyzer crystal to determine also the polarization state of the scattered X-ray beam. Credit: Image courtesy of Luigi Paolasini.

An international team of scientists has developed a novel X-ray technique for imaging atomic displacements in materials with unprecedented accuracy. They have applied their technique to determine how a recently discovered class of exotic materials – multiferroics – can be simultaneously both magnetically and electrically ordered. Multiferroics are also candidate materials for new classes of electronic devices. The discovery, a major breakthrough in understanding multiferroics, is published in *Science* dated 2 September 2011.

The authors comprise scientists from the European Synchrotron Radiation Facility (ESRF) in Grenoble (France), the University of Oxford and the University College London (both UK). Helen Walker from the ESRF is the main author of the publication.

Everybody is familiar with the idea that magnets are polarized with a north and a south pole, which is understood to arise from the alignment of magnet moments carried by atoms in magnetic materials. Certain other materials, known as ferroelectrics, exhibit a similar effect for electrical polarisation. The exotic "multiferroic" materials combine both magnetic and ferroelectric polarizations, and can exhibit a strong coupling between the two phenomena.



This photo shows the sample holder, made of copper, which was used in the experiment. The small gray crystal of TbMnO₃ that was studied, is in the center, between two electrodes to apply an electric field. Credit: Image courtesy of Luigi Paolasini.

This leads to the strange effect that a magnetic field can electrically polarise the material, and an electric field magnetise it. A class of strong multiferroics was discovered ten years ago and has since led to a new,

rapidly growing field of research, also motivated by the promise of their exotic properties for new electronic devices. One example is a new type of electronic memory, in which an electric field writes data into the memory and a magnetic detector is used to read it. This process is faster, and uses less energy than today's hard disk drives.

However, the origin of the electric polarisation in multiferroics remained mostly elusive to date. The team's work unambiguously shows that the polarization in the multiferroic studied proceeds from the relative displacement of charges of different signs, rather than the transfer of charge from one atom to another.

As the displacement involves a high number of electrons, even small distances can lead to significant polarisation. The actual distance of the displacement still came as a surprise: about 20 femtometres, or about 1/100,000th of the distance between the atoms in the material. Measuring such small displacements was actually believed to be impossible.



The European Synchrotron Radiation Facility is located in Grenoble, France. The experiments were performed using beams of X-rays provided by one of the world's most brilliant light sources. Credit: ESRF

"I think that everyone involved was surprised, if not staggered, by the

result that we can now image the position of atoms with such accuracy. The work is testament to the fantastic facilities available in Grenoble to the UK science community," says Prof. Des McMorrow, Deputy Director of the London Centre for Nanotechnology, leader of the UCL part of the project.

Walker and her colleagues developed a smart new experimental technique exploiting the interference between two competing processes: charge and magnetic scattering of a powerful, polarized X-ray beam. They studied a single crystal of TbMnO₃ which shows a strong multiferroic coupling at temperatures below 30K, and were able to measure the displacements of specific atoms within it with an accuracy approaching one femtometre (10-15m). The atoms themselves are spaced apart 100,000 times this distance.

The new interference scattering technique has set a world record for accuracy in absolute measurements of atomic displacements. (It is also the first measurement of magnetostriction in antiferromagnets.) Most significantly the identification of the origin of ferroelectricity in a multiferroic material is a major step forward in the design of multiferroics for practical applications.

"By revealing the driving mechanism behind multiferroics, which offer so many potential applications, it underlines how experiments designed to understand the fundamental physics of materials can have an impact on the wider world," concludes Dr. Helen Walker who led the work at the ESRF.

Provided by European Synchrotron Radiation Facility

Citation: Smallest atomic displacements ever observed (2011, September 1) retrieved 17 July 2024 from <https://phys.org/news/2011-09-smallest-atomic-displacements.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.