IBM breakthrough captures high speed measurements of individual atoms

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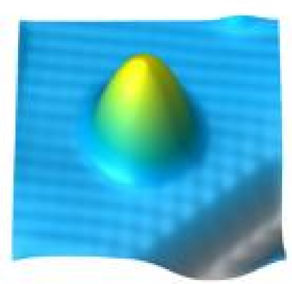

CuN and atom. Scanning tunneling microscope topograph of an iron atom (yellow bump) on a nitride-covered substrate (blue) which may someday enable single-atom bit-cells for memory chips. Next to the iron atom is a one-atom-high step in the nitride surface (grey).

(PhysOrg.com) -- Last week IBM researchers published a breakthrough technique in the peer-reviewed journal *Science* that measures how long a single atom can hold information, and giving scientists the ability to record, study and "visualize" extremely fast phenomena inside these atoms.

Just as the first motion pictures conveyed movement through high-speed photography, scientists at IBM Research - Almaden are using the Scanning Tunneling Microscope like a high-speed camera to record the behavior of individual atoms at a speed about one million times faster than previously possible. IBM researchers in Zurich invented the Scanning Tunneling Microscope in 1981 and were awarded with the Nobel Prize.

For more than two decades IBM scientists have been pushing the boundaries of science using the Scanning Tunneling Microscope to understand the fundamental properties of matter at the atomic scale, with vast potential for game-changing innovation in information storage and computation.

The ability to measure nanosecond-fast phenomena opens a new realm of experiments for scientists, since they can now add the dimension of time to experiments in which extremely fast changes occur. To put this into perspective, the difference between one nanosecond and one second is about the same comparison as one second to 30 years. An immense amount of physics happens during that time that scientists previously could not see.

"This technique developed by the IBM Research team is a very important new capability for characterizing small structures and understanding what is happening at fast time scales," said Michael Crommie, University of California, Berkeley. "I am particularly excited by the possibility of generalizing it to other systems, such as photovoltaics, where a combination of high spatial and time resolution will help us to better understand various nanoscale processes important for solar energy, including light absorption and separation of charge."

In addition to allowing scientists to better understand the nanoscale phenomena in solar cells, this breakthrough could be used to study areas such as:

• Quantum computing. Quantum computers are a radically different type of computer - not bound to the binary nature of traditional computers - with the potential to perform advanced computations that are not possible today. With today's breakthrough, scientists will have a powerful new way to explore the feasibility of a novel approach to quantum computing through atomic spins on surfaces.

• Information storage technologies. As technology approaches the atomic scale, scientists have been exploring the limits of magnetic storage. This breakthrough allows scientists to “see” an atom’s electronic and magnetic properties and explore whether or not information can be reliably stored on a single atom.

How it Works

Since the magnetic spin of an atom changes too fast to measure directly using previously available Scanning Tunneling Microscope techniques, time-dependent behavior is recorded stroboscopically, in a manner similar to the techniques first used in creating motion pictures, or like in time lapse photography today.

Using a “pump-probe” measurement technique, a fast voltage pulse (the pump pulse) excites the atom and a subsequent weaker voltage pulse (the probe pulse) then measures the orientation of the atom's magnetism at a certain time after excitation. In essence, the time delay between the pump and the probe sets the frame time of each measurement. This delay is then varied step-by-step and the average magnetic motion is recorded in small time increments. For each time increment, the scientists repeat the alternating voltage pulses about 100,000 times, which takes less than one second.

In the experiment, iron atoms were deposited onto an insulating layer only one atom thick and supported on a copper crystal. This surface was selected to allow the atoms to be probed electrically while retaining their magnetism. The iron atoms were then positioned with atomic precision next to non-magnetic copper atoms in order to control the interaction of the iron with the local environment of nearby atoms.

The resulting structures were then measured in the presence of different magnetic fields to reveal that the speed at which they change their magnetic orientation depends sensitively on the magnetic field. This showed that the atoms relax by means of quantum mechanical tunneling of the atom's magnetic moment, an intriguing process by which the atom's magnetism can reverse its direction without passing through intermediate orientations. This knowledge may allow scientists to engineer the magnetic lifetime of the atoms to make them longer (to retain their magnetic state) or shorter (to switch to a new magnetic state) as needed to create future spintronic devices.

"This breakthrough allows us - for the first time - to understand how long information can be stored in an individual atom. Beyond this, the technique has great potential because it is applicable to many types of physics happening on the nanoscale," said Sebastian Loth, IBM Research. "IBM's continued investment in exploratory and fundamental science allows us to explore the great potential of nanotechnology for the future of the IT industry."

Source: IBM

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