Electron Motion Filmed

LUND, Sweden, Feb. 28, 2008 -- ***An electron's rapid motion has been filmed for the first time***, with **attosecond** laser pulses showing how an electron rides a light wave after being separated from an atom.

Until now it has been impossible to photograph electrons, since their extremely high velocities result in blurry pictures. The movie of electron motion was created by scientists at Lund University in Sweden. Their method involved using a stroboscope and a laser that generates the extremely short light pulses needed to capture the movement of an electron once it is pulled away from an atom.

"It takes about 150 attoseconds for an electron to circle the nucleus of an atom. An attosecond is 10-18 seconds long, or, expressed in another way, an attosecond is related to a second as a second is related to the age of the universe," said Johan Mauritsson, an assistant atomic physics professor in the Faculty of Engineering at Lund University. He and professor Anne L'Huillier lead the seven-member research team that developed the technology.

While it has been possible to create attosecond pulses for the past several years, it is only recently that researchers have been able to successfully use them to film electron movements, since the attosecond pulses by themselves are too weak to take clear pictures. Scientists have previously relied on indirect methods to study electron movement, such as by metering their spectrum, which only measures the result of the movement. Now researchers can observe the entire event.

In addition to the attosecond laser pulse that helped capture the image, the researchers used a second laser to successfully guide the motion of the electron so they could capture the collision of an electron and an atom on film.

"We have long been promising the research community that we will be able to use attosecond pulses to film electron motion. Now that we have succeeded, we can study how electrons behave when they collide with various objects, for example. The images can function as corroboration of our theories," Mauritsson said.

They also hope to reveal more about what happens inside an atom when a single electron leaves -- how and when the other electrons fill in the resulting gap.

"What we are doing is pure basic research. If there happen to be future applications, they will have to be seen as a bonus," Mauritsson said.

The length of the film corresponds to a single oscillation of the light, but the speed was slowed down considerably for the event to be seen by the human eye. The filmed sequence shows the energy distribution of the electron (See the movie here).

"By taking several pictures of exactly the same moment in the process, it's possible to create stronger, but still sharp, images. A precondition is for the process to be repeated in an identical manner, which is the case regarding the movement of an electron in a ray of light. We started with a so-called stroboscope. A stroboscope enables us to 'freeze' a periodic movement, like capturing a hummingbird flapping its wings. You then take several pictures when the wings are in the same position, such as at the top, and the picture will turn out clear, despite the rapid motion," Mauritsson said.

The research appears in *Physical Review Letters.*

Attosecond pulses and pulse trains give us a tool to study how light interacts with matter at a detailed level never possible before! Attosecond science is in its birth stage, representing a great challenge. Not surprisingly, attosecond pulses are now the "hottest" topic of strong field laser physics and possible applications are raising equally great interest in the scientific community. The vision is that the generation of attosecond pulses will become a new tool for fundamental studies of electronic processes at the natural time scale, the attosecond time scale (one atomic unit is 24 attoseconds) and atomic dimensions. Thus atomic, molecular and even nuclear physics will be investigated on these atomic scales, bringing a revolution in our microscopic knowledge and understanding of matter.

There is much excitement about the accomplishment and the promise Chang's work holds for helping scientists understand how the world's smallest building blocks actually work. The technique could lead scientists to understand how energy can be harnessed to transport data, deliver targeted cancer therapies or diagnose disease. The finding marks the first significant breakthrough in the laser pulse field in four years.

How Big Is A Petabyte, Exabyte, Zettabyte, Or A Yottabyte?

By Julian Bunn in Globally Interconnected Object Databases.

Bytes(8 Bits)

- 0.1 bytes: A binary decision
- 1 byte: A single character
- 10 bytes: A single word
- 100 bytes: A telegram OR A punched card

Kilobyte (1000 Bytes)

- 1 Kilobyte: A very short story
- 2 Kilobytes: A Typewritten page
- 10 Kilobytes: An encyclopaedic page OR A deck of punched cards
- 50 Kilobytes: A compressed document image page
- 100 Kilobytes: A low-resolution photograph
- 200 Kilobytes: A box of punched cards
- 500 Kilobytes: A very heavy box of punched cards

Megabyte (1 000 000 Bytes)

- 1 Megabyte: A small novel OR A 3.5 inch floppy disk
- 2 Megabytes: A high resolution photograph
- 5 Megabytes: The complete works of Shakespeare OR 30 seconds of TV-quality video
- 10 Megabytes: A minute of high-fidelity sound OR A digital chest X-ray
- 20 Megabytes: A box of floppy disks
- 50 Megabytes: A digital mammogram
- 100 Megabytes: 1 meter of shelved books OR A two-volume encyclopaedic book
- 200 Megabytes: A reel of 9-track tape OR An IBM 3480 cartridge tape
- 500 Megabytes: A CD-ROM OR The hard disk of a PC

Gigabyte (1 000 000 000 Bytes)

- 1 Gigabyte: A pickup truck filled with paper OR A symphony in high-fidelity sound OR A movie at TV quality
- 2 Gigabytes: 20 meters of shelved books OR A stack of 9-track tapes
- 5 Gigabytes: An 8mm Exabyte tape
- 10 Gigabytes:
- 20 Gigabytes: A good collection of the works of Beethoven OR 5 Exabyte tapes OR A VHS tape used for digital data
- 50 Gigabytes: A floor of books OR Hundreds of 9-track tapes
- 100 Gigabytes: A floor of academic journals OR A large ID-1 digital tape
- 200 Gigabytes: 50 Exabyte tapes

Terabyte (1 000 000 000 000 Bytes)

- 1 Terabyte: An automated tape robot OR All the X-ray films in a large technological hospital OR 50000 trees made into paper and printed OR Daily rate of EOS data (1998)
- 2 Terabytes: An academic research library OR A cabinet full of Exabyte tapes
- 10 Terabytes: The printed collection of the US Library of Congress
- 50 Terabytes: The contents of a large Mass Storage System

Petabyte (1 000 000 000 000 000 Bytes)

- 1 Petabyte: 5 years of EOS data (at 46 mbps)
- 2 Petabytes: All US academic research libraries
- 20 Petabytes: Production of hard-disk drives in 1995
- 200 Petabytes: All printed material OR Production of digital magnetic tape in 1995

Exabyte (1 000 000 000 000 000 000 Bytes)

- 5 Exabytes: All words ever spoken by human beings.

Zettabyte (1 000 000 000 000 000 000 000 Bytes)

- The world's technological capacity to receive information through one-way broadcast networks was 0.432 zettabytes of (optimally compressed) information in 1986, 0.715 in 1993, 1.2 in 2000, and 1.9 (optimally compressed) zettabytes in 2007 (this is the informational equivalent to every person on earth receiving 174 newspapers per day).[9][10]

Yottabyte (1 000 000 000 000 000 000 000 Bytes)

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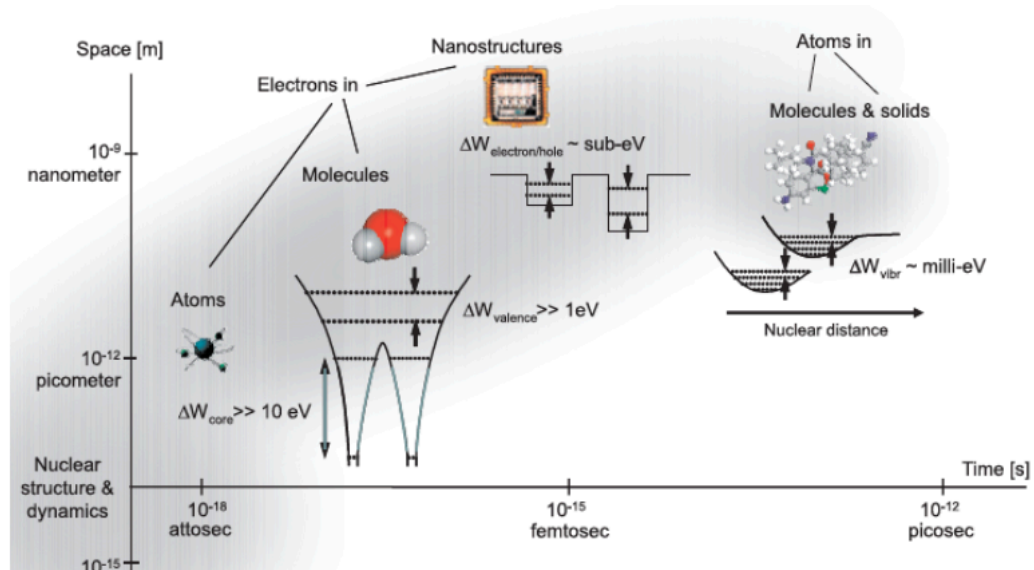
YoctoNewton Detector Smashes Force Measurement Record

A team from NIST measures the smallest force ever recorded, beating the previous best by three orders of magnitude



F. Krausz, M. Ivanov, *Reviews of Modern Physics* **81**, 163 (2009).

The International System of Units (SI) has illuminated scientific measurement since 1795 when the first six SI prefixes were introduced. These ranged from mega (10^6) to milli (10^{-6}) and served scientists well for almost two hundred years.

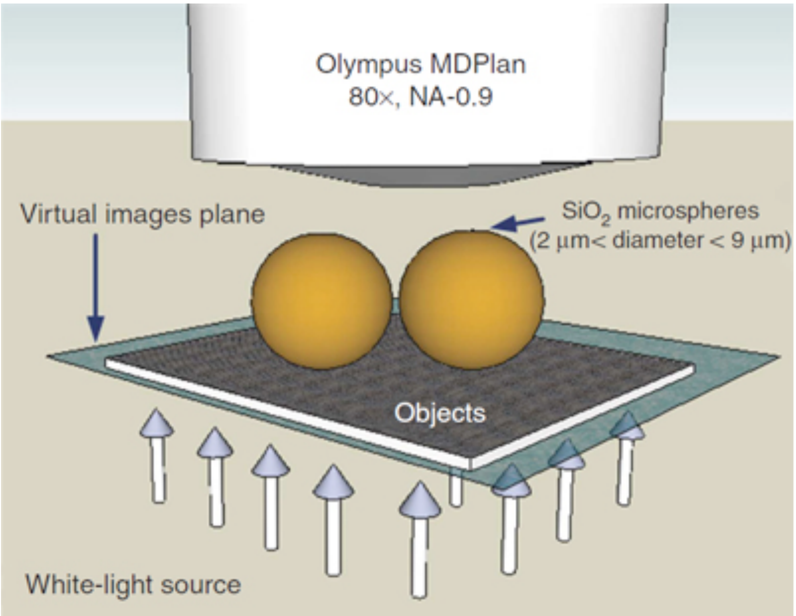
In 1960, however, the International Bureau of Weights and Measures which standardizes and regulates the system, decided that a greater range of prefixes were needed and introduced the tera (10^{12}), giga (10^{12}), nano (10^{-9}) and pico (10^{-12}) prefixes. Since then, this organization has introduced various new prefixes at either end of the scale culminating with the introduction of the yotta (10^{24}) and yocto (10^{-24}) prefixes in 1991.

These most recent prefixes have yet to be widely used but that looks set to change with the announcement today by Michael Biercuk and buddies, at the National Institute of Standards and Technology in Boulder Colorado, that they've built a device capable of detecting **yoctonewtons.**

Physics saves the Day

Microscope resolution is limited by diffraction, or the bending and spreading of light when it encounters obstacles like glass. What we see through microscopes is also restricted by cells in the eye's retina, which can only detect light with wavelengths between 390 and 750 nanometers (between violet and red colors, respectively).

These limitations prevent us from directly seeing objects smaller than 200 nanometers — just larger than a rabies virus or Mycoplasma, the smallest-known bacteria. **Physicists and engineers have circumvented the 200-nanometer barrier with electron microscopy, laser fluorescence and nanoscale metamaterials**, but they're expensive, kill live samples or are difficult to use. So Li and his colleagues sought a new method.



In one experiment with glass beads between 2 microns and 9 microns wide, they could see 50-nanometer-wide holes in gold foil, or 8 times beyond the limits of conventional microscopy. They were also able to see the tiny data grooves on a Blu-Ray disc.

"This is quite cheap and easy to implement, while the alternatives are far more expensive and complicated," Li said.

Physicist and engineer Igor Smolyaninov of the University of Maryland, who wasn't involved in the research, has used metamaterials to image objects as small as 70 nanometers in size. He doesn't think the new results are unreliable or untrue, but does see some limitations to the technique.

"They looked at artificial structures. Metal lines, holes and such. These are not a virus or bacteria, which are much, much more difficult to see because they move around," Smolyaninov said. "I tried to do this before but couldn't convince myself it was real. If they can pull it off, I'll be extremely happy."

$$l_p = \sqrt{\frac{\hbar G}{c^3}}$$