

[Phys. Rev. Lett. 100, 073003](#)

(issue of 22 February 2008)

[Title and Authors](#)**21 February 2008**

Electron Stroboscope

Researchers have recorded snapshots of electron motion at close to the particle's own natural timescale, which is less than a femtosecond (10^{-15} seconds). The experiment combines ultrashort light pulses with steady laser light to extract an electron from an atom in a controlled way. With control over the precise moment of extraction, the team was able to cleanly image the electron's quantum state, as they describe in the 22 February *Physical Review Letters*. This technique could help researchers probe electron-atom interactions in more detail and begin using electrons to observe atoms in the poorly-understood state following ionization.

One technique for controlling electron motion uses the strong, oscillating electric field of an infrared laser to ionize a cloud of atoms. During each cycle, the field points up, then down, then up again, so it can pull an electron downward and then slam it back up against its atom. The electron scatters off its atom and is then yanked to the right by a steady, sideways electric field, toward a detector. The detected positions of many electrons create an image of the electrons' motion during scattering and also provide information on the state of recently-ionized atom.

But this technique lacks precision. From an electron's point-of-view, the laser field oscillates slowly, and it pulls electrons from atoms during a range of times near the moment of peak field strength, rather than releasing them all-at-once. So the resulting image on the detector is fuzzy and represents electrons in a variety of scattering conditions.

Now a team led by Anne L'Huillier and Johan Mauritsson of Lund University in Sweden has combined this laser technique with precisely timed trains of ultrashort light pulses to cleanly image electron motion. The pulses in the train were just three



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In a flash. To capture an unblurred image of a hummingbird, you can flash a strobe light at the same frequency as its fluttering wings. A similar "stroboscope" method uses sub-femtosecond light pulses synchronized with an oscillating laser field to repeatedly ionize electrons at the same moment in the laser's cycle and get clean images.

hundred attoseconds (10^{-18} seconds) long. The researchers synchronized the pulse train with the oscillations of a relatively weak infrared laser, so that their cloud of helium atoms received a strong, ionizing "kick" at a precise time during each laser cycle. Each attosecond pulse released a few electrons, some of which were thrown back against their atoms before being pushed sideways and detected.

Accumulating data from many ionization events, the team created clean images of the quantum state of electrons ionized at a single moment in the laser oscillation cycle. The images are the first of their kind that show such controlled electron-atom scattering. The team calls their system a stroboscope, after another device that uses periodic flashes of light to capture a still image of a hummingbird's wings, for example.

Each experiment generated a "bullseye" pattern showing the locations in which electrons struck the detector plate. To demonstrate that each image represented precisely one moment during the laser cycle--rather than a range of ionization times--the team shifted the timing of the attosecond pulses with respect to the laser field cycle. If electrons were ionized at a time when the laser field gave them an extra boost upward, the pattern shifted upward; if the ionizing pulse came a half-cycle later, the bullseye shifted downward. This pattern shifting wouldn't have been possible with longer-lasting ionization periods.

The next step will be further controlling and studying electron-atom interaction in more detail, says team member Kenneth Schafer of Louisiana State University in Baton Rouge. He also hopes researchers will use electrons scattered off their atoms to observe the unsettled state of atoms immediately after ionization.

Louis DiMauro of Ohio State University in Columbus is impressed by the demonstration of precisely timed ionization and imaging. There's really no other experiment where you can visualize rescattering," he says. "These are the sorts of experiments that demonstrate that if you have these attosecond pulses you have unprecedented control over electron dynamics that we didn't have before."

--Calla Cofield

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Coherent Electron Scattering Captured By an Attosecond Quantum Stroboscope

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