**Attosecond science**

# The fast show

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**Extremely short laser pulses can illuminate electrons in motion**

ON THE atomic scale, things move mind-bogglingly quickly. Electrons jump between orbits or escape the nucleus altogether in attoseconds—that is, million, million, millionths of a second. Indeed, one attosecond is to one second what one second is to the age of the universe. Seeing such acrobatics takes wit and ingenuity, but it is possible. Moreover, if such processes could be manipulated—and the early signs are that they can be—then it would have applications in fields as far apart as computing and medicine.

A report just drafted by America's National Research Council, “Controlling the Quantum World”, outlines how scientists might manipulate the inner workings of a molecule. A long-term workshop at the Kavli Institute for Theoretical Physics, part of the University of California, Santa Barbara, is also investigating how this might be achieved. And, at a conference held recently at the institute, Ferenc Krausz of the Max Planck Institute of Quantum Optics in Garching, Germany, and Marc Vrakking of the FOM Institute for Atomic and Molecular Physics in Amsterdam described one way that it could be done.

Lasers work by creating a chain reaction in which photons of light prompt the generation of further photons. These photons are emitted in bursts. Shortening each burst sufficiently is what makes attosecond science possible. The two researchers employed what they call “high harmonic pulse generation” to create pulses a few hundred attoseconds long. They did this by using a laser that emits short pulses of light to drive a second laser that then emits even shorter pulses. In fact, the pulses are so rapid that they come close to the limit imposed by Heisenberg's famous uncertainty principle, which states that the precision of a time measurement is limited by the precision of a corresponding energy measurement.

## Atto boys

Dr Krausz and Dr Vrakking fired their laser at a molecule of deuterium. Deuterium, also known as heavy hydrogen, is a simple molecule, consisting of two atomic nuclei and two electrons. The sample under investigation became positively charged because zapping it with the laser removed one of the electrons. The researchers found that the molecule then separated into a deuterium atom, consisting of a nucleus and an electron, and a deuterium ion, consisting of a nucleus.

Using conventional laser pulses causes atoms and ions to be ejected to the right and left at random. Using ultrafast laser pulses, though, makes the atoms fly off to the right and the ions to the left. The researchers were thus able, in effect, to control on which of the two deuterium atoms the electron resides at the end of their experiment. That is to say, they had separated the atoms from the ions.

Exactly how this works is complicated—not least because all of the atoms are interacting simultaneously with the laser and with each other. But the researchers think that the laser pushes the electron, which initially binds the two atoms together, back and forth between the two ions until, at some point, the distance between the two gets too large and it is no longer able to jump from one to the other.

The ability to manipulate electrons in this way is important because electron-sharing is essential to chemical bonding. Ultrafast lasers could thus be used to change the outcome of chemical reactions. Proponents point to possible applications in magnetic information-storage devices, which would lead to much more powerful computers. Other possibilities include the development of compact, portable X-ray lasers for medical imaging that needs to be done outside hospital radiology departments, and bright ultrafast X-ray lasers for use within those departments.

The motion of electrons is the fundamental basis of chemistry. Watching the steps in the dance of the electrons will help chemists work out why some atoms bind when others do not, why reactions take the time that they do, and why some molecules bend one way and not the other. Brighter X-ray lasers could also be used to reveal the atomic details of chemical catalysis or the way that light energy is absorbed and stored during photosynthesis, according to the National Research Council report. Knowing exactly how to capture sunlight and turn it into chemical energy would be a prize indeed.