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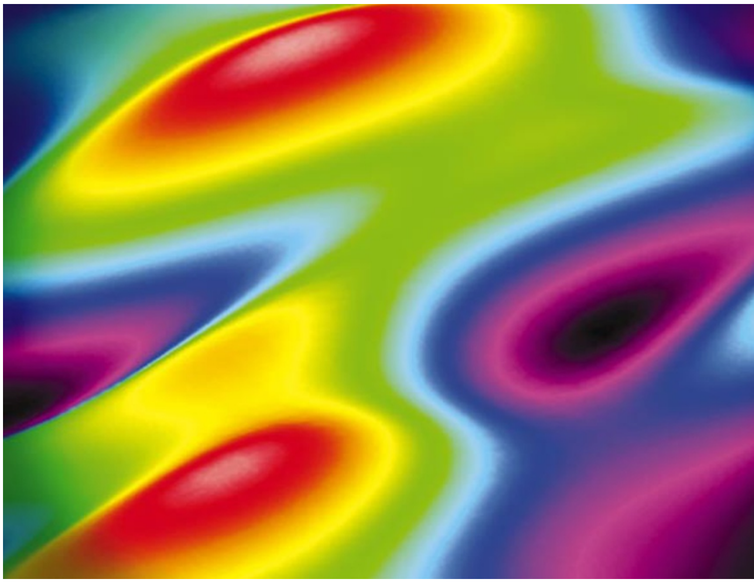

SUPER-K

Rapid response: the first direct visualization of electron movement in an atom (left).

Born again: Japan's Super-K neutrino detector is back online after having its shattered sensors replaced.

Attosecond science

The fast show

"It has been a fantastic year," beams Ferenc Krausz. His team at the Vienna Institute of Technology has used some of shortest laser pulses ever generated to track electrons moving within an atom. This motion is so quick that the vibrations of atoms — themselves among the fastest events subjected to scientific scrutiny — seem sluggish in comparison. Fundamental insights into atomic behaviour are likely to follow, as well as ideas for developing new kinds of laser.

For more than a decade, pulses of laser light just a few hundred femtoseconds (10^{-15} s) long have been used to follow the movement of atoms and molecules during chemical reactions. But tracking electrons requires even shorter pulses. An electron orbits a hydrogen atom in just 24 attoseconds (10^{-18} s), for example. Methods for producing suitably short pulses have emerged in the past couple of years[1,2], and 2002 saw their first real application.

To get a sufficiently short laser pulse, Krausz bombarded neon gas with pulses of visible light 7 femtoseconds long, which sparked collisions between the neon atoms' nuclei and their electrons. This activity generated bursts of X-ray radiation about 100 attoseconds long, which Krausz focused and combined to make a single 650-attosecond pulse.

Using such pulses, Krausz was able to track the movement of electrons around the nucleus of a krypton atom for the first time. A 650-attosecond pulse was used to initiate the Auger process — the rearrangement of electrons around an atom that follows the removal of an electron from an inner orbit.

By applying their pulse, the researchers knocked an inner electron out of its orbit, leaving an unstable hole. This caused an electron from an outer orbit to fall into the hole, which in turn displaced another electron — the Auger electron — from its outer orbit.

The researchers tracked the Auger electron using a femtosecond laser pulse, which allowed them to work out the time between the initial X-ray pulse and the expulsion of the Auger electron. They were able to pin the length of this process down to about 7.9 femtoseconds (ref. 3).

Other methods had already produced similar estimates by indirect measurements, but Krausz's experiment confirmed that sub-femtosecond pulses could be used to study the process by manipulating the electrons themselves. "This is the dream of attosecond science," says Paul Corkum, a physicist at the Steacie Institute for Molecular Sciences in Ottawa, Canada. He suggests that insights into atomic behaviour could also come from studying the way in which electrons are scattered in the collisions that create the short X-ray pulses[4].

X-rays can also be generated when electrons move between different atomic orbitals. Krausz hopes that future attosecond studies will improve our sketchy knowledge of the processes involved. If we understood these, he argues, it might be possible to build a compact X-ray laser to study molecular structures in materials science and biology. ■

Jim Giles

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Comeback: Neutrino physics

Tanked up and ready for action

Yoji Totsuka had planned for a quiet 2002, as he neared the end of his stint as director of Japan's Kamioka Observatory. But those plans were shattered in November 2001, along with almost 7,000 photomultiplier sensors, when a shockwave triggered by one imploding sensor swept through the observatory's water-filled neutrino detector.

Instead of quietly drawing his tenure to a close, Totsuka has been trying to figure out what happened — and working overtime to repair the damage. "I'm still wondering why we could not anticipate that stupid accident," he says. "I don't have an answer yet."

The detector, known as Super-Kamiokande or Super-K, is some 240 kilometres northwest of Tokyo. Its headline achievement was providing evidence that neutrinos, a type of subatomic particle, possess mass. But the accident derailed other ongoing experiments, including a study of neutrinos beamed to Super-K from KEK, Japan's High Energy Accelerator Research Organization at Tsukuba, north of Tokyo.

A year of repairs has paid off, however. The detector has now been refitted with plastic-cased sensors, which should prevent a similar catastrophe, and the refilling of the 50-million-litre water tank will be finished before Christmas. The KEK experiment is expected to resume in mid-January. Super-K's sensitivity is half of what it was before the accident, but funding for a full recovery by 2006 is likely to be made available.

Totsuka is now director of KEK and has been succeeded at Kamioka by Yoichiro Suzuki. "The most important thing," says Suzuki, "is to get some great results as a means of thanking the people who have supported us." **David Cyranoski**