Researchers in Germany say they have measured the electrical field of visible light for the first time, an achievement that could eventually lead to new tools for high-energy physics.

Ferenc Krausz reported the work in the 27 August issue of Science magazine. Along with colleagues from the Max Planck Institute for Quantum Optics (Garching, Germany), Bielefeld University (Bielefeld, Germany), and the Vienna University of Technology (Vienna, Austria), he shot electrons at a pulse of 750-nm laser light and measured how the light affected the electrons.

The electromagnetic field of visible light varies at a rate of $10^{15}$ oscillations each second; no instrument exists to measure field fluctuations with that temporal accuracy. To measure changes that take place in about a femtosecond, they needed something they could characterize in attoseconds, an order of magnitude lower than existing systems.

The team uses tightly controlled 250-as pulses in the extreme-UV (EUV) to soft-x-ray range of the spectrum. The EUV pulse knocks electrons off atoms of neon gas, and the team scans those electrons across the visible laser pulse. As the electrical field of the light pulse oscillates, it changes the energy level of the electrons, speeding them up or slowing them down. The researchers measure the changes with an electron spectrometer and use that measurement to get a picture of how the electrical field is changing.

"In principle it's quite simple," says Krausz. "Electrons that are set free get a kick from the laser field."

The system works, says Eleftherios Goulielmakis of the Max Planck Institute, because the electrons come in pulses of 250 as, while the electric field oscillates at 2.5 fs.

"This experiment provides, for the first time, a direct access to the exact value of the electric field of ultrashort laser waveforms and opens the way for further studies and control of atomic and molecular processes," Goulielmakis says.

Key to the whole setup is the ability to produce laser pulses with exactly the same waveform from one pulse to the next, Krausz says. The team achieved that last year, and earlier this year showed it was able to control and characterize the 250-as EUV pulse (see oemagazine, May 2004, p. 18).

"This maybe becomes important for any applications in which you have to know how the field values evolve with time," Krausz says.

Eventually, this work could lead to the development of laser-based particle accelerators for studying high-energy physics, he says. Synchrotron-based accelerators have to be kilometers long and cost hundreds of millions of dollars to build. In principle, Krausz says, a laser-based accelerator would only have to be a few tens of meters long, and thus cheaper and less complex, but it would also have to be very precise in how much energy it imparts to particles.

"People are working on laser accelerators already now, but they are unable to produce particles with very well-defined energy," he says.

The work will also allow researchers to see how electrons move around in an excited atom. Krausz says this could yield insight into the physical processes at work, much the way chemists learn things by watching how atoms move within molecules, but at a finer resolution. If scientists can learn about how atoms emit x-ray photons as they relax back to their ground state, that might let them develop compact x-ray lasers, for instance, Krausz says. — Neil Savage

The kinetic energy of electrons varies up or down depending on the time at which they interact with the oscillating electrical field of the light pulse.