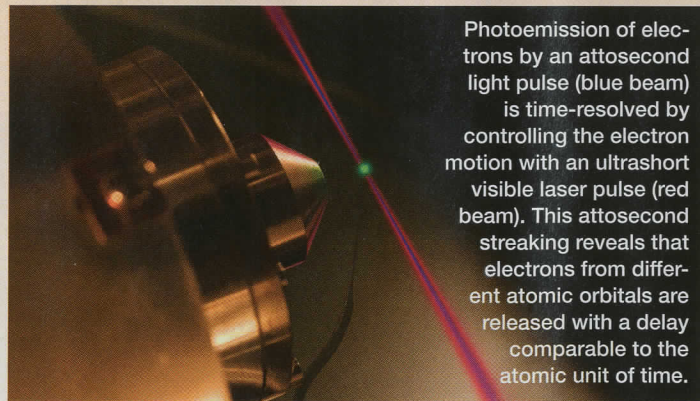


A Fleeting Look at the Details of Photoemission

Physicists have known about the photoelectric effect for well over a century, but some of the details have remained shrouded in mystery. For instance, after an atom has absorbed a single photon, how long does it take for it to emit an electron? And does that tiny lag time depend on which orbital expels the electron?

Thanks to cutting-edge ultrafast lasers, an international research team has measured this tiny time period in neon atoms (*Science* **328**, 1658). Along with their colleagues, Martin Schultze and Vladislav Yakovlev at the Max Planck Institute for Quantum Optics in Garching, Germany, found



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Photoemission of electrons by an attosecond light pulse (blue beam) is time-resolved by controlling the electron motion with an ultrashort visible laser pulse (red beam). This attosecond streaking reveals that electrons from different atomic orbitals are released with a delay comparable to the atomic unit of time.

that an electron leaves the $2p$ subshell 21 ± 5 attoseconds (as) later than an electron kicked out of the $2s$ level. That's an astonishingly small differential, but the work

still quantifies a process long assumed to be instantaneous. The researchers chose neon because it is more complex than helium but simpler to model theoretically than the other noble gases, Yakovlev said. Neon also has a relatively high photoioniza-

tion cross-section, which improved the signal-to-noise ratio of the experiments. The neon gas was bombarded by sub-100-as pulses of extreme ultraviolet light

at roughly 100 eV per pulse. The scientists timed the photoemission through a process called attosecond streaking, in which a time-of-flight spectrometer tracked the photoelectrons ejected from the neon atoms.

By calculating quantum mechanical models of electron trajectories, the researchers traced the $2p$ and $2s$ electron wave packets' average positions and velocities back toward the neon ions of origin and found that they terminated at roughly 0.3 \AA , or the radius of the electron shell. The experiment measured only the relative delay between the photoelectrons originating at the $2p$ and $2s$ levels, not the absolute length of time it took the

neon atom to absorb a photon and ionize. And of course, one needs to rely on quantum mechanics to approximate the multi-electron dynamics inside the atom. Still, ultrashort-pulse experiments could help test some of the approximations of atomic and subatomic physics and reveal new avenues for research.

According to Yakovlev, this experiment could not have been done five years ago. "The recent advances in attosecond technology have allowed us to make measurements with extremely good time resolution of just a few attoseconds, which was unmeasurable before," he said.

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