ScienceDaily

Attosecond physics: A zeptosecond stopwatch for the microcosm

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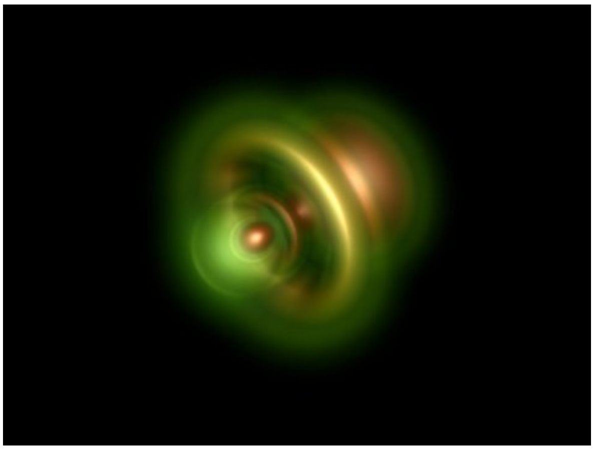
Source: Ludwig-Maximilians-Universitaet Muenchen (LMU)

Summary: For the first time ever, laser physicists have recorded an internal atomic event with an accuracy of a trillionth of a billionth of a second.

FULL STORY



Once a photon has ejected an electron from a helium atom, it is possible to calculate the probable position of the remaining electron. The most likely position of the electron is shown in the image as the brightest area around the atomic nucleus (which itself is not visible in the image).

Credit: M. Ossiander (TUM) / M. Schultz (MPQ)

For the first time ever, laser physicists have recorded an internal atomic event with an accuracy of a trillionth of a billionth of a second.

When light strikes electrons in atoms, their states can change unimaginably quickly. Laser physicists at LMU Munich and the Max Planck Institute of Quantum Optics (MPQ) have now measured the duration of such a phenomenon – namely that of photoionization, in which an electron exits a helium atom after excitation by light – for the first time with zeptosecond precision. A zeptosecond is a trillionth of a billionth of a a second (10-21 s). This is the first absolute determination of the timescale of photoionization, and the degree of precision achieved is unprecedented for a direct measurement of the interaction of light and matter.

When a light particle (photon) interacts with the two electrons in a helium atom, the changes take place not only on an ultra-short timescale, but quantum mechanics also comes into play. Its rules dictate that either the entire energy of the photon is absorbed by one of the electrons, or the energy is distributed between them. Regardless of the mode of energy transfer, one electron is ejected from the helium atom. This process is called photoemission, or the photoelectric effect, and was discovered by Albert Einstein at the beginning of the last century. In order to observe what occurs, you need a camera with an incredibly fast shutter speed: The whole process, from the point at which the photon interacts with the electrons to the instant when one of the electrons leaves the atom, takes between 5 and 15 attoseconds (1 as is 10-18 seconds) as physicists have worked out in recent years.

Using an improved method of measurement, the Munich physicists can now accurately capture events that occur on timescales down to 850 zeptoseconds. The researchers directed an attosecond-long, extremely ultraviolet (XUV) light pulse onto a helium atom to excite the electrons. At the same time, they fired a second infrared laser pulse at the same target, lasting for about four femtoseconds (1 fs is 10-15 seconds). The ejected electron was detected by the infrared laser pulse as soon as it left the atom in response to the excitation by XUV light. Depending on the exact state of the oscillating electromagnetic field of this pulse at the time of detection, the electron was accelerated or decelerated. By measuring this change in speed, the researchers were able to establish the duration of the photoemission event with zeptosecond precision. In addition, the researchers were also able to determine, for the first time, how the energy of the incident photon is quantum mechanically distributed between the two electrons of the helium atom in the final few attoseconds before the emission of one of the particles.

“Our understanding of these processes within the helium atom provides us with a tremendously reliable basis for future experiments,” explains Martin Schultze, a specialist in laser physics at LMU's Chair of Experimental Physics, who led the experiments at the MPQ. He and his team were able to correlate the zeptosecond precision of their experiments with theoretical predictions made by their colleagues in the Institute of Theoretical Physics at the Technical University of Vienna. With its two electrons, helium is the most complex system whose properties can be calculated completely from quantum theory. This makes it possible to reconcile theory and experiment. “We can now derive the complete wave mechanical description of the entangled system of electron and ionized helium parent atom from our measurements,” says Schultze.

Story Source:

Materials provided by **Ludwig-Maximilians-Universitaet Muenchen (LMU)**. *Note: Content may be edited for style and length.*

Journal Reference:

1. M. Ossiander, F. Siegrist, V. Shirvanyan, R. Pazourek, A. Sommer, T. Latka, A. Guggenmos, S. Nagele, J. Feist, J. Burgdörfer, R. Kienberger, M. Schultze. **Attosecond correlation dynamics**. *Nature Physics*, 2016; DOI: 10.1038/nphys3941

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<www.sciencedaily.com/releases/2016/11/161108123820.htm>.
