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Optical pulses reach attosecond length

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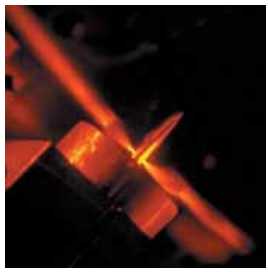
TIME-RESOLVED SPECTROSCOPY

In the world of ultrashort optical pulses, the femtosecond (fs) has been superseded by the attosecond (as, or 10^{-18} s). An international collaboration of ten scientists claims to have generated and detected isolated soft x-ray pulses of 650-as duration. Scientists at the Vienna University of Technology, Austria, along with others at the National Research Center (Ottawa, Canada) and the University of Bielefeld, Germany, have developed experimental tools and techniques that could enable attosecond-resolution spectroscopy of bound electron dynamics in atoms and molecules.



A high-intensity few-cycle (7-fs) red light beam pumps the neon-gas attosecond-pulse source. The characteristic fluorescence emission from neon originates from the ionizing atomic gas as it streams out of the volume inside a thin metal tube with a couple of holes in its wall to transmit the pump laser and the emerging x-ray beam. (Photo courtesy of G. TEmpea; Vienna U. of Technology)

To generate attosecond pulses, the team directed a 750-nm, 7-fs pulsed laser beam with an on-axis peak intensity of 9 x 10^{14} W/cm^2 into a 3-mm-long 200-mbar volume of neon gas. The result was a train of harmonic pulses in the extreme ultraviolet and soft-x-ray range (around the 14-nm wavelength range). The scientists then passed the soft x-rays along with the collinear beam of visible light through a zirconium band-pass filter to transmit a low-divergence harmonic soft-x-ray beam at 90 eV, along with an annular beam of visible light. A molybdenum-silicon reflector focused and intensified the soft-x-ray pulse, also introducing a delay with respect to the visible light. The visible light and x-ray pulses then co-irradiated a krypton atomic gas target to produce the final x-ray pulse of 650 ±150 as duration.

After generating the pulse, measuring its duration was the next challenge. The team correlated the pulse envelopes of the visible-light and soft-x-rays, which is conventionally done using angle-resolved x-ray-induced photoemission. Rather than averaging the intensity across the envelope of the light field, the team controlled the x-ray energy by oscillating the light field. This technique probed the x-ray pulse duration and its timing jitter with respect to the visible light. The detected spectra agreed closely with a quasiclassical model, showing that the x-ray pulse was locked to the visible light with subfemtosecond precision.

Further, in the first-ever demonstration of the new attosecond metrology, the team reportedly traced the electric field oscillations in a visible light wave with a resolution of better than 150 as. Such resolution in x-ray pump-probe spectroscopy could soon lead to direct study of ultrafast processes like ionization or the creation of inner-shell vacancies. The current fluence in this experiment, however, will need improvement to enable such studies, say the scientists.

While the research has been widely embraced as important progress in the realm of attosecond timescales, some specialists in the field have claimed that the data may not support the findings of an isolated pulse rather than a train of pulses. The claims have sparked a debate that may be worth following as it unfolds.

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REFERENCE

1. M. Hentschel et al, Nature 414, 509 (Nov. 29, 2001).