Researchers demonstrate way to shape electron beams in time through interaction with terahertz electromagnetic fields

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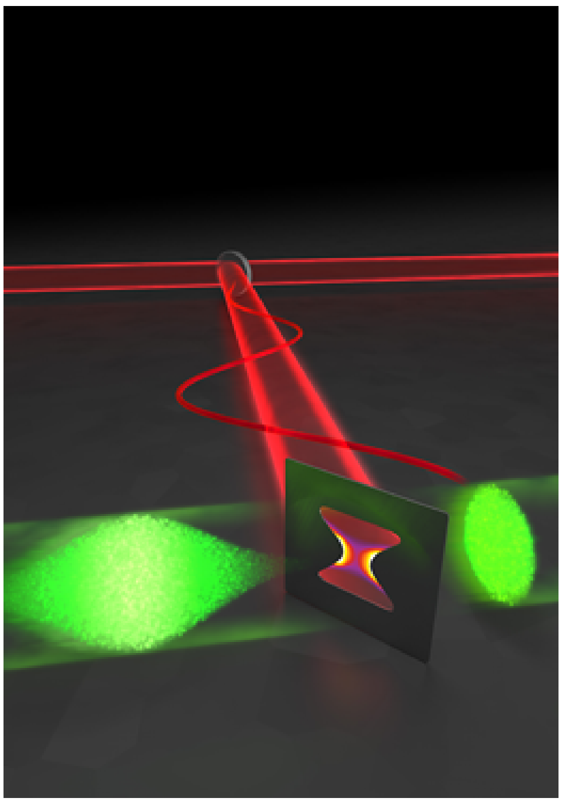

Pulses of electrons (green, coming from the left) impinge on a micro-structured antenna which is powered by laser-generated terahertz radiation (red). The interaction compresses the duration of the electron pulses to a few femtoseconds. Credit: Christian Hackenberger

(Phys.org)—A small team of researchers with Ludwig-Maximilians-

Universität München and the Max-Planck-Institute of Quantum Optics, both in Germany has successfully demonstrated a means for shaping electron beams in time through interactions with terahertz electromagnetic fields. In their paper published in the journal *Science*, the team describes their technique and why they believe it may lead the way to ultrafast microscopy and diffraction techniques. In a Perspectives piece in the same journal issue, Claus Ropers with the University of Göttingen, describes the benefits of developing faster electron microscopy, outlines the technique used by the researchers with this new effort and offers some insight into where the science is headed.

There is no doubt that electron microscopy techniques have led to incredible advances in the understanding of matter at the molecular and atomic scale. But such devices could be made even better, Ropers explains, by making them run faster, or ultrafast, i.e. with pulses measured in femtoseconds. This is because there is motion at the atomic scale—using short bursts of electrons to capture the mechanics of such motion would open up a whole new world of discovery. To that end, researchers have developed devices with that goal in mind.

To produce short bursts of electrons in traditional devices, a metal surface is illuminated by a laser, causing electrons to be emitted into a vacuum—unfortunately they do not all travel at the same speed, which means they spread apart as they move towards a target—coulomb forces cause even more stretching, which results in problems in time resolution in microscopy devices. To get around this, researchers have tried multiple approaches that rely are various types of devices that manipulate the electron stream. In this new effort, the researchers used optics and terahertz radiation instead.

The idea is to cause faster moving electrons to slow down a little bit and slower moving electrons to speed up a little bit, resulting in all of the electrons in a group traveling at the same speed towards a destination.

This is achieved with the new technique by having terahertz fields act on the electrons in a microstructure—its bow-tie shape enhances the field in the desired way via tilting. In testing their device, the researchers found that they could measure pulse durations of just 75 fs, a ten times reduction in value over those that were not modified.

More information: C. Kealhofer et al. All-optical control and metrology of electron pulses, *Science* (2016). DOI: 10.1126/science.aae0003

Abstract

Short electron pulses are central to time-resolved atomic-scale diffraction and electron microscopy, streak cameras, and free-electron lasers. We demonstrate phase-space control and characterization of 5-picometer electron pulses using few-cycle terahertz radiation, extending concepts of microwave electron pulse compression and streaking to terahertz frequencies. Optical-field control of electron pulses provides synchronism to laser pulses and offers a temporal resolution that is ultimately limited by the rise-time of the optical fields applied. We used few-cycle waveforms carried at 0.3 terahertz to compress electron pulses by a factor of 12 with a timing stability of