Using lasers to create ultra-short pulses

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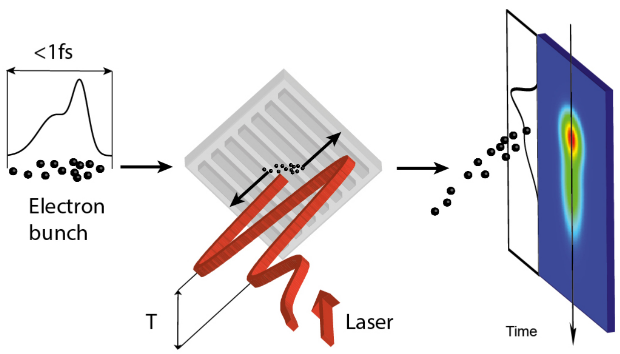

Credit: Peter Hommelhoff

Physicists at Friedrich-Alexander Universität Erlangen-Nürnberg (FAU) have entered new territory with regard to the pulsing of electron beams. Their method could soon be used to develop electron microscopes suitable for ultra-short time scales such as needed for observing the motion of atoms.

Electron microscopes have opened up a whole new world to researchers: state-of-the-art scanning and transmission devices can now even image individual atoms. Despite achieving this enormously high resolution, operating with a constant electron beam has its disadvantages. Ultra-fast reactions, such as the breaking of chemical bonds or the vibrations of atoms, cannot be imaged with this method. Because of this problem, microscopes have been developed in recent years that use pulsed electron beams. "This can be compared with a stroboscope which captures the movement of the test object using a rapid sequence of flashes," explains Professor Peter Hommelhoff, Chair of Laser Physics at FAU. "This principle has now been applied to electron pulses."

Laser-controlled electrons

The particular challenge here is to generate pulses that are as short as possible - as electron 'packets' with shorter lengths reduce the time scale at which atomic movements can be imaged. By using a laser to manipulate a stream of electrons, they have succeeded in producing electron packets with a length of 1.3 femtoseconds—a femtosecond is equivalent to one millionth of one billionth of a second. To achieve this, the physicists had to direct a beam of electrons over the surface of a silicon lattice, where they superimposed the optical field from laser pulses onto it in two sections. Dr. Martin Kozák, a member of Hommelhoff's team and primary author of the study, explains: "We use the laser to control the frequency of the periodic field and synchronize it with the speed of the electrons. This allows the electrons to gain or lose energy, and we can generate ultra-short packets from a continuous beam."

Pulses in the attosecond range possible

In addition to this controlled acceleration and deceleration, the FAU physicists have succeeded in laterally deflecting the electrons from an angled silicon lattice using laser pulses. The electrons are deflected in one direction or the other, depending on exactly when they interact with the laser field. This detection method is also used in streak cameras, which have already achieved resolutions in the femtosecond range. The method developed in Erlangen will actually achieve temporal resolutions in the attosecond range or a billionth of one billionth of a second. One application in which streak cameras are used is to observe the propagation of light.

More information: M. Kozák et al, Optical gating and streaking of free electrons with sub-optical cycle precision, *Nature Communications* (2017). DOI: 10.1038/NCOMMS14342

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