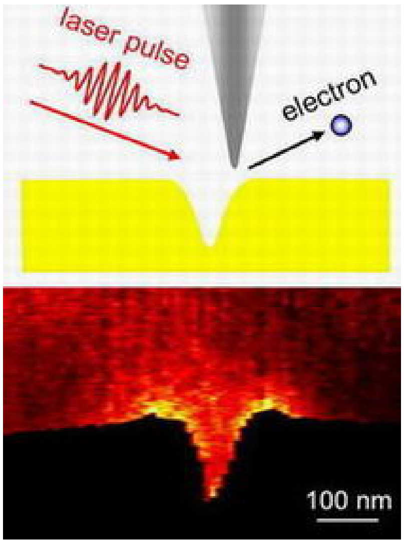
Electron flashes for the nanoworld -- a new source of ultrashort electron pulses



Schematic of the experiment with metal needle (gray) and surface groove (yellow structure). In the experiments, the needle is illuminated with a 0.007 ps short light pulse and raster scanned across the nanostructure. The locally varying electron yield is monitored. Bottom: Electron image of the nano groove. The colored part of the image displays the local electron generation rate (bright: high yield), which allows for a determination of the profile and the local electromagnetic field strength of the nano groove. Credit: MBI

Researchers at the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy (MBI) in Berlin, Germany, have developed a novel source of extremely short electron pulses.

The electron source is based on an ultra-sharp metallic needle illuminated with short light pulses from a laser. “With these electron pulses, it is possible to directly observe fast processes in the nanoworld”, Claus Ropers explains, who performed the work in collaboration with Daniel Solli, Claus-Peter Schulz, Christoph Lienau and Thomas Elsaesser.

The researchers report their findings in the present issue of *Physical Review Letters* (Volume 98, 043907 (2007)).

Nanostructures play a key role in physics, chemistry and materials sciences, and they are at the foundation of modern microelectronics and communication technology. These structures with dimensions of few nanometers exhibit physical and chemical properties which can be tailored in a wide range.

In order to determine the dimensions and other structural characteristics of nanostructures, researchers often employ powerful electron microscopes. Such instruments only deliver static images of the time averaged state of the sample investigated. The function of nanosystems is, however, often closely related to dynamical processes occuring on time scales of less than one picosecond (1 ps, one millionth of a millionth of a second). Therefore, intense research efforts worldwide are devoted to develop methods capable of imaging such processes, for example as a series of snapshots. Besides ultrashort pulses of light, x-ray and electron pulses are particularly suited for this purpose, as they can provide direct information on rapid structural changes.

The team at the MBI has now demonstrated a new technique to generate ultrashort and localized electron pulses. A metallic needle of only 40 nm diameter is illuminated with laser light pulses of only 0.007 ps duration. The intensity of the incident light is enhanced at the needle tip to an extent that it leads to strong emission of electrons. These charged particles can be used to investigate a sample close to the needle. The particluar excitation conditions result in an extremely short duration of the electron pulses of less than 0.02 ps which determines the temporal resolution of this new “electron camera”.

The potential of this “point-like” electron source for the imaging of nanostructures has been demonstrated in experiments, where the illuminated needle is raster-scanned in close proximity across a 50 nm wide nano-groove in a gold surface. Along the cross-section of the metal groove, the electron yield varies due to the varying generation conditions. This allows for a direct determination of the profile and the electromagnetic field distribution at the groove with nanometer precision. In the same way, microelectronic devices on the nano scale and their properties can be investigated.

Currently, the electron pulses are used in first time-resolved experiments on nanostructures to image ultrafast processes. Beyond the application of the source in the raster scanning scenario, the researchers suggest a broad applicability for electron diffraction experiments with highest temporal resolution on solids, surfaces or molecular systems.

Source: Forschungsverbund Berlin