Attosecond camera for nanostructures

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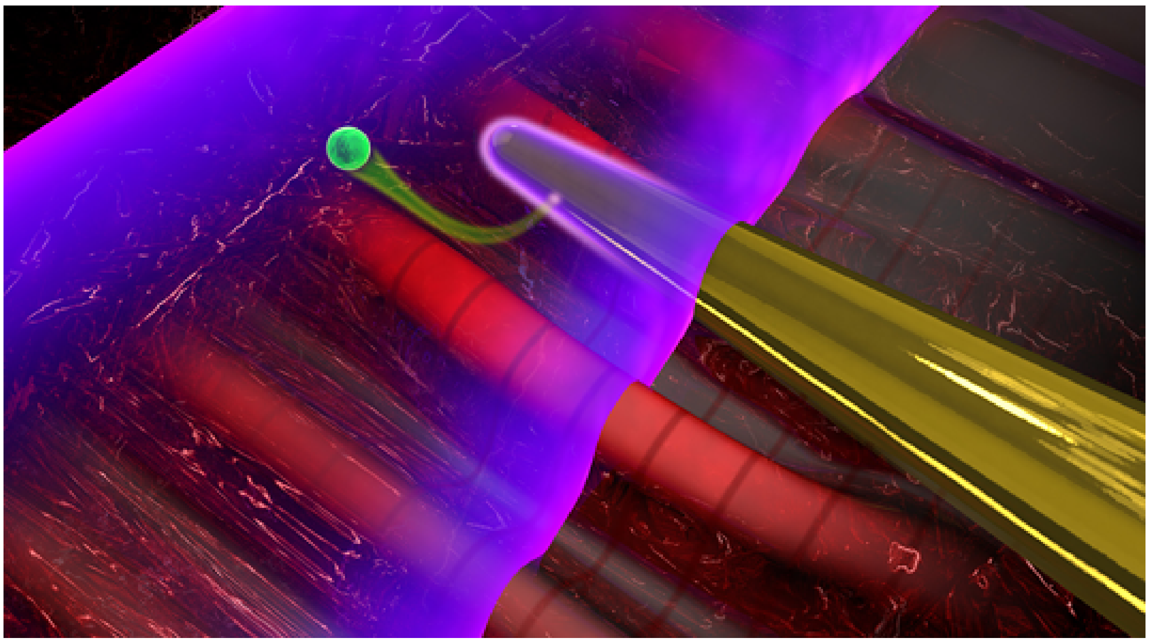

When laser light interacts with a nanoneedle (yellow), electromagnetic near fields are formed at its surface. A second laser pulse (purple) ejects an electron (green) from the needle, which can be used to characterize the near fields. Credit: Christian Hackenberger

Physicists based at Ludwig-Maximilians-Universitaet (LMU) in Munich and the Max Planck Institute for Quantum Optics have observed a nanoscale light-matter phenomenon which lasts for only attoseconds.

When light strikes a metal, its electromagnetic field excites vibrations of the electrons in the metal. This interaction results in the formation of so-called near fields - electromagnetic fields that are localized close to the surface of the metal. Precisely how such near fields behave under the influence of light has now been investigated by an international team of physicists at LMU Munich and the Max Planck Institute for Quantum Optics (MPQ), in close collaboration with researchers at the Chair of Laser Physics at the Friedrich-Alexander-Universität Erlangen-Nürnberg.

The researchers focused intense infrared laser pulses onto a gold nanoneedle. These pulses are so short that they consist of only a few oscillations of the light field. When the light impinges on the nanowire it excites collective vibrations of the electrons associated with the gold atoms near the surface of the wire. These electron motions are responsible for the generation of near fields at the surface of the wire.

To study the timing of the near field's response to the light field, the physicists directed a second light pulse with an extremely short duration of just a couple of hundred attoseconds (1 as lasts for a billionth of a billionth of a second) onto the nanostructure very shortly after the first light pulse. This second flash actually detaches some electrons from the nanowire. When they reach the surface, they are accelerated by the near fields and can be detected, allowing the dynamics of the near fields to be characterized. Analysis of these electrons showed that the near fields were oscillating with a time shift of about 250 attoseconds with respect to the incident light, and that they were leading in their vibrations. In other words, the near-field vibrations reached their maximum amplitude 250 attoseconds earlier than the vibrations of the light field.

"Fields and surface waves generated in nanostructures are of central importance for the development of opto-electronics. With the imaging technique we have demonstrated here, they can now be sharply resolved," explains Professor Matthias Kling, the leader of the Ultrafast Nanophotonics group in the Department of Physics at LMU.

The experiments pave the way for more complex studies of light-matter interactions in metals that are of interest for nano-optics and the light-driven electronics of the future. Such electronics would work at the frequencies of light. Optical fields oscillate at rates of a million billion times per second, i.e. with petahertz frequencies - about 100,000 times faster than the clock frequencies attainable in conventional electronic devices.

More information: B. Förg et al, Attosecond nanoscale near-field sampling, *Nature Communications* (2016). DOI: 10.1038/ncomms11717

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