Researchers build a probe capable of capturing the motion of electrons in a nanoparticle

January 6 2012, by Bob Yirka

(PhysOrg.com) -- Scientists have known for quite some time that when light strikes objects, electrons are excited causing a tiny bit of oscillation to occur that results in the creation of an electric field. They also know that the amount of oscillation differs between different types of materials; electrons in metals such as gold and silver, for example, tend to oscillate more than do electrons in other materials. But what hasn't been well understood is what happens with electron oscillations in metals that are smaller than the wavelengths of light that are striking it.

To find out a team of researchers from the California Institute of Technology set up a laser that pulses very quickly for a very short period of time, exciting the electrons on the target, while at the same time also striking a photo cathode to create an electron pulse. As they describe in their report paper published in *Science*, the team has found that by timing the laser pulse, they can then effectively cause an interaction between the generated electrons and those in the electric field. And in so doing, they found that in some cases the introduction of the electrons caused an increase in energy, while at other times it caused a decrease.

The reason for the increase or decrease has to do with the moment in time that the electrons enter the electric field. If the electron arrives just ahead of an electric wave, it can in essence ride that wave causing an overall increase in energy, whereas if it lands in a trough, it causes a loss, as energy is dissipated due to electrons colliding. In many respects the phenomenon seen here is very similar to what has been found in recent research with tsunamis. If a tsunami wave comes ashore at the same moment that a natural wave is also coming ashore, the result is a much bigger wave than if the tsunami wave arrives when a trough is heading ashore.

The reason this is all exciting is because it means that it might be possible to change the way such things as solar arrays are used to collect energy, or how much heat is generated by computer chips. Also, as the team points out, it's important because the underlying technology itself is a breakthrough of sorts in capturing high-speed events with very high precision which could help researchers in many fields, not just electronics.

More information: Subparticle Ultrafast Spectrum Imaging in 4D Electron Microscopy, *Science* 6 January 2012: Vol. 335 no. 6064 pp. 59-64. DOI: 10.1126/science.1213504

ABSTRACT
Single-particle imaging of structures has become a powerful methodology in nanoscience and molecular and cell biology. We report the development of subparticle imaging with space, time, and energy resolutions of nanometers, femtoseconds, and millielectron volts, respectively. By using scanning electron probes across optically excited nanoparticles and interfaces, we simultaneously constructed energy-time and space-time maps. Spectrum images were then obtained for the nanoscale dielectric fields, with the energy resolution set by the photon rather than the electron, as demonstrated here with two examples (silver nanoparticles and the metallic copper–vacuum interface). This development thus combines the high spatial resolution of electron microscopy with the high energy resolution of optical techniques and ultrafast temporal response, opening the door to various applications in elemental analysis as well as mapping of interfaces and plasmonics.

PERSPECTIVE: Plasmonic Modes Revealed, Science 6 January 2012: Vol. 335 no. 6064 pp. 47-48. DOI: 10.1126/science.1215588

Abstract
When nanostructures made of metals such as gold and silver are illuminated with visible light, plasmonic modes can be excited that cause conduction electrons to oscillate. This motion creates a pattern of electric fields, extending both within and outside the structure, that can be tuned by changing the particle size and shape to efficiently couple light to electronic processes. Practical applications of this coupling include improved harvesting of light for photovoltaics (1) and enhanced sensitivity for sensors based on light-emitting messenger molecules (2). Although there is well-developed theoretical understanding of how photons interact with nanostructures that are much smaller than their wavelength, we have few methods for measuring electric fields nearby and within nanoscale structures during photonic excitation. On page 59 of this issue, Yurtsever et al. (3) report using time-resolved electron energy gain/loss spectroscopy in an electron microscope to obtain spatially resolved maps of electric fields that result when nanoscale metal objects are illuminated by incident photons.