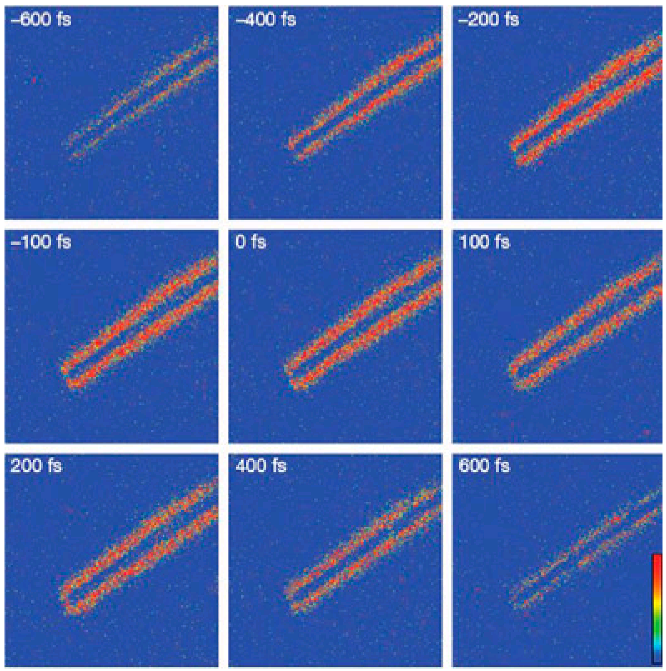
Evanescent waves bring new window into the nanoworld

Dec 20, 2009 3 comments



Best of both worlds electrons + light = nanoscale clarity

Researchers at Caltech in the US have invented a new type of imaging technique that merges the best qualities from electron and light microscopy. The hybrid technique, dubbed "photon-induced near-field electron microscopy" can image nano-objects with femtosecond time resolution. It could be used to directly visualize ultrafast events that occur on tiny length scales.

Nanotechnology is now firmly established as an important area of research and increasingly scientists need to be able to image nanostructures in more fine detail. The new imaging technique, devised by Ahmed Zewail's team, combines the nanoscale spatial resolution of electron microscopy with the femtosecond time resolution of ultrafast light pulses.

Efficient interaction

The researchers illuminate the nanostructure to be imaged (for example, a carbon nanotube or silver nanowire) by firing it with a femtosecond laser pulse to create an "evanescent wave". Unlike ordinary, free light, evanescent waves exist only near a surface and because of this they interact efficiently with surface electrons.

Zewail and colleagues exploit this fact by focusing a pulse of electrons onto the nanostructure being imaged while simultaneously firing light pulses at it. In this way the electrons gain energy from the light field which are then detected. The researchers create an image of the nanostructure by selecting only accelerated electrons and the number of collected electrons is proportional to the strength of the evanescent field.

The electrons used in the new microscopy technique travel at 70% of the speed of light. This is why they only spend a fraction of a femtosecond near the surface of a nano-sample. To increase electron-light interactions at such short time intervals, the researchers need to magnify the light fields. They do this by using two synchronized femtosecond light pulses.

Snapshots of evanescence

By varying the time delay between the exciting light pulses and the imaging electron pulses, it is possible to obtain "snapshots" of the evanescent field as it evolves over a matter of femtoseconds. According to the scientists, using even shorter pulses should allow them to track the ultrafast processes that occur in photonic and plasmonic devices, for example.

The electrons probes are also relatively "clean", comments F Javier Garcia de Abajo at the Institute of Optics in Madrid, Spain – who was not involved in the research. "Moderate electron beam intensities cause only marginal perturbations in the sample, thus allowing faithful imaging."

Propagating light fields along nanostructure surfaces are important in nanophotonic devices that carry and process optical signals, he adds. The new technique could be further improved to study such propagations, thus opening up a new way to study the nanoworld.

The work was published in *Nature*.

About the author

Belle Dumé is a contributing editor to *nanotechweb*.

3 comments

Add your comments on this article

1 **John Duffield**
Dec 20, 2009 11:57 PM
United Kingdom

Interesting article. Evanescent waves are extremely interesting, not just for people involved in "electron optics", but for people involved in quantum electrodynamics too, wherein we find papers like www.iop.org…189

"Abstract: Former QED-based studies of evanescent modes identified these with virtual photons. Recent experimental studies confirmed the resulting predictions about non-locality, non-observability, violation of the Einstein relation and the existence of a commutator of field operators between two space-like separated points. Relativistic causality thus is violated by the near-field phenomenon evanescent modes while primitive causality is untouched".

Of course, evanescent waves need to relate back to propagating waves, so another interesting material by the same author is at arxiv.org…0803.2596 where we read:

"A 'refined' model of a photon (Fig.2) maintains the shape of a 'wellenzug' like Fig.1, multiplied with an 'enveloping' shape like the single pulse of Fig.3..."

Edited by John Duffield on Dec 21, 2009 12:16 AM.

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2 **T.Roc**
Dec 21, 2009 3:15 AM
Santiago, Chile

details

How are the electrons measured after this interaction? (or 'collected')

I've started a thread on this topic at Sapo's Joint.
saposjoint.net…viewtopic.php

Reply to this comment   Offensive? Unsuitable? Notify Editor

3 **abdilridahasaani**
Dec 22, 2009 2:05 PM

Evanescent wves and new technology

These waves are electromagnetic as well as they can be acoustic and other quantum modes when two different facing media are present there. In a typical mechanism, these waves can exert radiation pressure to trap electrons for certain practical applications where illumination or cooling is required to gain an insight into some minute structures including biological objects. Being electromagnetic waves, their mathematical treatment (wave equations) may require the solution of Maxwell's equations in the medium of interest with certain boundary conditions for the fields components involved as well as the parameters implied in the continuity equation.
The attenuation coefficient and the propagation constant are also essential in this type of analysis as the evanescent waves are nearfield stationary waves with an intensity decaying exponentially with the distance from the wave-originating point. Evanescent wave modes occur also when toroidal plasmas are heated by electron cyclotron radiation under resonance conditions. Therefore, they are another new tool for gaining an insight in imaging by using electrons.
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