Lenses look further afield

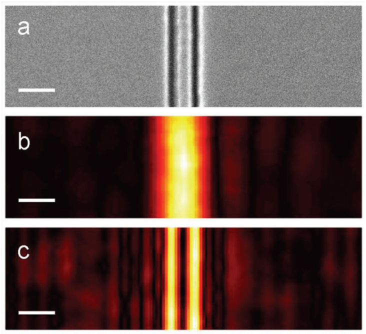
CHARACTERIZATION

Initial experiments by researchers at the University of California, Berkeley show proof of concept of a superlens that is capable of imaging beyond the diffraction limit of light [Liu *et al.*, *Nano Lett.* (2007) 7, 403].

Optical imaging at the nanoscale is restricted by the fact that lenses cannot resolve spatial features below the diffraction limit – half the light wavelength. This means that small-scale information is not carried into the far-field but fades away as evanescent waves. Recent developments in optical imaging have produced superlenses that overcome this limitation over a wide range of frequencies.

Current superlenses couple the evanescent waves scattered by the object to surface excitations produced by a material that has a negative refractive index. The strong enhancement by the surface excitations can compensate for the evanescent wave decay, enabling the lenses to produce a perfect image.

However, even with these developments, superlenses are not able to project the image beyond the near-field. The team from Berkeley has addressed this problem by developing a Ag far-field superlens (FSL) that has a subwavelength grating. Periodic corrugations in the grating convert the evanescent waves, enhanced by surface plasmons (SPs) from the Ag surface, into propagating waves that are capable of traveling into the far-field. "This conversion has to be performed in a controlled manner so that the high-resolution information carried by the original evanescent waves can be faithfully retrieved," explains Zhaowei Liu.



(a) Scanning electron microscope image of a test object. Linewidth is 50 nm and the gap is 70 nm. (b) Image obtained by a conventional optical microscope, numerical aperture = 1.4. (c) Image obtained by a far-field superlens (FSL). All the scale bars represent 200 nm. (Courtesy of Xiang Zhang, University of California, Berkeley.)

The FSL has a unique optical transfer function (OTF), which is the ratio of the image contrast to the specimen contrast.

When plotted as a function of spatial frequency, the OTF confirms that objects can be imaged in the far-field. The OTF shows the FSL couples with the first-order diffraction of the evanescent component, and couples negligibly with any other components. It also strongly enhances incident evanescent waves over a band of wavevectors. This allows the user to map an evanescent band into a propagating band with ease and removes any ambiguity that may arise relating to the image at specific wavelengths.

By varying the metal used, the working wavelength of the FSL can be tuned to a different range, including the visible region. By combining the FSL with a regular optical microscope, images of an object consisting of two 50 nm wide lines, separated by a 70 nm gap can be resolved using 377 nm light.

"Current experiments only show one-dimensional image resolution improvement, but there is no physical limitation to extend this into two dimensions," says Liu. "That is our next step."

Katerina Busuttil

Atoms pair-up before a break-up

ELECTRONIC PROPERTIES

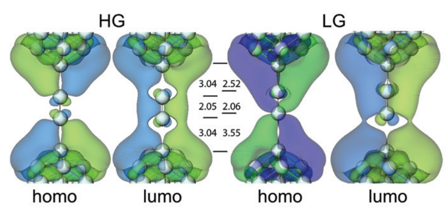
Fluctuations in conductance are observed when a nanowire suspended between two electrodes is elastically deformed. A collaboration between an experimental group headed by Alexei Marchenkov and Uzi Landman's theoretical team at Georgia Institute of Technology, has shown that these fluctuations are the result of a pair of atoms moving backwards and forwards in the narrowed region of an elongated wire [Marchenkov *et al.*, *Phys. Rev. Lett.* (2007) **98**, 046802]. This discovery is a major step toward understanding the structural and transport properties of nanowires.

The researchers fabricated Nb nanowires using the mechanically controlled break-junction technique, which involves repeatedly bending a thin strip of Nb until it breaks. Bending causes elongation in the wire such that a point is reached where the wire is composed of only a single chain of atoms bridging the bulk of Nb.

Conductance measurements were carried out under cryogenic conditions. At such low temperatures, the stretched nanowire is stable for a sufficient length of time to allow conductance measurements to be taken between the electrodes.

The nanowire elongation is reversible over a range of 1 Å. Data show a sudden rapid decrease in conductance when the wire is elongated to below 1 Å. "We saw that the conductance actually jumps between two values. Close to the onset of the rapid drop, the conductance was mostly rather high and then there would be random short periods were it drops to a significantly lower value. On the other side of the interval, the pattern reversed itself and mostly the low conductance values were spotted with the random occurrence of sharp spikes of high conductance," says Marchenkov.

Density functional theory (DFT) calculations and theoretical simulations indicate a pair of atoms (a dimer) is in constant motion, shuttling to and fro between a high- and low-conductance configuration. When the dimer is located near one electrode, electrons have further to 'hop' between the dimer and the opposing electrode. This causes the drop in conductance. High conductance is observed when the dimer is located at the center, equidistant between the electrodes, as there is a shorter distance to 'hop'.



Model of the Nb nanowire with electrical leads at the outside and a dimer at the center. Left, the dimer is centered, and shows high electrical conductivity. Right, the dimer is not centered, and shows lower conductivity. (© 2007 American Physical Society.)

Landman says, "We also wish to control resonant enhancements of electrical conductance through nanowires to develop high sensitivity and selectivity sensing devices, and coded signal transportation."

Katerina Busuttil