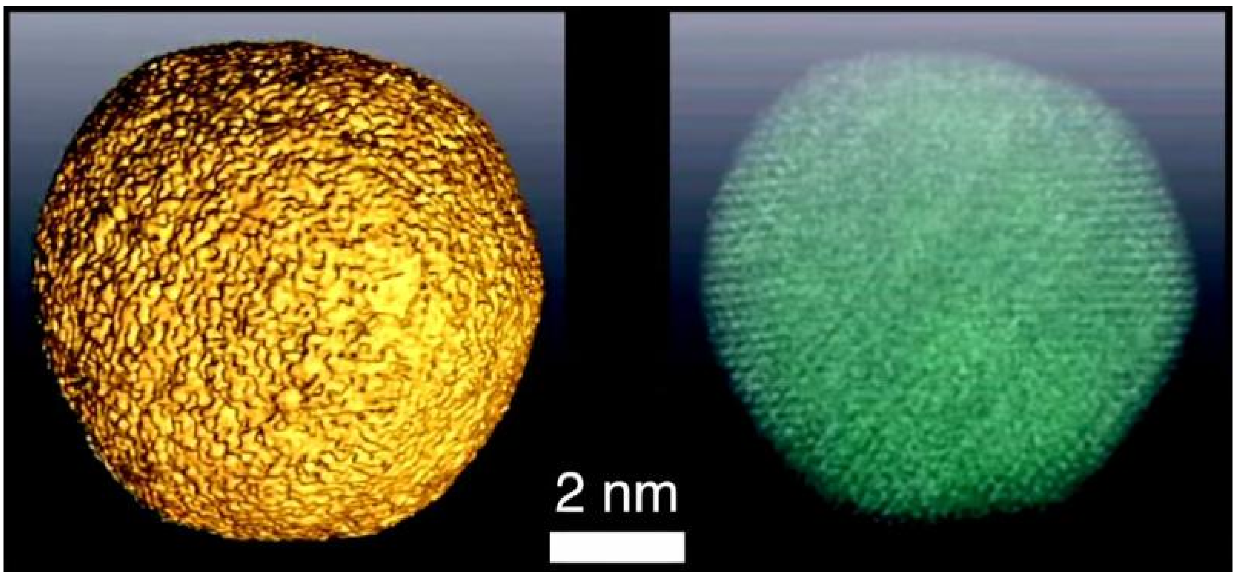
Engineers devise method for producing high-res, 3D images of nanoscale objects

April 8 2015, by Bjorn Carey And Leslie Willoughby



To design the next generation of optical devices, ranging from efficient solar panels to LEDs to optical transistors, engineers will need a 3-dimensional image depicting how light interacts with these objects on the nanoscale.

Unfortunately, the physics of light has thrown up a roadblock in traditional imaging techniques: the smaller the object, the lower the image's resolution in 3-D.

Now, engineers at Stanford and the FOM Institute AMOLF, a research laboratory in the Netherlands, have developed a technique that makes it possible to visualize the optical properties of objects that are several thousandths the size of a grain of sand, in 3-D and with nanometer-scale resolution.

The research is detailed in the current issue of *Nature Nanotechnology*.

The technique involves a unique combination of two technologies, cathodoluminescence and tomography, enabling the generation of 3-D maps of the optical landscape of objects, said study lead author Ashwin Atre, a graduate student in the lab group of Jennifer Dionne, an assistant professor of materials science and engineering.

The target object in this proof-of-principle experiment was a gold-coated crescent 250 nanometers in diameter – several hundred times as thin as a human hair. To study the optical properties of the crescent, they first imaged it using a modified scanning electron microscope. As the focused electron beam passed through the object, it excited the crescent energetically, causing it to emit photons, a process known as cathodoluminescence.

Both the intensity and the wavelength of the emitted photons depended on which part of the object the electron beam excited, Atre said. For instance, the gold shell at the base of the object emitted photons of shorter wavelengths than when the beam passed near the gap at the tips of the crescent.

By scanning the beam back and forth over the object, the engineers created a 2-D image of these optical properties. Each pixel in this image also contained information about the wavelength of emitted photons across visible and near-infrared wavelengths. This 2-D cathodoluminescence spectral imaging technique, pioneered by the

AMOLF team, revealed the characteristic ways in which light interacts with this nanometer-scale object.

"Interpreting a 2-D image, however, can be quite limiting," Atre said. "It's like trying to recognize a person by their shadow. We really wanted to improve upon that with our work."

To push the technique into the third dimension, the engineers tilted the nanocrescent and rescanned it, collecting 2-D emission data at a number of angles, each providing greater specificity to the location of the optical signal.

By using tomography to combine this tilt-series of 2-D images, similar to how 2-D X-ray images of a human body are stitched together to produce a 3-D CT image, Atre and his colleagues created a 3-D map of the object's optical properties. This experimental map reveals sources of light emission in the structure with a spatial resolution on the order of 10 nanometers.

For decades, techniques to image light-matter interactions with sub-diffraction-limited resolution have been limited to 2D. "This work could enable a new era of 3D optical imaging with nanometer-scale spatial and spectral resolution," said Dionne, who is an affiliate of the Stanford Institute for Materials and Energy Sciences at SLAC.

The technique can be used to probe many systems in which light is emitted upon electron excitation.

"It has applications for testing various types of engineered and natural materials," Atre said. "For instance, it could be used in manufacturing LEDs to optimize the way light is emitted, or in solar panels to improve the absorption of light by the active materials."

The technique could even be modified for imaging biological systems without the need for fluorescent labels.

More information: "Nanoscale optical tomography with cathodoluminescence spectroscopy" *Nature Nanotechnology* (2015) DOI: 10.1038/nnano.2015.39

Provided by Stanford University