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surface-to-volume ratio and size of the nanowires, explained the photoconduction gain.

With the mechanism understood, the researchers are now studying different semiconductor materials and nanowire structures, looking to extend the spectral response to the visible and near-infrared. They also are trying to commercialize the technology. "Most likely, the first commercial applications will be for imaging, such as the night-vision, surveillance or automotive sectors, where sensitivity is highly valuable," Wang said. □

Hank Hogan

Nano Letters, April 2007, pp. 1003-1009.

Speedy Spectroscopy of Single Nanoparticles

Nanoparticles present distinct research problems. Because of variations among production batches, investigators tend to choose to study individual particles. Doing so, however, is technically challenging, and it is difficult to generate meaningful data.

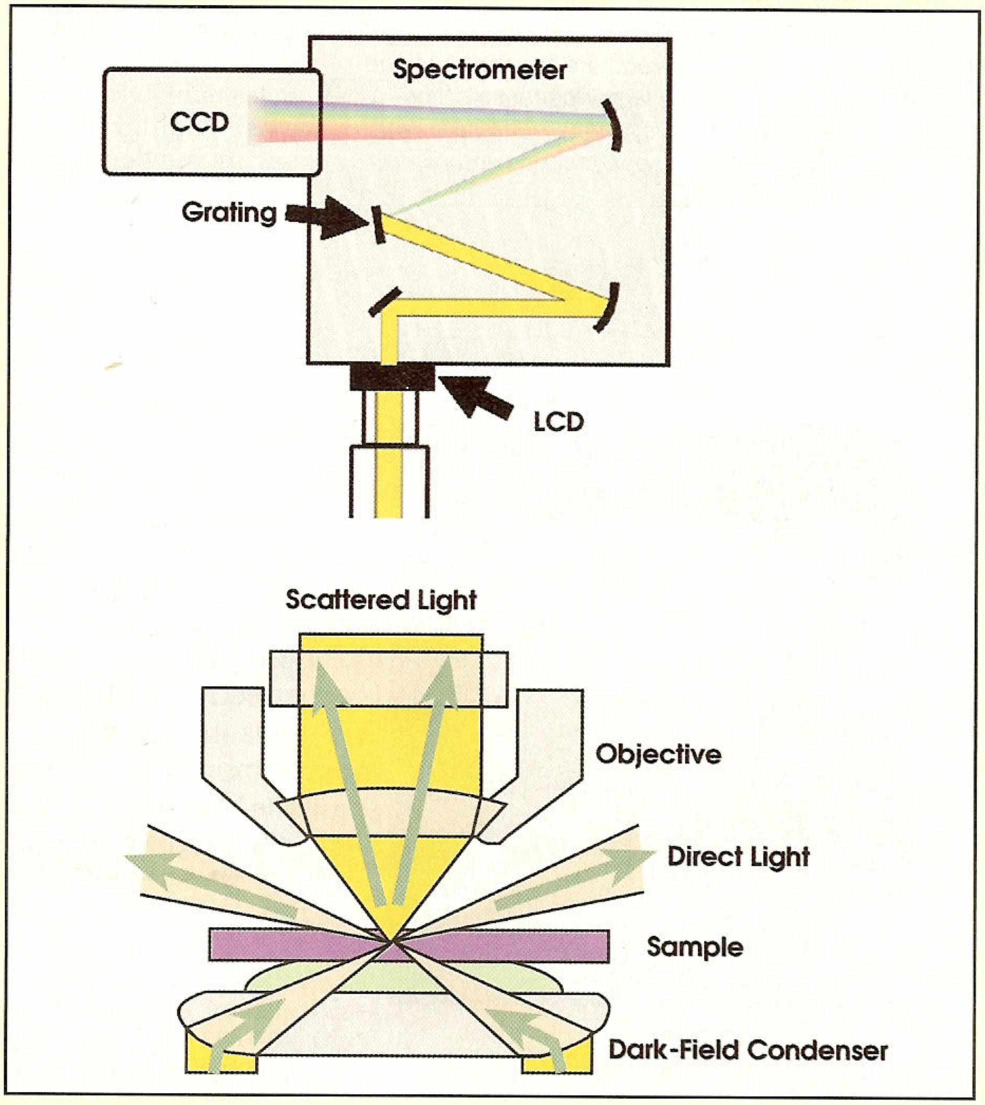
Now a team from the University of Mainz in Germany has demonstrated a technique it has dubbed fast single-particle spectroscopy, which is orders of magnitude more rapid than other methods. The researchers used it to monitor the growth of gold nanorods, taking advantage of their size- and shape-dependent optical properties. They found that the short axis of the rods grew faster than the long one, an expected but nonetheless illuminating result.

"The exact evolution of the particle shape itself has never been observed before, and it is, therefore, by itself quite interesting to see," said Jan Becker, a graduate student and research team member.

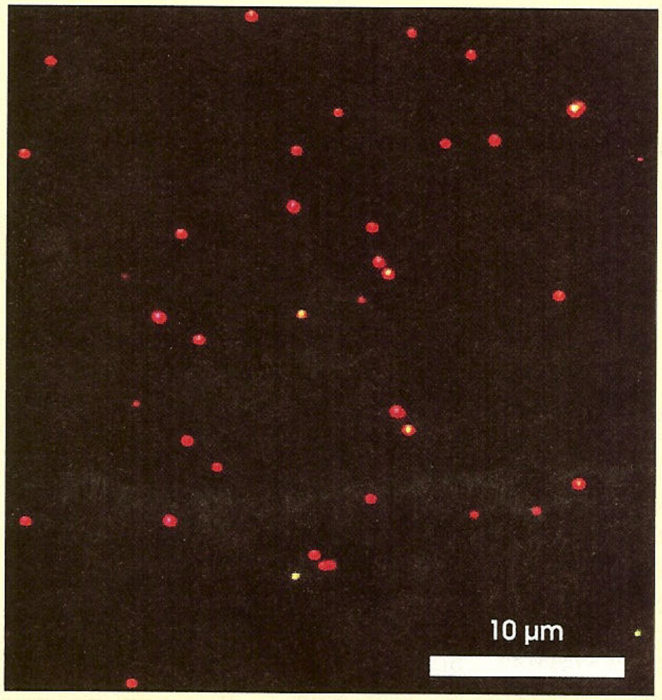
The novel technique uses no mechanical parts, instead employing an LCD as an electronically addressable shutter. In their demonstration, the scientists used an LCD from Holoeye Photonics AG of Berlin, placing it at the entrance slit of a spectrometer. They chose this LCD because its 32-μm² pixel size matched the diffraction-limited spot size of one nanoparticle in their setup.

The rest of the setup consisted of an Acton spectrometer, a Princeton Instruments CCD camera and a standard dark-field microscope. With this arrangement, the team could set the LCD pixels to transparent and capture the corresponding particle's spectra. The setup allowed them to image up to 20 vertically separated spectra, with a total measurement time of 150 s for 160 particles versus the 1500 that would be needed using a sequential approach.

Becker noted that speed helps turn individual results into collective findings. "We can measure up to 1000 spectra in a single day. This allows



By using an LCD at the entrance of the spectrometer as an electronically addressable shutter, researchers created a single-particle spectroscopy setup that is at least 10 times faster than other methods for studying large numbers of nanoparticles. Images courtesy of Jan Becker, University of Mainz.



This is a typical dark-field microscope image of a gold nanorod sample. The nanorods are the red dots and are 20 × 50 nm, appearing larger because of the diffraction limit. Researchers monitored their growth using a fast single-particle spectroscopy setup.

us to collect sufficient statistics to observe even small subpopulations of different-shaped particles in a sample."

The researchers first took a black-and-white image of the entire sample, then selected groups of nanoparticles and monitored them individually. Finally, they set all pixels to black and subtracted the result from the data to remove background light.

The light-scattering spectrum of gold nanorods depends on their size and shape, and the researchers exploited this to monitor the growth of nanoparticles immobilized on a glass capillary, measuring single-particle growth continuously with a 30-s time resolution. They found that the short axis grew faster than the long one, with an overall volume increase of 5 nm^3/s, or about that expected from diffusion-limited growth.

The investigators now are using the technique to study various samples, looking for interesting nanoparticle subpopulations that they can scrutinize. They plan to optimize the spectrometer and to make other changes that will improve measurement sensitivity and overall stability.

The technique does have a downside because about half of the light is lost as a result of polarization filters on the LCD. This can be overcome by using two beams and polarizing beamsplitters.

"We will be working on realizing this setup as funding becomes available," Becker said. □

Hank Hogan

Nano Letters, ASAP Edition, May 2, 2007, doi: 10.1021/nl070627g.