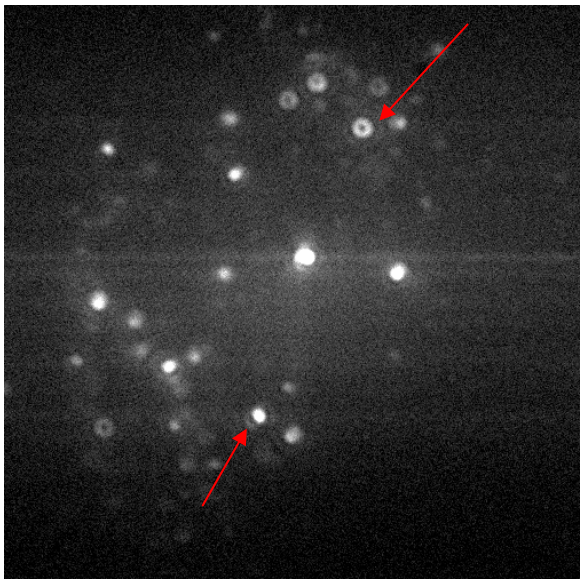
Optical Anisotropy of Individual Semiconductor Quantum Dots

We have found highly anisotropic optical emission from individual indium phosphide quantum dots on a glass substrate. Quantum dots are semiconducting crystals of nanometer dimension, sometimes called artificial atoms. The electronic and optical properties of these particles depend strongly on their size. This dependence, due to quantum confinement, has resulted in many new optical concepts, from fluorescence labeling of biomolecules to photovoltaic solar energy conversion. Optical anisotropy has been reported for quantum dots grown epitaxially on crystalline substrates where the orientation and shape of the particles is influenced by the substrate. However, for cubic semiconductor crystals grown from solution, the existence of a preferred direction for optical absorption or emission is not expected. These InP quantum dots will contribute to our efforts in chemical imaging at the molecular level due to their potentially anisotropic interaction with particular surface analyte molecules and their stability under intense illumination.

InP particles of 2-3 nm diameter were sprayed from solution at low concentration onto a glass coverslip and illuminated with a laser using a total internal reflection geometry. Fluorescence emission was collected by the same objective lens and imaged with a CCD camera. This optical arrangement yields an image of the optical emission pattern, similar to the radiofrequency intensity pattern generated by a radio antenna. That is, there is zero intensity radiated parallel to the direction of the dipole, giving a donut-shaped pattern if the optical dipole is vertically oriented. If the dipole is horizontal, the emission pattern is elliptical. A tilted dipole can be observed as an asymmetric combination of these two patterns.



In the images that we obtained, most of the particles appeared to be oriented either perpendicular (donuts) or parallel (ellipses) to the glass substrate, with few having intermediate orientations. A typical image is shown at right, with vertical and horizontal particle axes shown by the red arrows. The reasons for this behavior are not clear, but may be due to the interaction with the glass surface. Another possibility is that the particles are not single quantum dots but aggregates of more than one. Photon correlation measurements are underway to prove that the particles observed are indeed single nanoparticles. Particles with either orientation were also observed to blink off and on periodically, a phenomenon that commonly occurs with individual quantum dots.

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