Institut für Festkörperphysik

Abteilung Atomare und Molekulare Strukturen

Leibniz Universität Hannover

Vortragsankündigung

Donnerstag, den 12.01.2023
um 14:00 Uhr
Königlicher Pferdestall, Festsaal
Appelstrasse 7

spricht

Prof. Dr. Iwan Moreels

(Universität Gent)

zum Thema

“Optoelectronic Properties and Quantum Applications of Colloidal Nanocrystals“

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Abstract

Colloidal semiconductor nanocrystals bear many resemblances with their epitaxial counterparts, yet there are also essential differences. In this seminar, I will use the basic properties of 2D quantum wells and 0D quantum dots as starting point to discuss how we can exploit chemical synthesis to produce a variety of sizes and shapes of colloidal nanocrystals, each with their peculiar optoelectronic properties.

In the first part, I will highlight how we can produce 2D CdSe nanocrystals with controlled thickness and lateral dimensions, yielding emission colors spanning from the UV to the red part of the spectrum. This in turn allows us to precisely tune the exciton and biexciton binding energies, with values, in contrast with epitaxial quantum wells, exceeding room temperature even for the biexciton binding energy. The optoelectronic properties not only depend on the geometry of the 2D nanocrystal through quantum confinement of charge carriers, by growing a shell of a second semiconductor around the CdSe core, we can also engineer the electron-hole Coulomb interactions, which leads to a pronounced shift of the band gap. However, the same dielectric screening which enhances the electron-hole attraction, is also responsible for stronger same-charge repulsive interactions in biexcitons, implying a limit to the enhancement of biexciton binding energies.

While our 2D nanocrystals are typically too large to show photon antibunching and serve as a quantum light source, 0D colloidal quantum dots are becoming a viable, solution-processed alternative. For instance, in contrast with epitaxial quantum dots, they can operate at room temperature, and their emission can be tuned to any desired wavelength by simply controlling the composition and size of the quantum dots.

In the second part, I will discuss how to synthesize highly fluorescent CdSe/CdS colloidal quantum dots that show (nearly) no intermittence. Next, as these quantum dots have intrinsic fluorescence lifetimes that extend beyond 100 nanosecond, I will show how one can increase the emission rate by charging them with up to 20 electrons, which increases the radiative recombination rate, while at the same time the nonradiative Auger rate remains suppressed due to the proper choice of quantum dots core and shell dimensions. Finally, I will demonstrate that the single-photon emission can be improved by spectrally filtering out the biexciton emission, which, again due to the unique features of our quantum dots, can be performed at room temperature due to the exceptionally large blue shift of the biexciton emission. In particular, this blue shift is achieved by exploiting strain and piezoelectric fields in our CdSe/CdS pure-phase wurtzite quantum dots, which is known to increase the electron-hole separation and exciton-exciton repulsive interactions, especially for quantum dots with a large CdSe core.