Carrier Temperatures in CdSe Quantum Dots Using Detailed Balance Method

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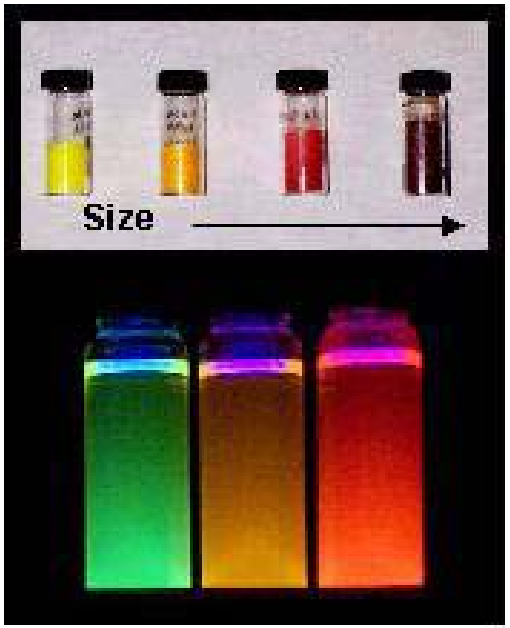
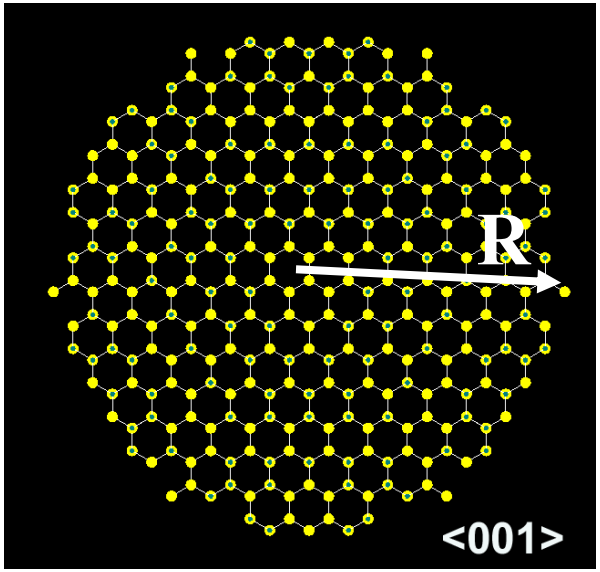
Overview

- CdSe Quantum Dots, the Band Gap, Phonon Bottleneck, and Carrier Temperatures Explained
- Motivation/Interest
- Equipment
- Our Method and Results
- Data Comparison
- Future Work
- Acknowledgements

What is a CdSe quantum dot and why is it interesting?





[*Strouse Group*]

$$Color \sim E_{Gap} + \frac{1}{R^2} - \frac{1}{R}$$

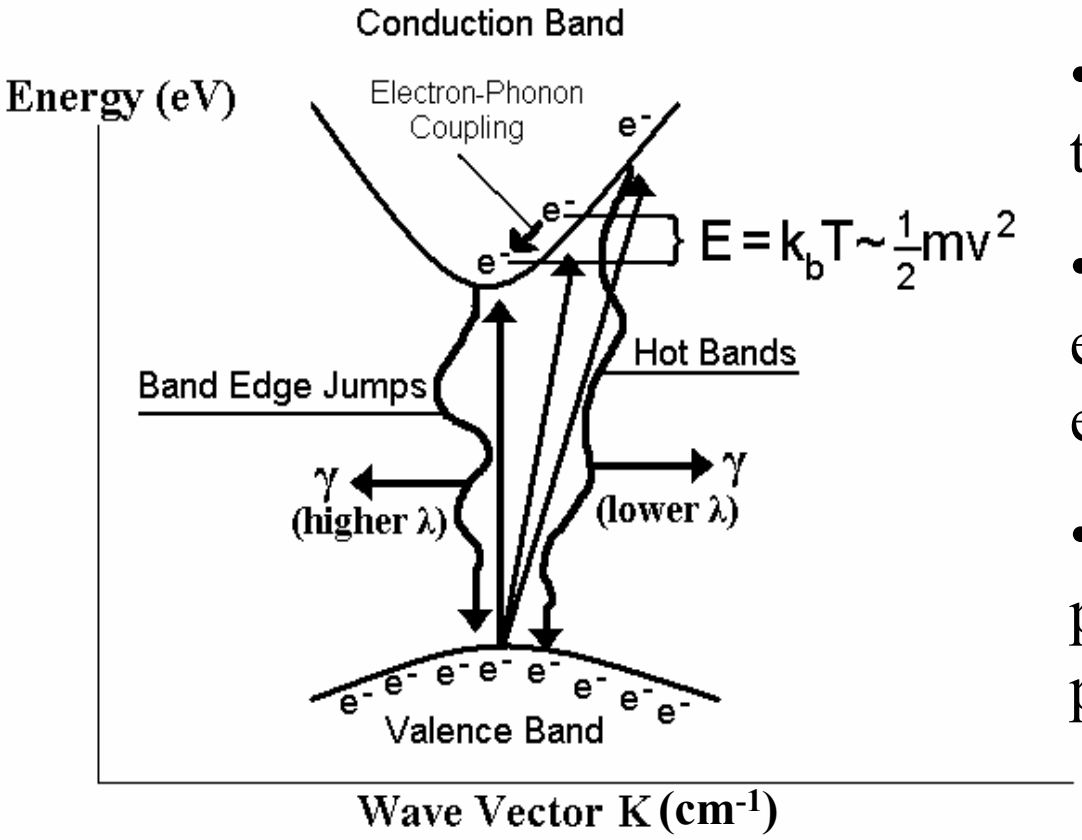
(simplified equation)

$$\Delta E_{1S_{3/2}-1S_e}(R) = E_{gap} + \left(\frac{h^2}{8\mu_{e,h}}\right)\frac{1}{R^2} - \left(\frac{e^2}{4\pi\varepsilon_0\varepsilon}\right)\frac{1}{R} + Smaller\ \ Terms\ (R)$$

Confinement **Coulombic**

[*Brus, LE (1983)*]

The Band Gap



- Band Edge Jumps = Couple, then release photon
- Hot Bands = Coupling is not efficient, so release photon early
- If Hot Bands are more probable then there is a phonon bottleneck

Motivation/Interest

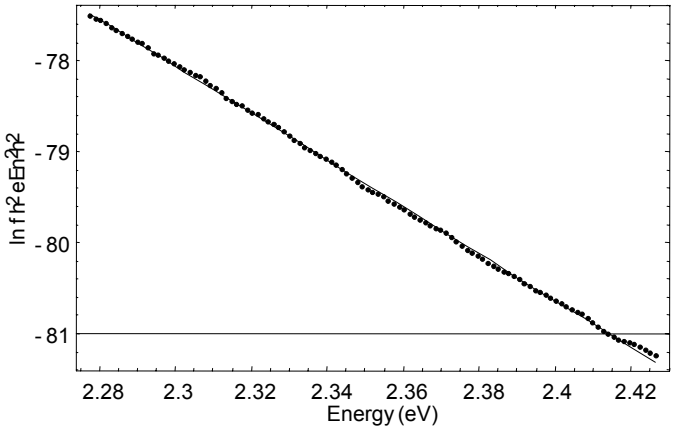
- Quantum Computing
- Solar Panels
- For the sake of discovery

How we Arrive at a Carrier Temperature Value

- By collecting fluorescence and absorption
- Using the Bolton-Archer equation (derived from the detailed balance method):

$$\frac{Fluorescence}{Absorbance} \sim \frac{1}{T}E + c \quad \textit{(simplified version)}$$

$$\ln\left[\frac{f(v)}{\varepsilon(v)\eta^2(v)v^2}\right] = \frac{-h}{k_B T}v + 1\left[\frac{8\pi \ln(10)\tau_r}{10N_A c^2}\left(\frac{g_l}{g_u}\right)\right] + \frac{E_g}{k_B T}$$



Equipment

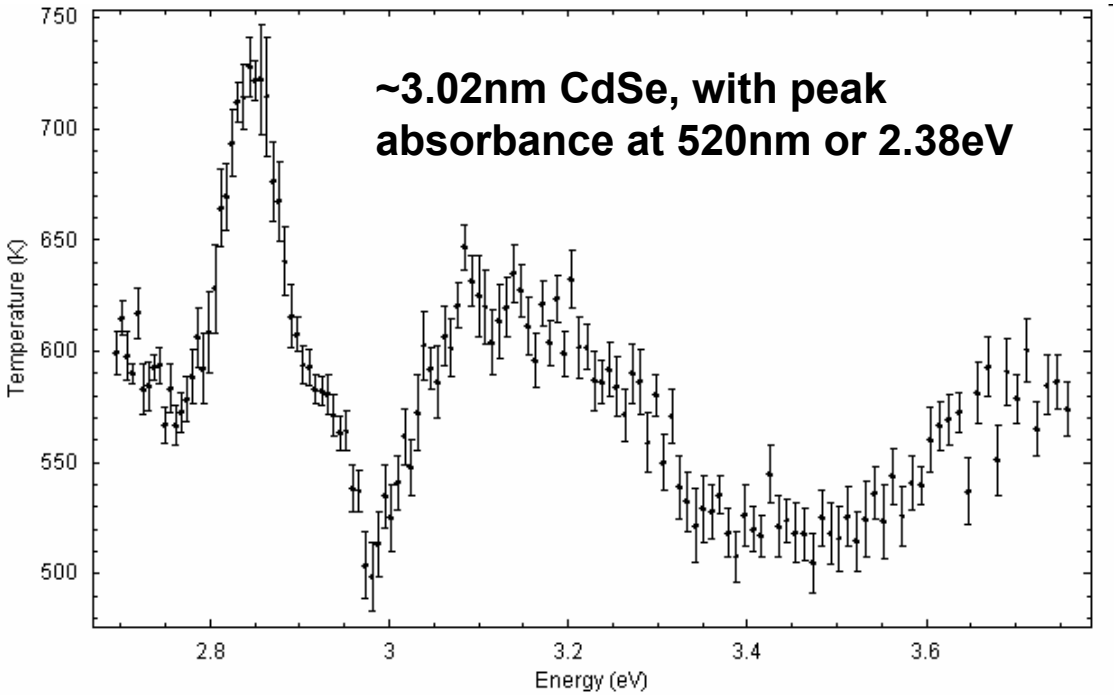
Cary Eclipse Fluorescence Spectrophotometer by Varian Labs

Fluorescence

Cary 50 Bio UV-Visible Spectrophotometer by Varian Labs

Absorption

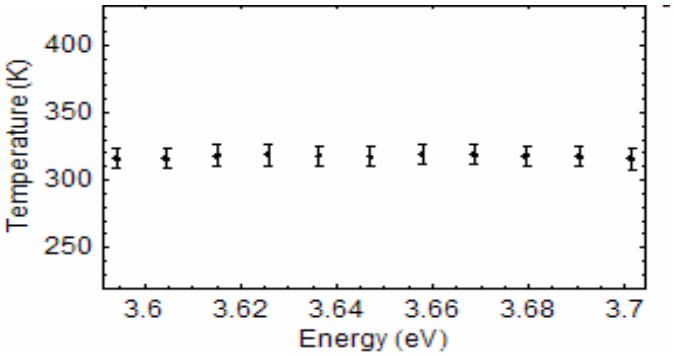
Data Comparison



•CdSe is much hotter!

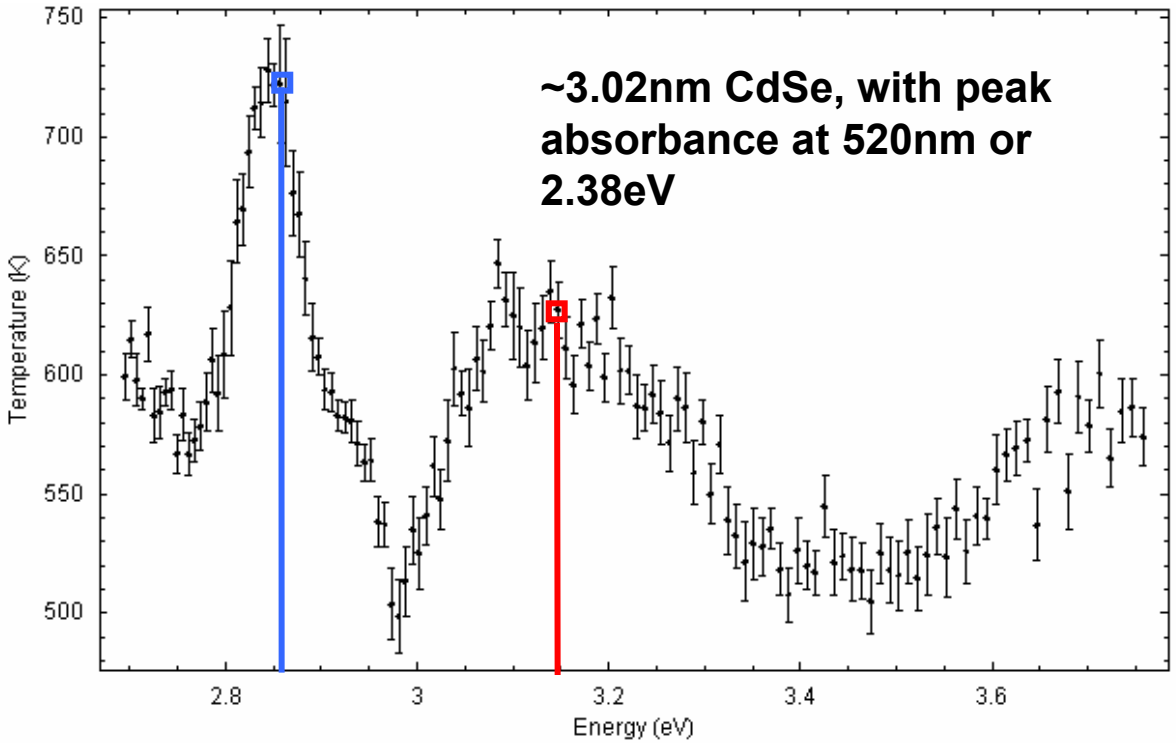
Control Experiment:

Anthracene in ethanol

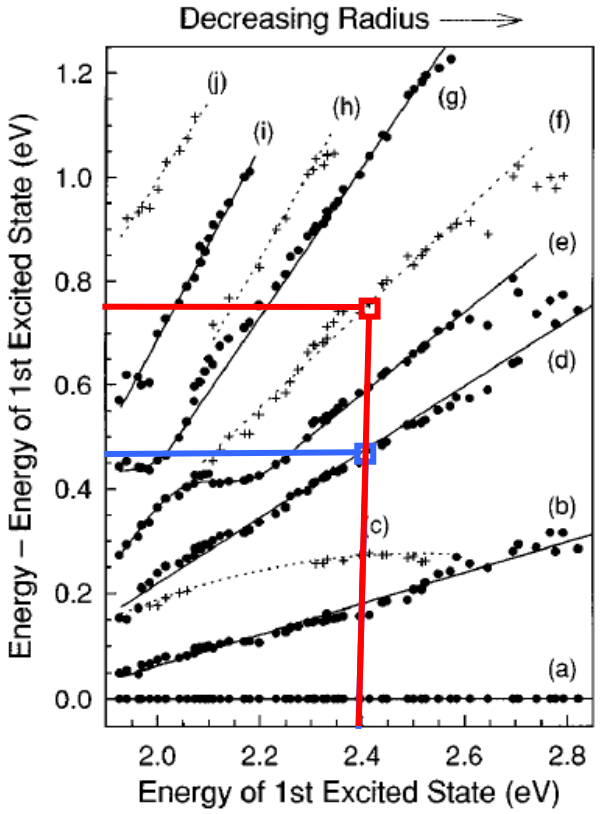


•Note the relatively flat nature of Anthracene compared to CdSe quantum dots

Data Conformation and Correlation



- Peaks match the electronic quantized states



[*Norris and Bawendi (1996)*]

Future Work

- We now know that the carrier temperatures are high, but why is this?
  - What is the cause of the Phonon Bottleneck?
    - Boltzmann distribution reasoning
- What things affect carrier temperature and how?

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What is a Carrier Temperature and Detailed Balance Method?

- The exciton (hole and electron) system is in a Boltzmann distribution cycle
- This thermodynamic cycle has an equilibrium temperature (hence 'Detailed Balance')
- That temperature can be extracted as the carrier temperature