Photoluminescence of InGaN Quantum Dots

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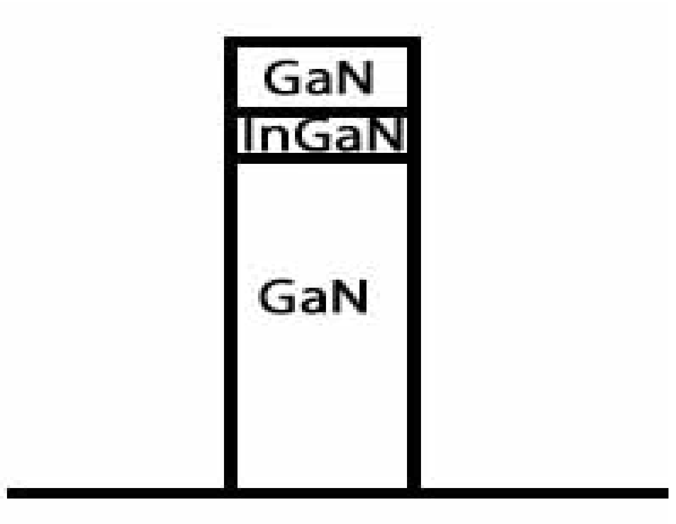
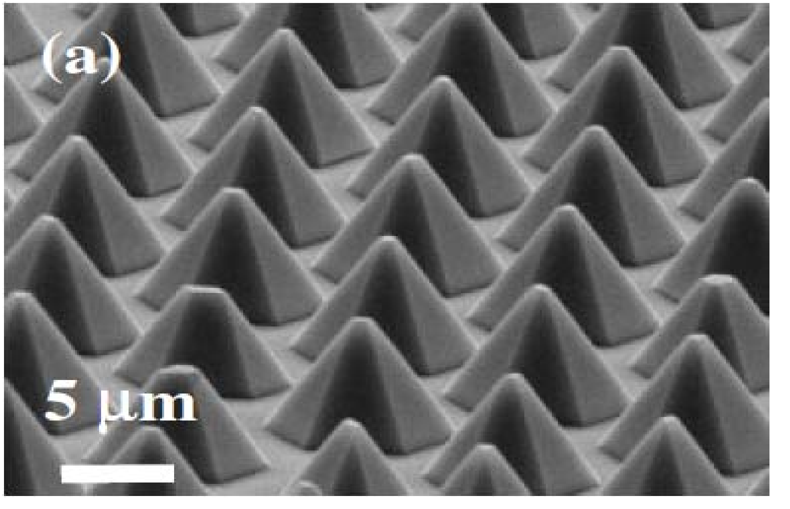
Quantum Dots



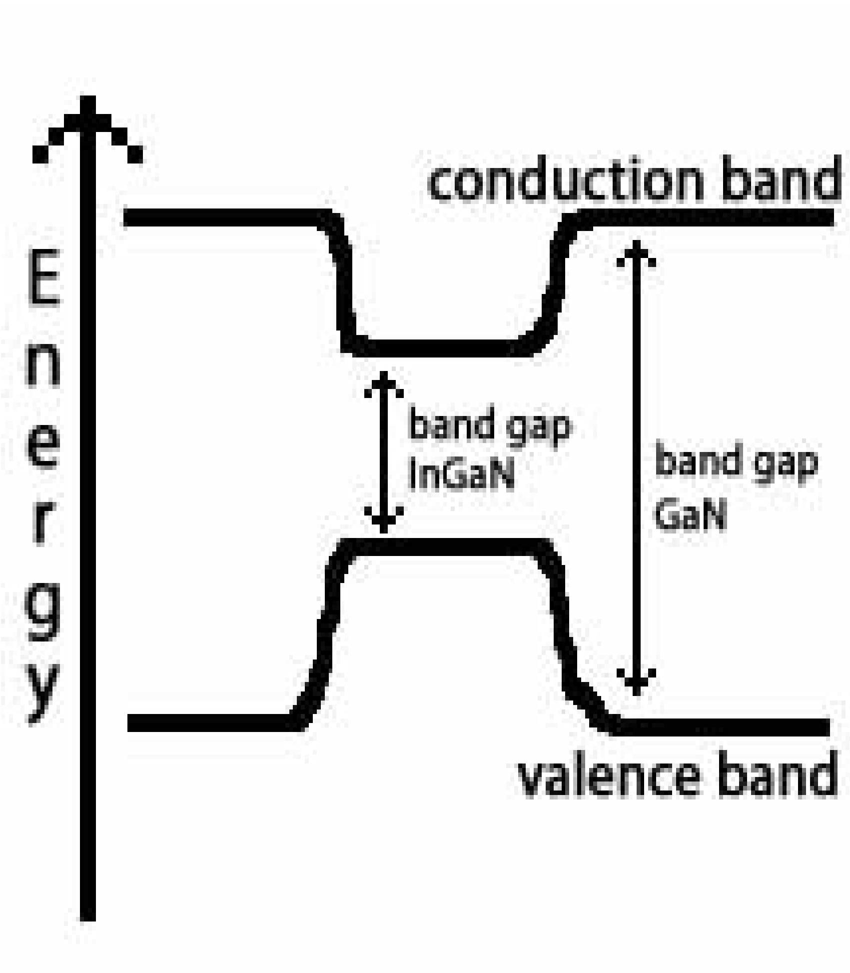
- A quantum dot (QD) is a semiconductor which is confined in all three spatial dimensions
- Properties are between those of a semiconductor and an individual molecule
- Used in LEDs, diode lasers, solar cells and quantum computation

- Made of InGaN surrounded by GaN
- Fabricated by etching down a sheet to make pilars ~5um dimensions
- Sample contains many arrays of QD of different densities



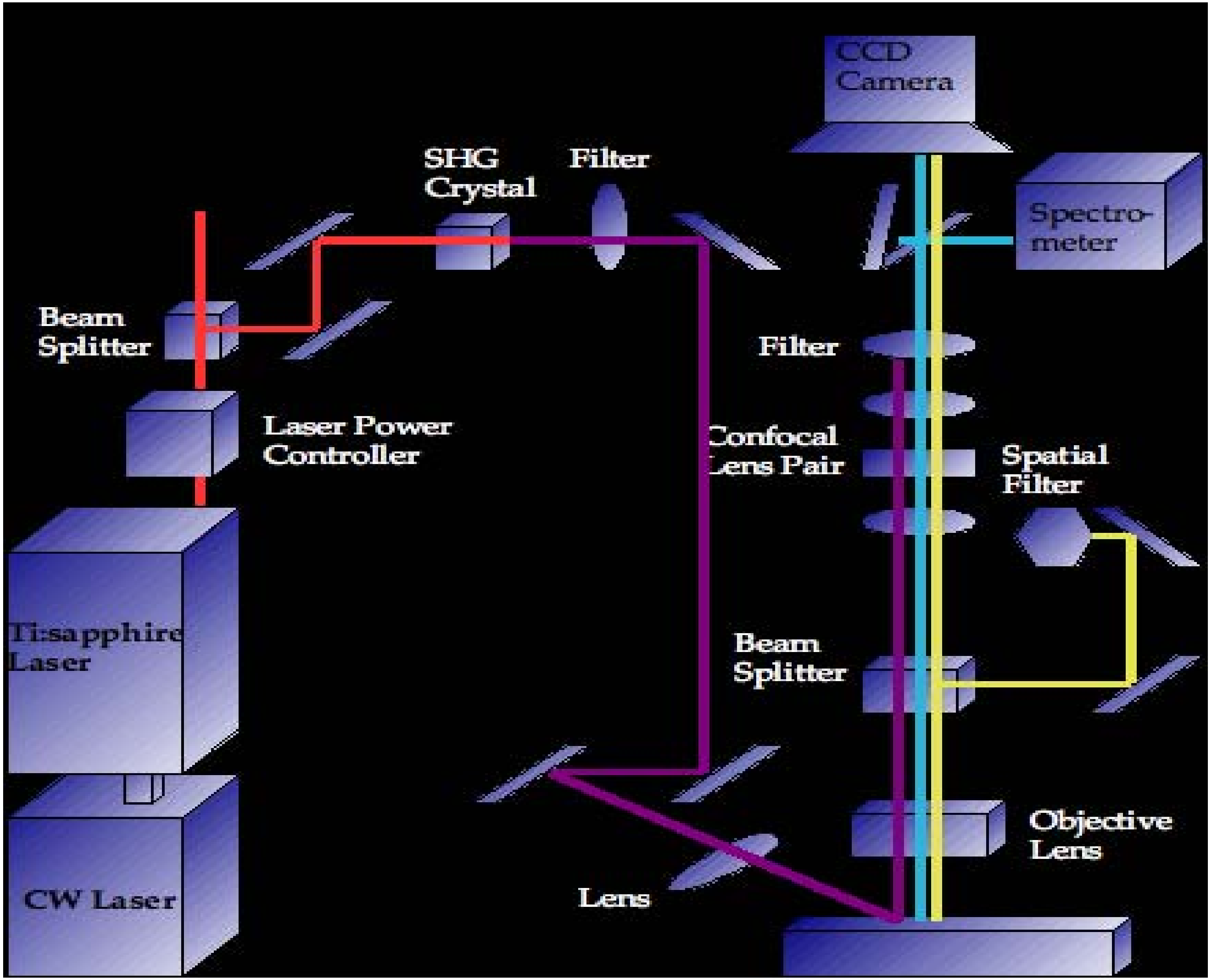
Martin, R.W. *Physica Status Solidi (a)*, 202(3), p.372-376

Quantum Dots

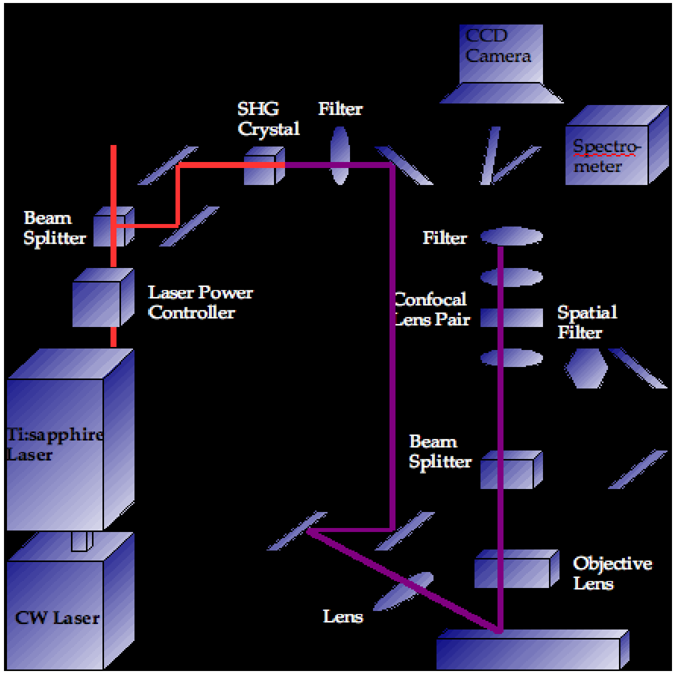


- Possible to excite only electrons in the QD by selecting a wavelength with the energy between that of the band gaps
  - Our sample requires 390 nm
- When the excited electrons return to the valence band they emit a photon process called photoluminescence (PL)
  - Our QD emit ~ 420 nm
- Because the photon wavelength is directly related to the band gap spacing we can study the structure of QDs examining the PL

Experimental Setup

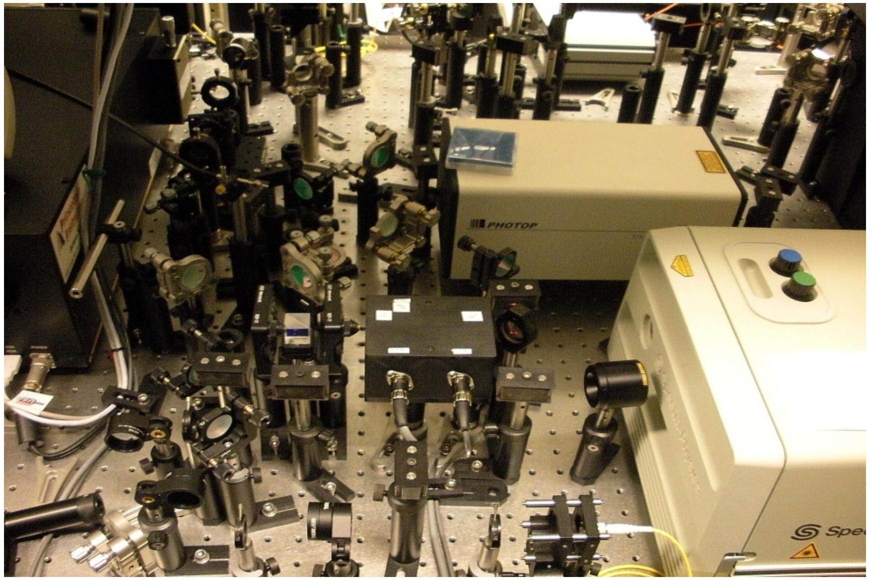


Laser Path



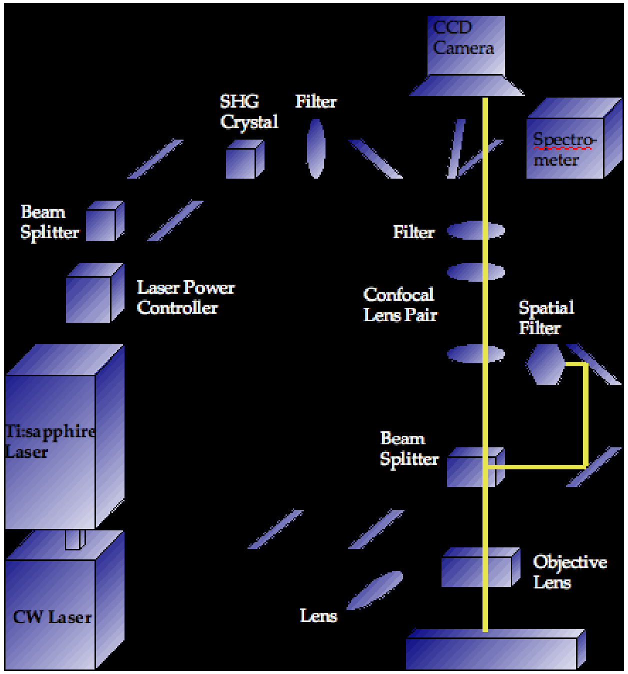
- Use CW laser to pump Ti:sapphire laser
  - Tunable 700 nm - 1100 nm
  - Pulsed laser – we mode lock at 80Hz
- Control Power
  - LPC- Digital
  - Polarizing Beam Splitter – rotating wave plate lets different amount of light through based on polarization

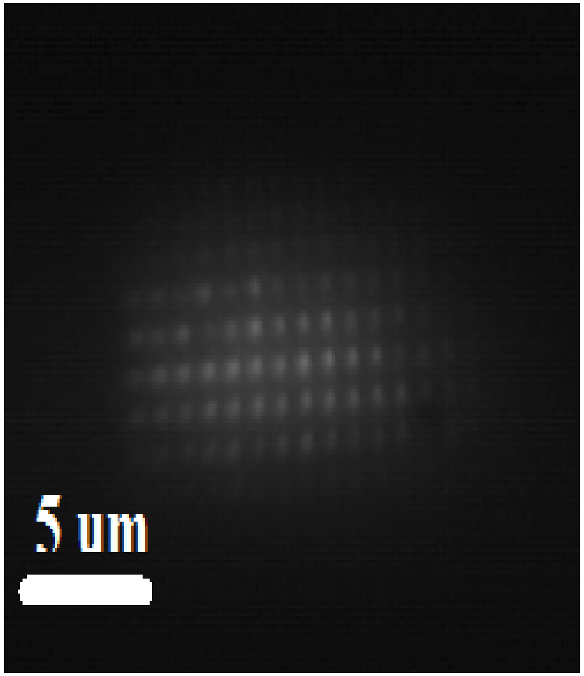
- SHG Crystal – changes wavelength to 390 nm
  - Photons “combined” to form one photon with half the wavelength
  - Coherent process that conserves energy and momentum

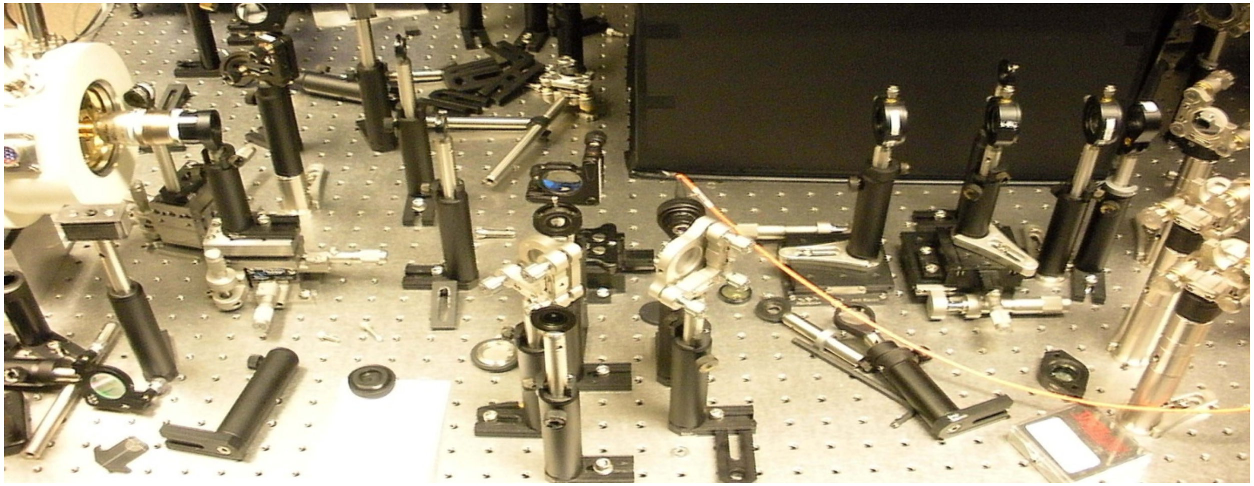


Finding The Sample

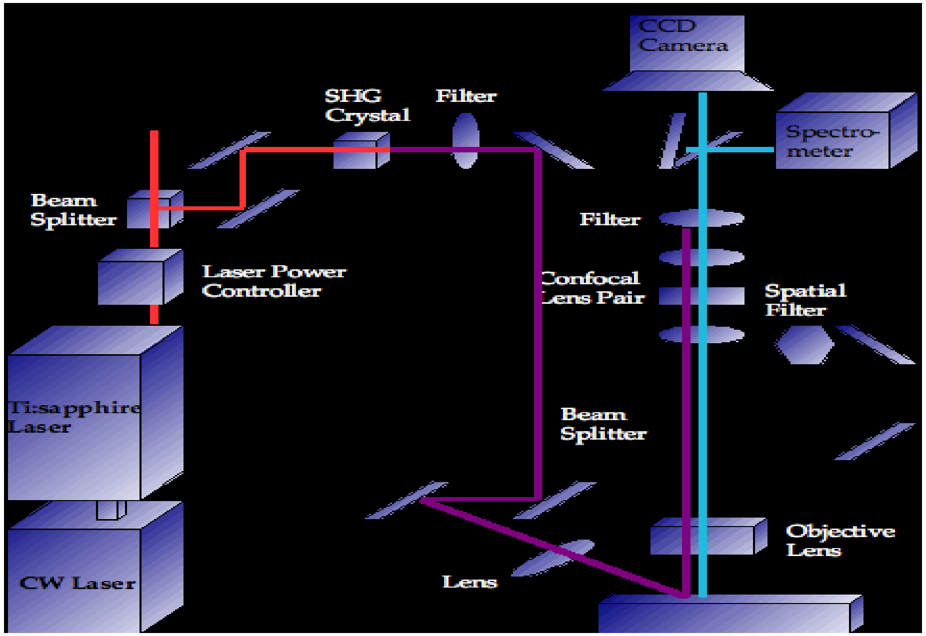
- Illuminate sample with white light
- Look at sample with CCD camera
  - photons hit pixels on CCD chip
  - Signal sent to computer to light up corresponding pixel on screen
- Move sample to appropriate spot by turning micrometers in cryostat stage







Data Collection



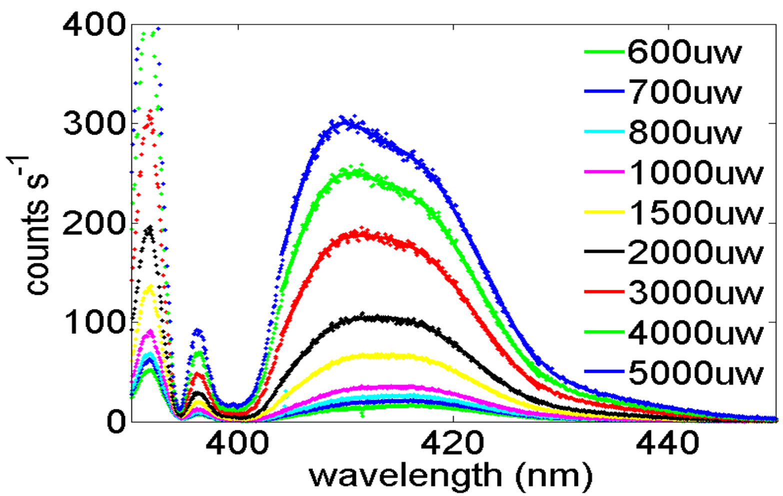
- Spatial filter is used to gather PL from a single QD
  - Pin hole placed in the image plane cuts off all light except for a small circle
  - Use the stage to move the spatial filter such that the hole lines up with light from the QD we want so study
- Spectrometer is used to make a histogram of the number of photons at each wavelength
  - luminescence from the QD goes through a diffraction grating and hits the CCD chip which records how many counts in each location
- Cryostat allows us to control the temperature
  - Cool sample by circulating liquid helium
  - Control temperature by balancing helium flow and amount of heat from internal heater

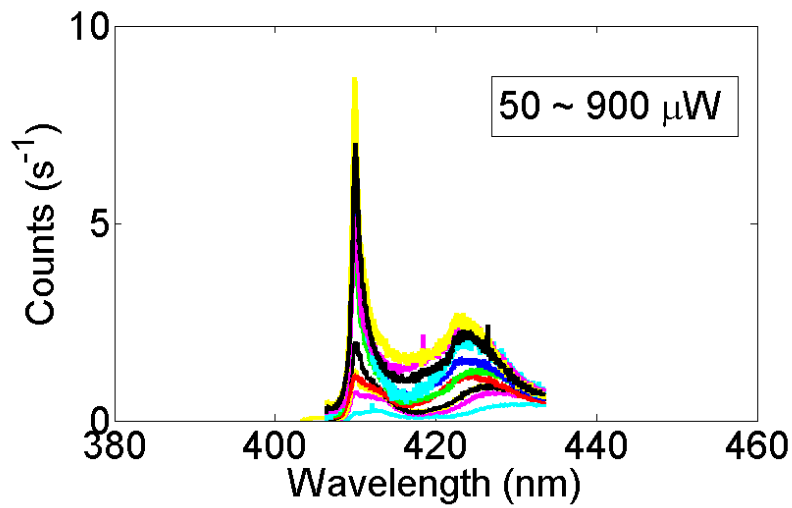
Excitation Dependent Time Integrated Photoluminescence

Dot One

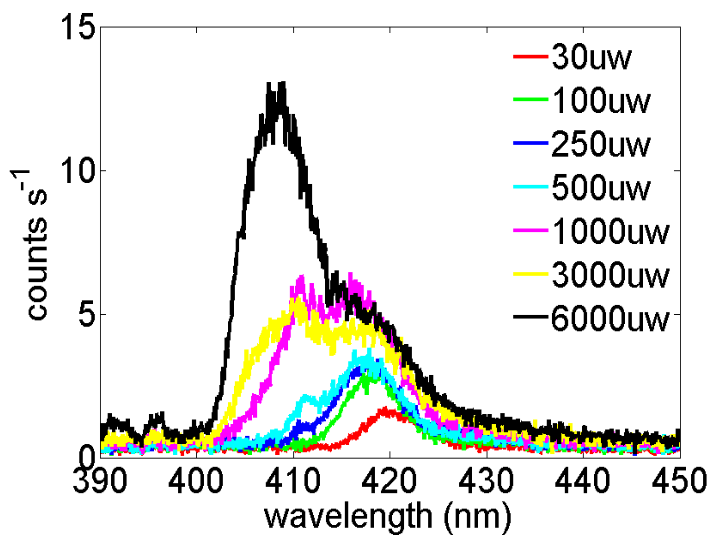
Dot Two

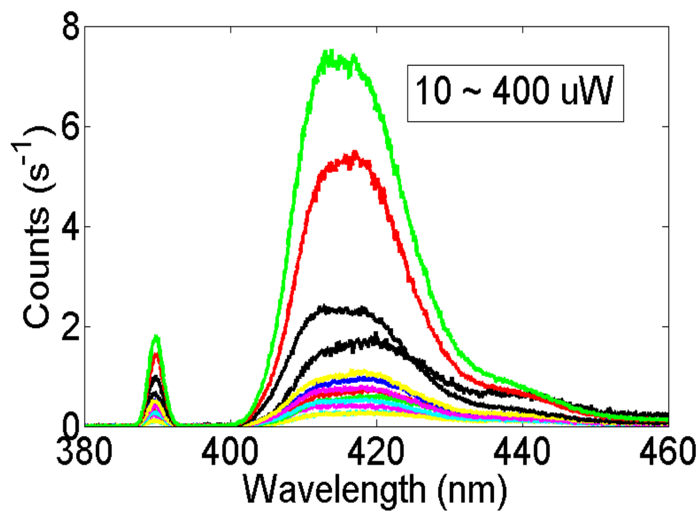
Room Temperature





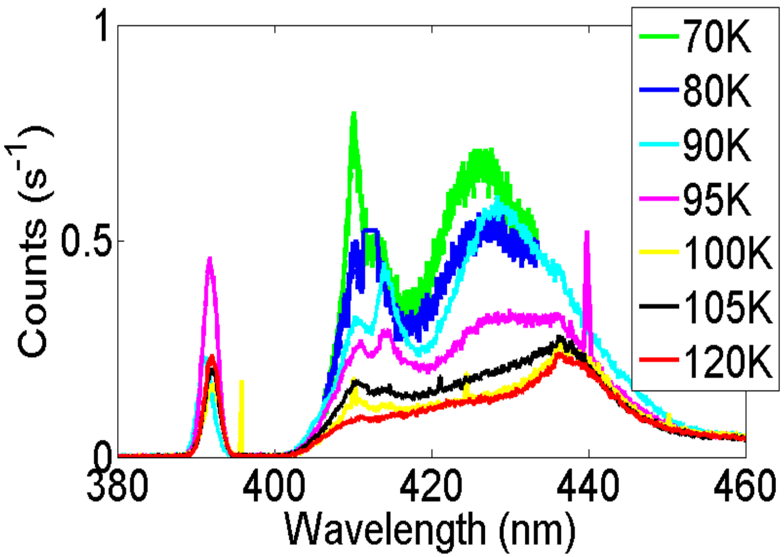
6K



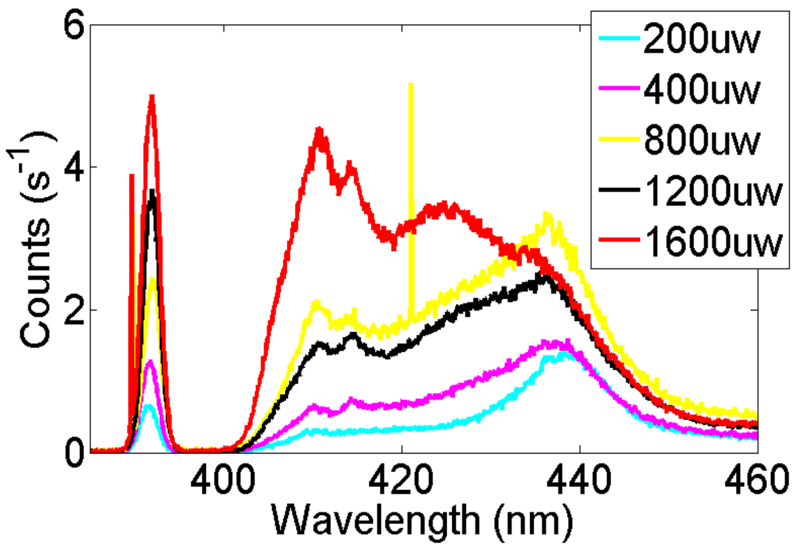


Further Photoluminescence for Dot Two

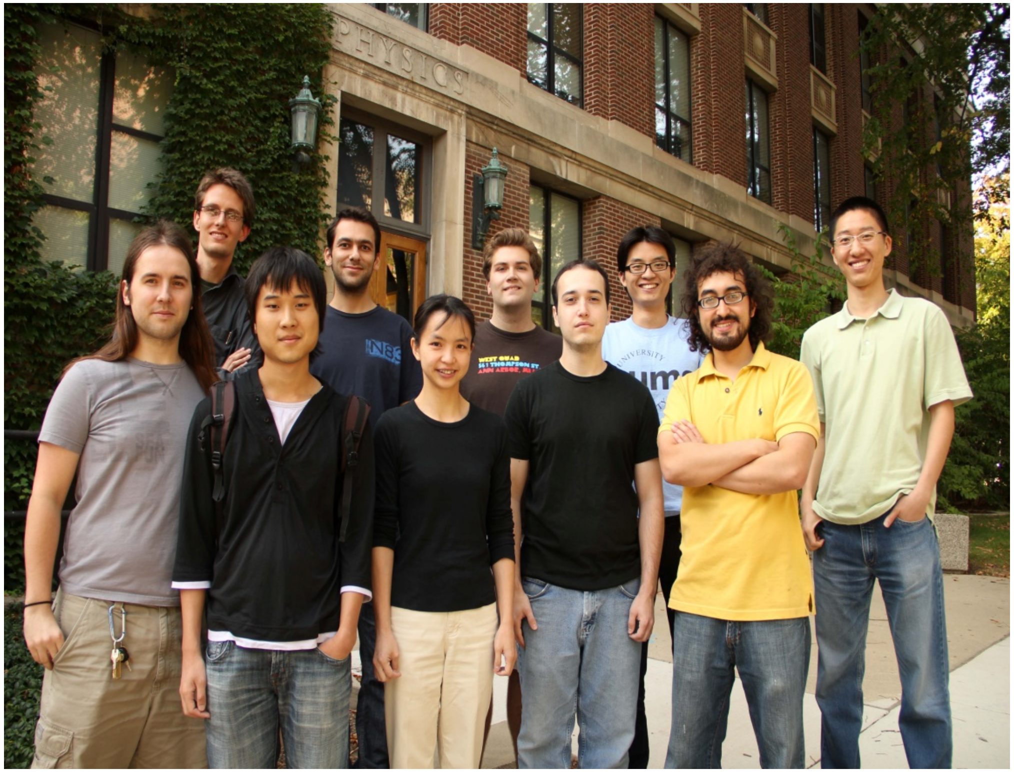
Temperature Dependence



Excitation Dependence at 105 K



- Summery of findings
  - Pump power increase -> blue shift
  - Temperature increase -> red shift
  - Broad peak at 300K corresponds to the two groups of peaks.
  - Possibility of exciton biexciton emission



This research was done as part of the 2011 Summer REU at the University of Michigan

I worked in Hui Deng's lab with Lei Zhang a curent graduate student, Connor Roncaioli an undergraduate.