# Optical Characterization of Gallium Arsenide Quantum Dots

Casey Timms
The University of Arizona
Schaibley Lab - Department of Physics
UROC Summer Research Institute
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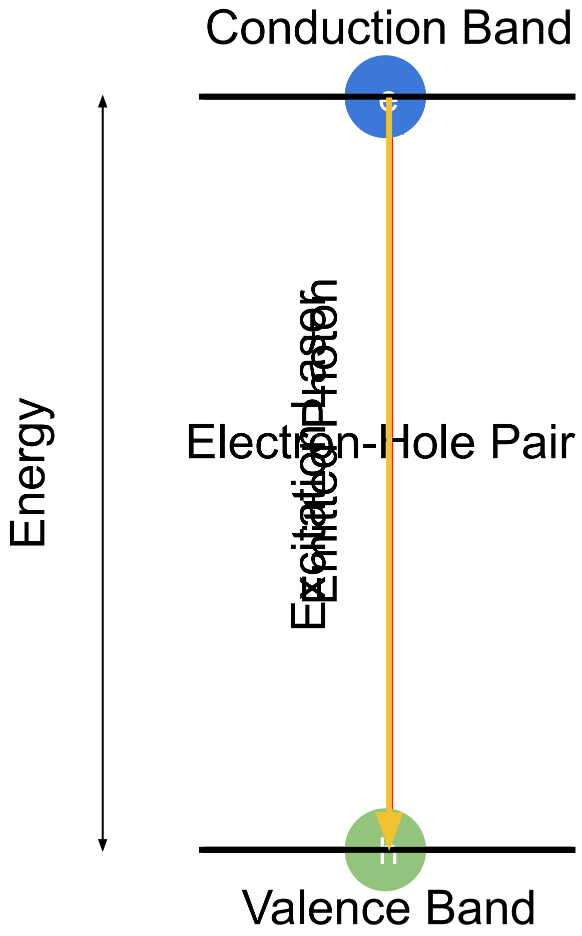
# Two-Level Systems

- A system that can occupy either a ground state or excited state.
- A laser moves the system to the excited state.
- In this state, an electron occupies the conduction band and a hole occupies the valence band.
- The electron and hole quickly recombine, releasing their stored energy as a light particle, called a photon.
- Photons formed in this way are called exciton emissions.



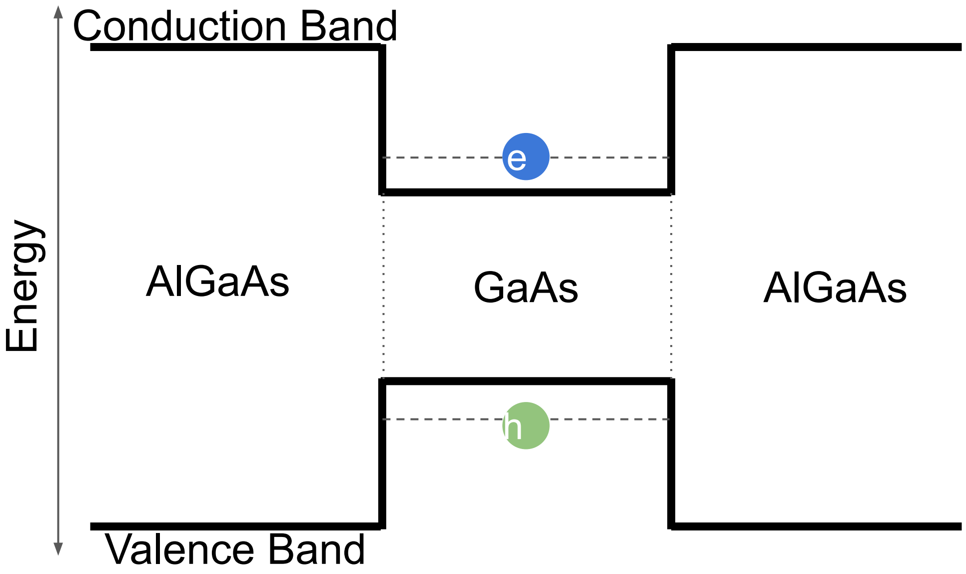
# Gallium Arsenide Quantum Dots

- Semiconductor devices that behave similarly to two-level systems.

- They are made by placing a layer of gallium arsenide (GaAs) between two layers of aluminum gallium arsenide (AlGaAs).

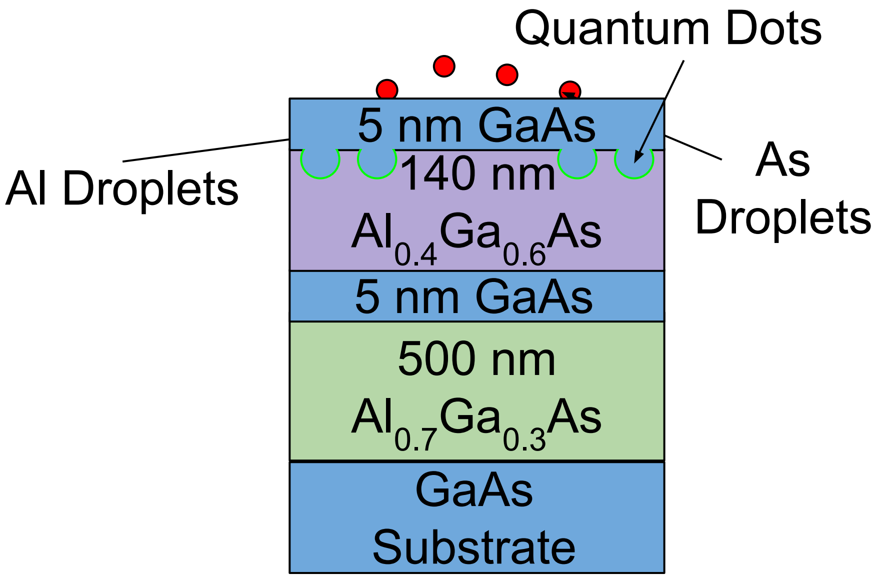
- The band gap difference between GaAs and AlGaAs creates a potential well.

- This well hosts low energy trapped states for electrons and holes to occupy.



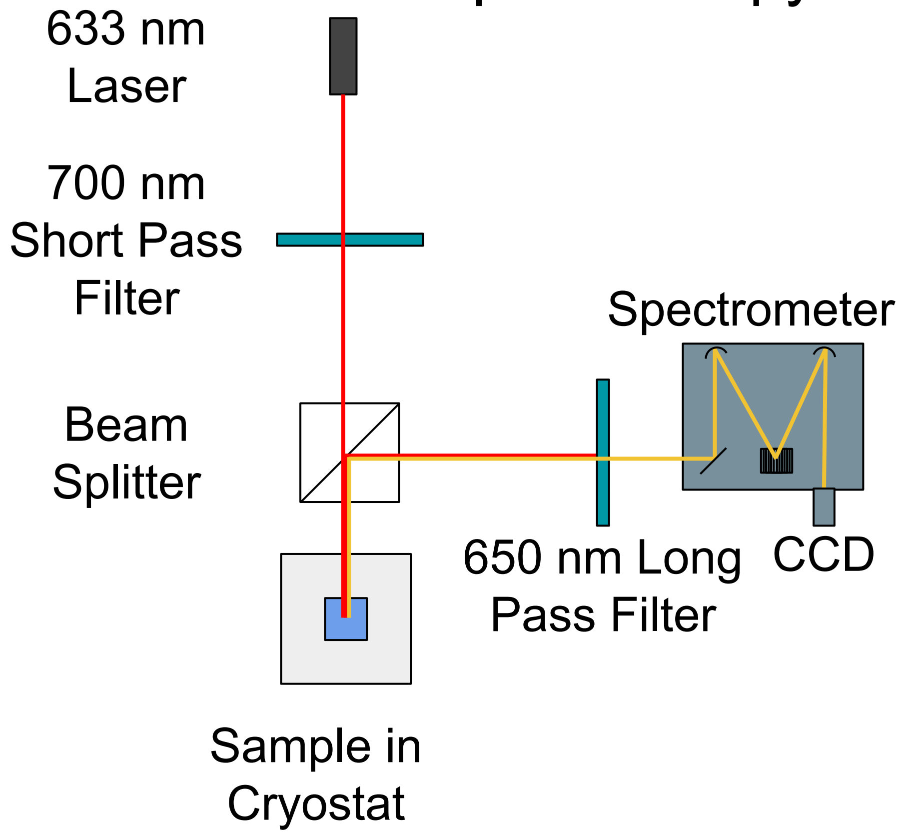
# Growth of GaAs Quantum Dots

- 500 nm of $Al_{0.7}Ga_{0.3}As$ was grown on a GaAs substrate and capped by a 5 nm layer of GaAs.
- A 140 nm $Al_{0.4}Ga_{0.6}As$ layer was grown on the GaAs cap.
- Aluminum Al droplets were deposited on the device, and Arsenic (As) droplets were sprayed onto the Al.
- This created nanoholes, which were filled by a 5 nm layer of GaAs, forming quantum dots.



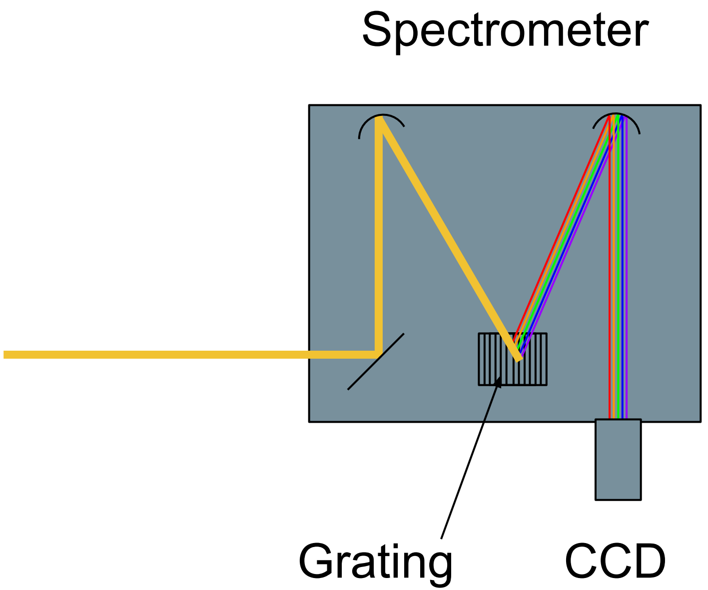
# Characterization Through Photoluminescence Spectroscopy

- First, we measured the energy of photons emitted by quantum dots through photoluminescence spectroscopy.
- Samples were held in a cryostat at 9 K.
- A 633 nm laser was passed through a 700 nm short pass filter and excited the sample.
- The emissions and reflected laser were directed through a 650 nm long pass filter.
- The filter blocked the laser, but allowed emissions to enter the spectrometer



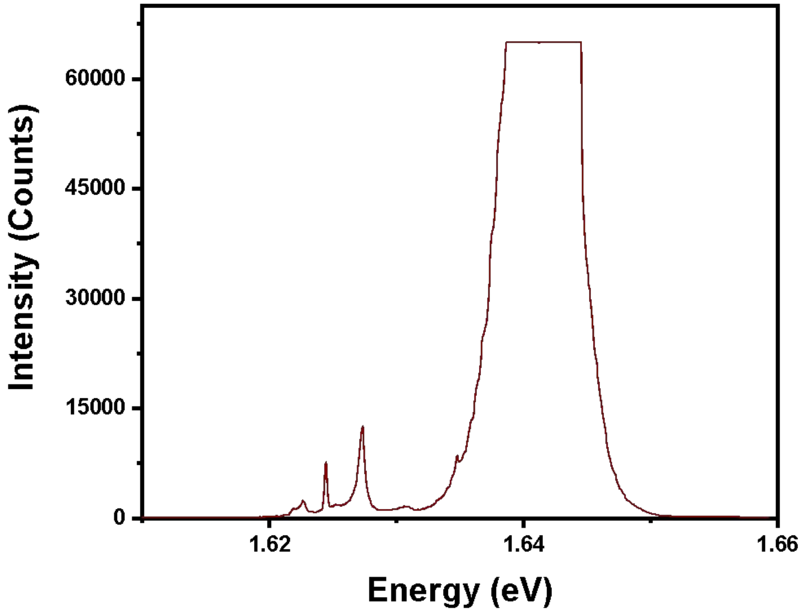
# Measurement Using a CCD Spectrometer

- Emissions struck a grating in the spectrometer and were separated into beams with different energies.
- Separated beams passed into a CCD camera, which measured their intensities individually.
- This allowed us to determine which photon energies were commonly emitted by the excited sample.



# PL From GaAs Sample

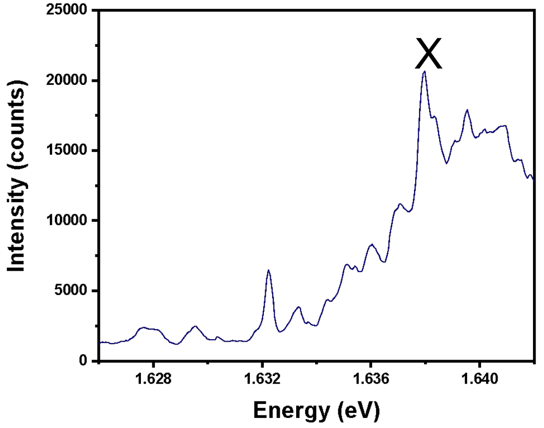
- Emission energies from GaAs samples were plotted against intensity to form a PL spectrum.
- The high intensity peak centered at 1.64 eV corresponds to a quantum well created by the 5 nm GaAs layer.
- The lower intensity peaks with lower energy are emissions from the quantum dot.
- We want to study quantum dots whose emissions are sharp isolated peaks.



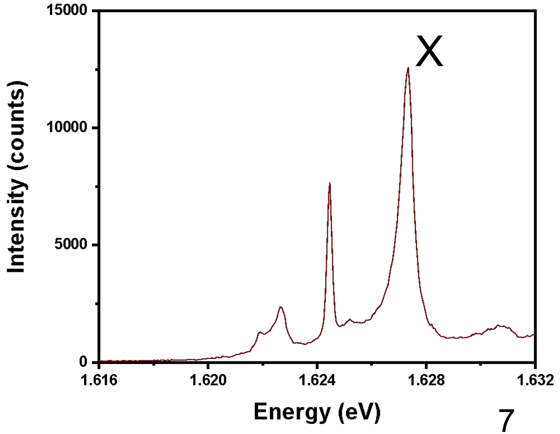
# Quantum Dot Emission Peaks from Two Samples

- PL data was collected from several quantum dots across two samples: sample A and sample B.
- Exciton emissions are identified as high intensity peaks, labeled X.
- Sample A had exciton emissions with an energy of approximately 1.637 eV.
- Sample B had exciton emissions with an approximate energy of 1.628 eV.

Sample A




Sample B



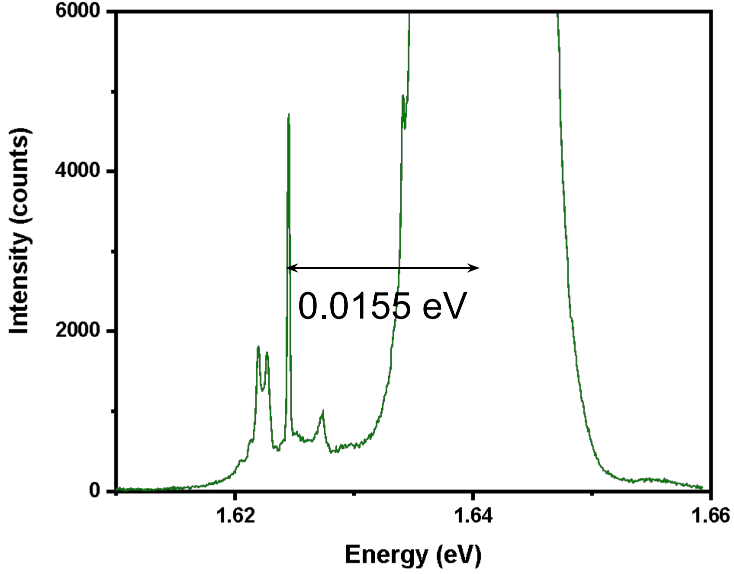
# Energy Separation

- Sample B hosted quantum dots whose exciton emissions had lower energy than those of sample A.

- Therefore emissions from these quantum dots are separated from the high intensity quantum well by 0.0155 eV.

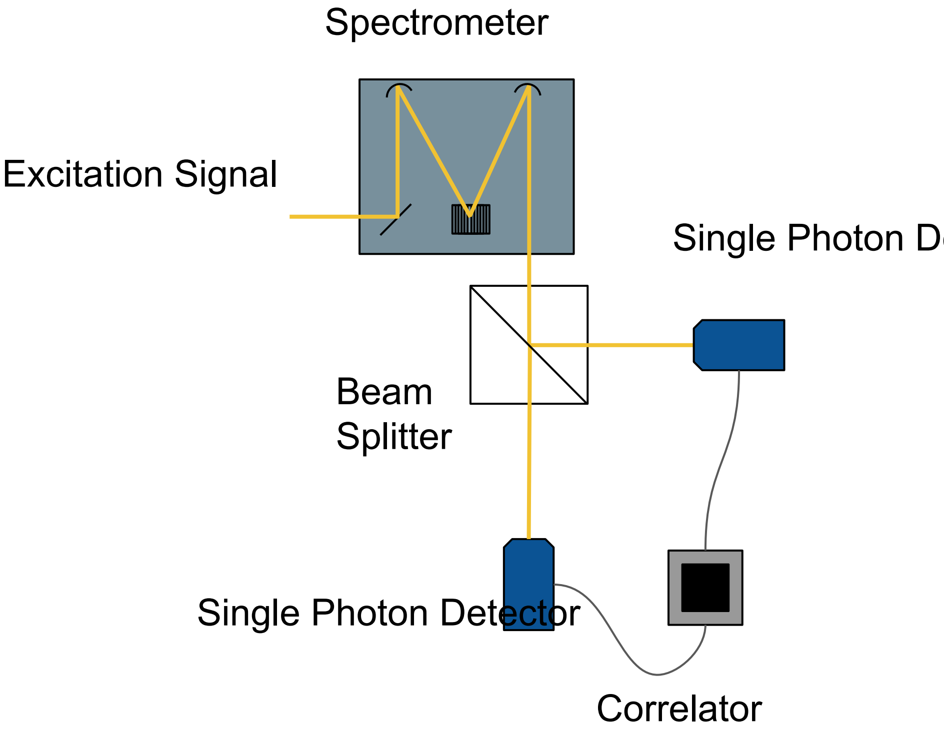
- This means that it is possible to filter out the quantum well, leaving only the exciton emissions

- Thus, future measurements should be performed on quantum dots from sample B.



# Applications and Next Steps

- Single photon emitters are applicable to quantum computing and quantum information technology.
- Thus, the next step is to determine if these quantum dots are single photon emitters.
- After emissions pass through the spectrometer, they will be directed through a beam splitter.
- Emissions will then strike one of two single photons detectors.



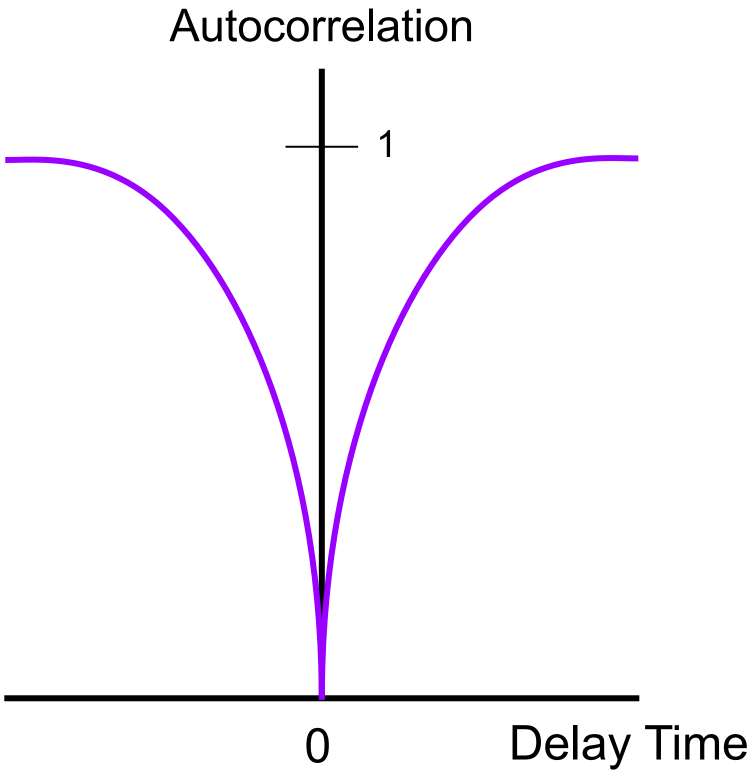
# Future Antibunching Measurements

- A single photon that passes through the beam splitter can only be detected by one single photon detector, not both.

- If the quantum dots are single photon emitters, then the probability both detectors firing at the same time is 0.

- In this case, we expect a plot of probability as a function of delay time to resemble the example.

- If these measurements are successful we will use resonant excitation to perform more complex characterization.



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# Questions?

Casey Timms
ctimms@arizona.edu