Quantum Dot On-Chip Lasers

Gerald Shafer, Rey Vega, Tatiana Velasquez and Thy Nguyen

Mentor: Jennifer Selvidge
Advisor: John Bowers

Optoelectronics Research Group

CALIFORNIA NANOSYSTEMS INSTITUTE

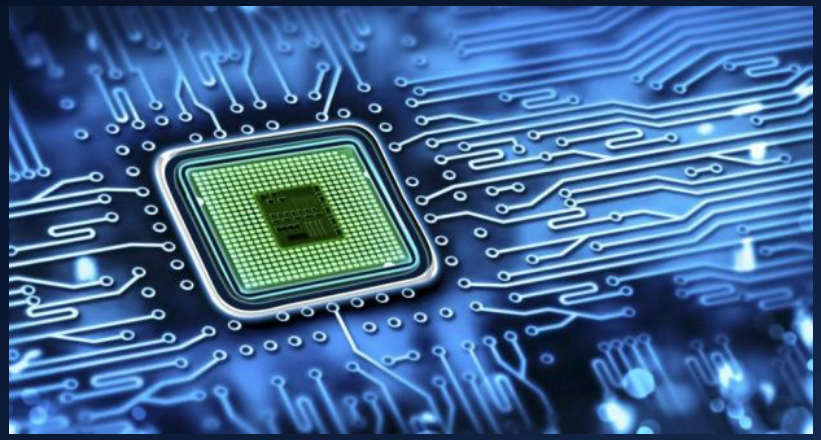
UNIVERSITY OF CALIFORNIA SANTA BARBARA

CSEP CENTER FOR SCIENCE AND ENGINEERING PARTNERSHIPS

Current Situation and Problems

- Electronics traditionally use metal wires on silicon chips
- Using only silicon and metals in circuits is limiting
- Improvements we can make with on chip quantum dot lasers:

1. Cost efficiency
2. Data Flow
3. Eco-friendly



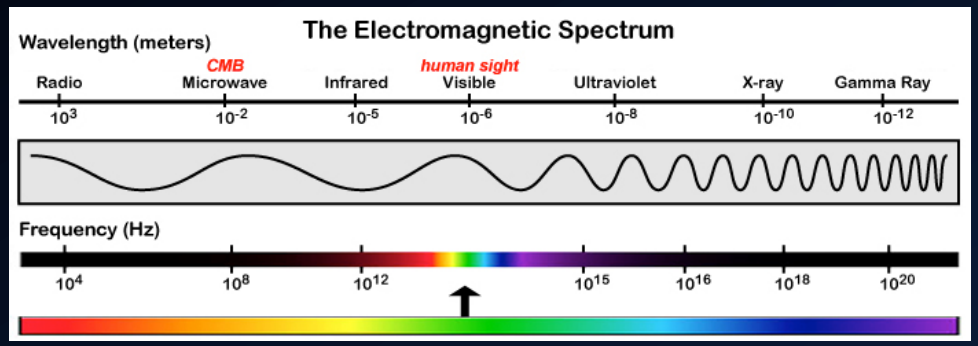
What are Semiconductors?

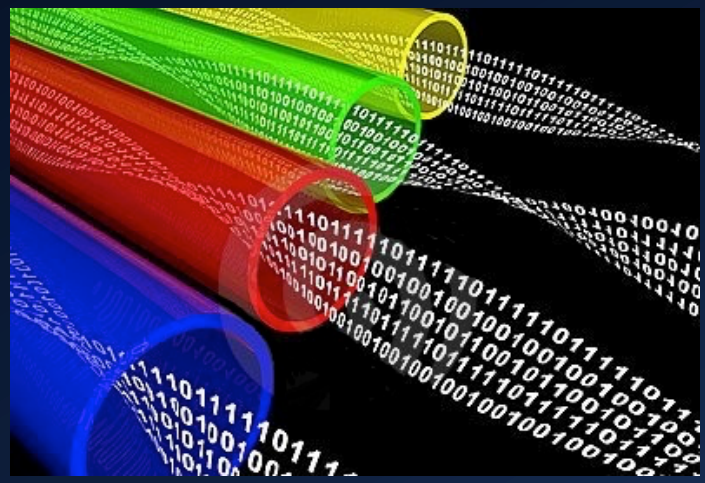
Light energy ⟷ Electrical Energy

Common Applications: Solar Panels, LEDs, and lasers

Background

- Quantum dots and silicon used in tandem create and carry light to send data in photonic integrated circuits
- Compound semiconductors are good light emitters





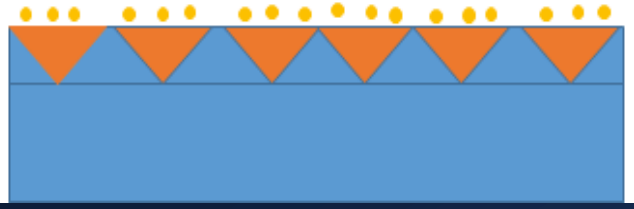
Process Flow

Unprocessed Silicon Chip

Laser quality GaAs grown in trenches

Using acids etch trenches in silicon chip

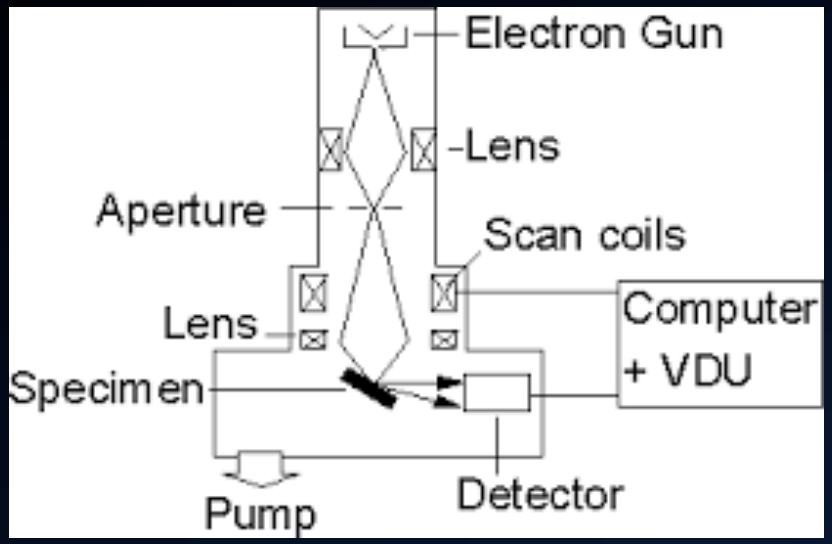
Quantum Dots grown on GaAs in trenches



Wet Etching the Chip

- Need a clean environment
- Pristine chip needed
- Cleaned with Potassium Hydroxide
- Hydroflouric acid etches the Silicon

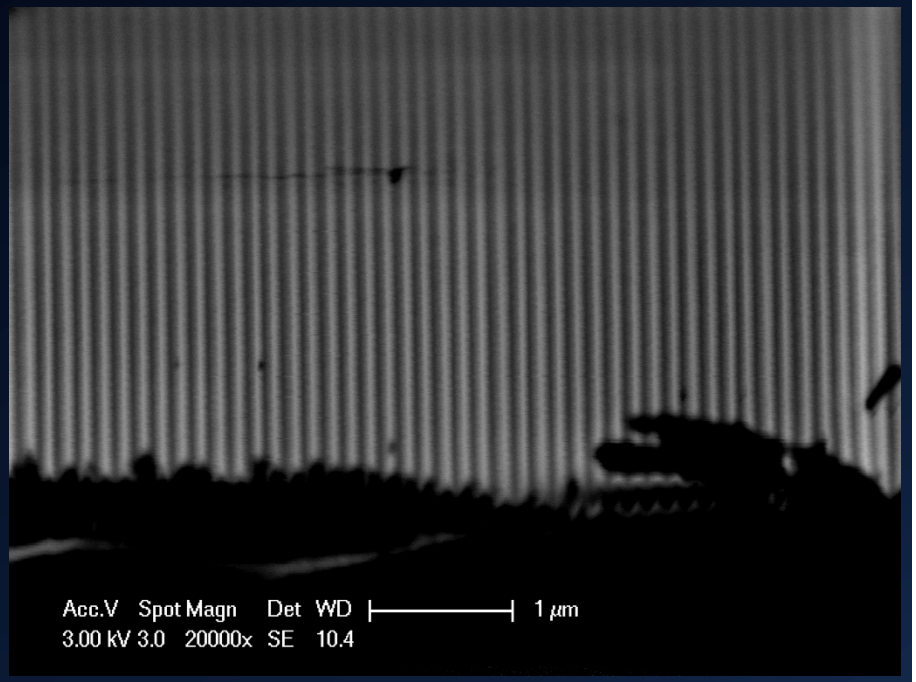
Scanning Electron Microscope (SEM)



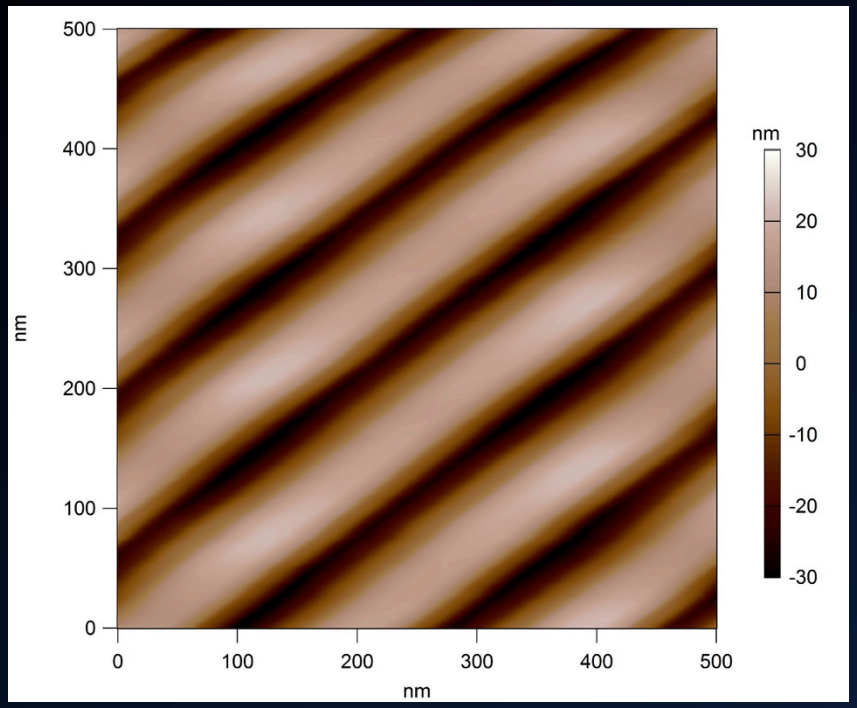
- Sample is in a vacuum
- electrons hit the substrate
- the special detector interprets the scattered electrons into an image

SEM of Chip

- Edge of our chip
- each trench is roughly .1 microns wide



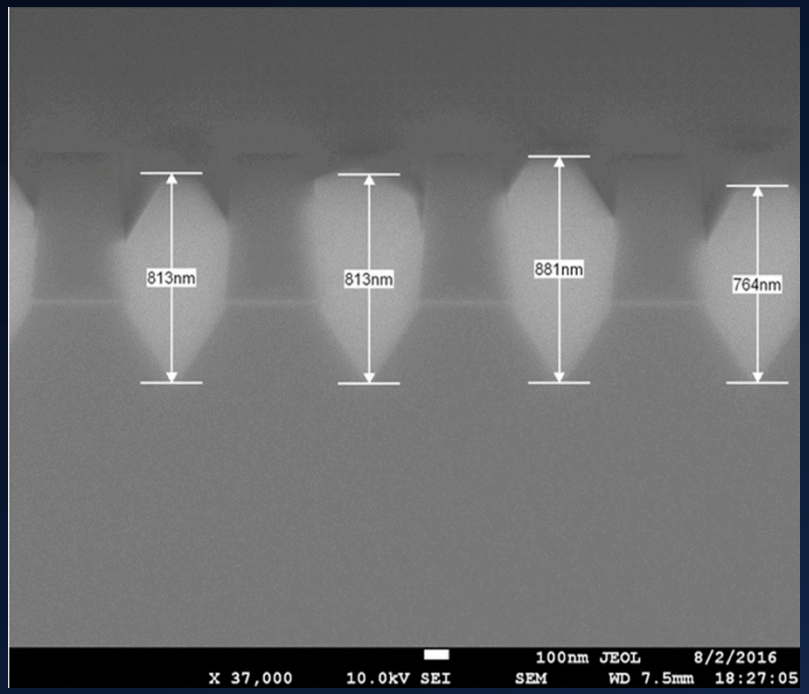
Atomic Force Microscopy (AFM)



- Measures the difference in force
- Difference in force translated into difference in height

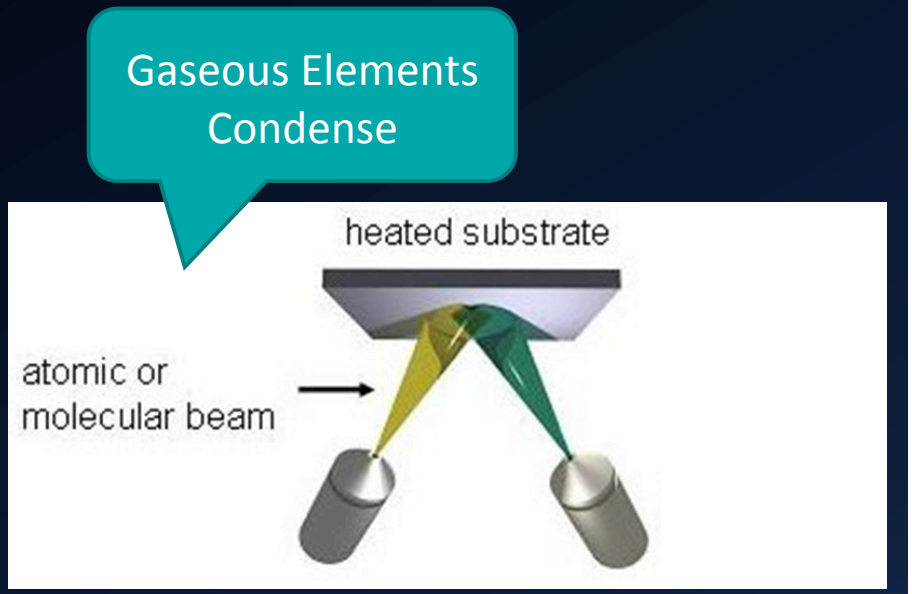
Filling the trenches

- Gallium Arsenide grown in Silicon trenches
- Need GaAs to grow the dots on

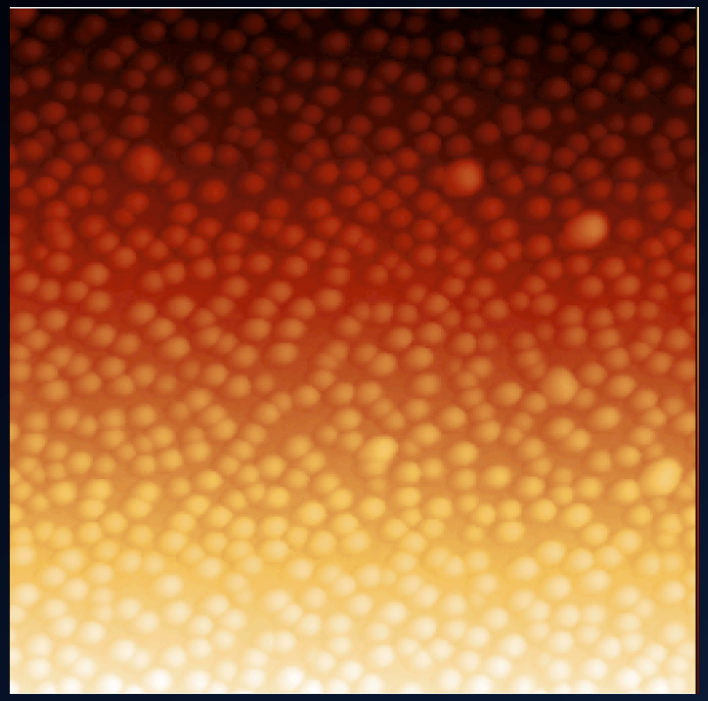


Growing Quantum Dots

- Grown layer by layer
- Time, Temperature, and Pressure
- Size determines wavelength



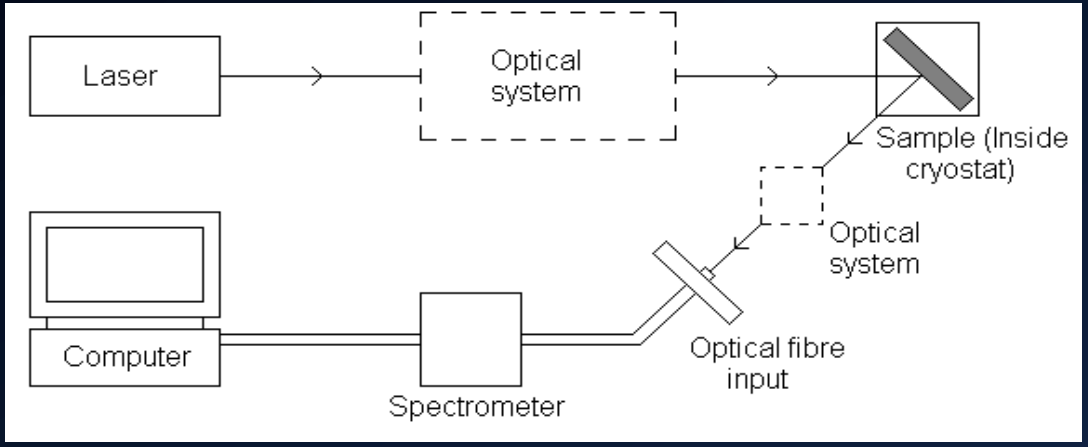
Compound quantum dots through thin film growth



AFM image of quantum dots
All of similar size→ all of similar emission wavelength
few large dots→ defects later processing will remove

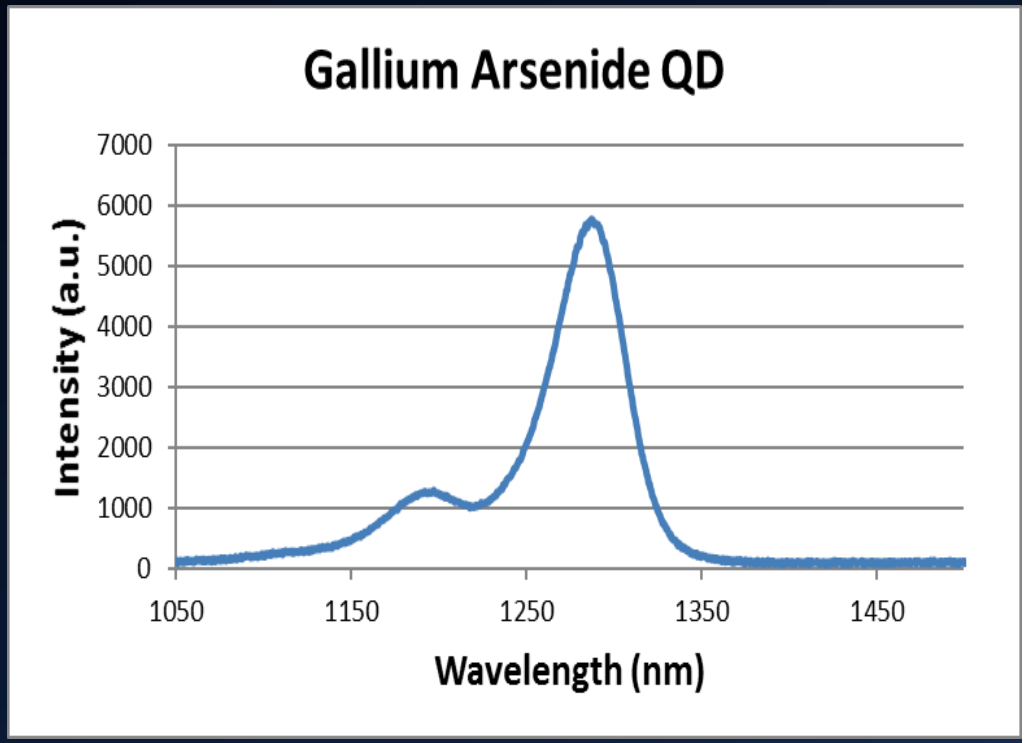
Photoluminescence Spectroscopy (PL)

- To measure emission wavelength
- Shine high energy laser on light emitting sample
- Sample absorbs and re-emits light at its characteristic wavelength
- Photodetector measures emission intensity and wavelength



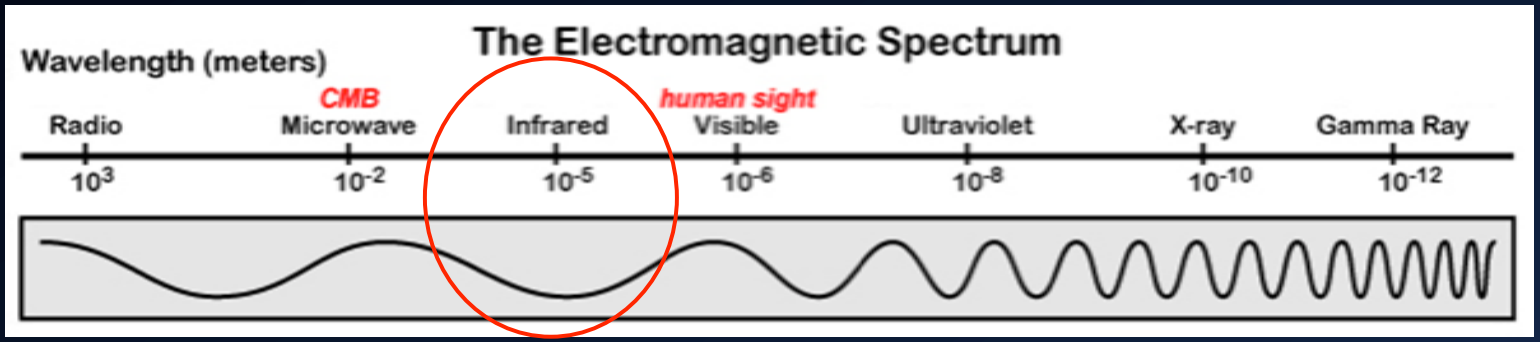
PL Data

- Desired wavelength for telecom: 1300 nm
- Current wavelength: 1275 nm



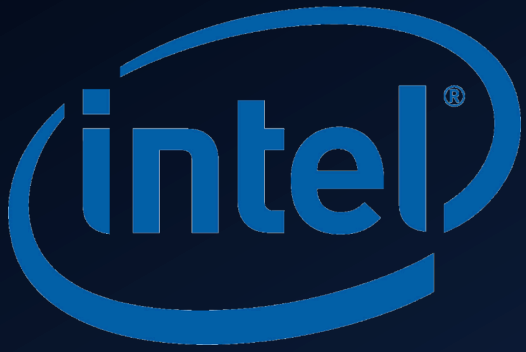
Conclusion

- Gallium Arsenide quantum dot growing process is still being modified
- 1300 nm (infrared)
- Reliable and Replicable results are needed



Other Possible Applications by sponsors

Raytheon



- Military technology often requires large processing power

benefit with better energy efficiency

-

Acknowledgments

Thank you:

Jennifer Selvidge

Anchal Agarwal

Ellie Sciaky

Jens-Uwe Kuhn