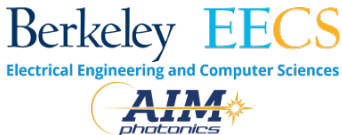# Development and Startup of a Micro-Photoluminescence Setup for Semiconductor Characterization and Optimization of Growth Parameters

George Higgins Hutchinson — Lei Wang
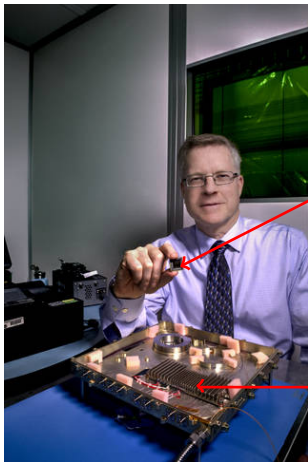Simone Šuran Brunelli — Jonathan Klamkin, PhD.

Slides source: gitlab.com/geohh/aim

August 12, 2018

Smithsonian
CHANNEL

Photonic Integrated Circuits (PIC): Improved LiDAR, etc.

PIC:
- Small
- Low cost
- No moving parts

Discrete Optics/Electronics:
- Large
- Expensive
- Multiple moving parts

Image credit: NASA/W. Hrybyk, https://www.nasa.gov/feature/goddard/2016/

nasa-engineers-tapped-to- build-first-i ntegrate d-ph oton ics-mod em

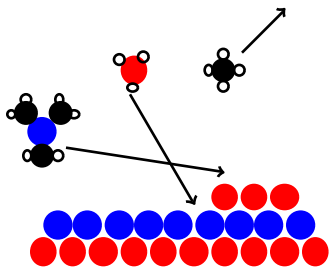# Metal Organic Chemical Vapor Deposition (MOCVD): Motivation and Theory

Figure: MOCVD process, building up an InP crystal from Indium and Phosphide precursors as organic byproducts escape

- PIC require lasers, waveguides, detectors
- Silicon unsuitable for lasers
- MOCVD to build III-V crystals for lasers

Characterization Techniques for Semiconductor Materials

MOCVD requires calibration to grow crystals of precise composition.
How do we measure out growths to improve future runs?

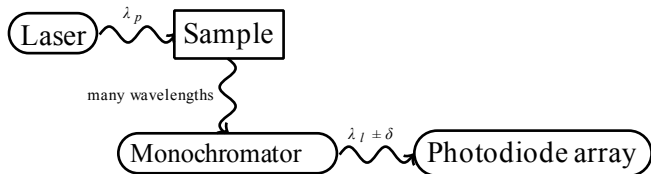| Separation between atoms in crystal	Morphology, topography, parasitic growths	Band gap energy (of direct band gap crystal)
↓	↓	↓
X-Ray Crystallography	Atomic Force Microscopy	Photoluminescence Spectroscopy

Photoluminescence Spectroscopy — Theory

Laser $\overset{\lambda_p}{\sim\!\!\sim}$ Sample

many wavelengths

Monochromator $\overset{\lambda_l \pm \delta}{\sim\!\!\sim}$ Photodiode array

1. Laser excites sample electrons
2. Sample emits light
3. Monochromator removes unnecessary wavelengths
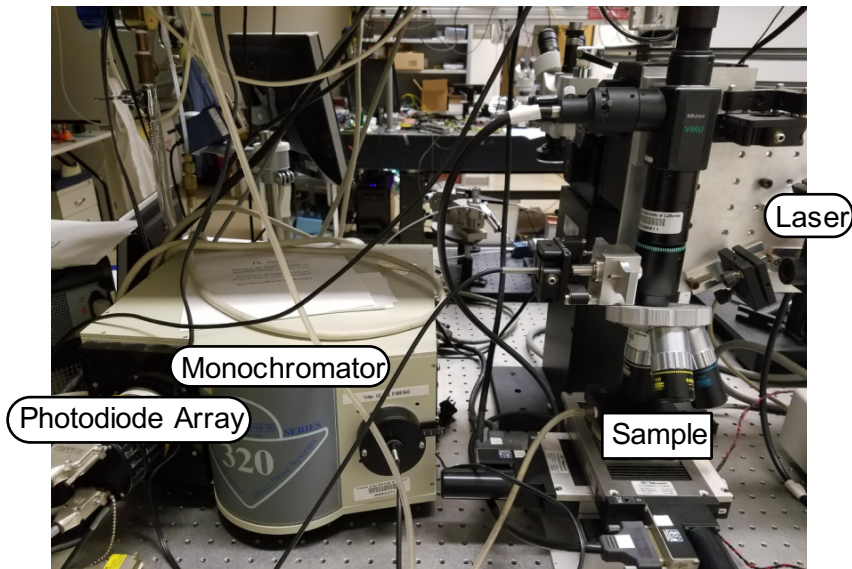4. Photodiode array counts photons at specific wavelengths

Photoluminescence Spectroscopy — Motivation

Figure: 1.5μm InGaAsP laser schematic, adapted from Q. Ke *et al.*

‣ My research goal: configure a PL setup

‣ Observing band gap helps interpolate actual crystal composition

My Experimental

PL Setup: Software Development Problems and Techniques

Lack of equipment documentation

↓

Reverse-engineering drivers and example code
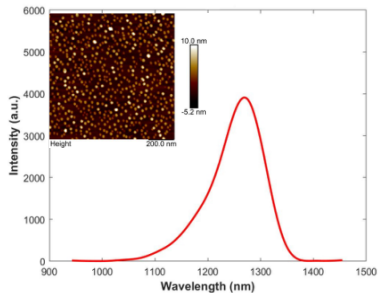
Need for future modifibility

↓

Object-oriented abstract device structure
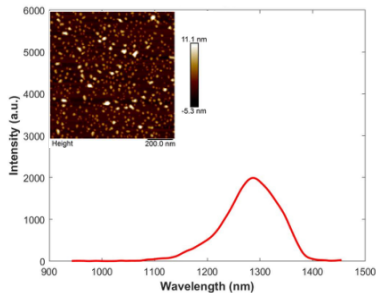
Need for long-term stability

↓

Dependency management tools

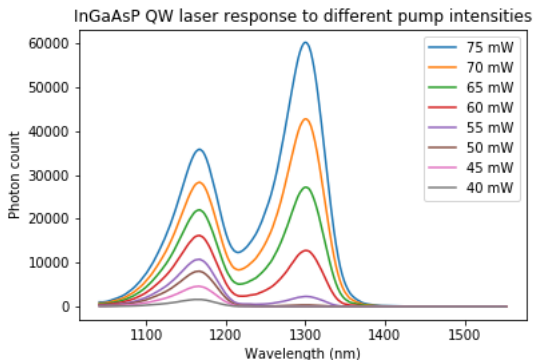# "Good" and "Bad" Quantum Dots under PL
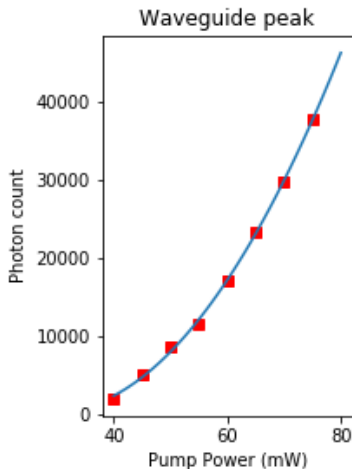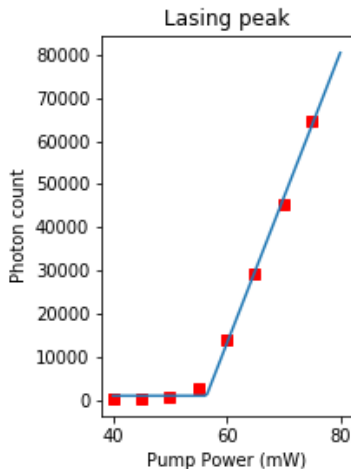

"Good" dots:
Tight size distribution, PL

"Bad" dots:
Wide size distribution, PL.

Complex structures: multiple PL peaks

1180nm peak: Waveguide? 1300nm peak: Laser?

Structures respond differently to pump intensity changes

Conclusions — A Work in Progress

Hardware:
- Photodetector: "It's dead, Jim."
  - Identified potential replacements
  - Contacted suppliers for quotes
- Defective lasers troubleshot & replaced

Software:
- Developed experimental software for available parts
- Software development techniques to maximize hardware modularity

Future Work

- ‣ Short Term: Replace Photodetector
  - ‣ Develop software for data acquisition/analysis

- ‣ Long Term: Add mapping functionality
  - ‣ Motorized stage control
  - ‣ Adapt data acquisition/analysis software for mapping

Acknowledgments

Bowers group, for providing the PL setup used in ``Identifying Structures based on PL Peaks'' data collection.