Status of WU Nitride Photocathode Development

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Recent Measurements

- Improvements made to RHEED system
- Construction of tube sealing/transfer/QE system
- Low-temperature growth of amorphous GaN and InGaN cathodes.
    - Cathode was fabricated with increased In concentration (25%). Growth for about 3 hours, ~100 nm/hour.
- QE and electron diffraction as a function of annealing.
- Optical transmission measurements.

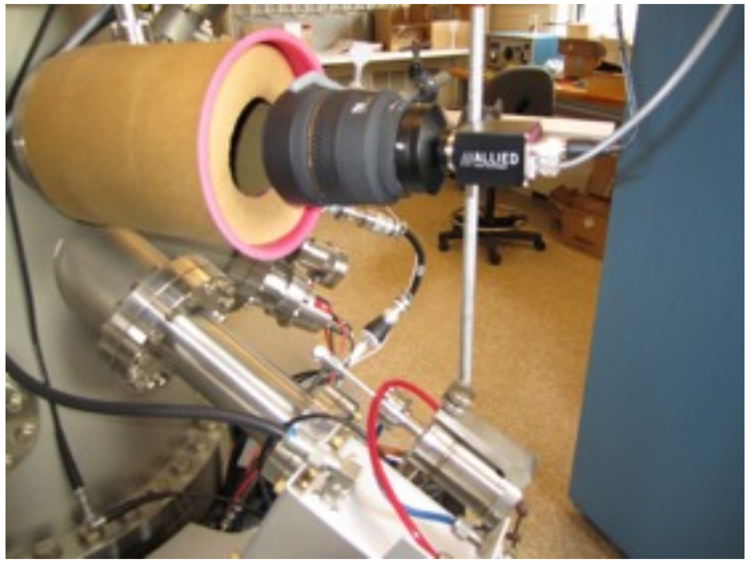
MBE Lab

- Photo of lab showing recent additions

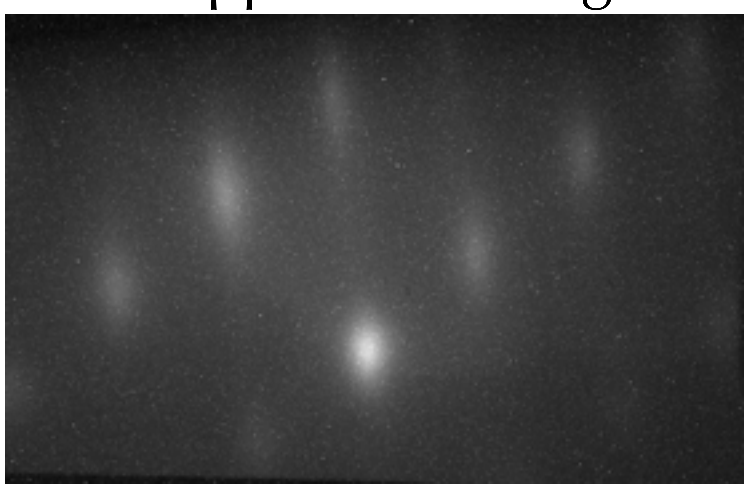
Amorphous Cathodes

- Began experimenting with a-GaN cathode produced a number of years ago for NMR materials studies
- Restored surface, Cs-activated. Obtained QEs ~5%, encouraging further studies
- Grew ~0.3micron, InGaN cathode with 25% Indium, looked at RHEED data and QE as a function of annealing.

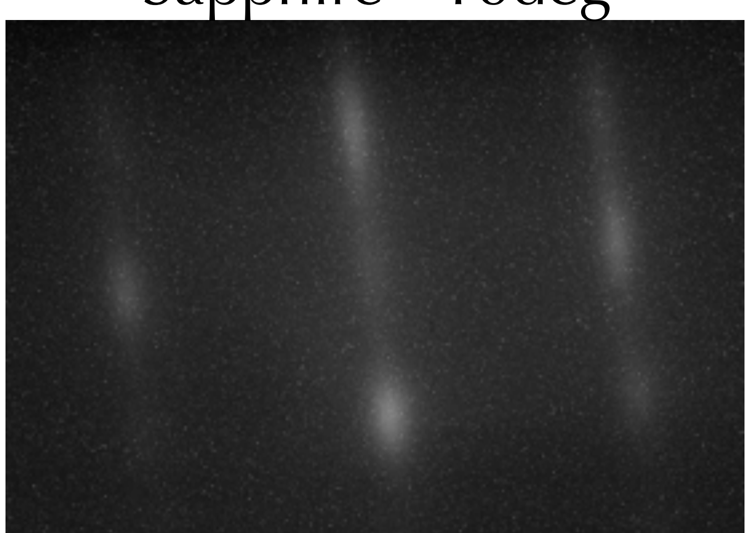
RHEED Measurements



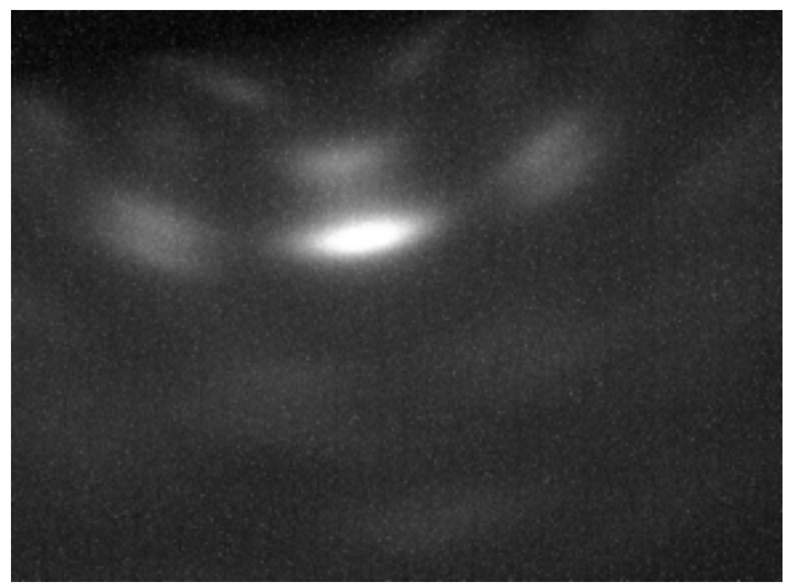
Sapphire - 70deg



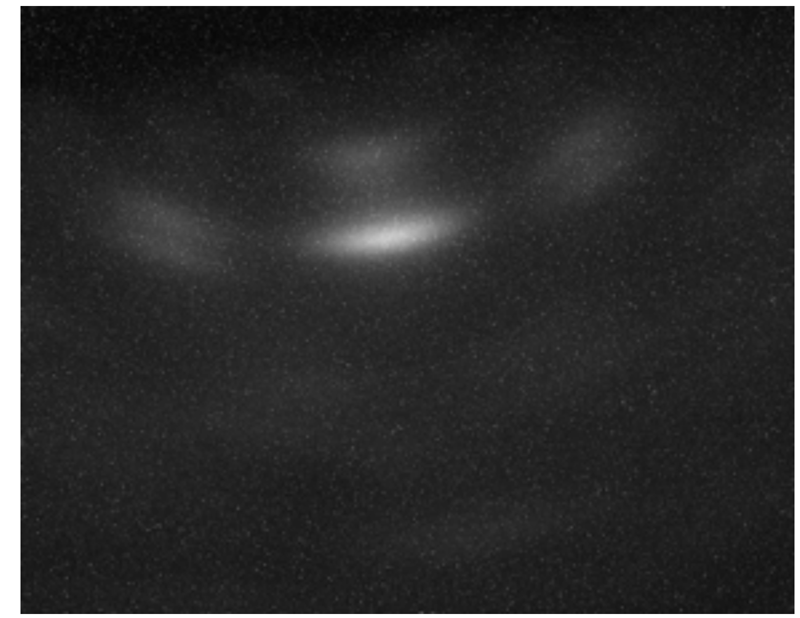
Sapphire - 10deg



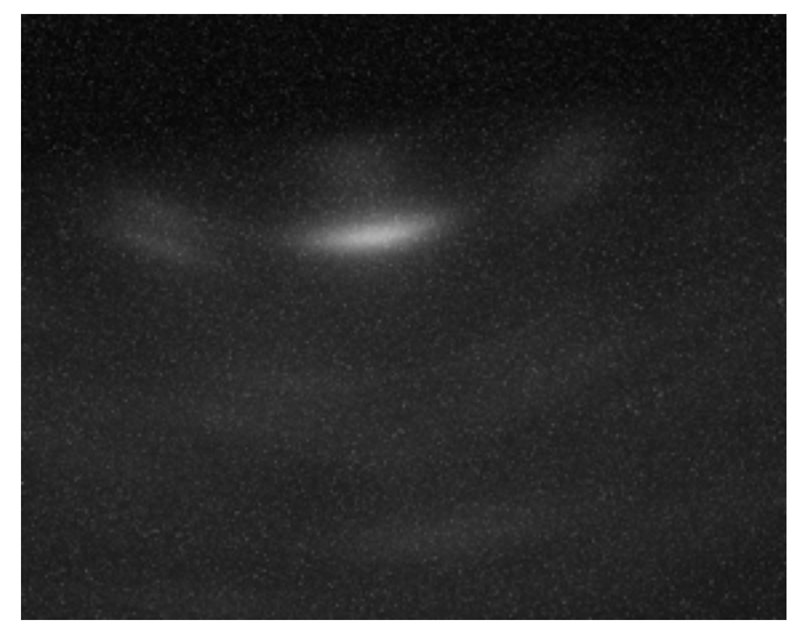
a-InGaN no anneal



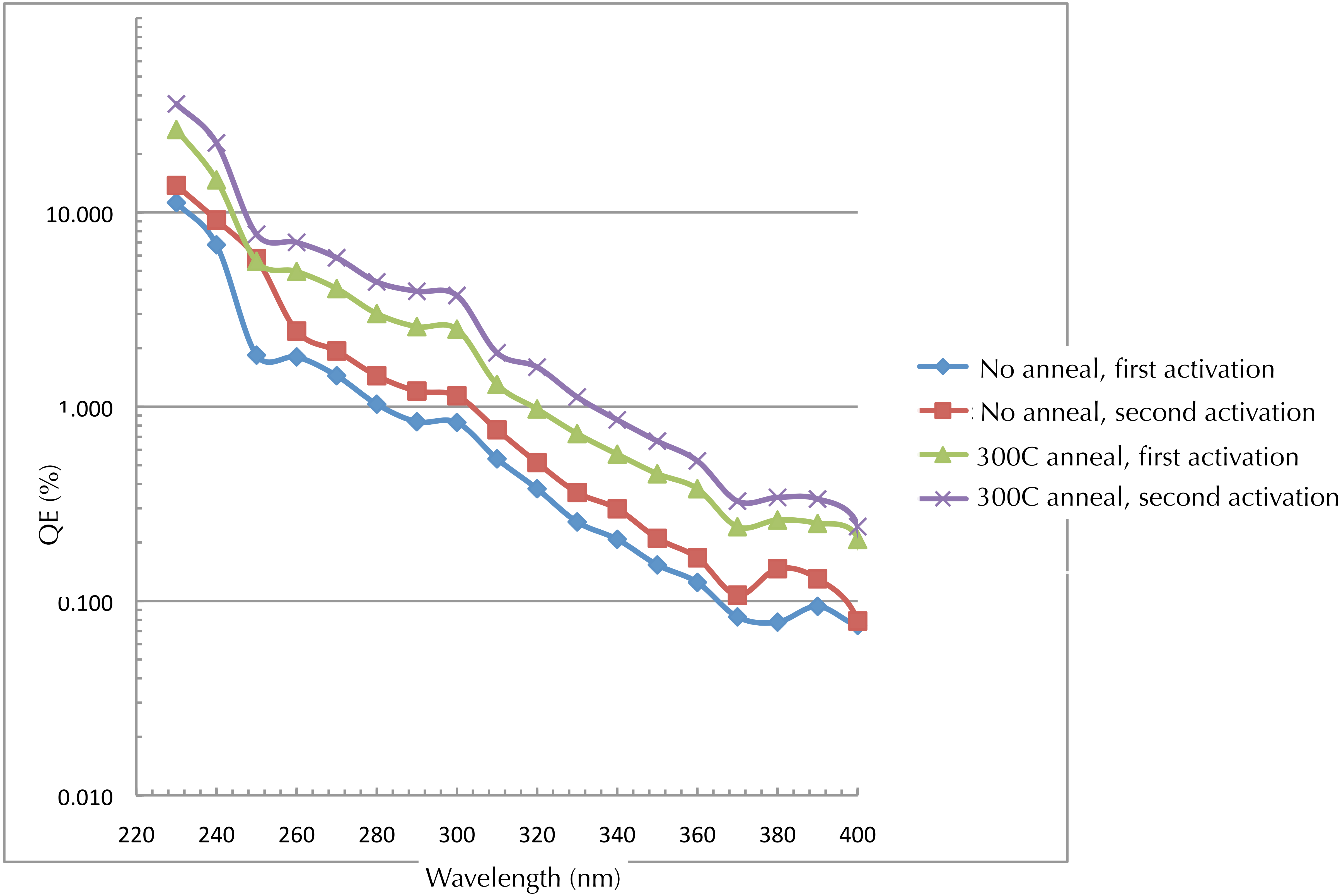
a-InGaN 300C



a-InGaN 390C

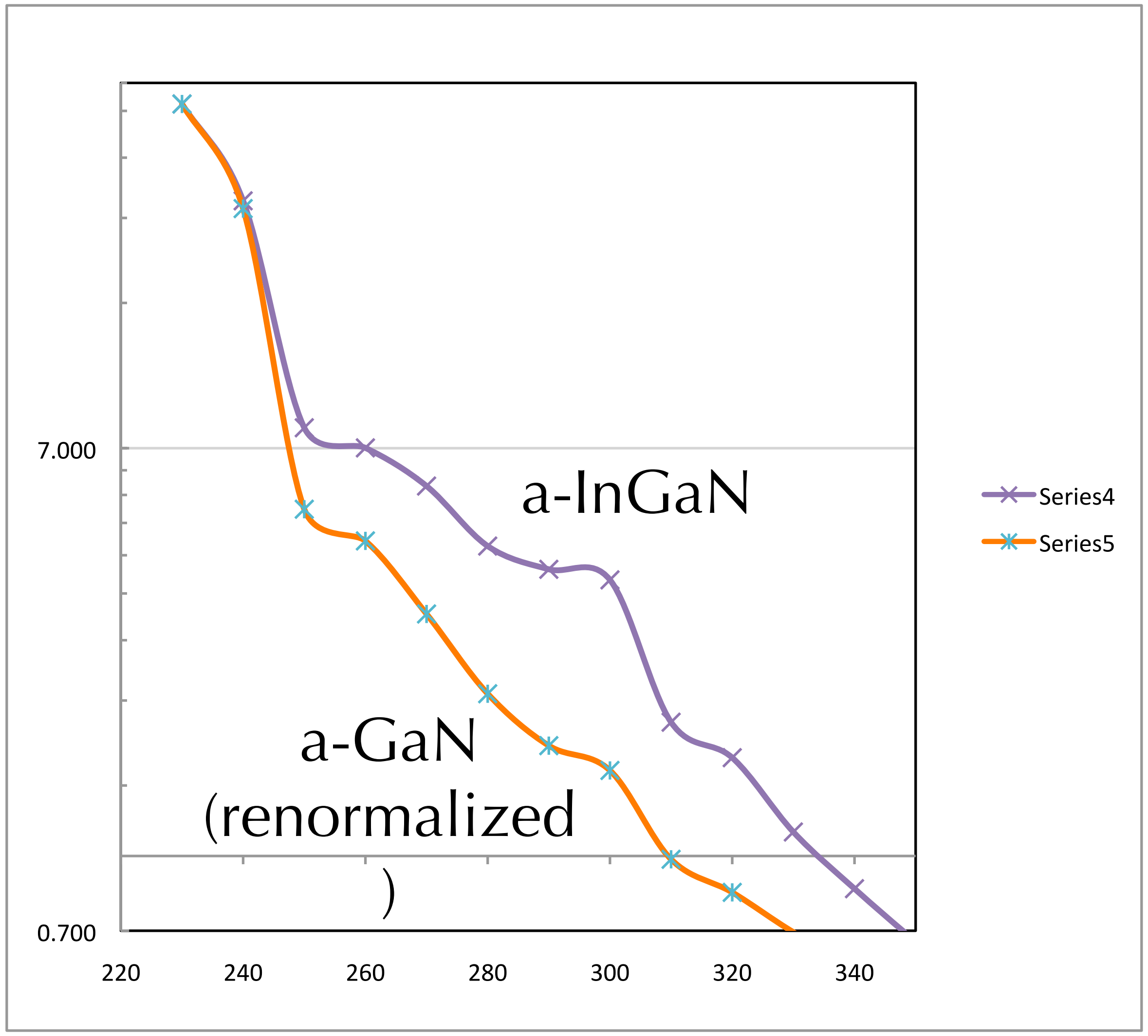


a-InGaN QE



10.000
1.000
0.100
0.010
QE (%)
220
240
260
280
300
320
340
360
380
400
Wavelength (nm)
No anneal, first activation
No anneal, second activation
300C anneal, first activation
300C anneal, second activation

Increased Indium

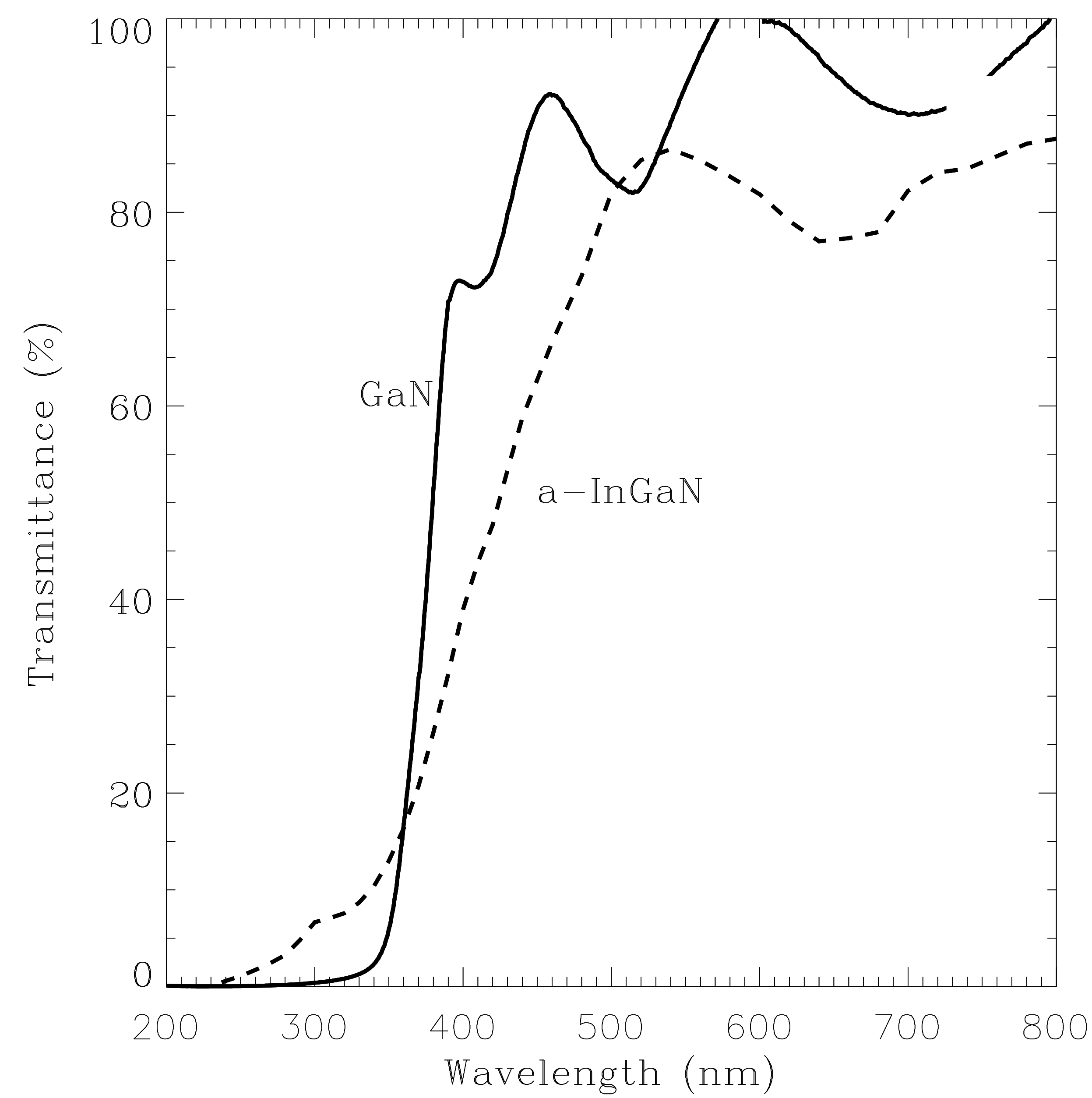


- Increased Indium concentration to 25% - increased quantum efficiency at all wavelengths, improved QE at long wavelengths

Optical Transmission

- Measured optical absorption using a Xe-lamp, double-grating monochrometer, UDT UV-enhanced reference photodiode and Keithley electrometer. Absorption is normalized to a measurement for an identical sapphire substrate with no coating.

- Compared with crystalline or amorphous GaN, broader band-edge, more absorption at long wavelengths showing band shifting.



Conclusions

- Increasing In concentration improves response at longer wavelengths (out to >400nm)
- Annealing improves QE up to about 300C, above which performance gain levels off.
- For amorphous cathodes, repeated exposure to Cs (with delay) increases QE even up to third activation.
- QE at UV increases to similar level as prior crystalline/epitaxial cathodes!
- Amorphous cathode growth allows use of new substrates - conductive coatings on glass for HV bias.

Future Work

Task List

- Optimize cathode structures
- Deposit a-InGaN on ITO-coated window, apply grid electrodes, apply voltage bias and measure gain-QE product versus voltages
- Experiment with "capping" cathodes with *In*, stripping methods for transfer.
- Transfer a-InGaN cathode grown on glass window to ANL (Spring 2011)
- Transfer glass MCP directly coated with nitride cathode material (Fall 2011)
- Finish development of new vacuum transfer stage for hot/cold indium sealing for transfer, transmission-mode QE measurments

Device Optimization

Growth Parameters

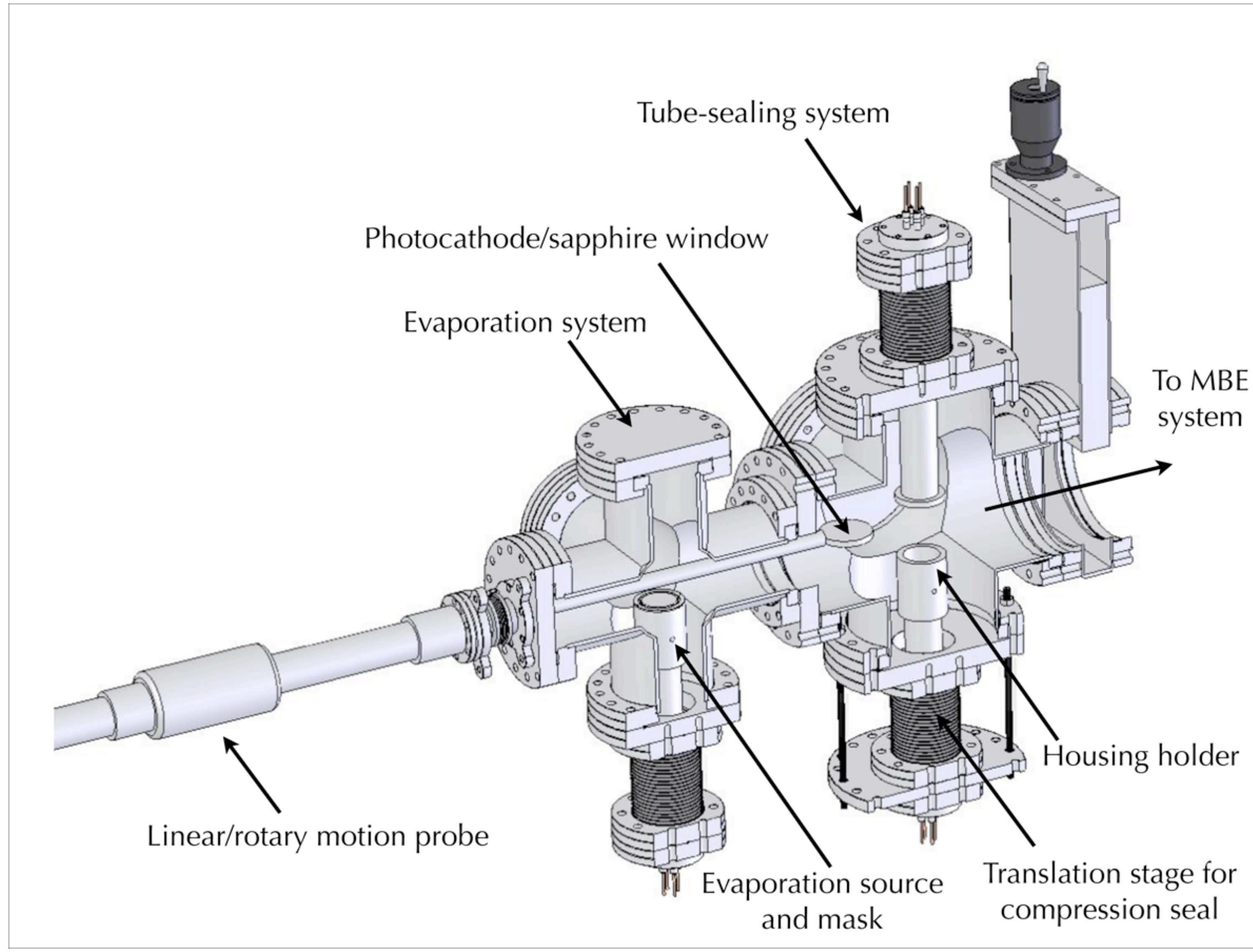
- Study a-InGaN cathodes on different substrates (sapphire windows, stainless steel, other glass windows with or without conductive coatings)
- Study effects of thermal annealing
- Study effects of variations in activation procedure: repeating Cs coatings, incorporation of oxygen during activation
- Increase *In* concentration
- Change doping levels

Characterization

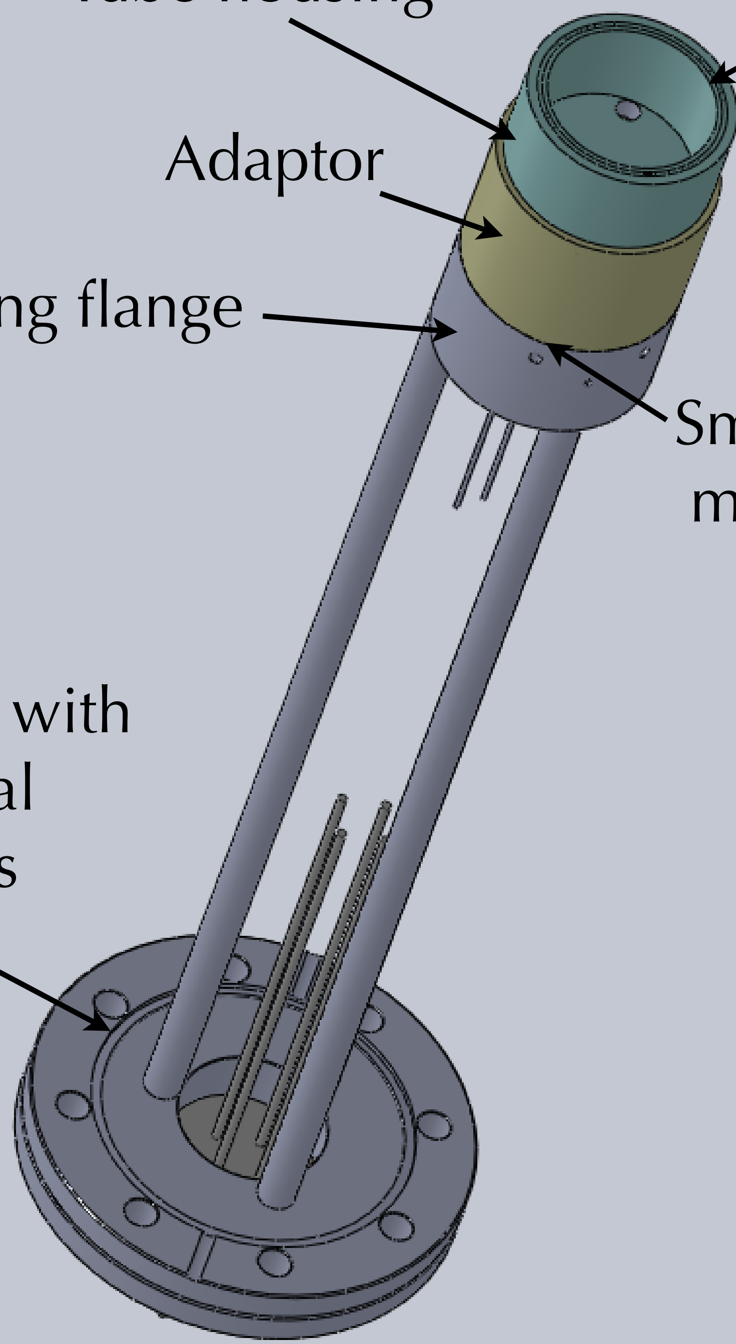
- In-situ QE measurements versus wavelength (WU)
- RHEED measurements and analysis during growth (WU)
- Room-temperature optical transmission measurements (WU)
- Hall measurements of carrier densities, conductivity (ANL)

Tube Testing and Sealing

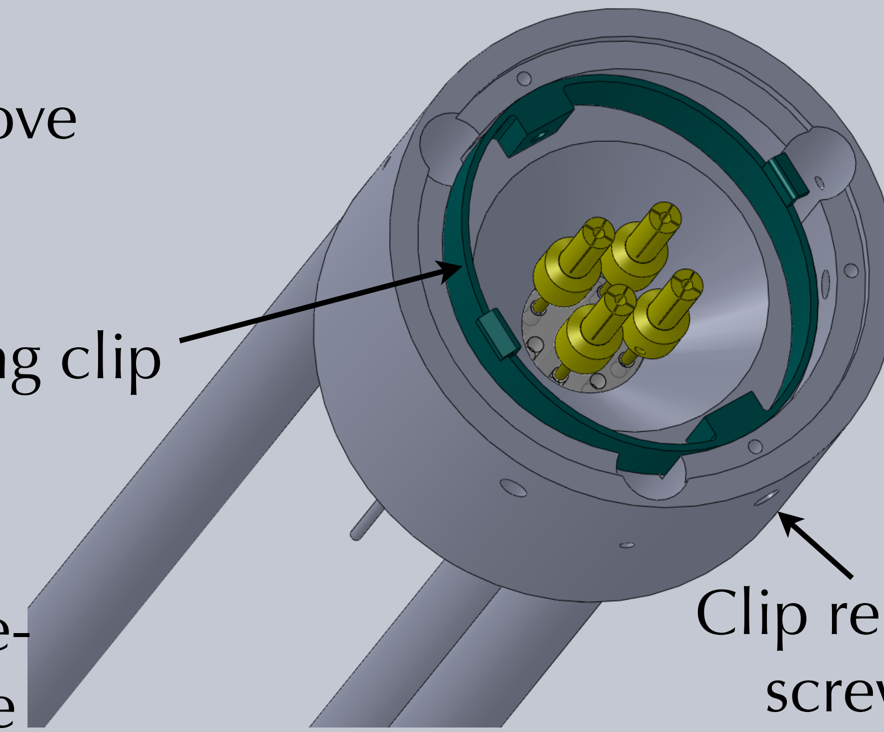
- Develop tube sealing/transfer/ testing system
  - Transmission-mode QE measurements for comparison with reflection mold measurements
  - Hot (150 C) and Cold Indium seals
    - Ti evaporator for coating of window and housing in vacuum, compression of In wire in O-ring grove
    - Incorporate SAES getter into housing



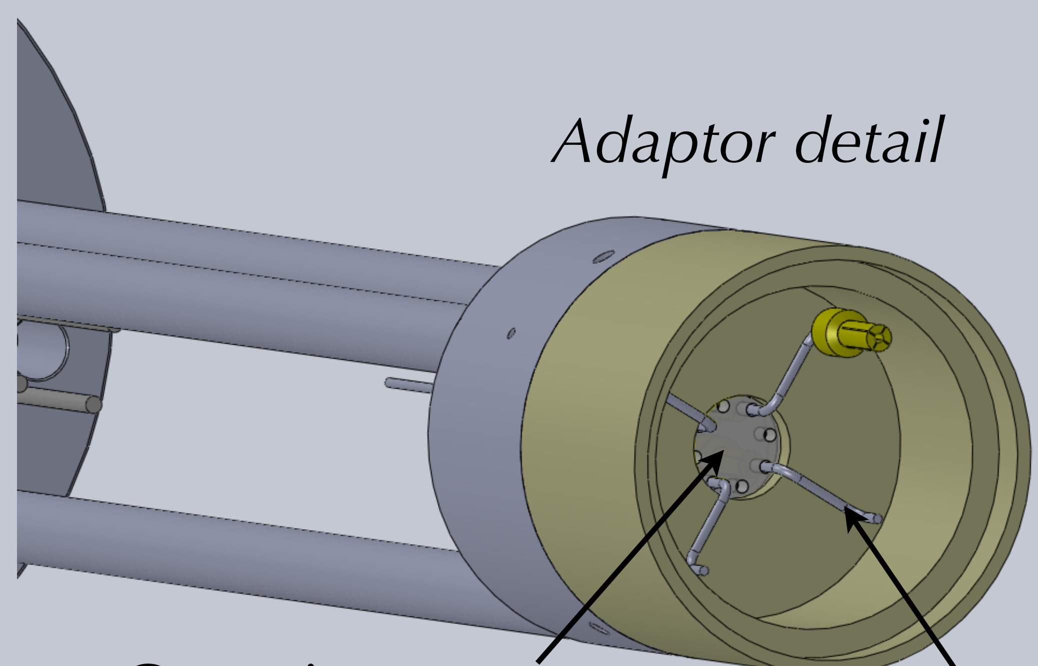
Push-rod Detail



Docking flange detail



Adaptor detail

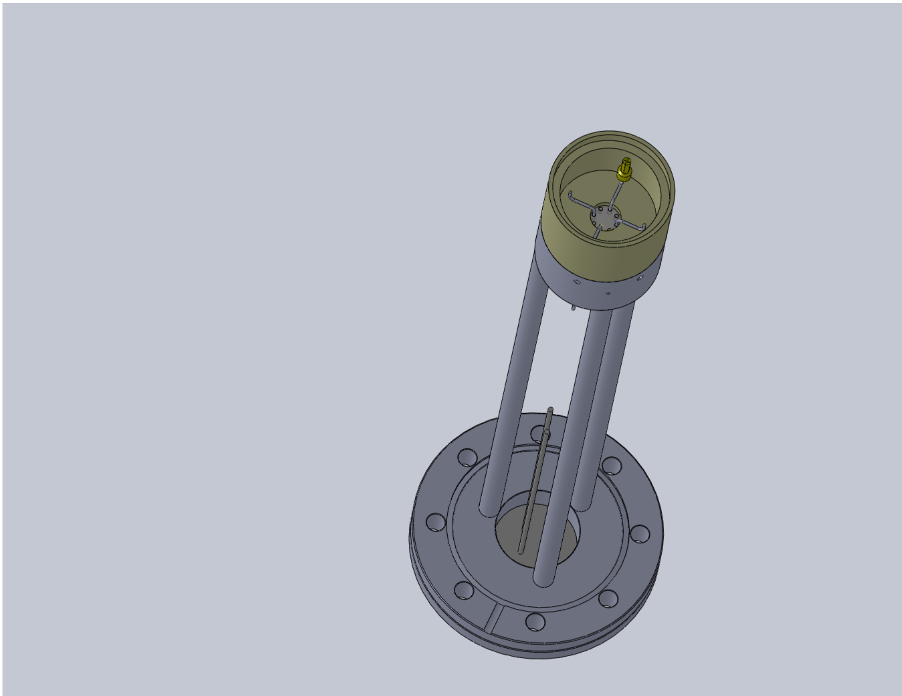


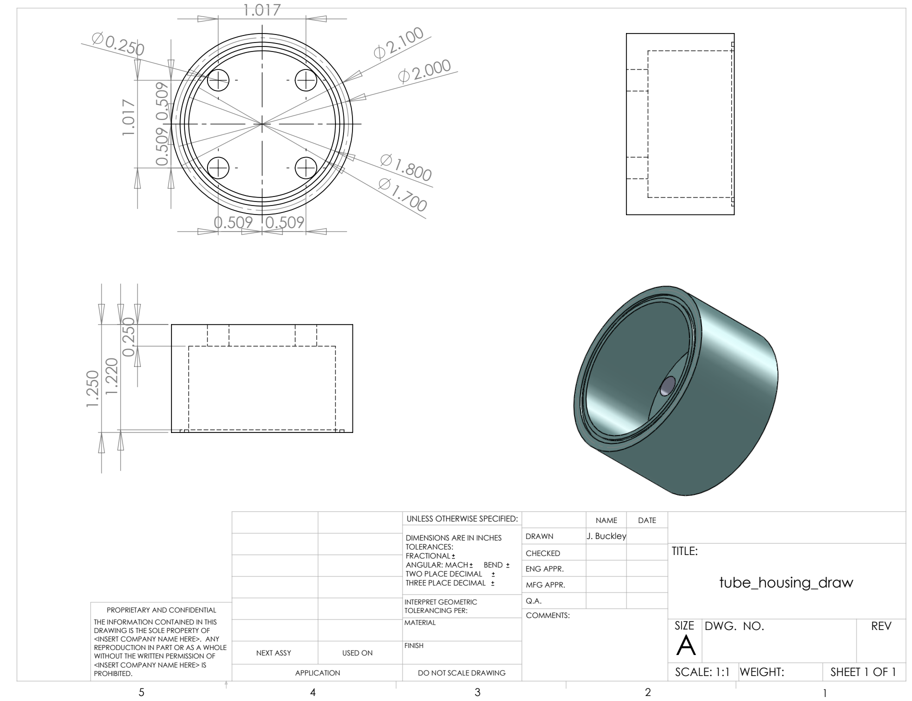
Resources Needed

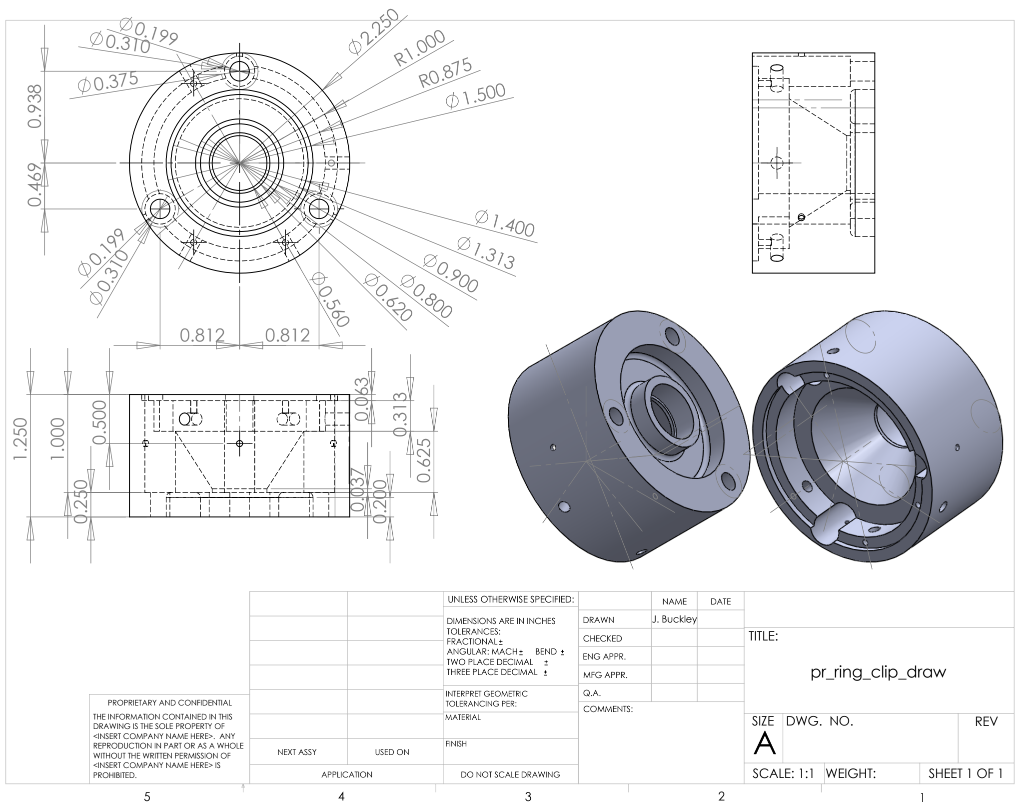
- Salary support (0.75 FTE Dan Leopold, 0.5 Grad Student)
  - Request in to DOE as part of our 3-year operating proposal
- Theory support
  - Band engineering/reverse-engineering for heterostructures, doping profiles, amorphous materials
- Measurement support
  - Carrier densities, X-ray diffraction for crystalline cathodes, AFM of surfaces
- Supplies ($20k/year ?)
  - Indium wire (2m length, cost?)
  - Cs-Ion source ($1.4k)
  - Epitaxial sapphire substrates ($4k estimate for ~20)
  - Source materials ($1k)
  - SAES getters (5m strip, ST-707-CTS-NI-8D, $130)
  - ~150C heater (components ~$2k)
  - Power supply (HP 6552A power supply $3.5k)
  - Machine shop time for transfer system ($5k)

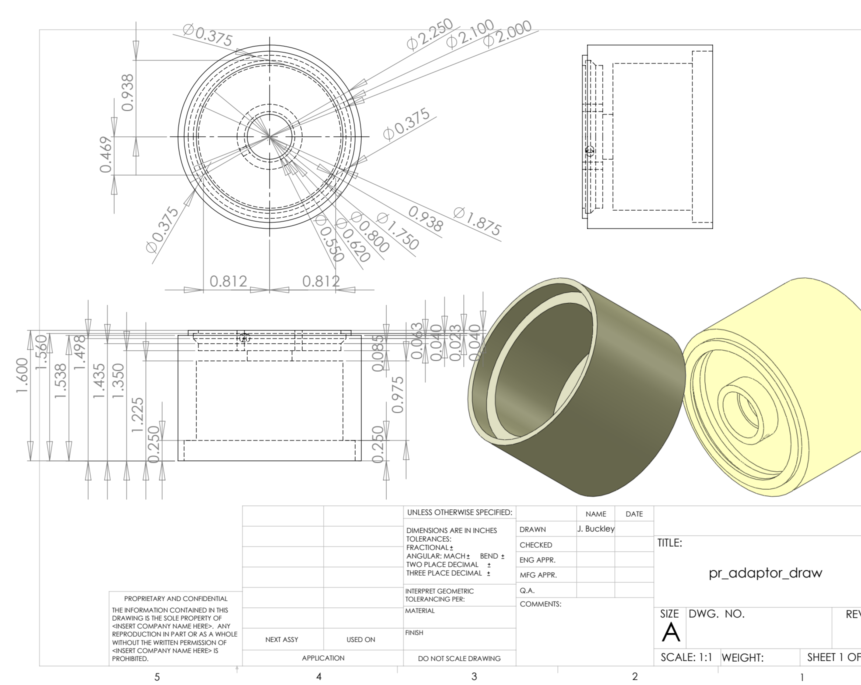
Backup Slides

Mechanical Design

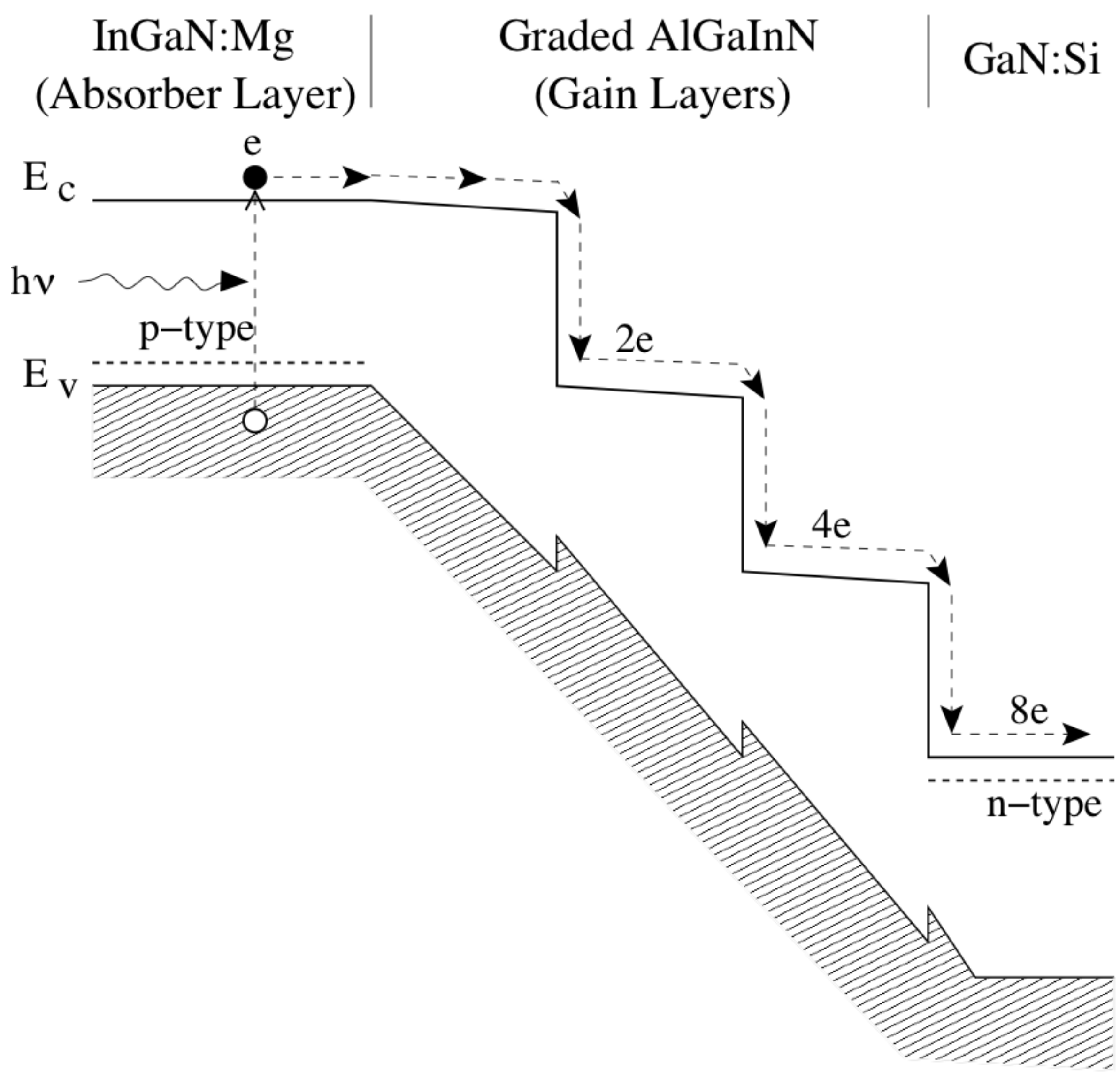








Solid State PM



- Eventually we might try more advanced band-engineering to achieve solid state PM