Spectral Response of GaAs (Cs, NF_3) Photocathodes

Teresa Esposito

Mentors: I. Bazarov, L. Cultrera, S. Karkare

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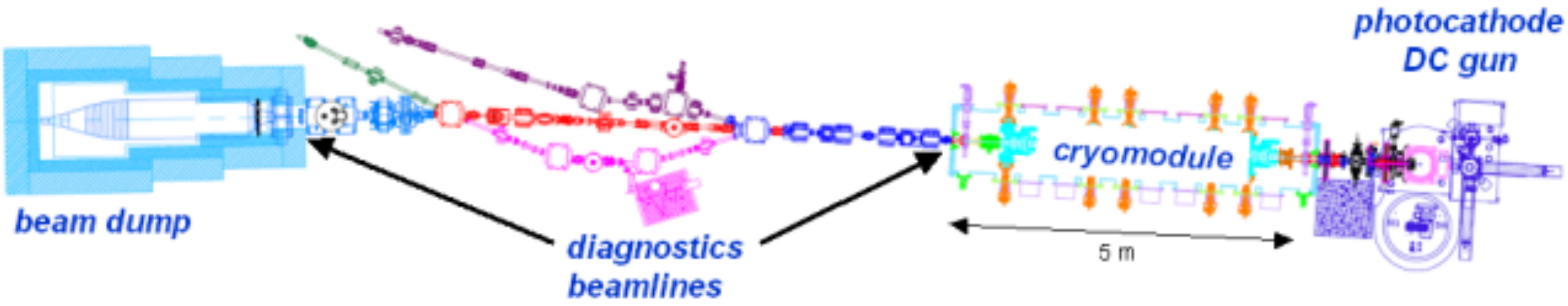
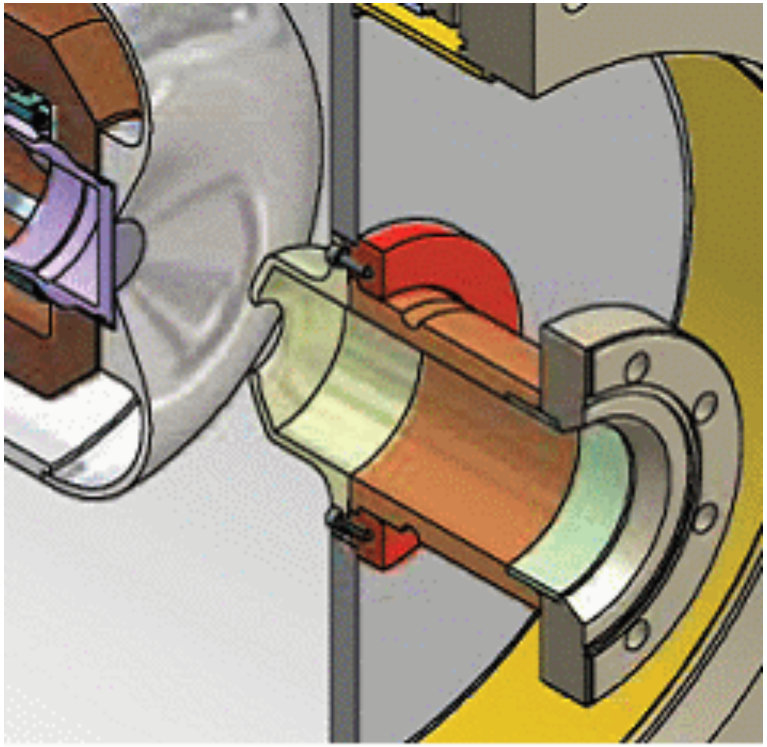


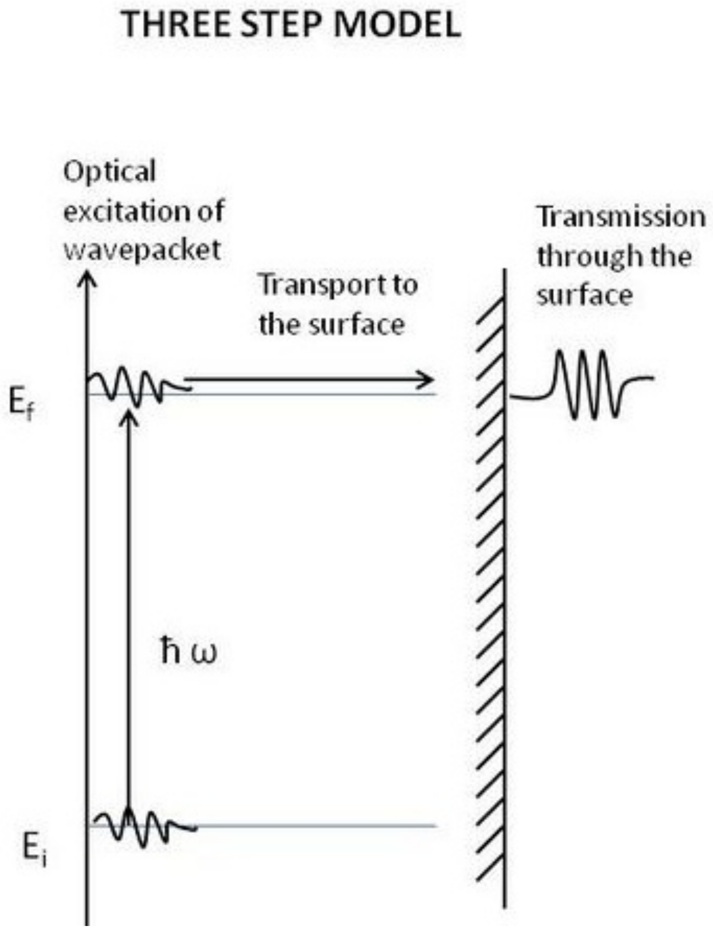
Photocathode Review

- Photocathode is used in ERL gun
- A laser pulse will trigger an electron bunch to be released
- Able to make electron bunches that are ideal for the ERL
  - High Quantum Efficiency
  - Low Mean Transverse Energy
  - Short time response



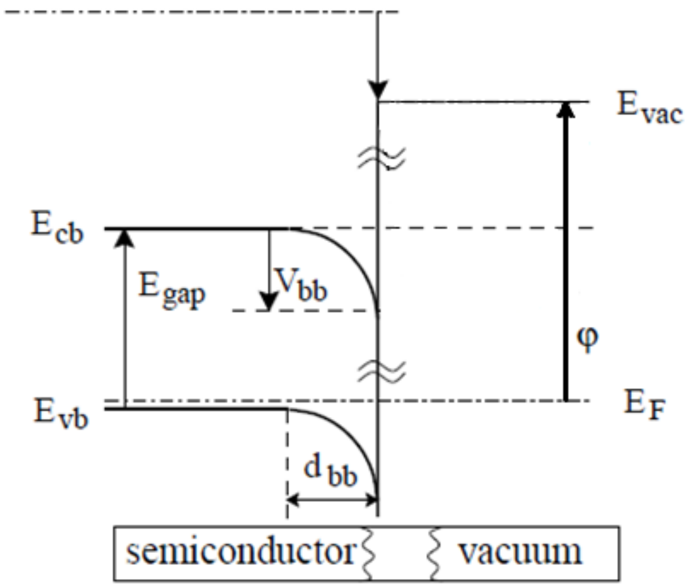
Three Step Model of Photoemission

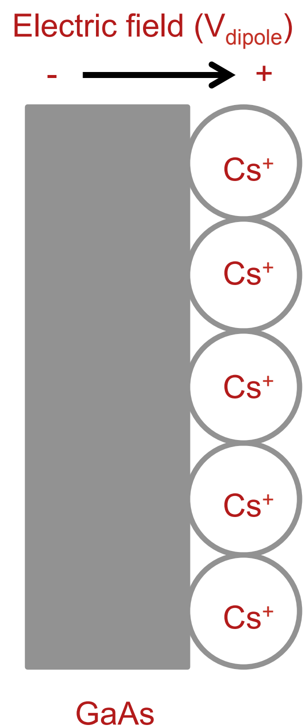
1) Photon absorption by an electron causing excitation from valence band to conduction band
2) Diffusion of electrons to the surface
3) Electrons escape from the bulk to the vacuum



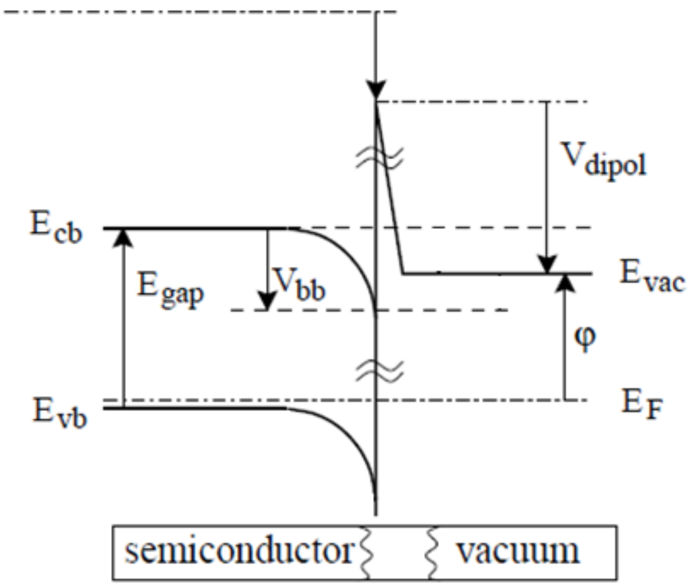
GaAs Photocathodes

Before Activation



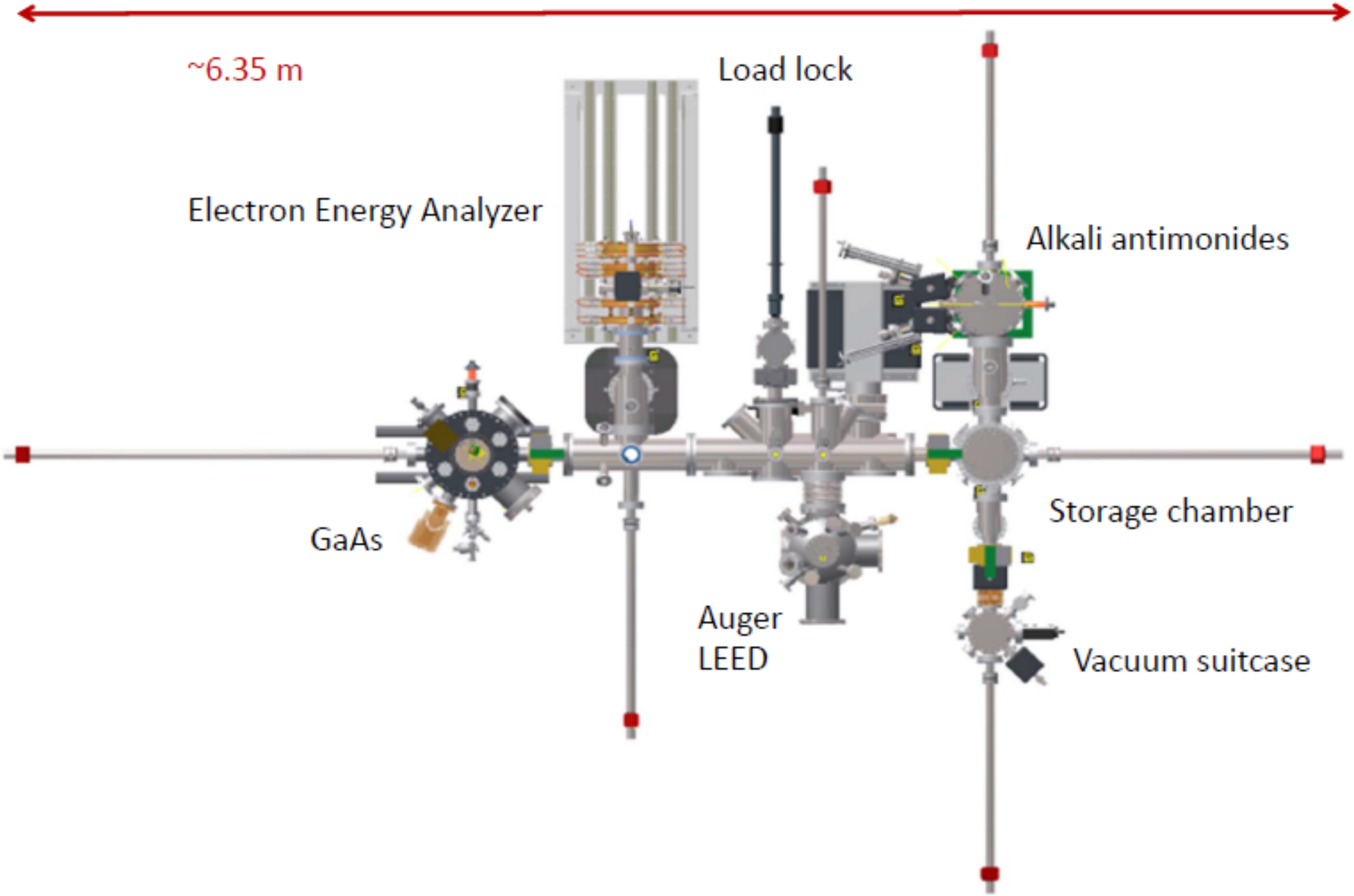


After Activation (NEA)



Lab Goals

- Study Process of Photoemission



Measuring Quantum Efficiency

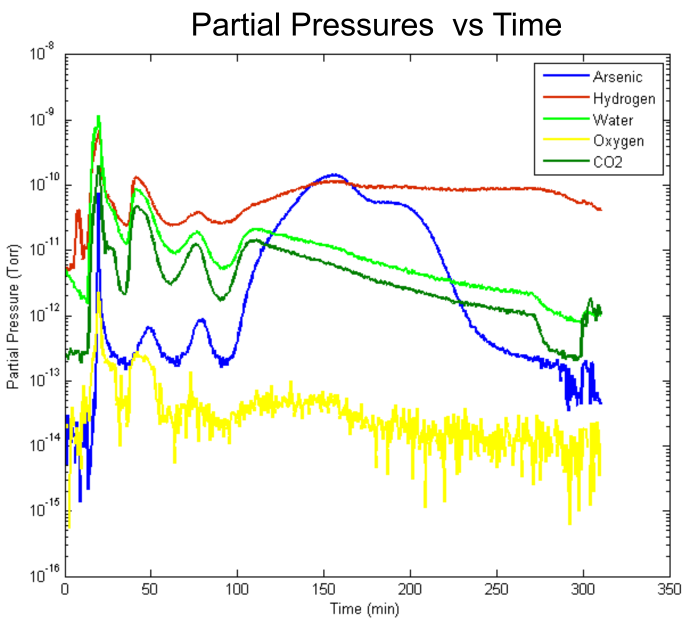
- Number of emitted electrons per incident photon
  - Shine a 532nm laser onto the surface of the cathode
  - Causes photoemission and creates a current
  - Current is measured using a picoammeter
  - Use laser power (Lp) and photocurrent (Pc) to calculate QE

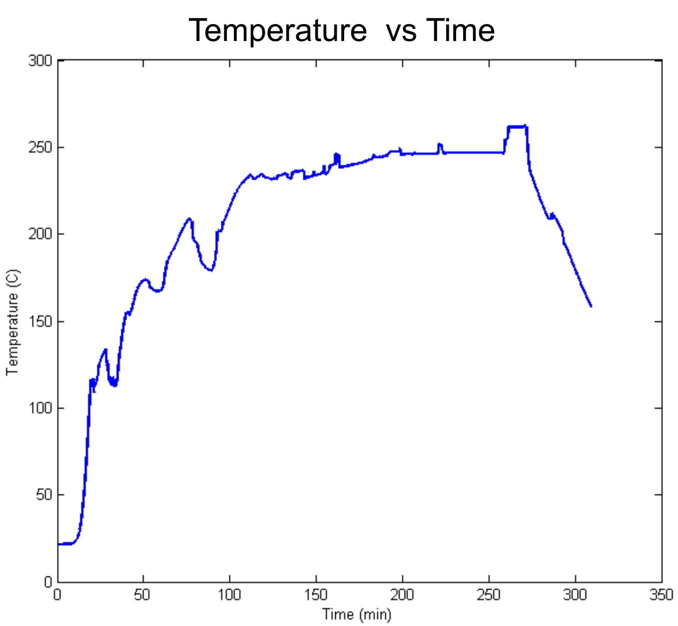
$$QE = Pc * h * c \,/\, Lp * e * \lambda$$

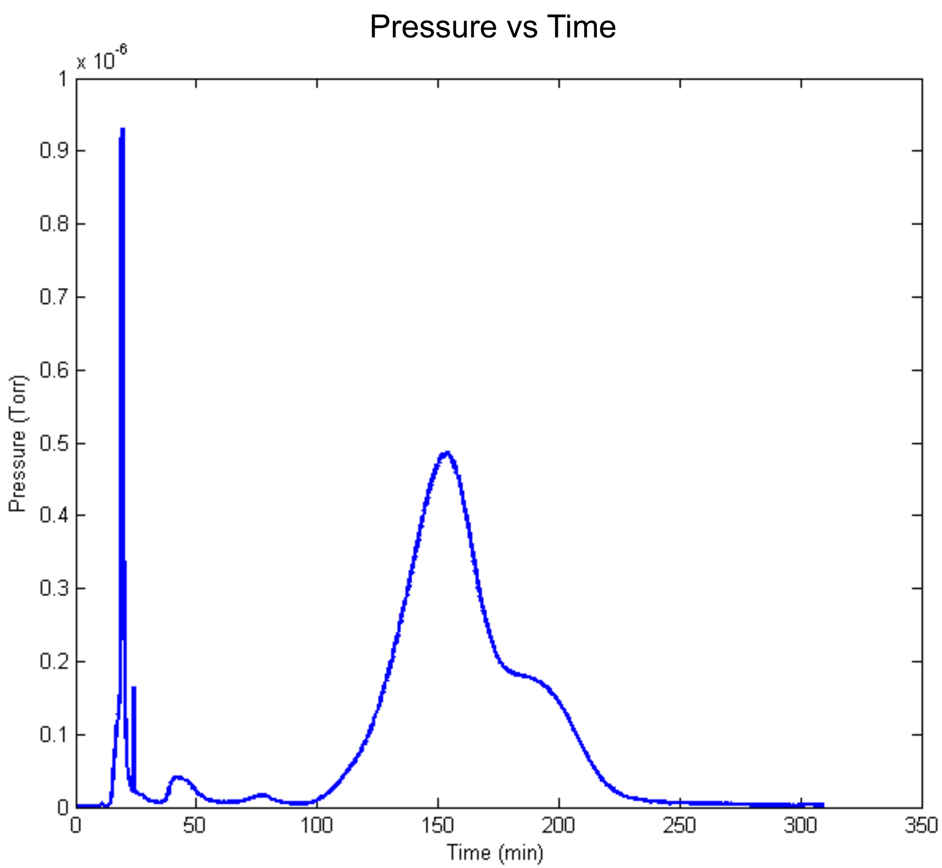
GaAs Samples

- Sample 1:
  - P-doped with Zn, doping level $6.3\text{x}10^{18}$ and $1.9\text{x}10^{19}$ holes/cm^3
  - Cleaned with Acetone, Trichloroethylene and Anodized
  - Heated to 650˚C under vacuum
- Sample 2:
  - GaAs grown by molecular beam epitaxy under UHV
  - Top 1000nm p-doped with C, doping level $2.0\text{x}10^{18}$ holes/cm^3
  - Covered with As Cap to protect from air
  - Heated to 300˚C under vacuum

As Cap Removal

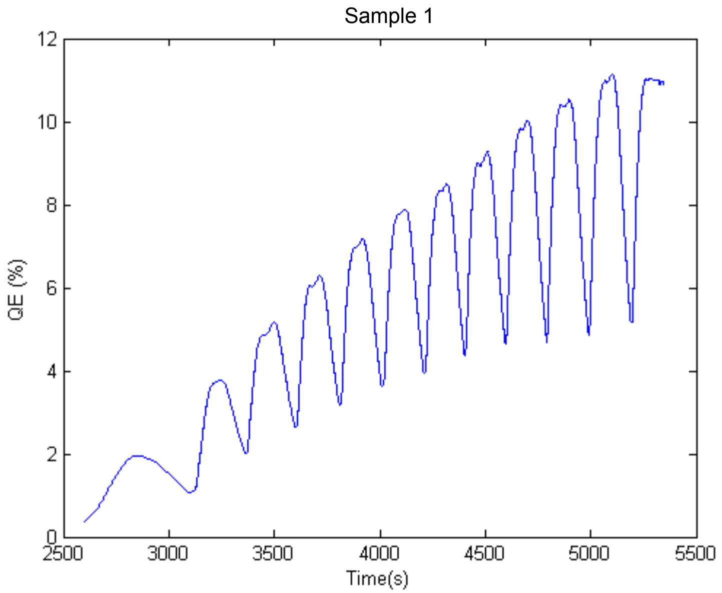




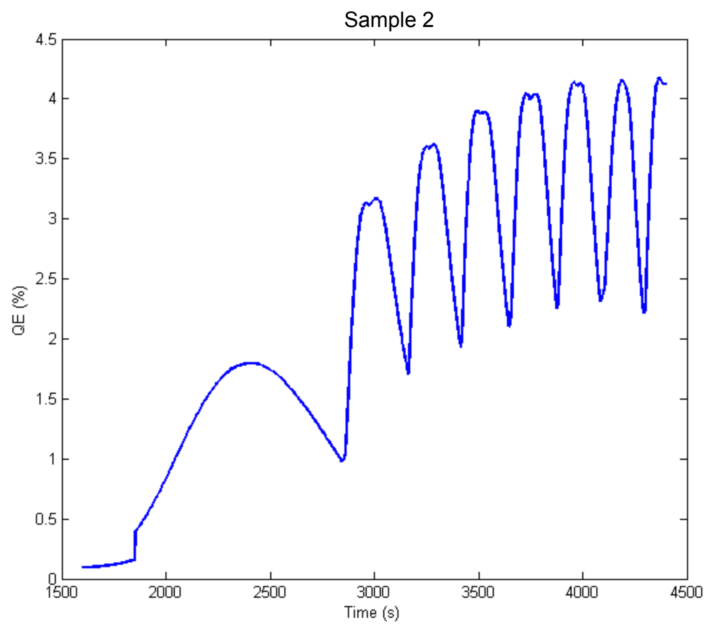


Activation With Cs and NF_3

- Yo-yo activation
- Sample 1
  - Consistent activation to 10% QE
  - 1/e Lifetime~80 hours

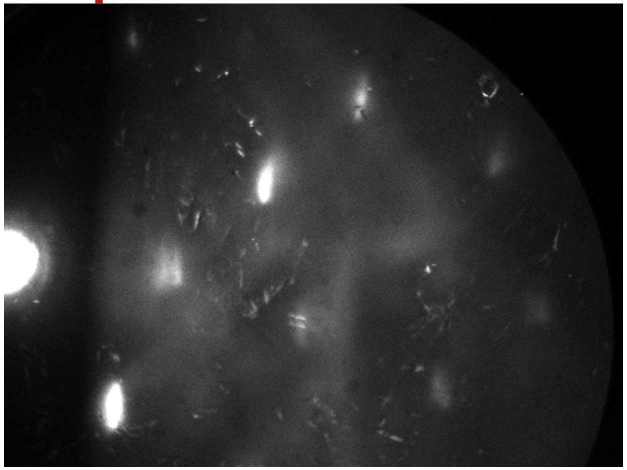


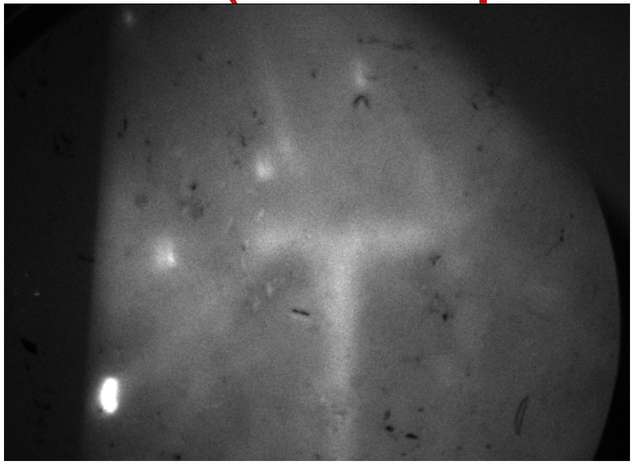
- Sample 2
  - Activation to 4.2% QE
  - 1/e Lifetime~25hours



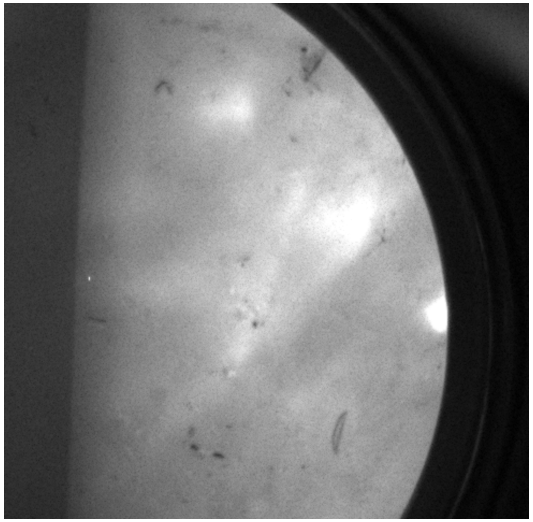
Reflective High Energy Electron Diffraction

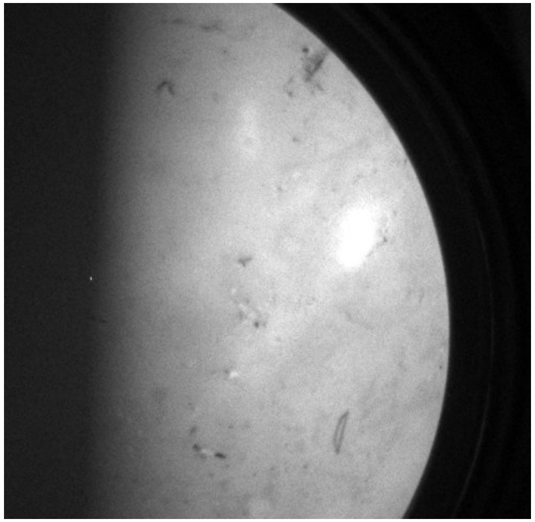
- Sample 1 Before and After (same position)





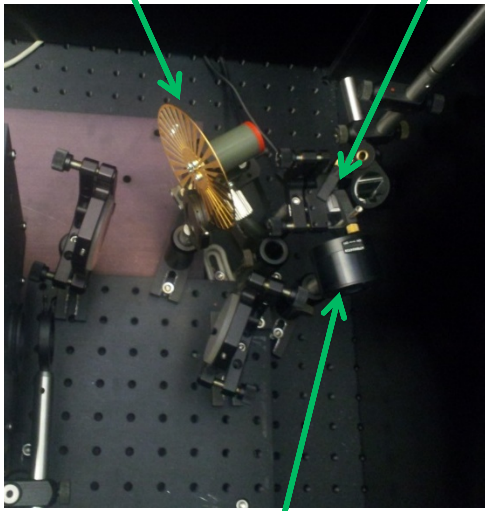
- Sample 2 Before and After

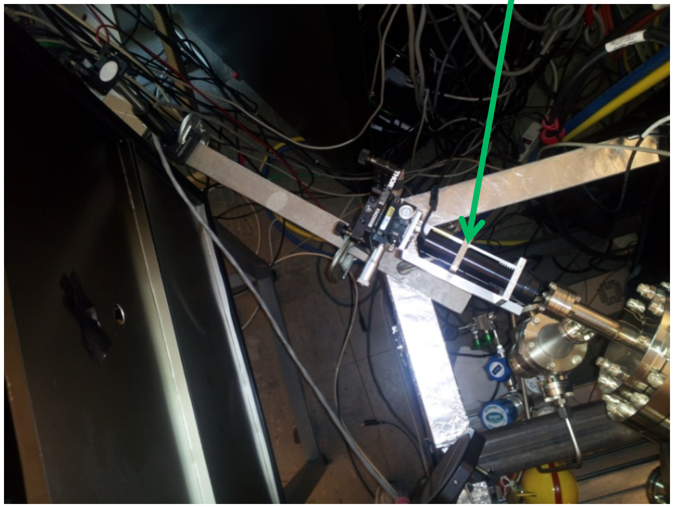




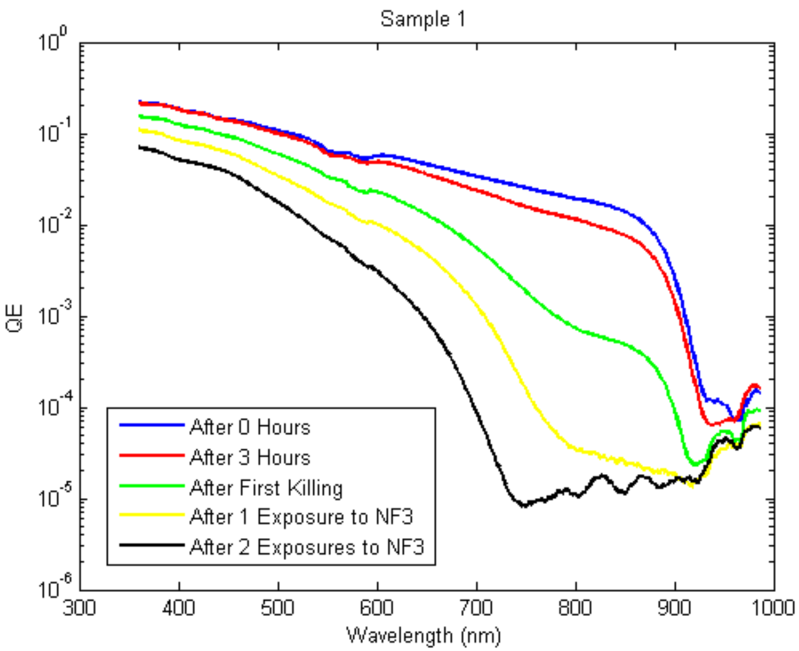
Spectral Response

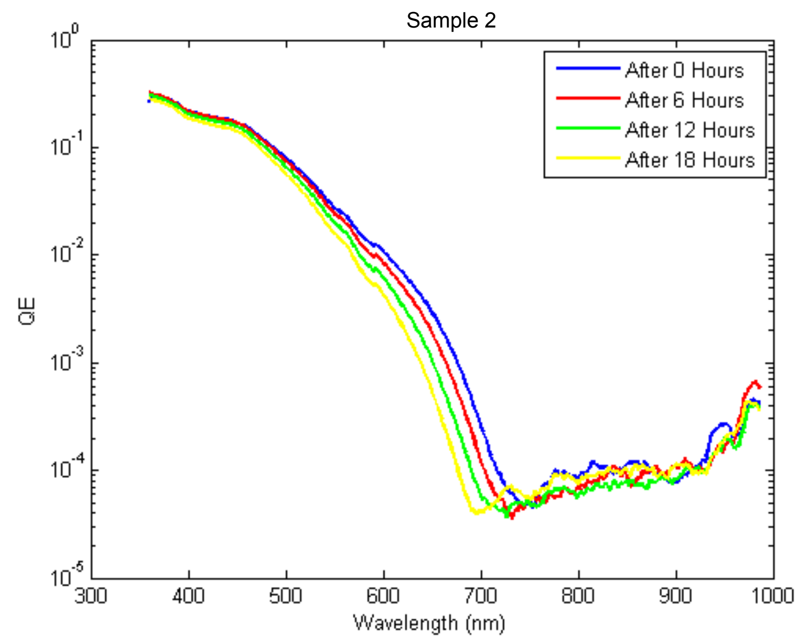
- Measure QE as a function of wavelength
- After the cathode is activated, QE is measured using a monochromator instead of a laser
- Isolates out one wavelength of light





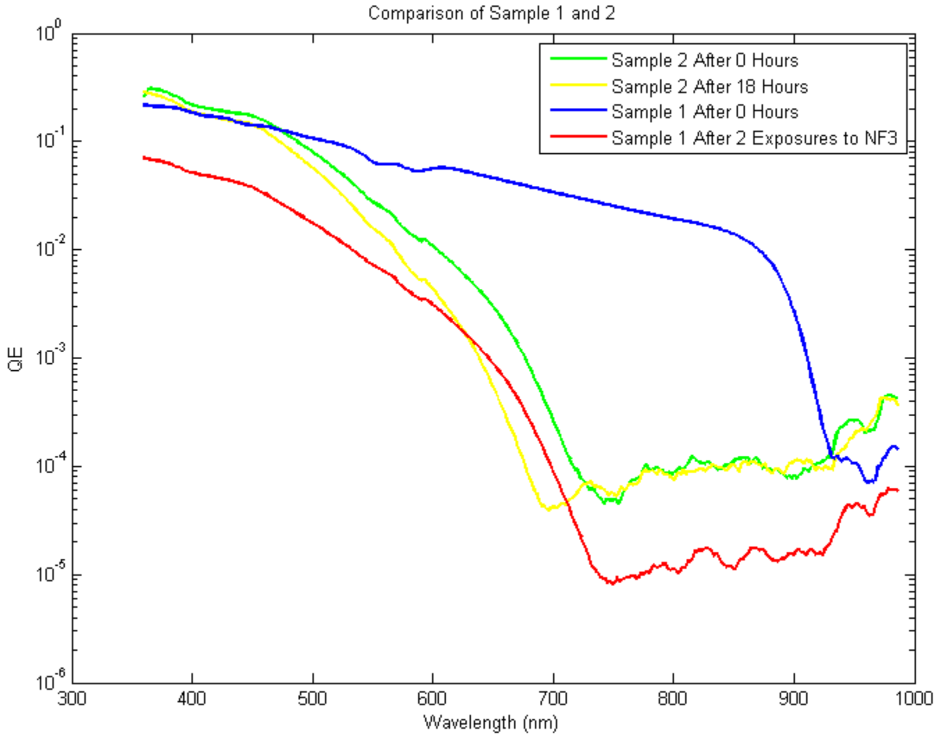
Spectral Response on Sample 1 & 2





- Continued measurements as cathode dies
- Band gap=1.33 eV (~900nm)
- Beyond band gap nothing gets excited
- When vacuum level is higher, even the excited electrons can’t escape

Comparison



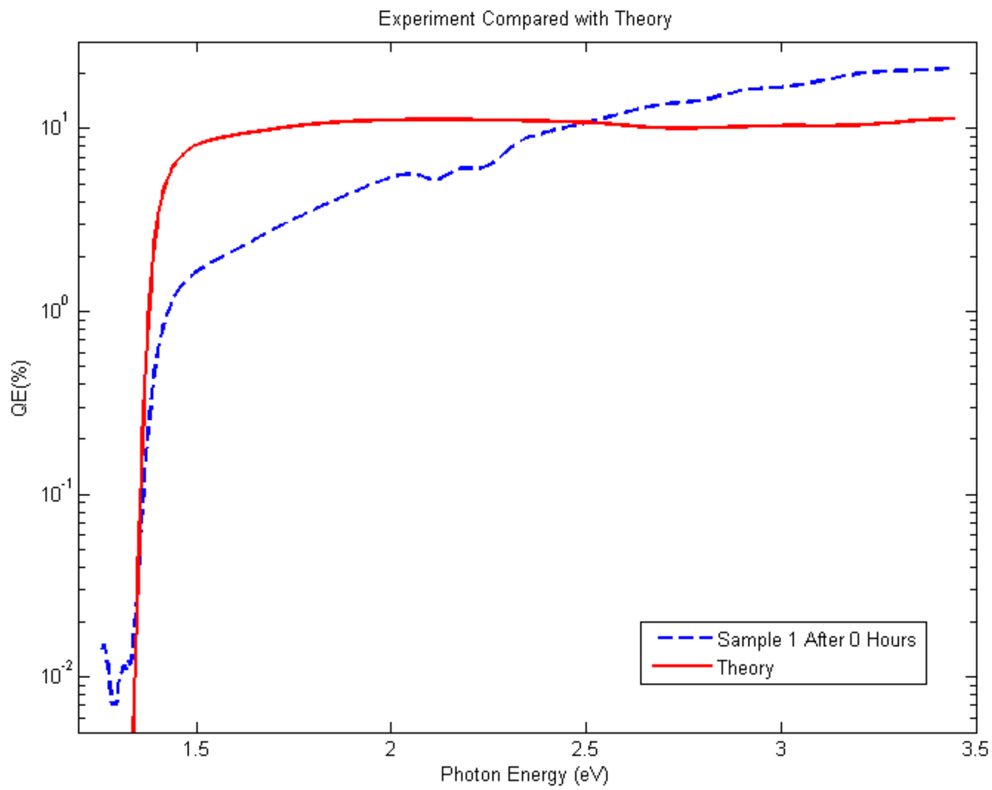
- Sample 2 behaves as Sample 1 after partial killing: may have never reached NEA
- Barrier is higher on Sample 2

Theoretical Calculation of SR

$$QE(hf)=B[1-R(hf)]/1+1/\propto($$

- QE can be calculated by modeling diffusion of electrons in GaAs
- Start and stay in a thermalized distribution
- GaAs properties
  - R(hf)=optical reflectivity
  - α(hf)=optical absorption coefficient
  - L=electron diffusion length (1.6μm)
- Surface Properties
  - B=Surface escape probability

Experiment vs Theory

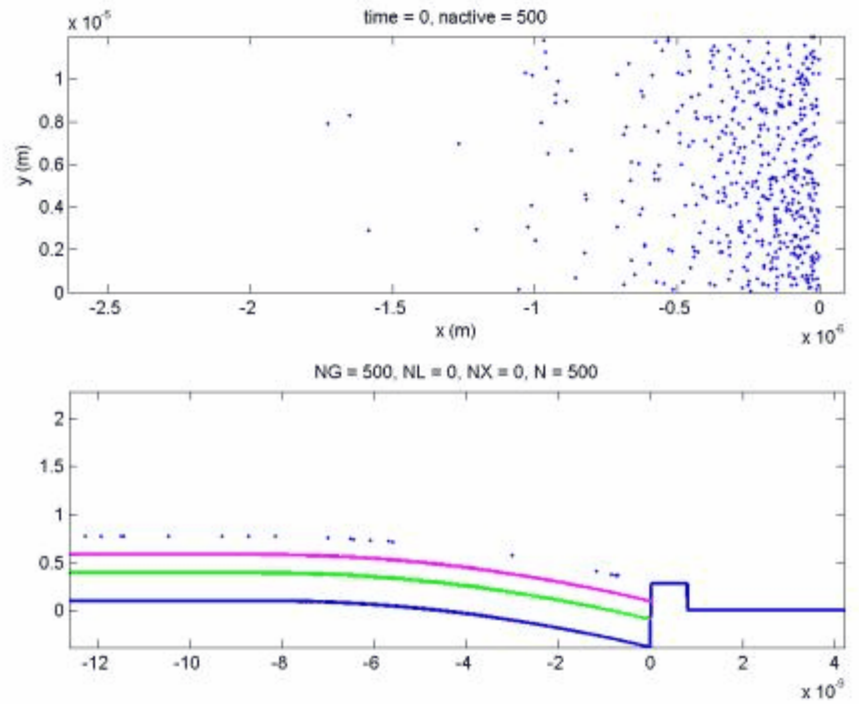


B=20%

- Drawbacks of theory
  - Does not explain band bending, barrier, scattering…

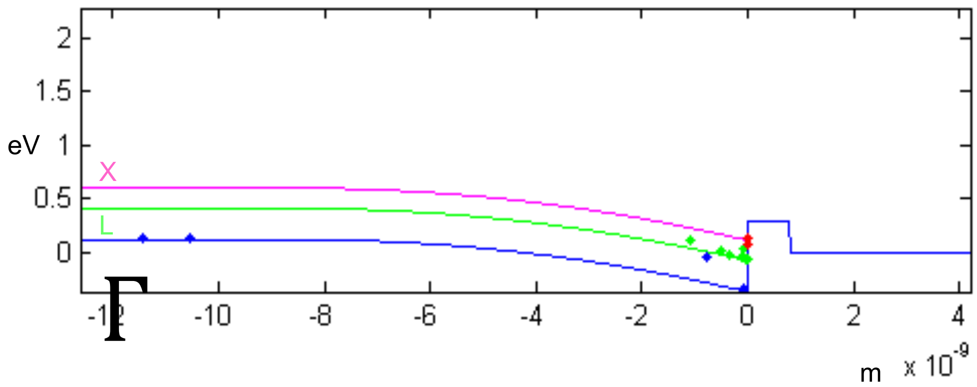
Monte Carlo Simulations

- Begin with electrons in a distribution caused by laser penetration
- Simulates the behavior of electrons in activated GaAs cathodes and tracks their position



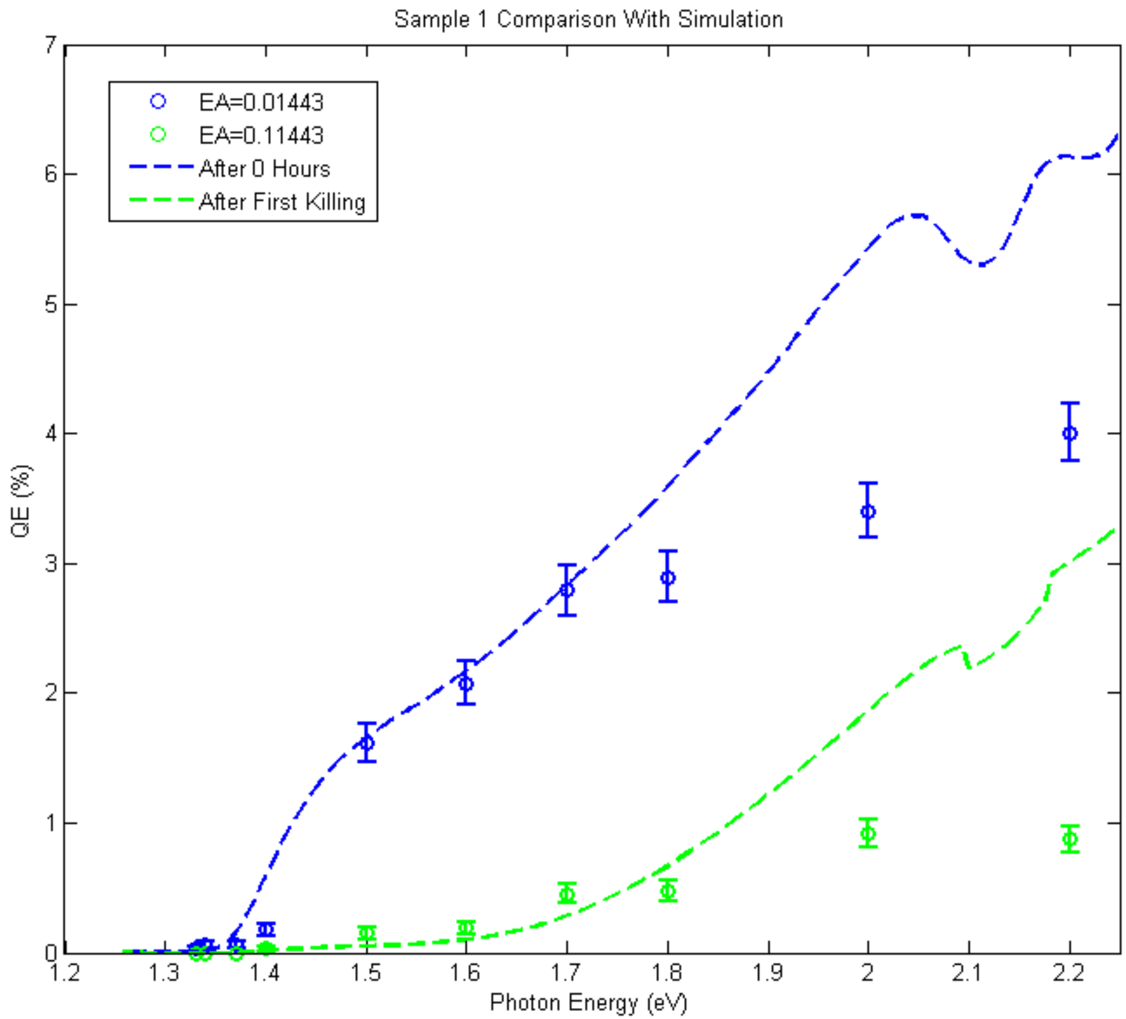
Running the Code

- We can run the code multiple times changing various parameters
- QE vs Incident Photon Energy
  - Can compare to experiment from spectral response
- Also changed was Surface Barrier height
  - Maximum Barrier= 0.28eV above Surface Barrier
  - Barrier Width= 0.8 nm



Sample 1 Simulation

- Doping level=1.0x10^{19}



Conclusions

- RHEED: after activation, the pattern gets more diffused
- Sample 1 has a smaller surface barrier than sample 2
- Sample 2 never reached negative affinity
- Monte Carlo simulations explain the experiment until about 1.8eV, so more work must be done to improve the code

Acknowledgements

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