Electron Amplification in Diamond

Progress Toward a Secondary Emission Enhanced Photo-injector

John Smedley

BROOKHAVEN NATIONAL LABORATORY

Collaborators

I. Ben-Zvi

A. Burrill

X. Chang

J. Grimes

T. Rao

Z. Segelov

Q. Wu

R. Hemley, CI, Washington

Z. Liu, CI, Washington

S. Krasnicki CI, Washington

K. Jenson, NRL, Washington

J. Yater, NRL, Washington

R. Stone, Rutgers U

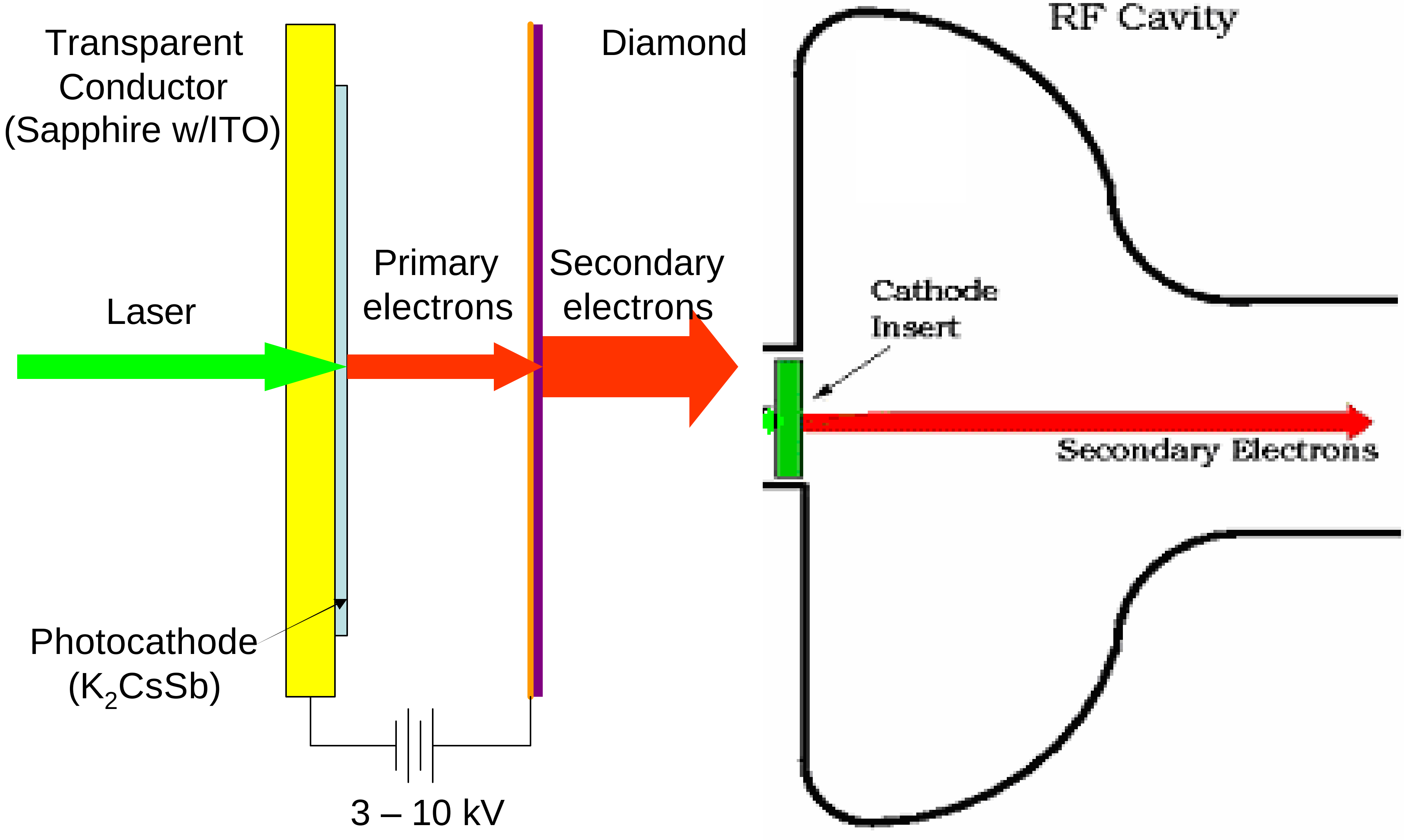
J. Bohon, Case Western U

P. Stephens, SUNY SB

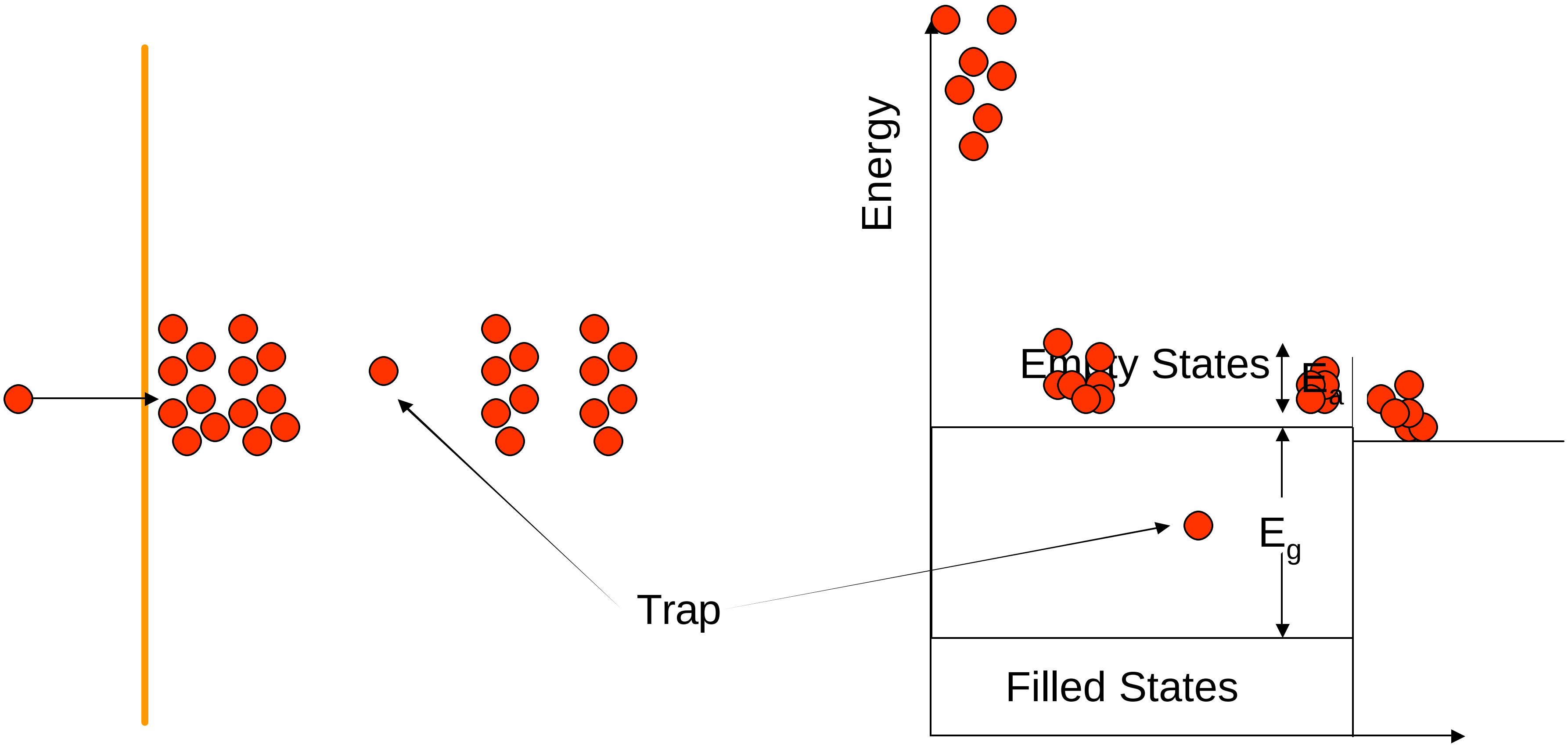
Overview

- The SEEP concept & capsule cathodes
- Electron transport in diamond
- Diamond characterization
- Secondary Yield Measurements
- Capsule Fabrication

Secondary Emission Enhanced Photo-injector



Electron Transport in Diamond



Secondary e^- lose energy via e-e and e^--phonon scattering

Eventually, e^- reach the bottom of the conduction band

Some e^- and holes will recombine (probability based on current and drift velocity)

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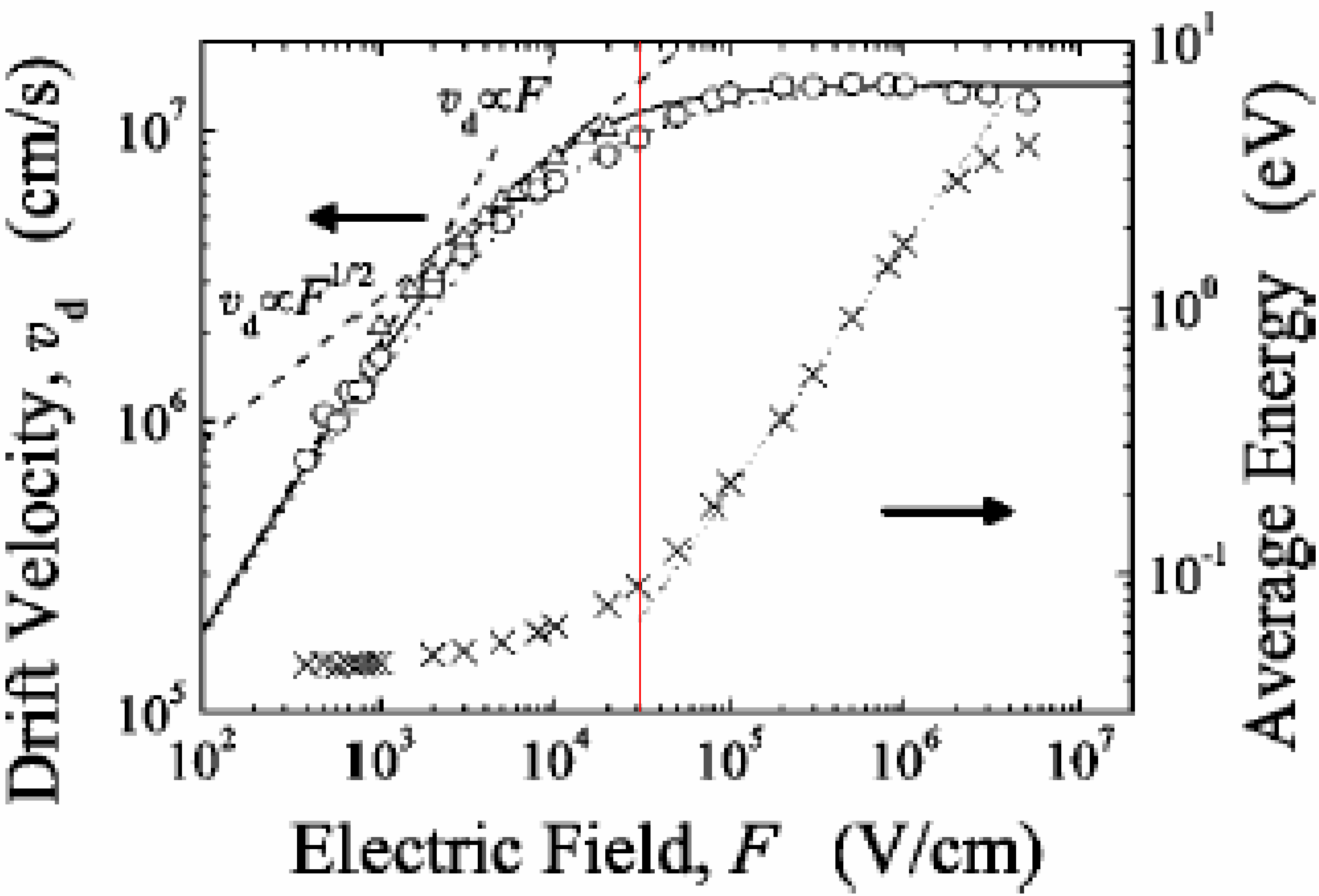
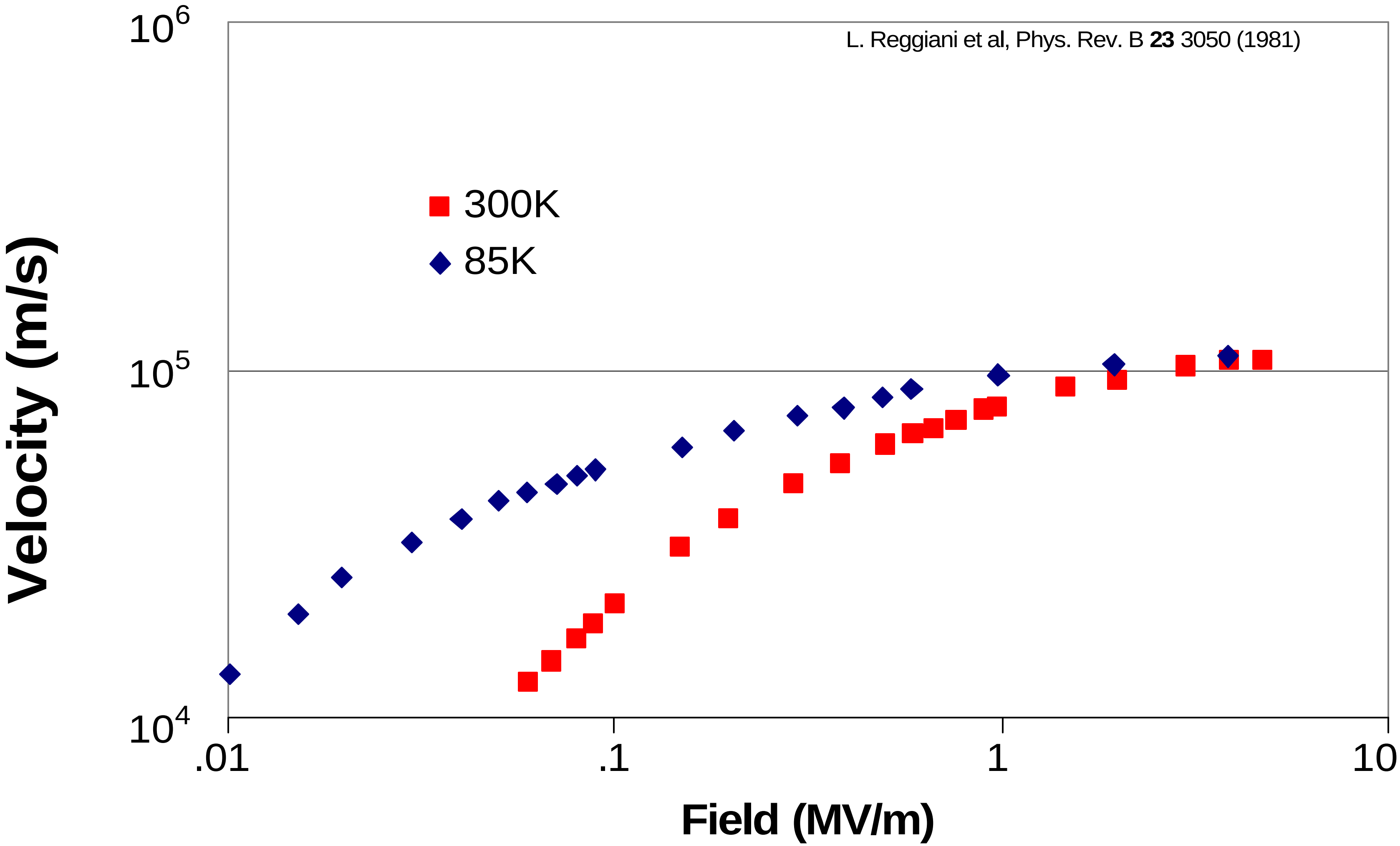
Electric Field and Drift Velocity



Temperature Dependence

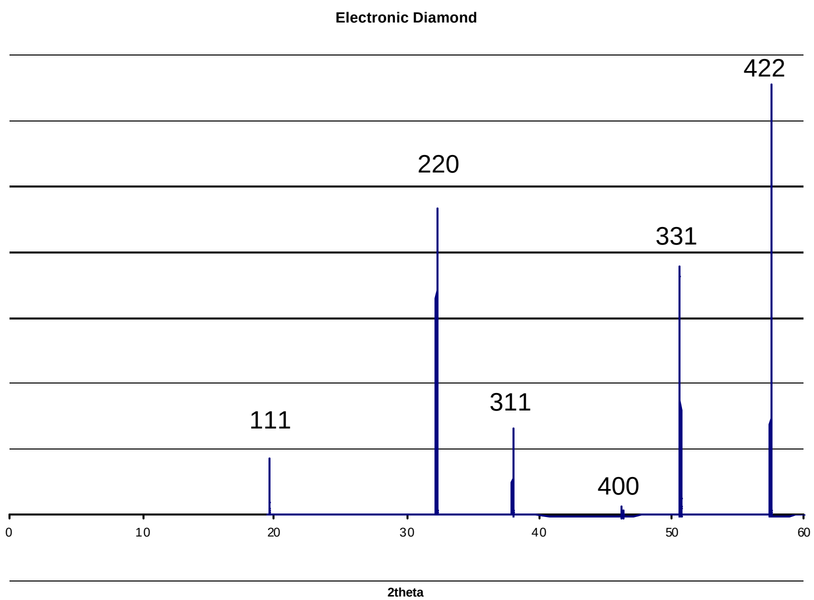


Diamond Characterization

- Crystalline Orientation
  - X-ray diffraction for bulk orientation
  - Electron diffraction for surface orientation
  - NEA depends on surface crystalline structure
- Impurity Content
  - Photoluminescence for trap density
  - FTIR to study nitrogen and hydrogen
- Even ppb impurity levels are critical
  - 1 ppb = $10^{14}/cm^3$ = 10^{12} potential charge traps

Powder X-ray Diffraction

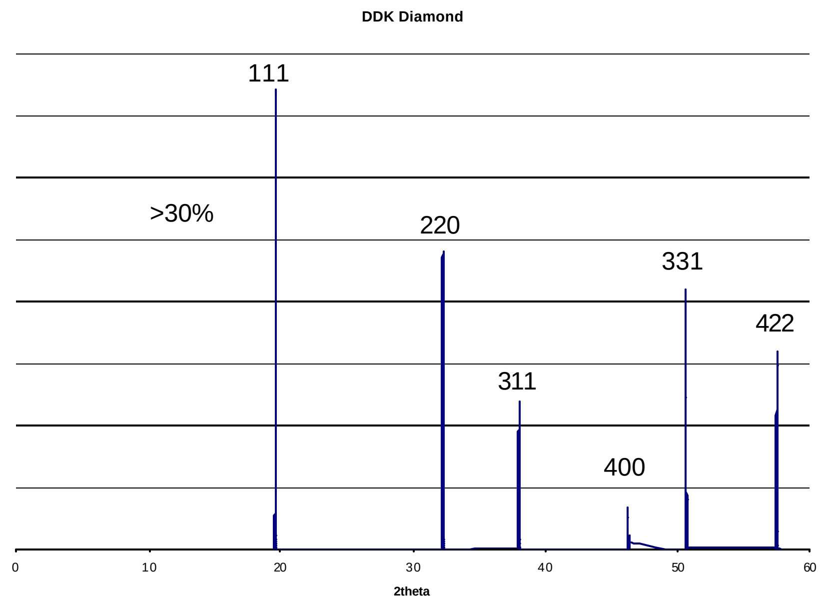
Most Interesting for Polycrystalline Diamonds



Standard Electronic Grade
Predominantly 110, 211 & 331

Natural Diamond was 110
Single crystal CVD was 100

111- Enhanced Polycrystalline



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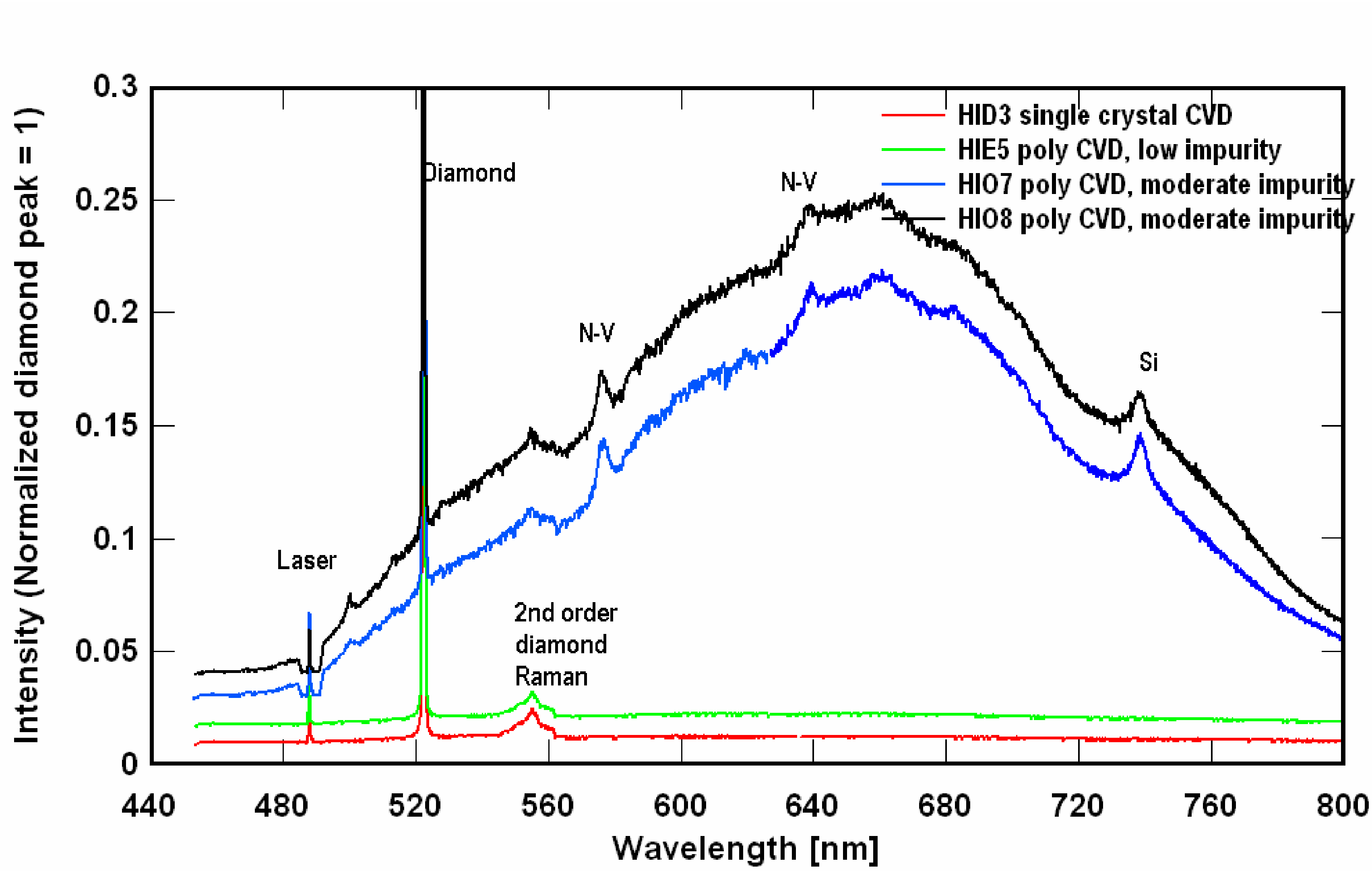
Raman/Photoluminescence



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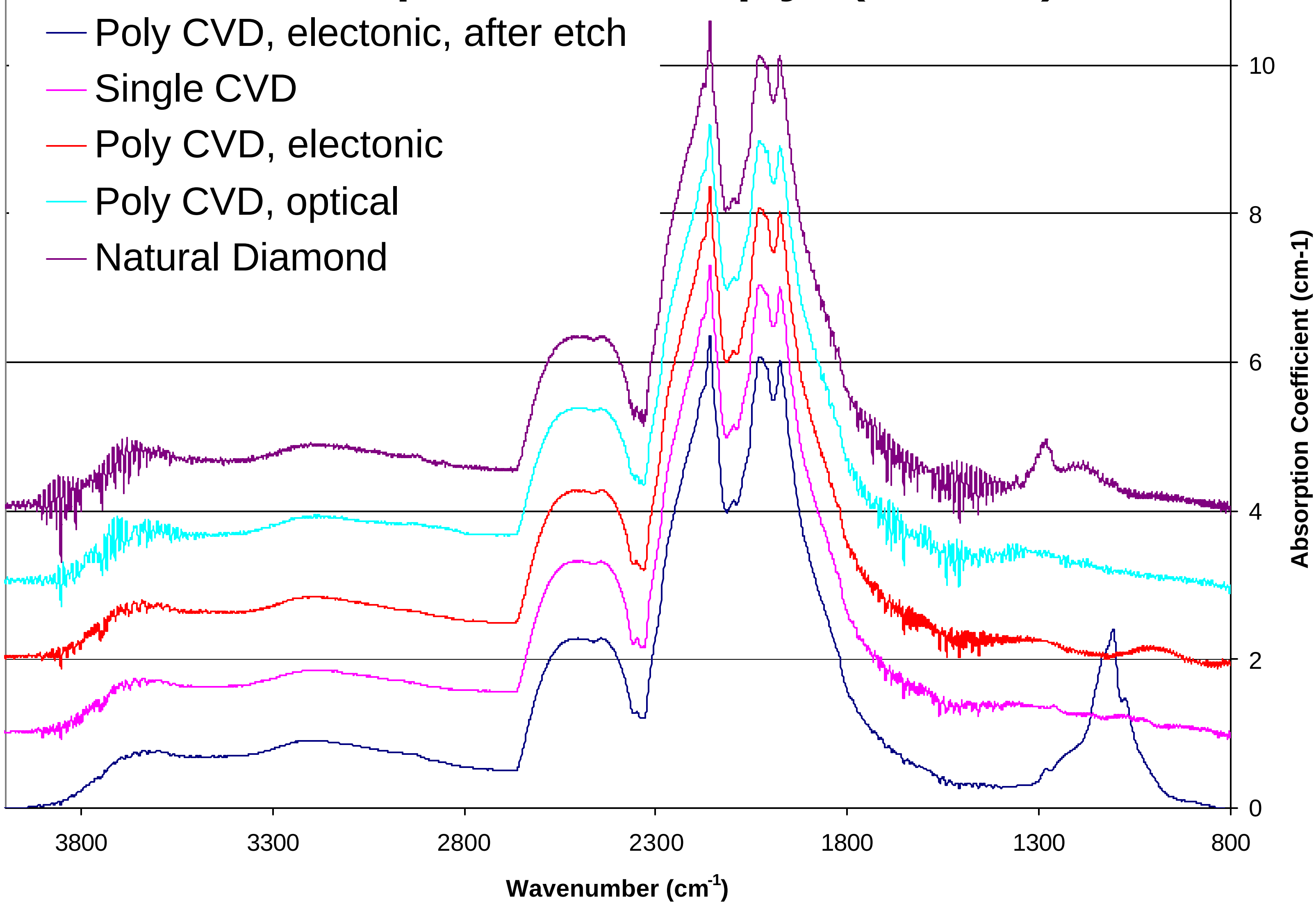
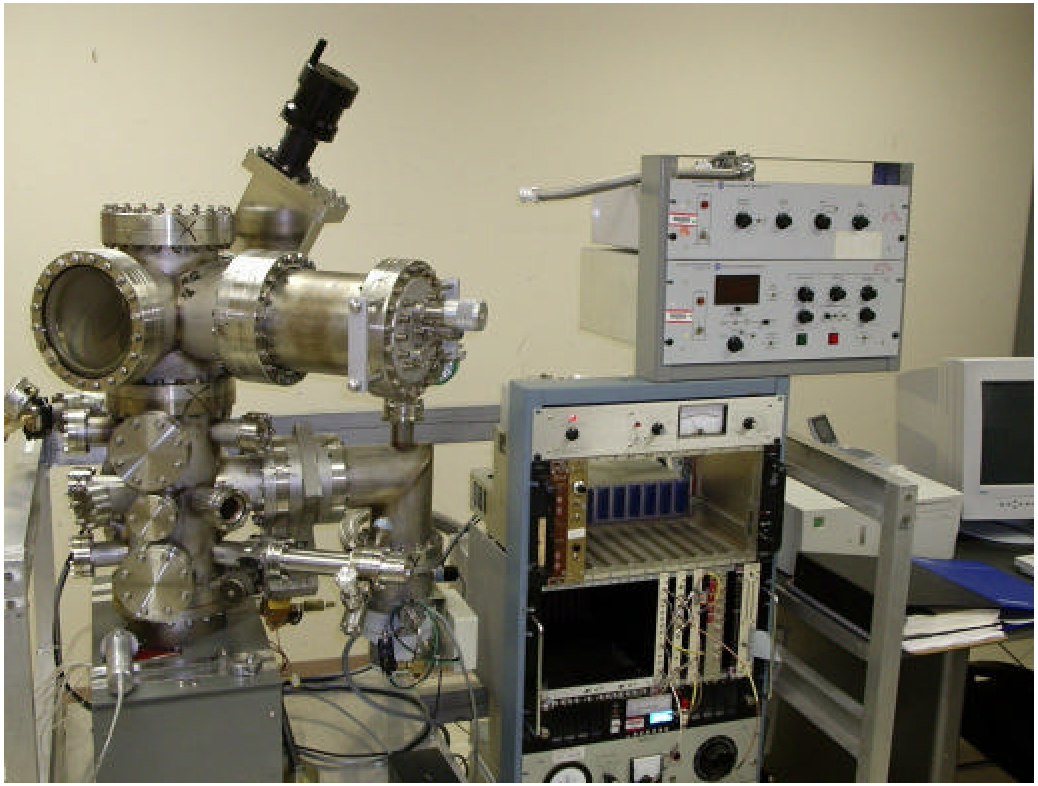
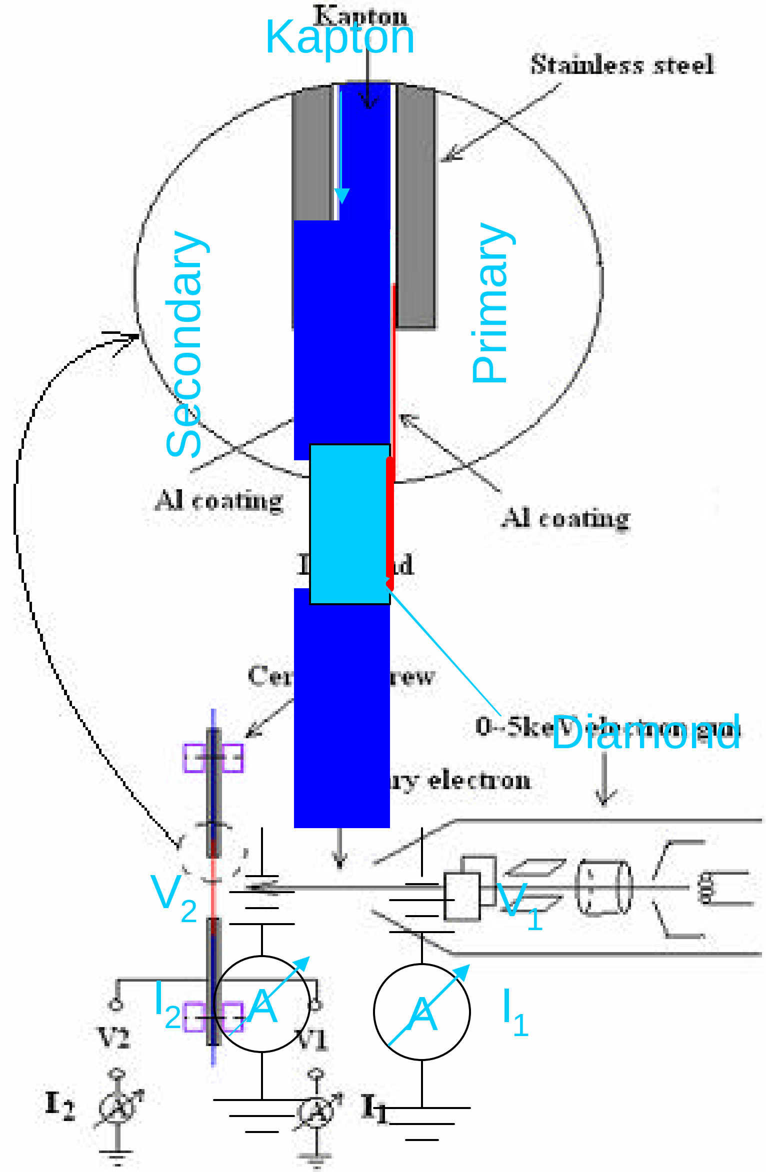
IR Spectroscopy (FTIR)



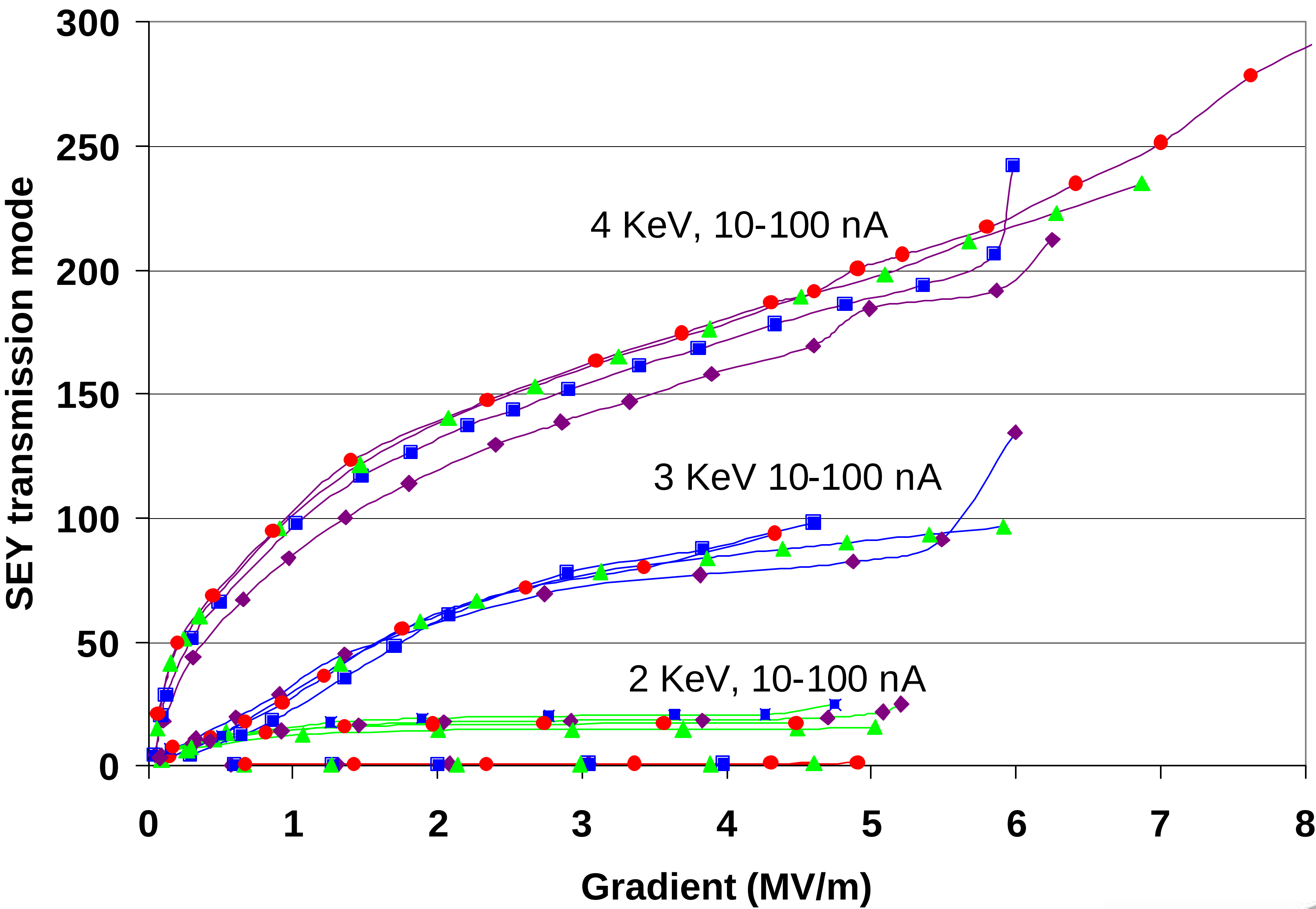
Experimental Arrangement





Two types of measurements
- Transmission – both sides metallized
- Emission – one side metallized, one side hydrogenated

SEY Natural Diamond, Transmission Mode



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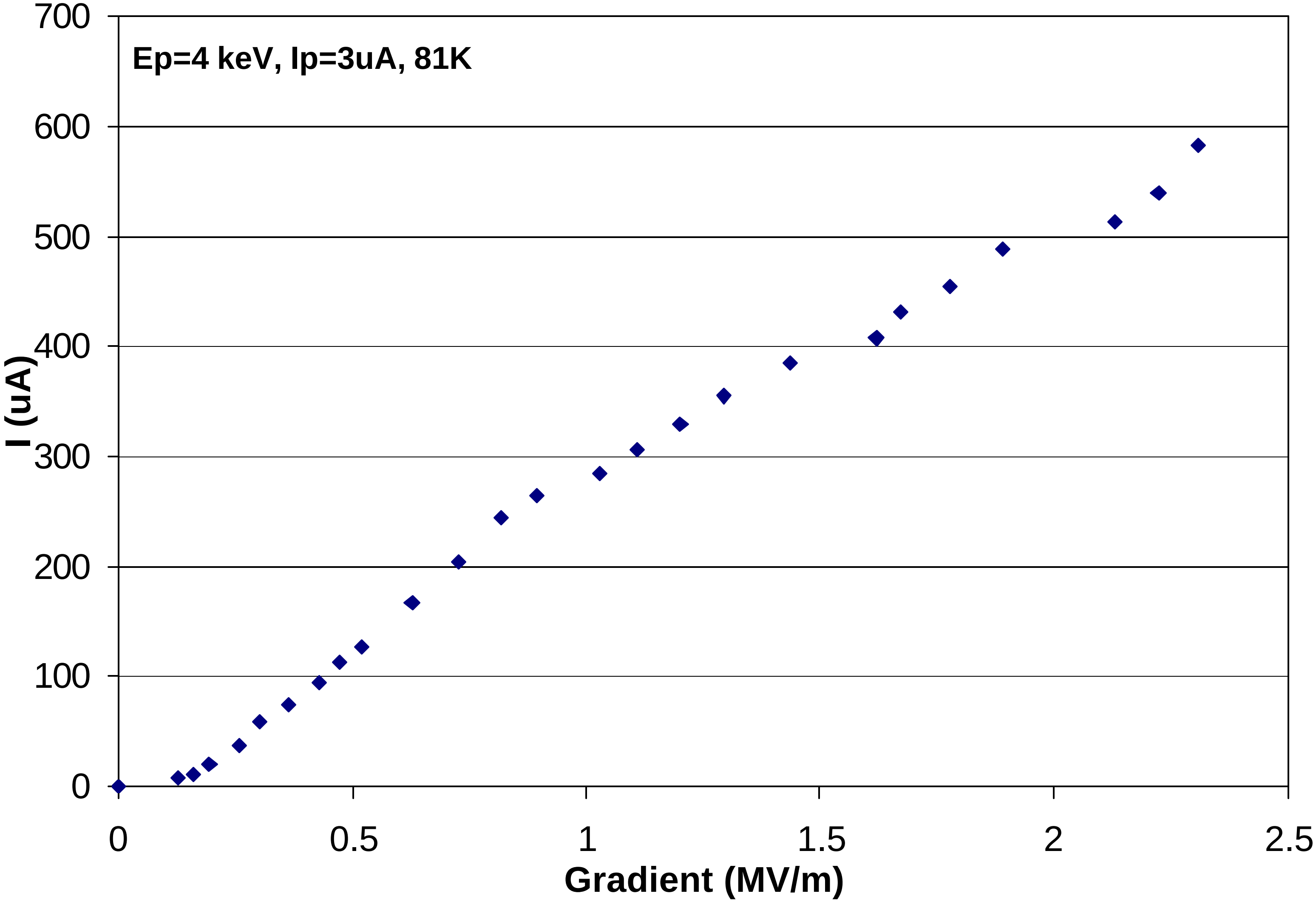
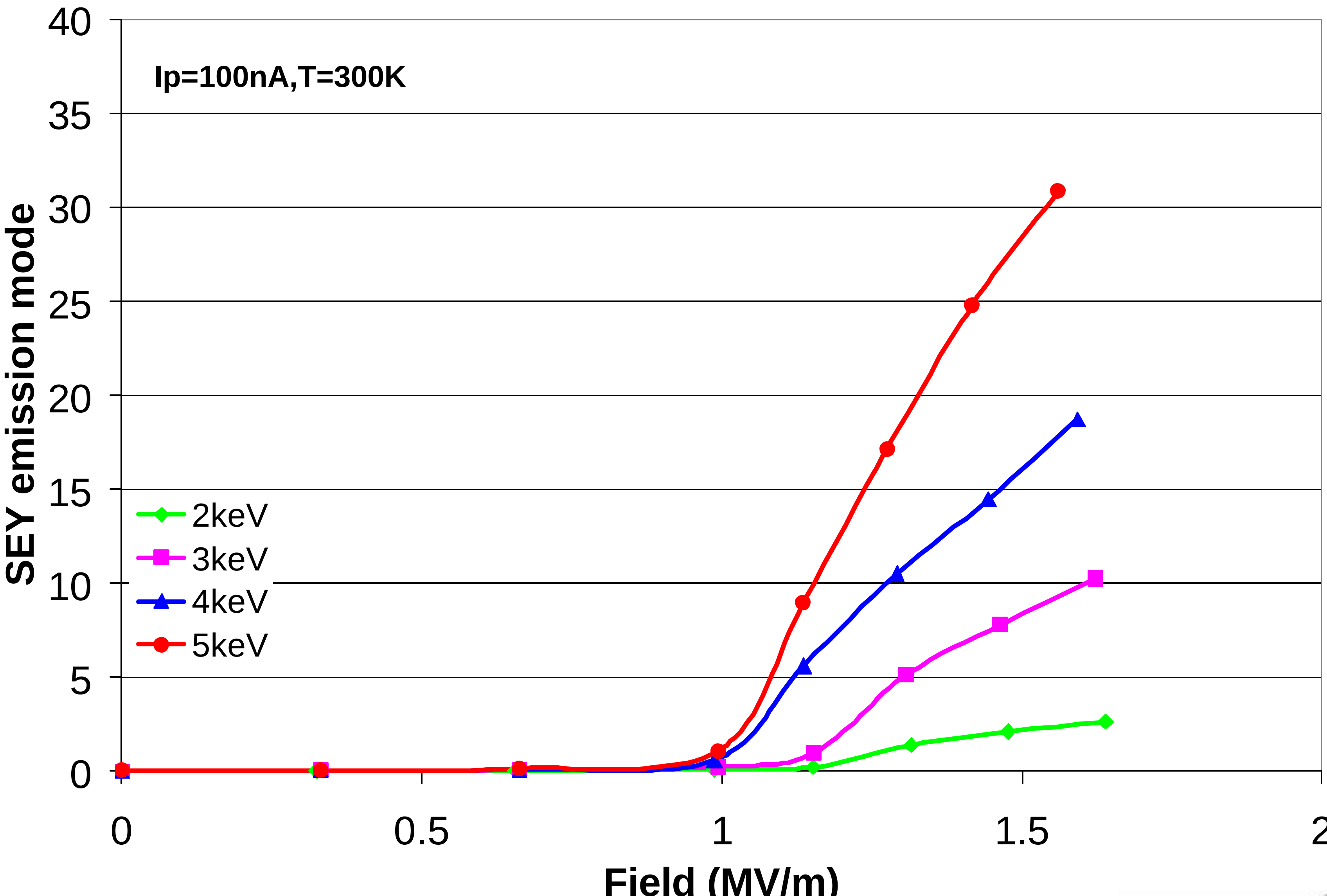
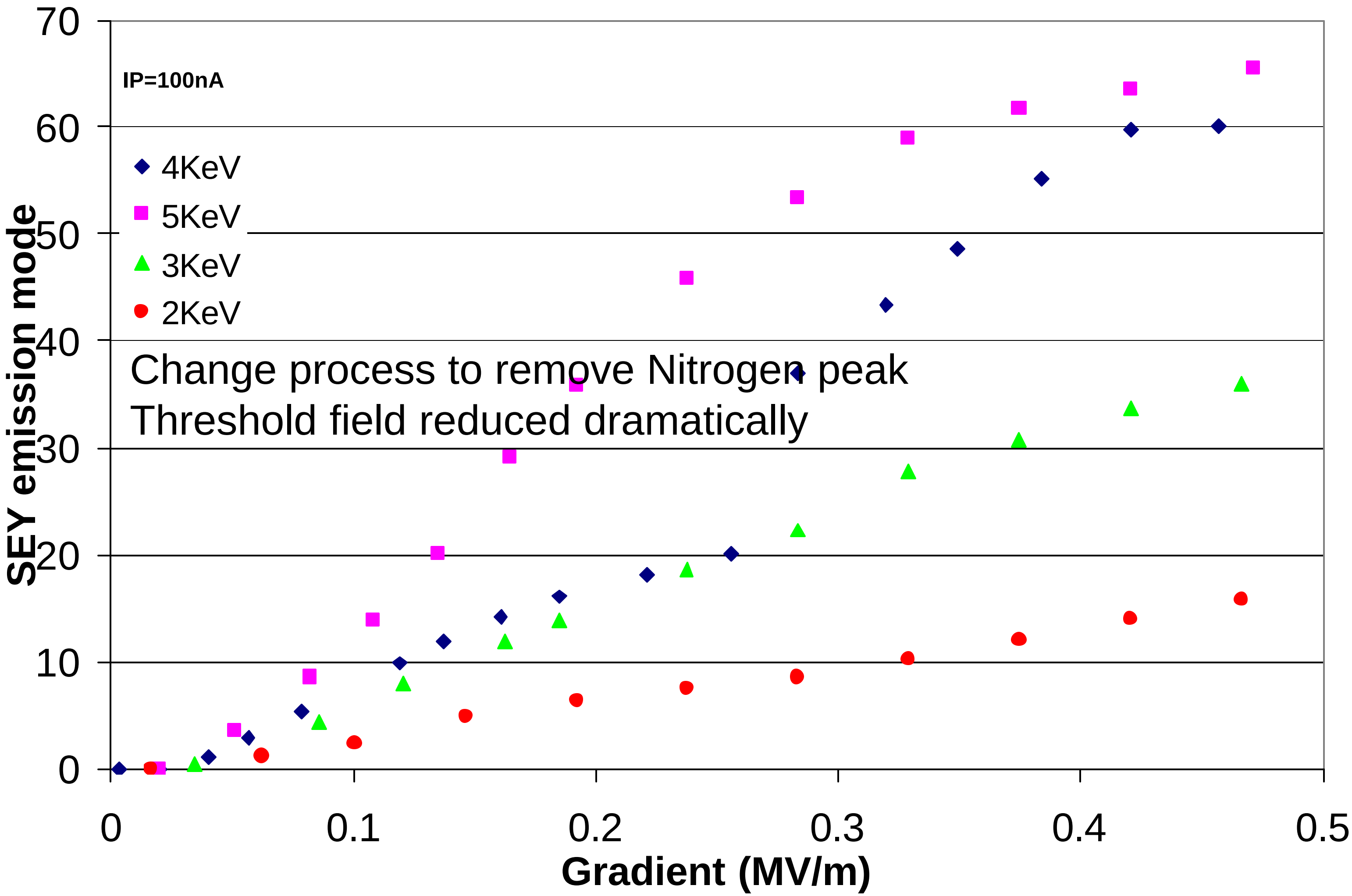
SEY Natural Diamond, Transmission Mode, 81K



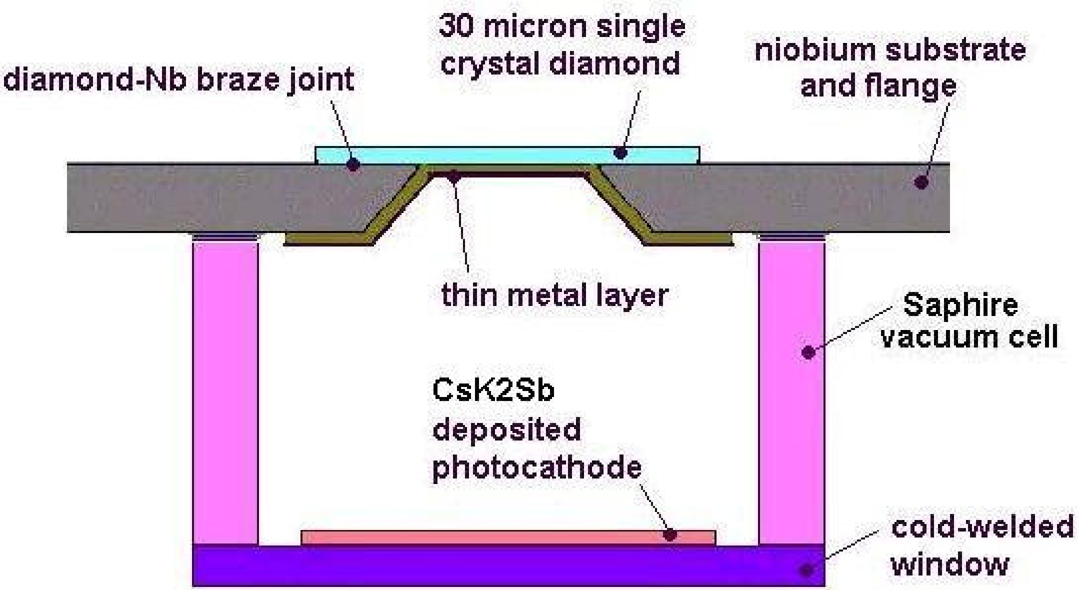
SEY Natural Diamond, Emission Mode



SEY Electronic Grade, Emission Mode



Diamond Capsule Fabrication



Diamond brazed on to Nb

Successfully vacuum tested

Polished from 200 to 70 micron thickness

Chemically treated brazed Nb

Ceramic brazed to Nb

Cold weld in progress

Conclusions

- A functioning SEEP injector will provide a path forward for ampere-class linacs and ERLs
- For sufficiently pure diamonds, transmission gains of over 200 have been demonstrated. ~14 eV of primary energy = 1 e-hole
- With proper preparation, emission gain of >60 with small emission threshold.
- H termination can provide a robust, NEA surface for electron emission. e^- affinity is affected by surface crystalline structure.
- Synthetic diamonds have desirable properties, although some development is still needed.
- The energy spread of the emitted beam is expected to be <1 eV
- With proper choice of the electric field in the diamond, $v = v_{sat}$ while energy spread is nearly unchanged

Still a lot to do!