Diamond Amplified Photocathode R&D Plans

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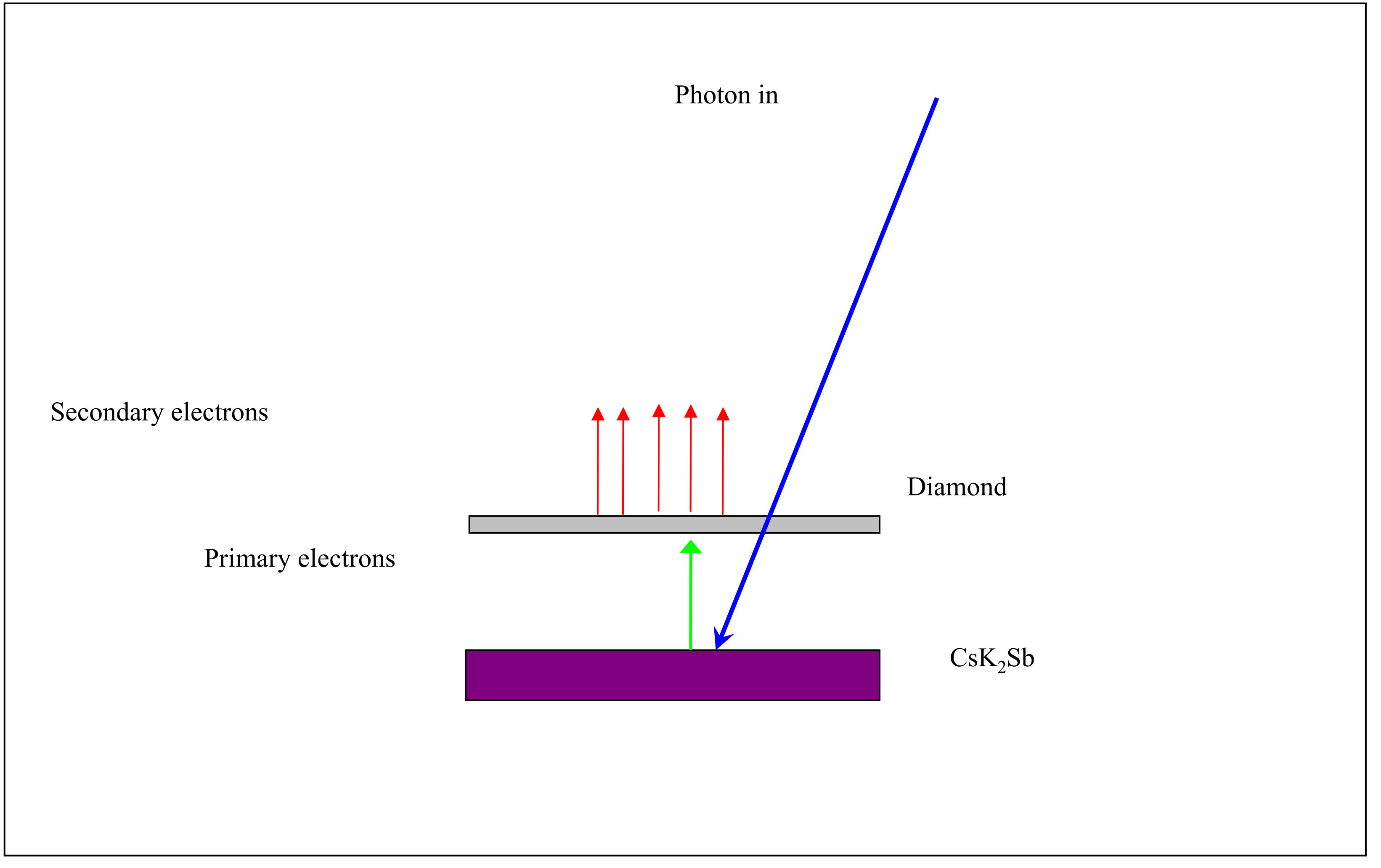
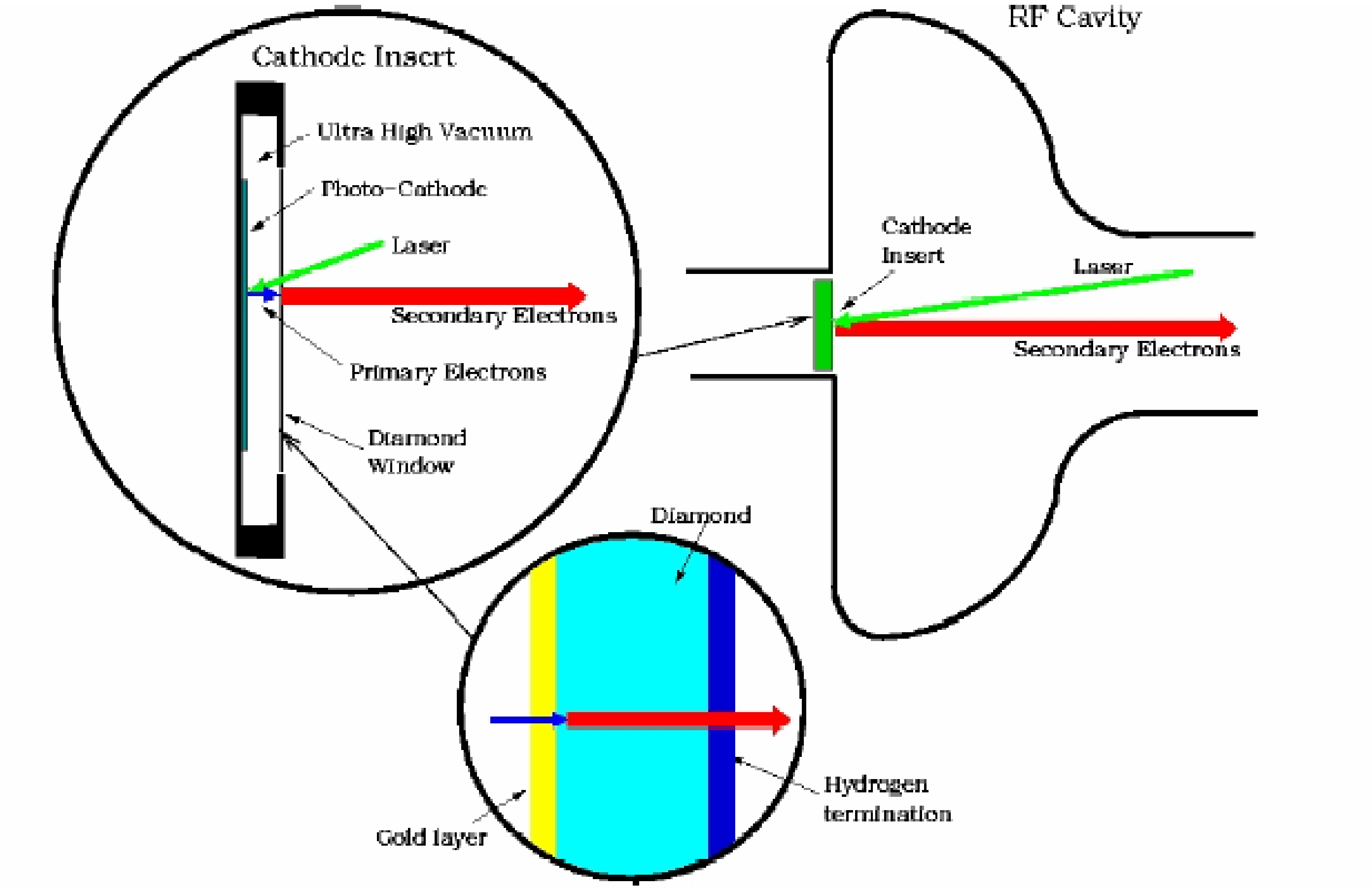
The basic idea



Motivation

- Capable of Average Current ~ 1A
- No contamination of cathode
- No contamination of cavity
- Ease of preparation& assembly
- Low thermal emittance
- Prompt emission

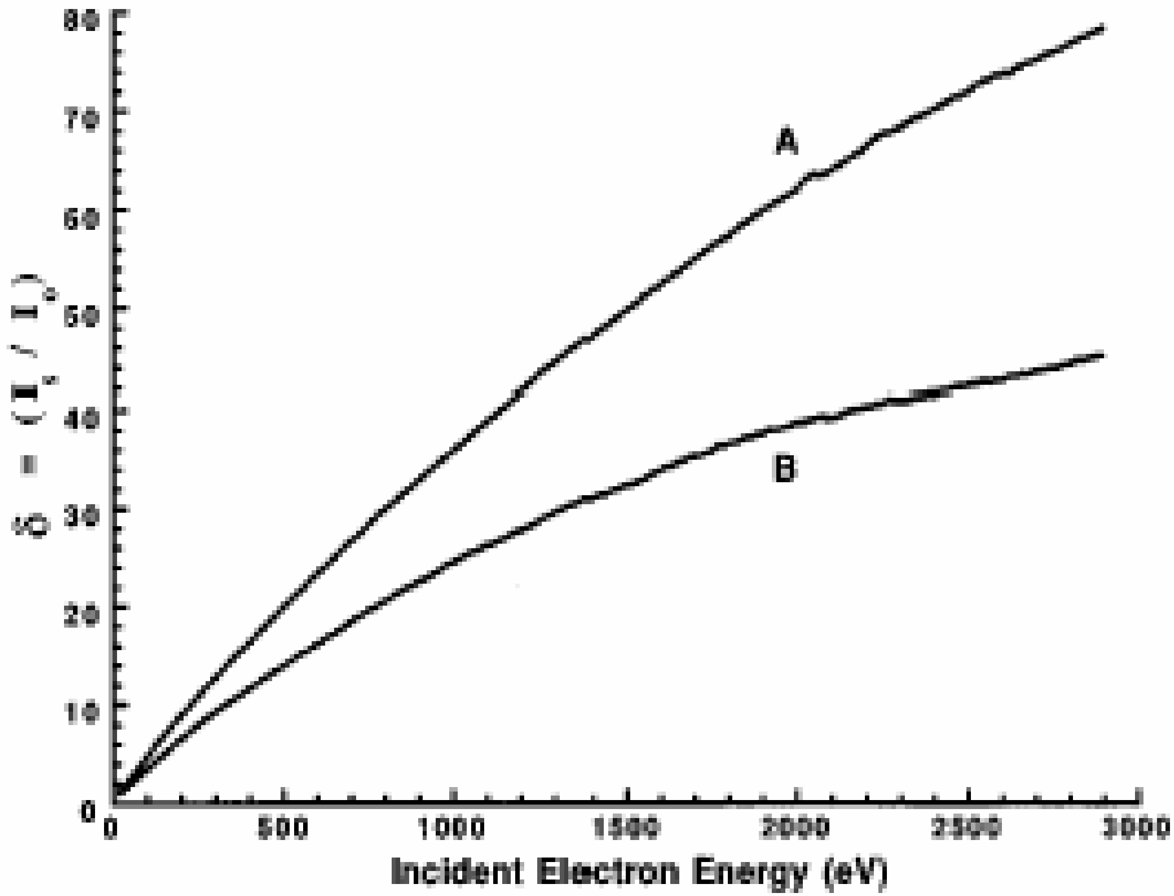
Schematic Arrangement of the System



- Diamond as a Secondary emitter
  - High gain amplification
  - Good thermal conductivity (~100W.cm^{-1}.k^{-1} at low T).
  - Strong mechanically
  - Thickness dictated by
    - Primary electron energy and penetration depth
    - Transport time
    - Escape depth
    - Thermal properties
    - Mechanical properties

Choice of Secondary Emitter: Diamond

High secondary electron yield > 80 for hydrogenated diamond



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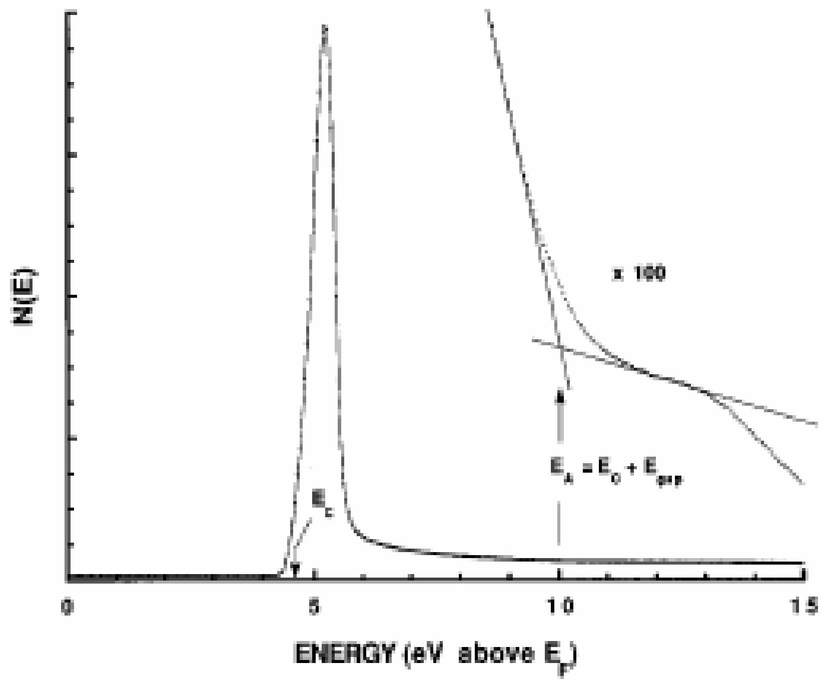
Electron Temperature



At birth < 1 eV

In Transport

Inelastic mean free path = 12.5 nm

Energy accumulated in 1 IMFP in 2 MV/m field = $12.5 \times 10^{-9} \times 2 \times 10^{6}$ eV

=0.25 eV

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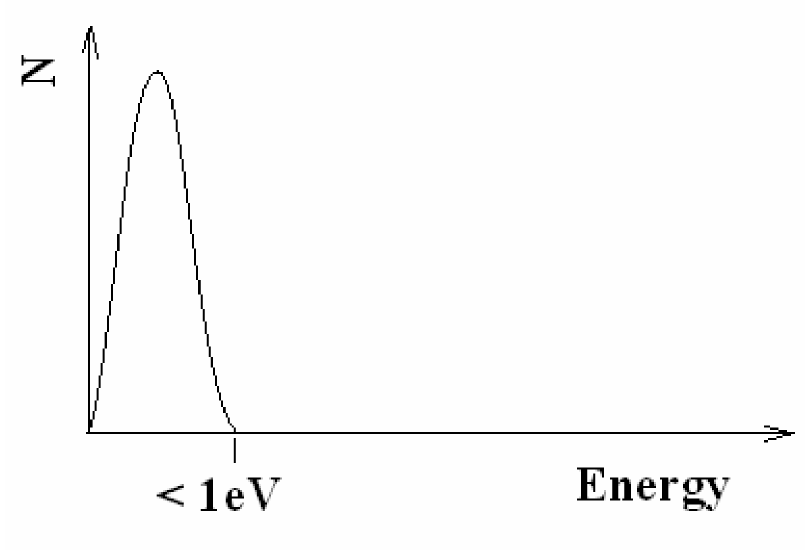
Transmission mode

- The SEY is expected to be higher than that in reflection mode
- The long high energy tail will disappear. Assume the field in diamond is 2MV/m the electron temperature is calculated to be ~ 0.35eV.



Electron temperature for transport mode

Temporal Issues

Transit time:

Drift velocity $V_d = 10^5(0.2xE+0.55) \sim 1x10^5$m/s for E=2 MV/m

E instantaneous electric field in the range of a few MV/m

Time of flight through 10 μm sample = 100 ps

Temporal Spread:

Number of IMFP steps in 10 μm sample = 8000

Number of Elastic collisions in 10 μm sample≈1.7x104

=>RMS broadening is negligible

Space Charge Broadening

Space Charge field = $Q/\pi R^2\varepsilon_0\varepsilon_r$=0.25 MV/m (Q=1nC, R=5mm)

Head to Tail Broadening =<10 ps

Thermal Load

- **Energy deposited by Primary electrons**

For 0.5 A secondary current and SEY of 100, primary current is 5 mA at ~ 3 keV in reflection mode. This corresponds to **15 W** of power

- **Heat load due to secondary electron current**

$$P_s = \int I_s E(t) V_d(t)/\varepsilon_r \, dt = \mathbf{17\ W}$$

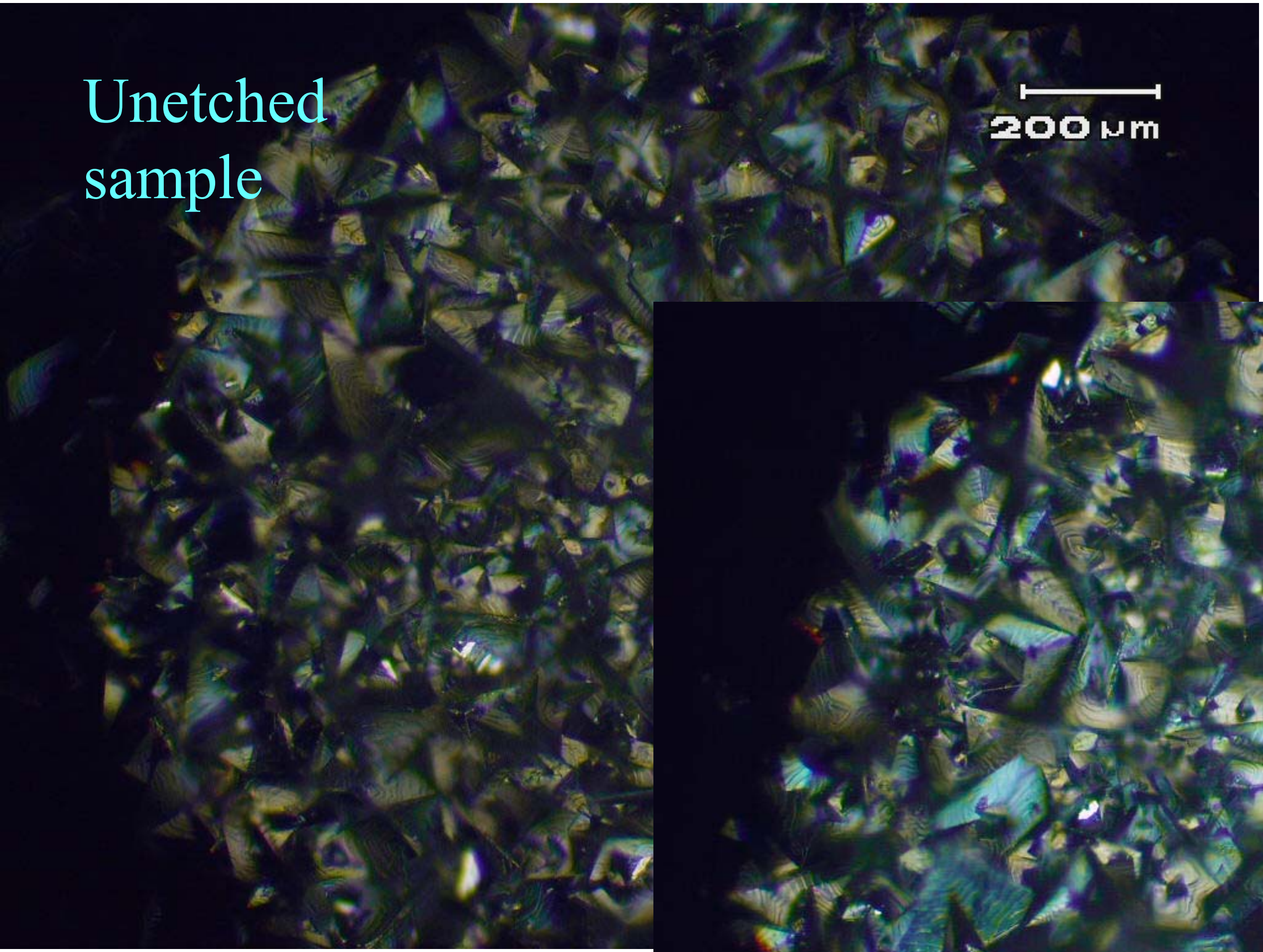
Increase of ~ 42 K across the diamond sample

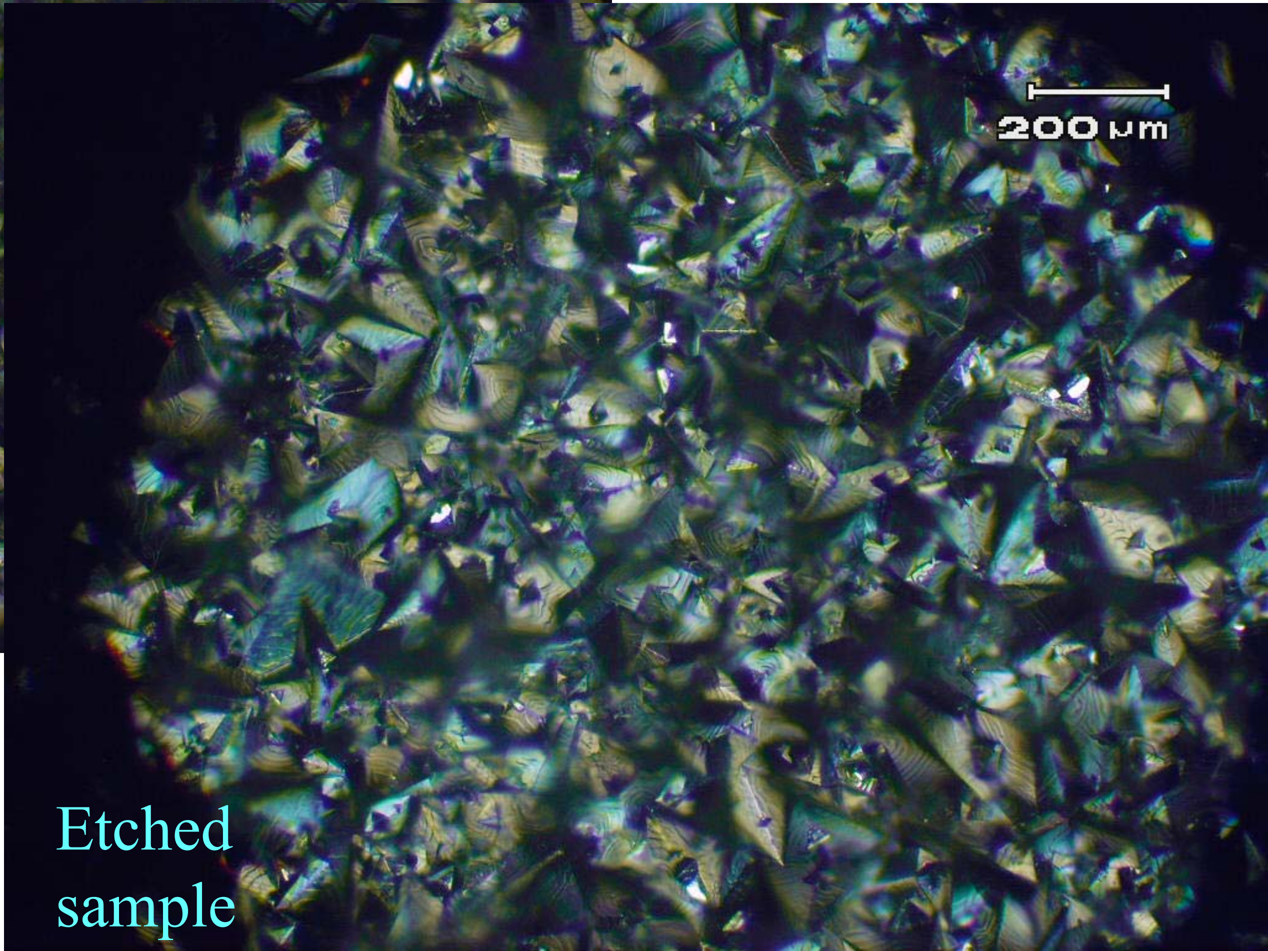
This heat load can be handled by LN cooling

Experimental Program I

- Measure SEY, and Energy spread
  - for transmission mode
  - in high field
  - In cryogenic temperatures
- Measure transit time and temporal broadening
- Determine High Current Performance (Heat load, electron temperature)
- Establish design criteria
  - Sample thickness
  - Doping concentration
  - Surface preparation

Diamond Samples

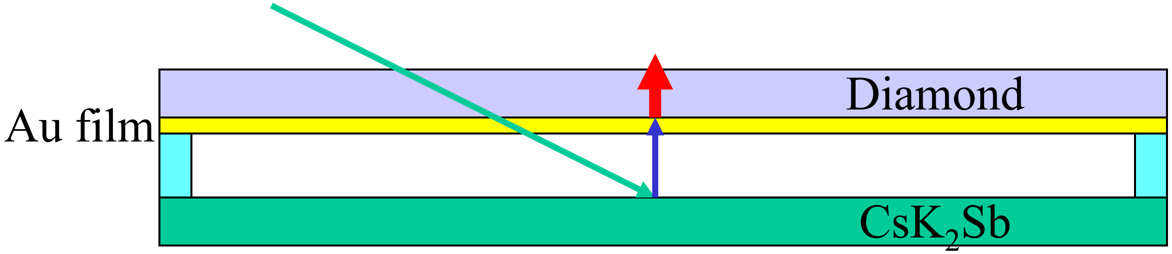




Experimental program II

- Prepare a capsule manufacturing station
- Fabricate choke joint for our AES/BNL/JLAB 1.3 GHz gun
- Test performance of capsules in SRF gun:
  - High Q and field
  - Get photocurrent
  - Measure performance, dependence on parameters

Encapsulated Emitter



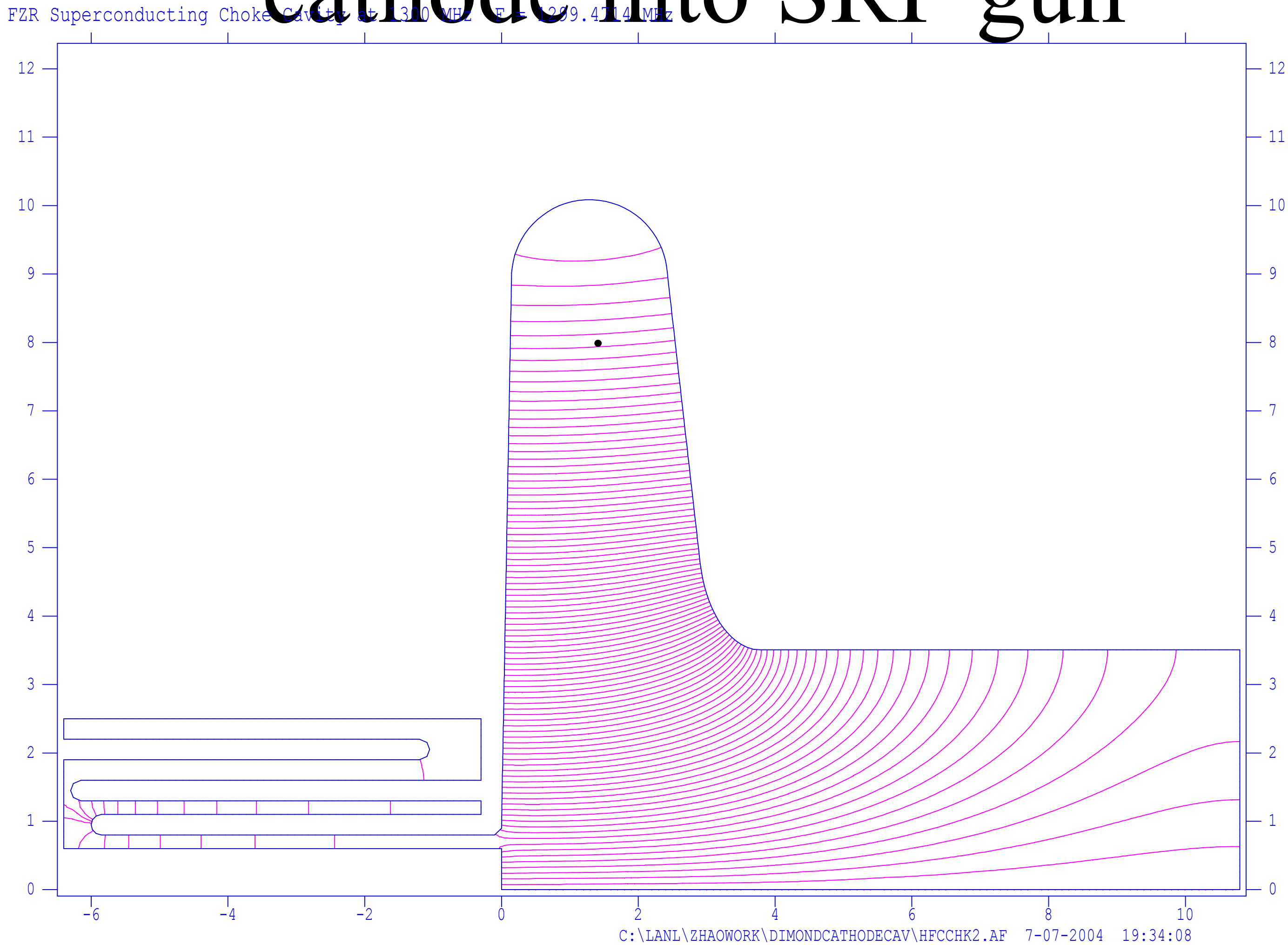
Very low Laser power

No contamination of cathode

No Contamination of Cavity

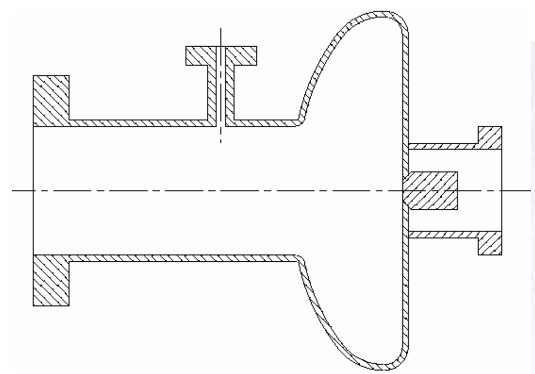
No need for Load Lock system

Choke joint for inserting diamond cathode into SRF gun



Test diamond effect on SRF cavity

- Initial results from JLAB:
  Q_0 over 10^8 with field over 4 MV/m.



Diamond held with GE Varnish

Conclusion

- Amplification of primary electrons using diamond as secondary emitter in an injector shows great promise
- An experimental program is in place to produce a high-current diamond-amplified photocathode.