# First Observation of an Electron Beam Emitted from a Diamond Amplified Cathode

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- **For many years people can either have cathode with:**
  - **High QE, high bunch charge, high average current, low emittance but very short lifetime**. *Semiconductor cathodes*
  - **Or, long lifetime but low QE, low average current, high emittance.** *Metallic cathodes*
- **For the first time we've demonstrated the cathode with:**
  - ***Effectively very high QE***
  - ***Very high bunch charge***
  - ***Very high average current***
  - ***Low emittance***
  - ***Extremely long lifetime.***

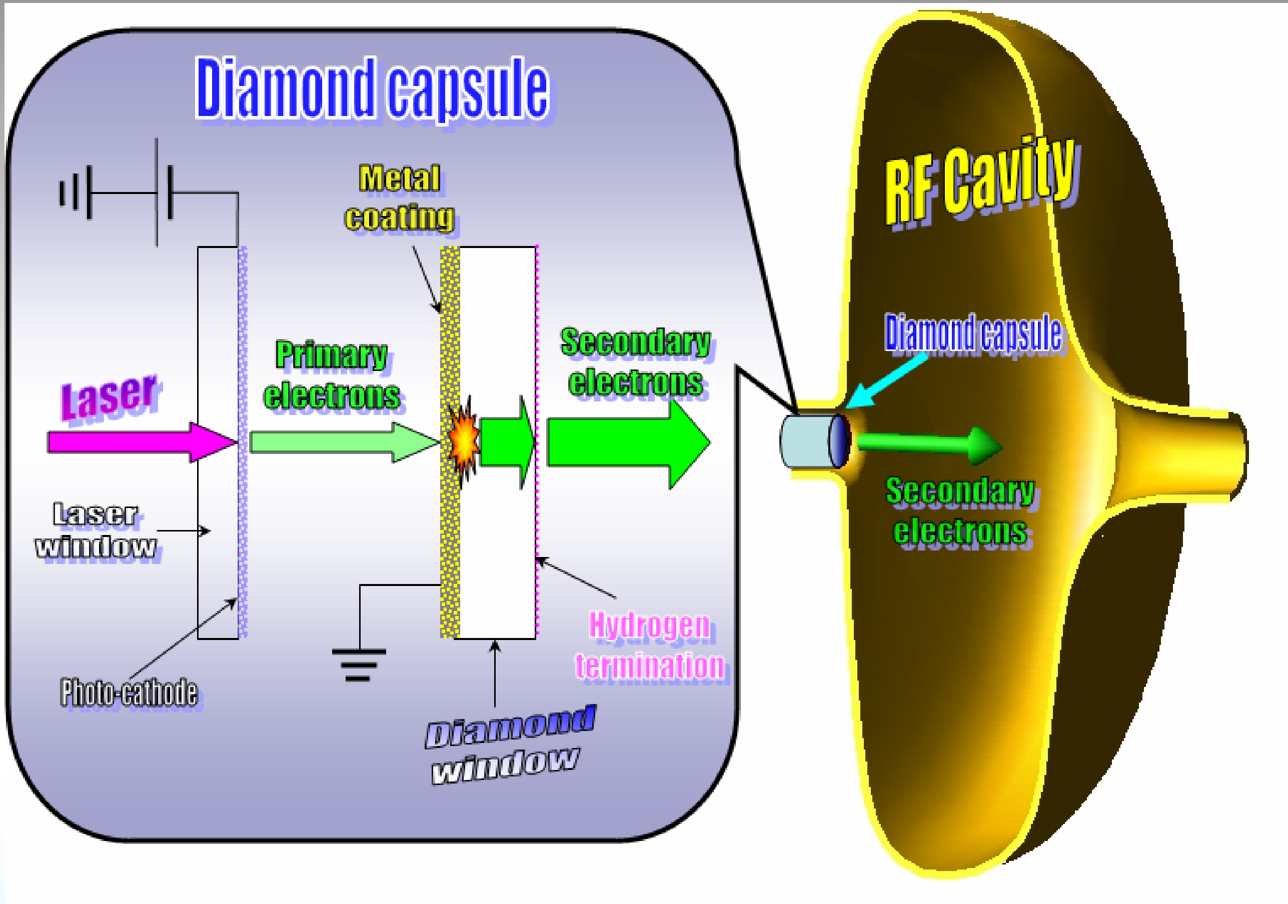
# *The Diamond Amplified Photo-cathode (DAP) concept*

I. Primary electrons penetrate the metal coating and generate electron-hole pairs.

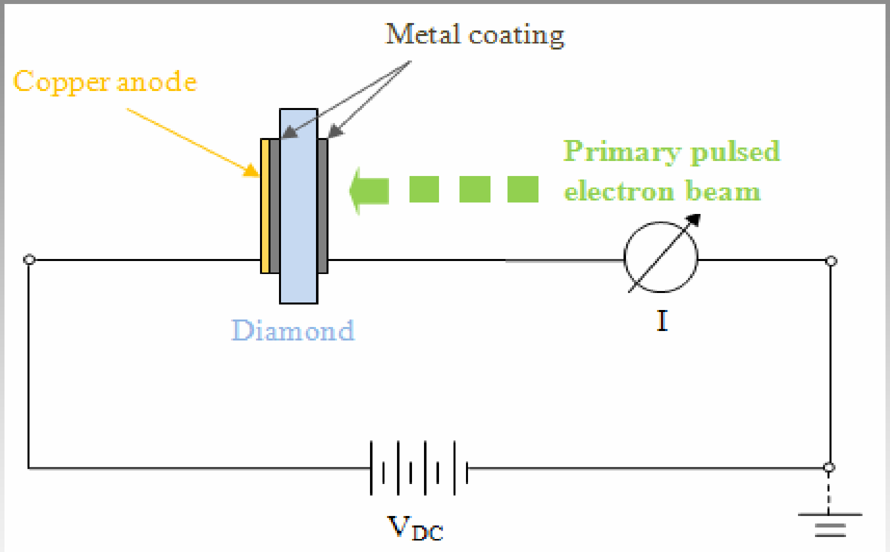
II. Electron-hole pairs are separated by the RF electric field at the right phase.

III. Secondary electrons drift through diamond.

IV. Secondary electrons are emitted from the hydrogenated Negative Electron Affinity (NEA) surface.

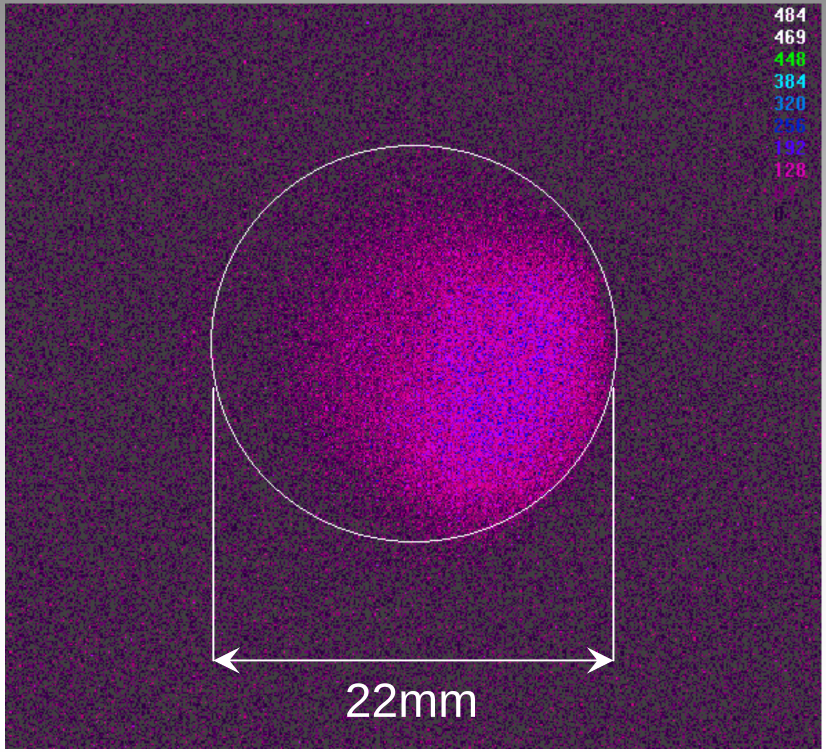


# *Transmission Mode Measurement*

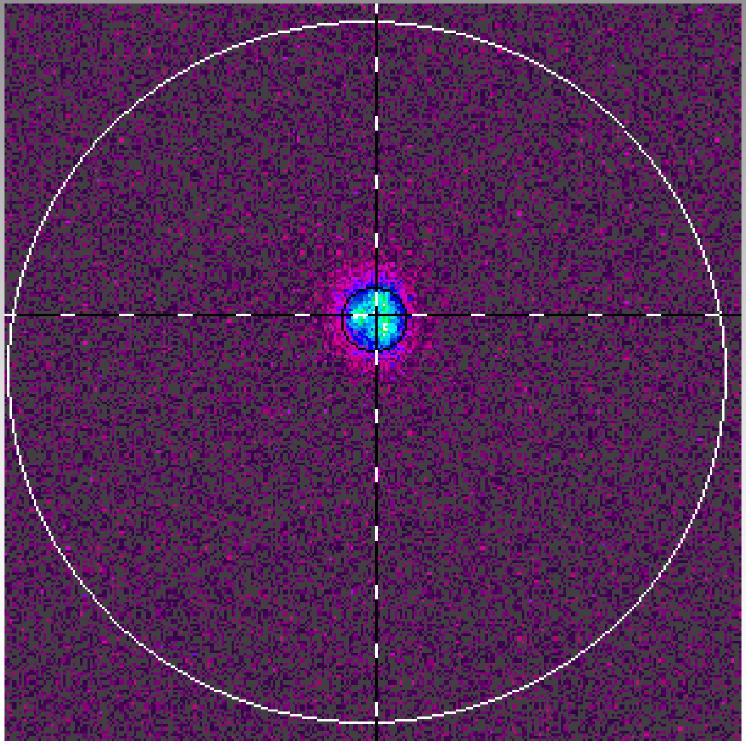



I. Single-crystal, high-purity, synthetic diamonds greatly reduce electron and hole trapping in the diamond's bulk.
II. Gain vs. field does not vary with the primary electron density.
III. The saturation gain is independent of temperature.
IV. Diamonds are very robust.
V. Can handle very large current densities.

# First observed beam from diamond amplified cathode




Without focusing

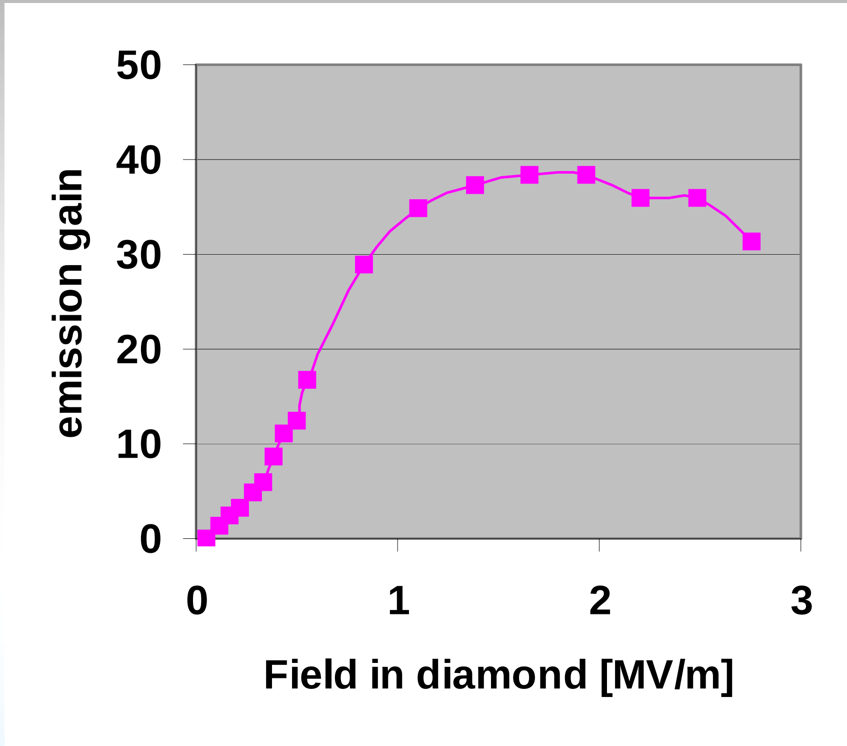


With focusing and reduced primary current

**IPri=300nA. HV: 3kV (1.7MV/m in diamond).
Freq. = 1kHz, Duty cycle = 0.001**

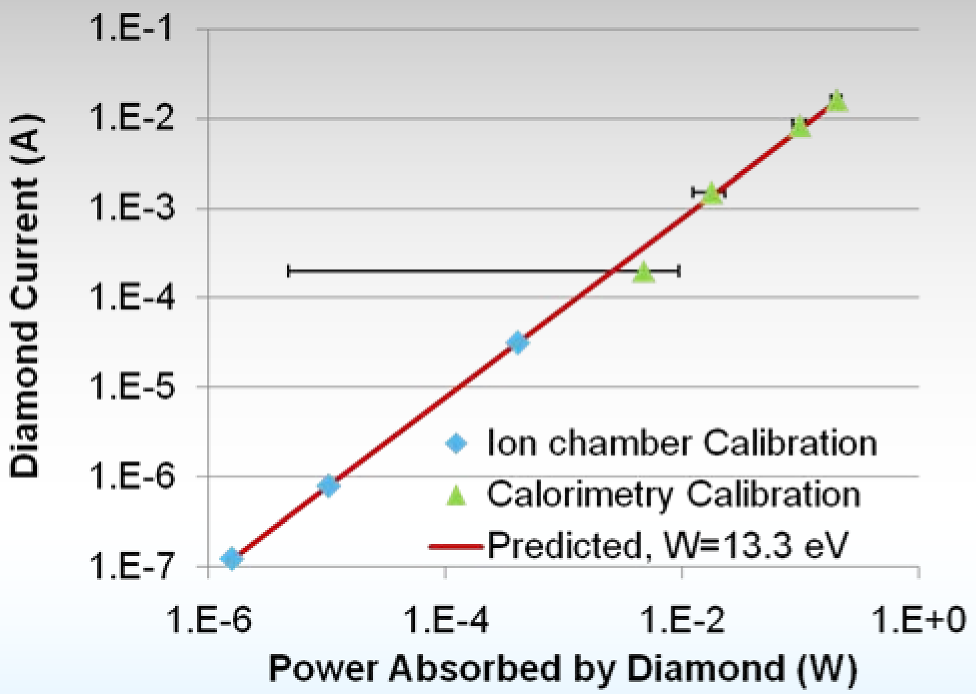
# Gain?

•*Gain of **40** was measured in our current test conditions.*

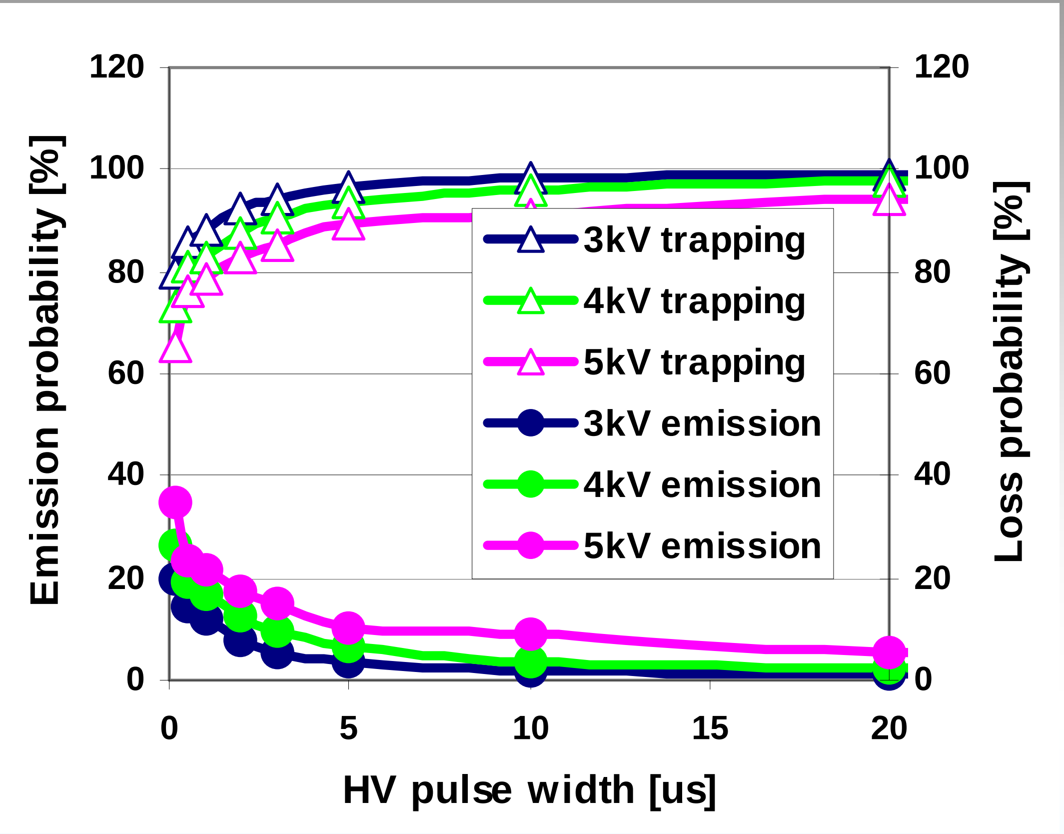


# Charge / bunch ?

- >**50pC/bunch/0.5mm²** (10nC/cm²) from the existing samples and conditions.
- Experiments using x-rays to generate current in diamond have demonstrated an average current of 40mA in a 2mm² area (**2A/cm²**)
- Current is linear with x-ray power from 100pW to 1W



# The emission probability on the hydrogenated surface?




**~40% @ 2.7MV/m, 200ns HV pulse width**

# Other characteristics of the diamond amplified cathode

- ***Emission is independent of temperature. (From LN to 200C in our tests).***
- ***Extremely robust***
  - ***No observable emission degradation after days of exposure to the air.***
  - ***About 50% degradation after exposure to the air for half year!***

# Summary

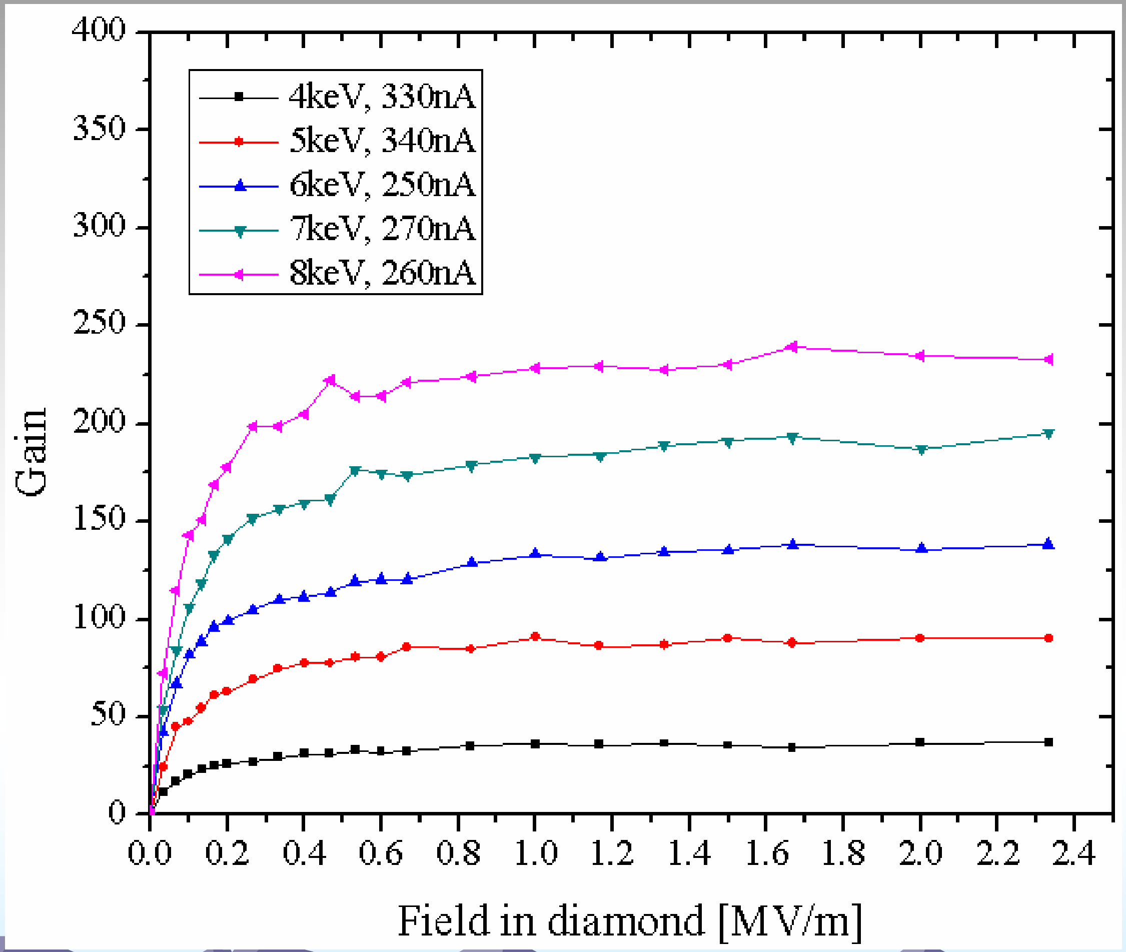
- **Phosphor screen image of the diamond amplified cathode emission is first time observed.**
- **At current experimental conditions we've measured:**
  - **Gain of 40**
  - **50pC/0.5mm$^2$/bunch of bunch charge.**
  - **Emission probability of 40% on hydrogenated surface**
- **Extremely robust.**

## Promising methods R&D in progress

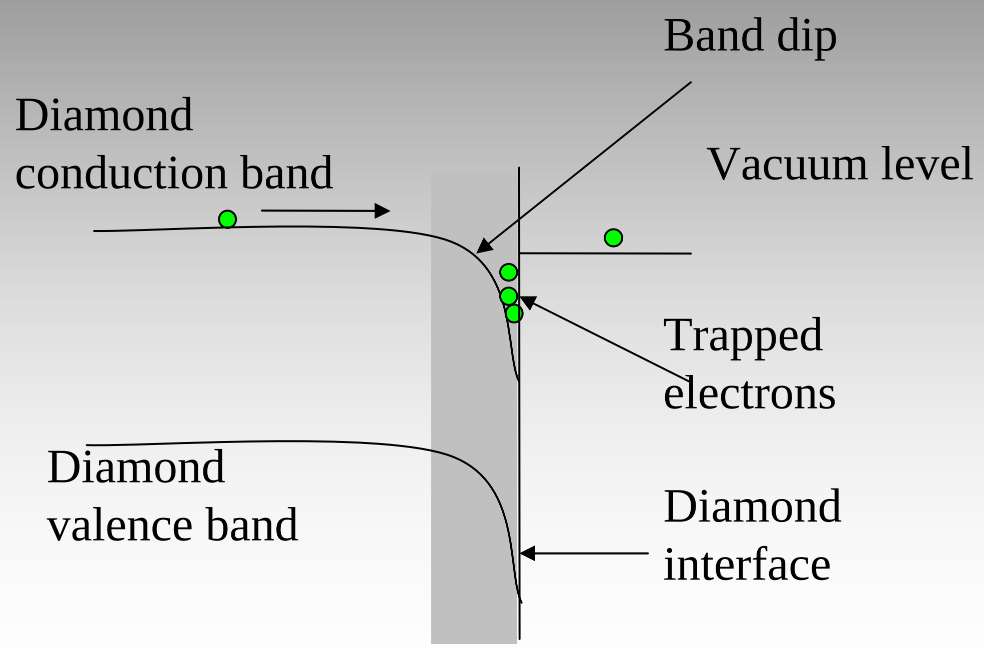
- **Emittance measurement (estimated to be ~0.1eV).**
- **Hydrogenation effects**
- **Other crystal orientations**
- **Room temperature RF gun test**
- **Other terminations**
- **SRF cavity test**
- **…**

Thank you!

# Transmission gain



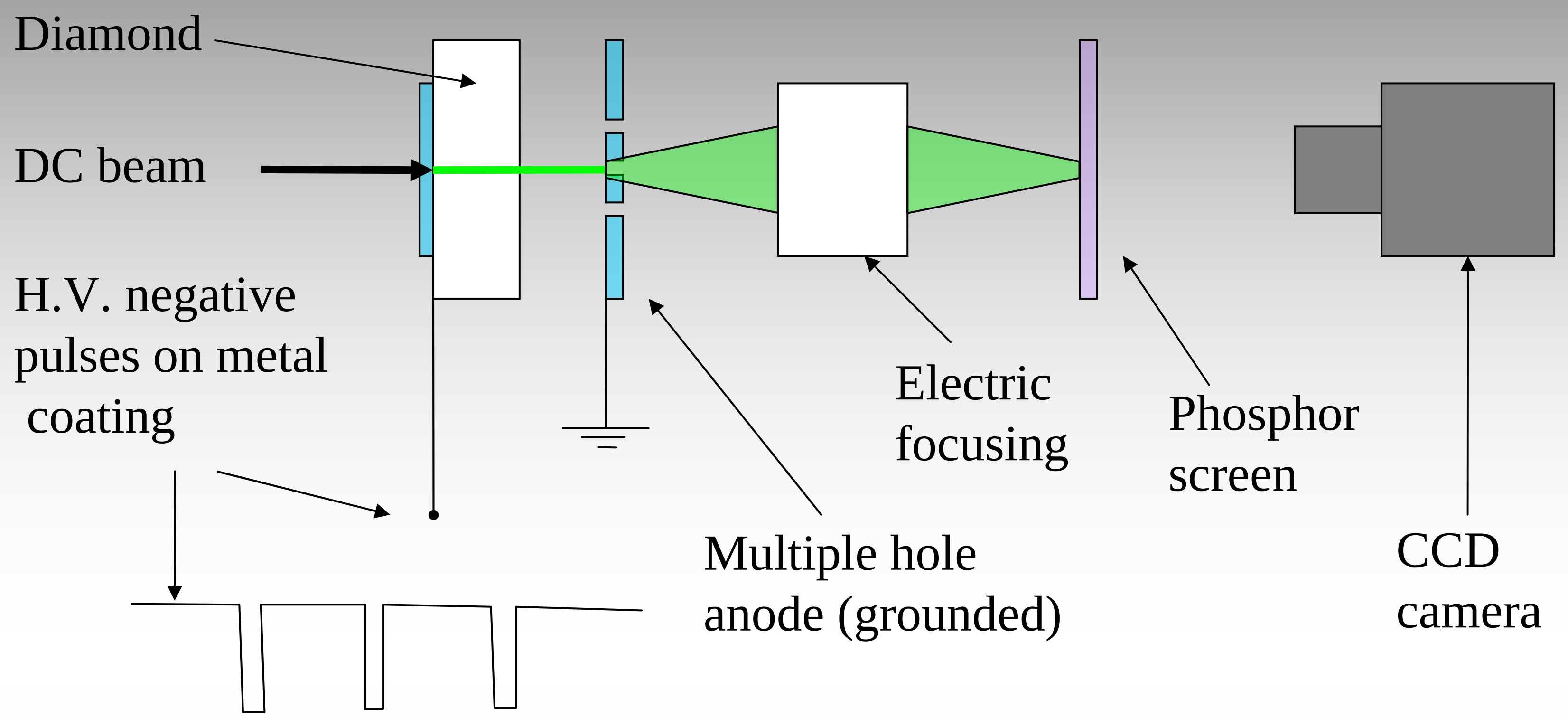
# Possible trapping mechanism



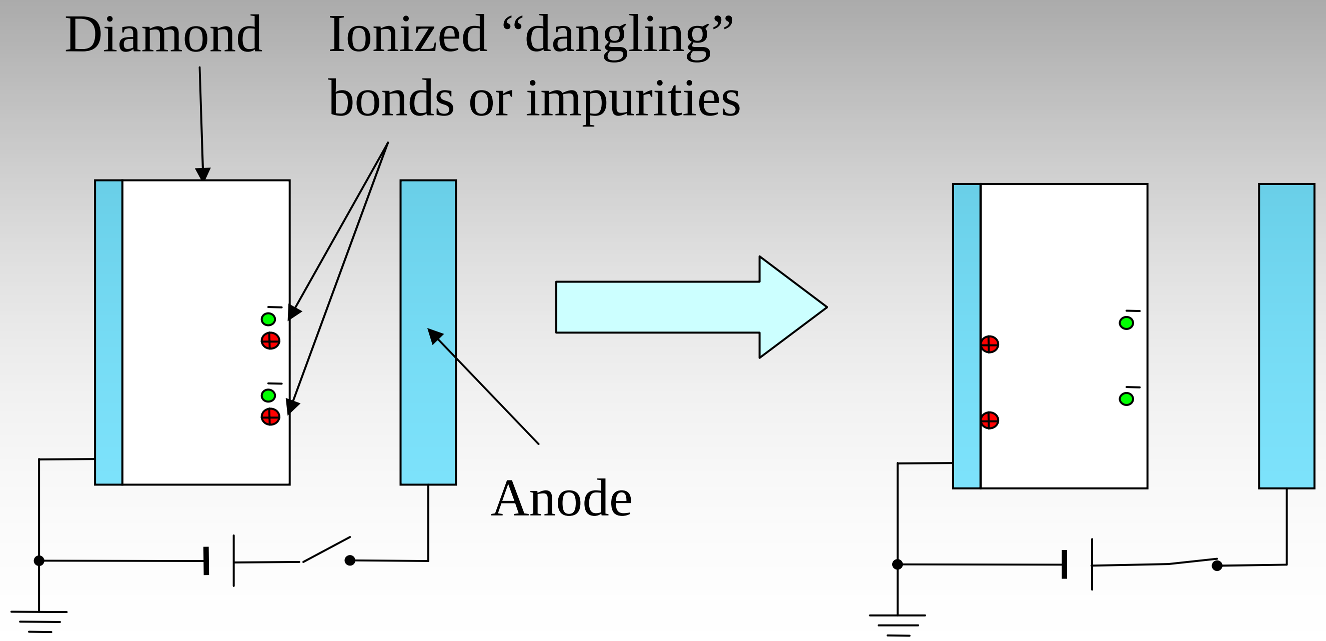

**Solutions:**

- **Improving hydrogenation**
- **Choose [110] or [111] orientation diamonds**
- **Li, Na or other alkali elements terminations.**

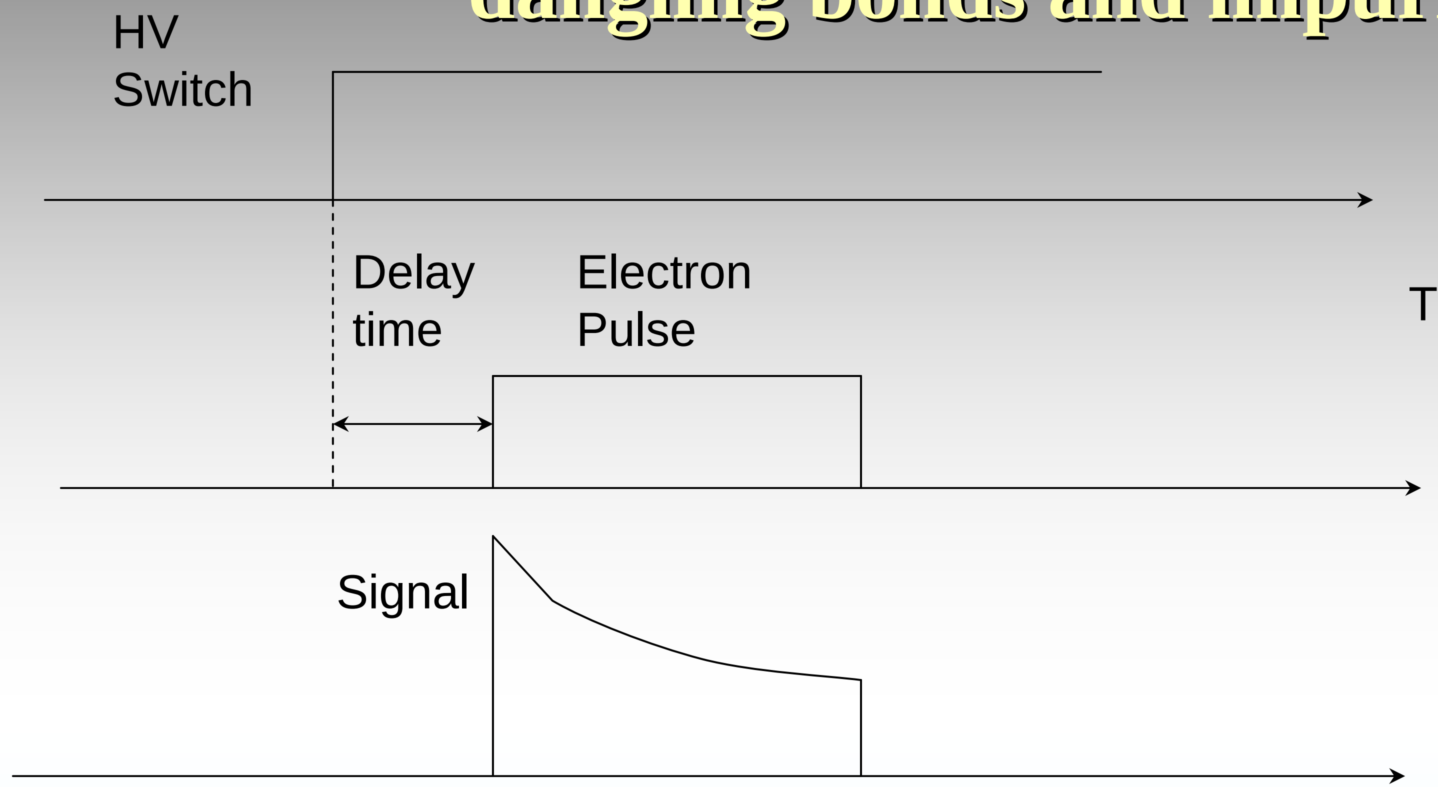
# Emission test diagram



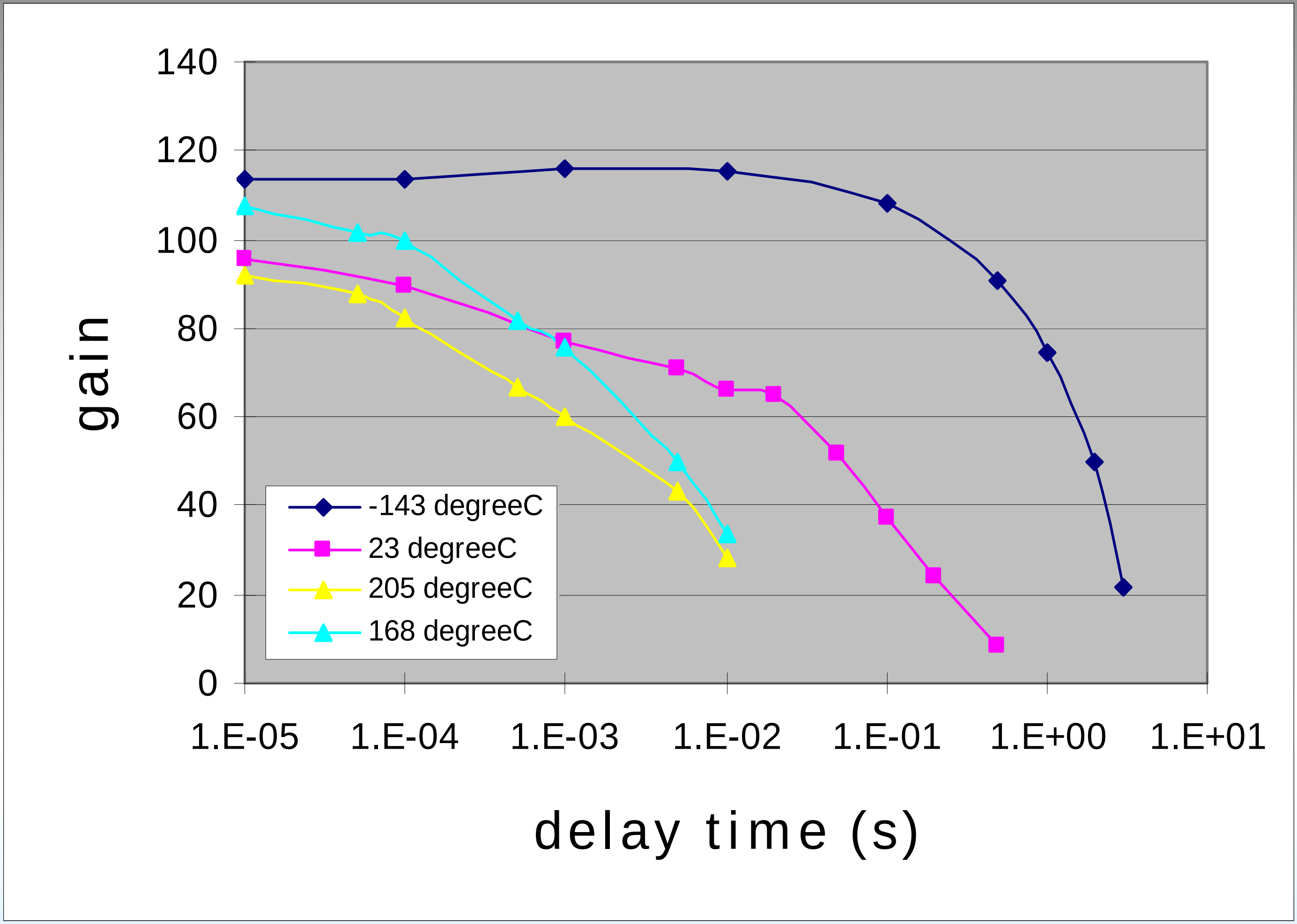
# Possible field shielding due to dangling bonds and impurities



# Test of field shielding due to dangling bonds and impurities

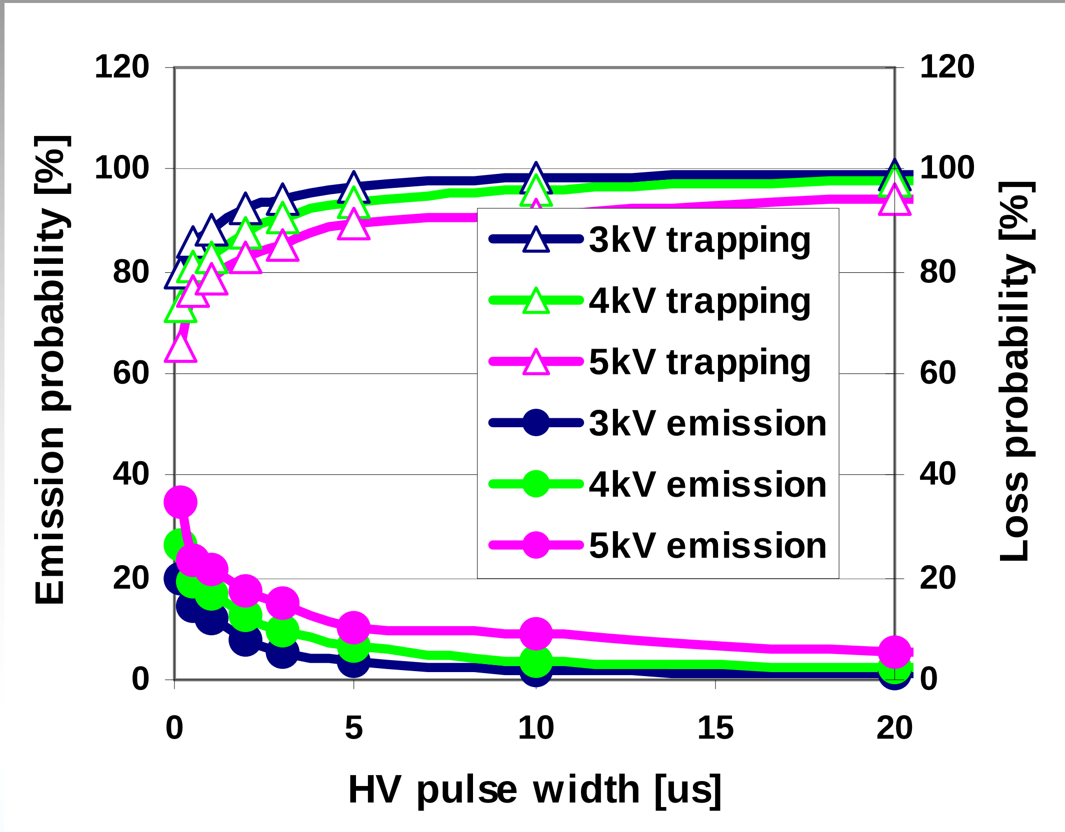


# High voltage is fixed at -500V

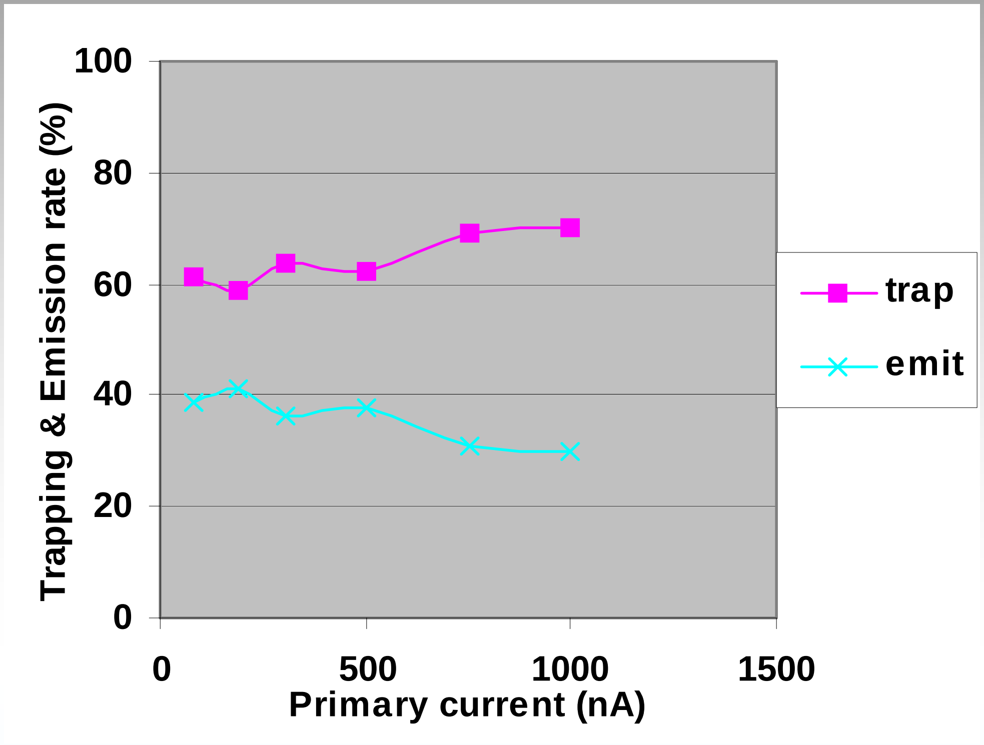


# The trapping probability near the H-surface?

- Control the emission pulse width and duty cycle accurately with the push-pull circuit
- Measure the integrated emission current. Calculate the emission gain.
- Compare to the data in the transmission mode to find the trapping probability.



# Trapping vs. primary current density



# Pulse response, 2 MV/m

- Pulse response to 1ns FWHM of x-rays (~10keV). Carrier transit time is consistent with expected velocity.