First beam from the diamond amplified cathode♪

Xiangyun Chang, Ilan Ben-Zvi, Andrew Burrill, Jorg Kewisch, David Pate, Triveni Rao,♪
John Smedley, Yi-Chun Wang, Qiong Wu♪

Outline

- Introduction
- Transmission mode measurement results
- Previous emission measurement
- Trapping mechanics
- Emission measurement with new circuits
- Emission images
- Future plan and conclusion

The Diamond Amplified Photo-cathode (DAP) concept

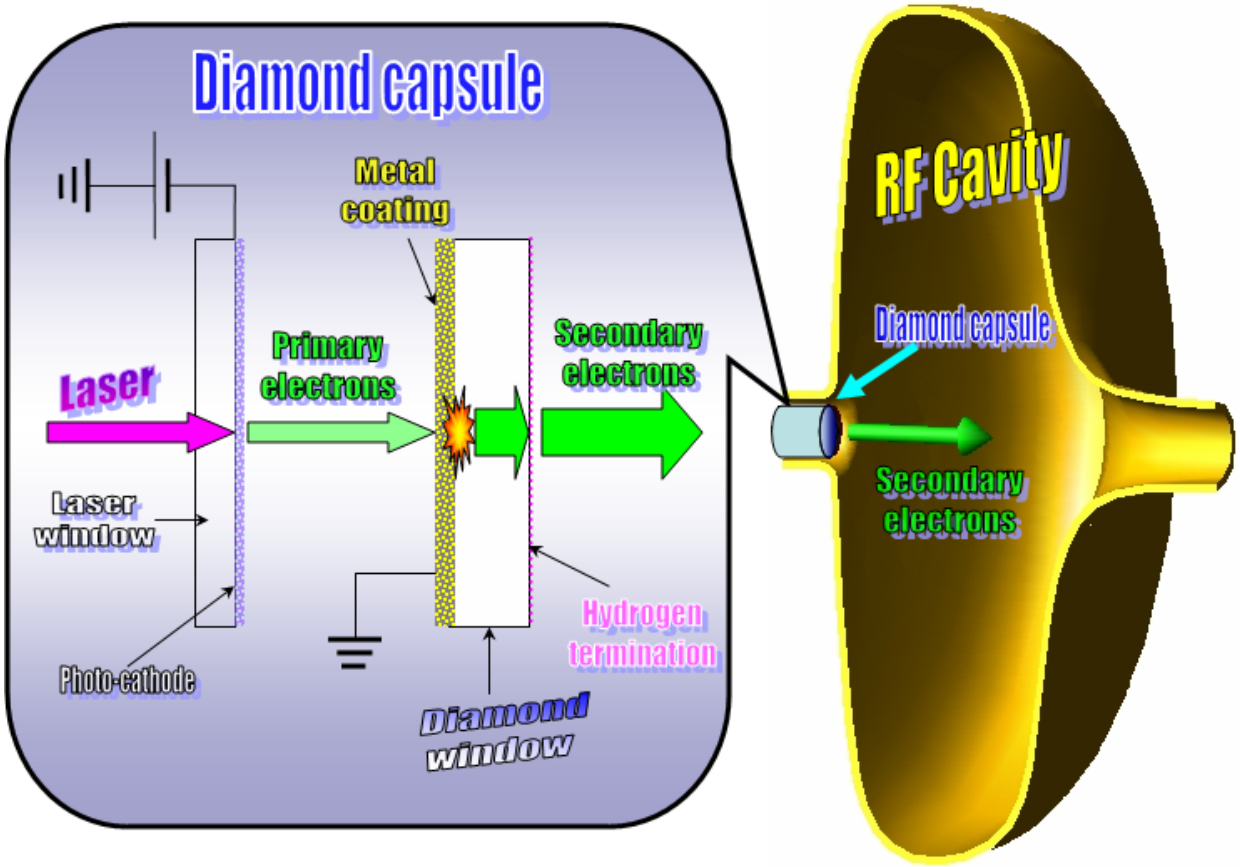
I. Primary electrons are generated by the conventional photo-cathode and are accelerated to about 10keV energy.♪

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

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

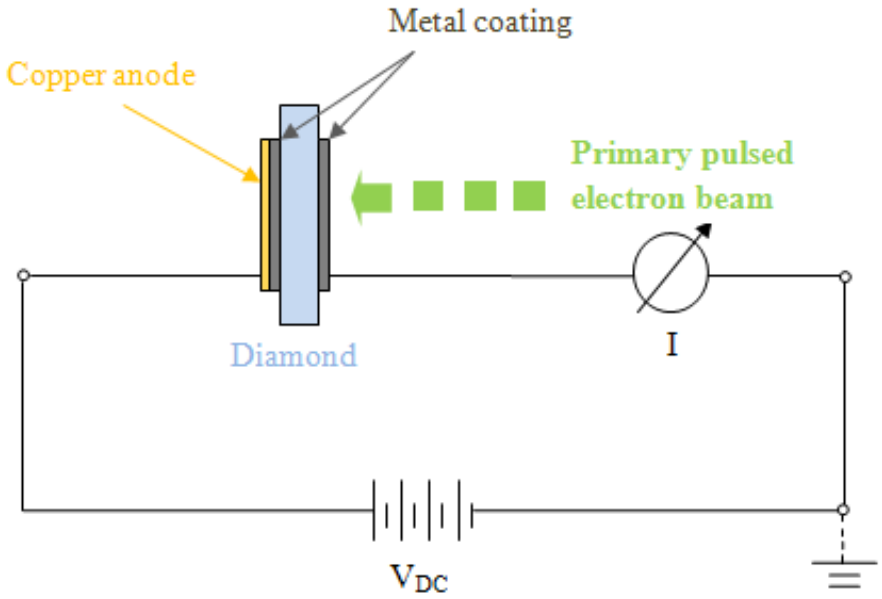
IV. Secondary electrons drift through diamond.♪

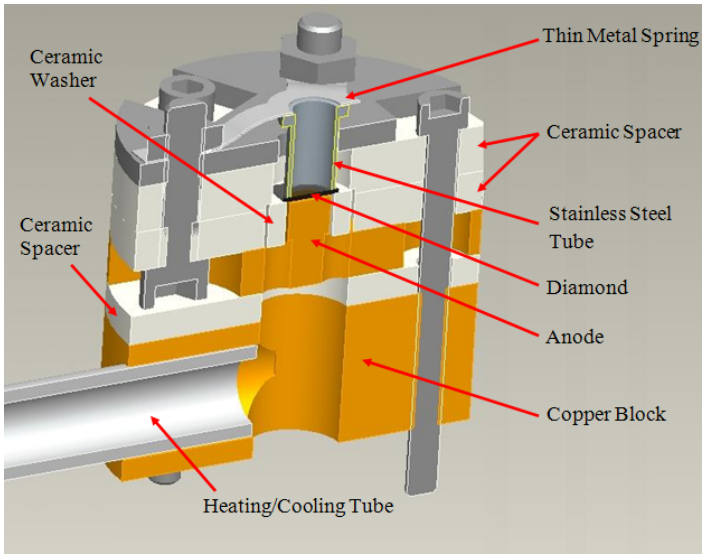
V. Secondary electrons are emitted from the hydrogenated Negative Electron Affinity (NEA) surface. ♪



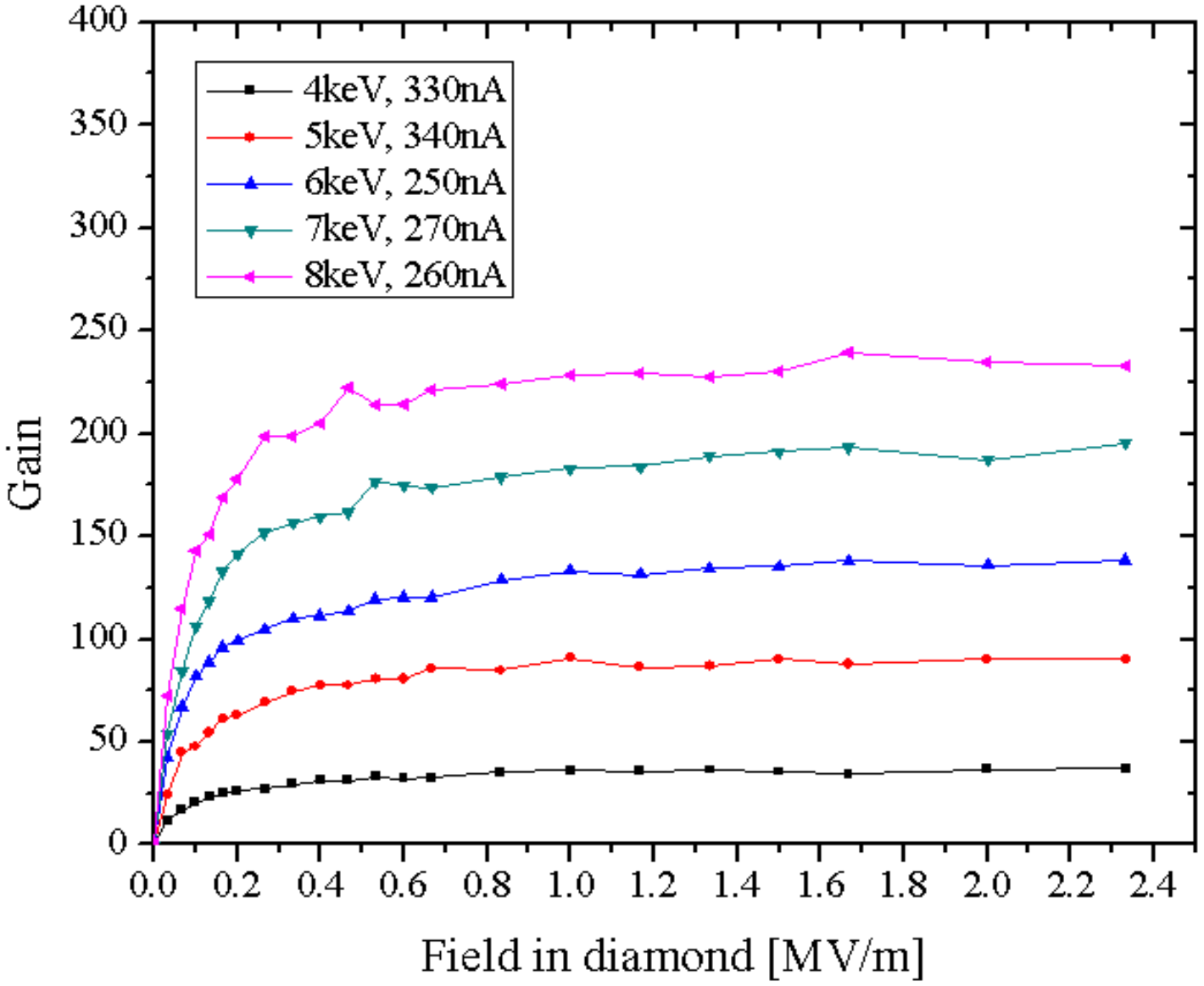
Schematic diagram of the DAP

Transmission Mode Measurement





Transmission mode measurements are designed to study the secondary electron generation and transportation in the diamond.

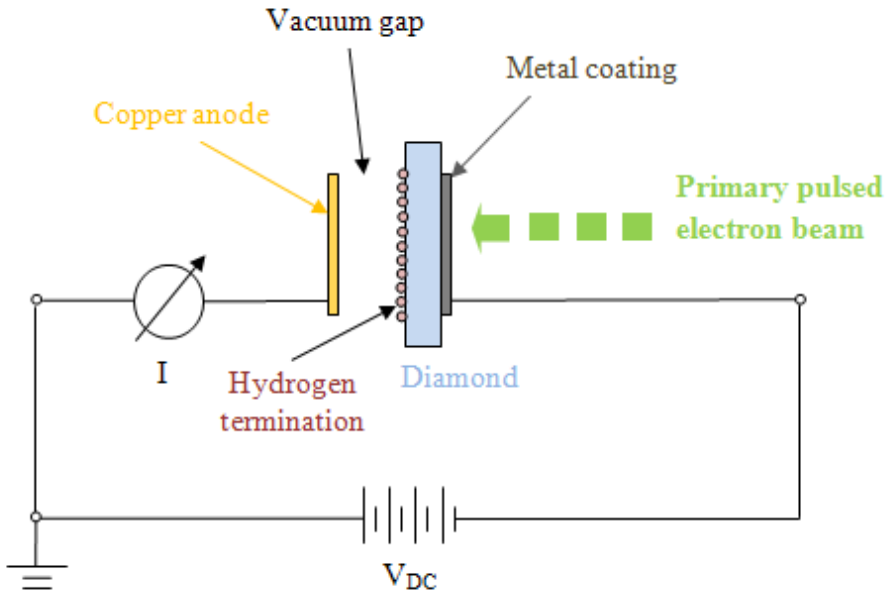


Single crystal diamond window gain with primary electron energy ranges from 4keV to 8keV.

Conclusions from the transmission mode study♪

- ✓ The electron-hole cloud generation in the diamond♪
- ✓ The e-h cloud separation by the external field♪
- ✓ The electron and hole transmission through single crystal pure diamonds♪
- ✓ Current density♪

DC Voltage Emission Mode Measurement♪

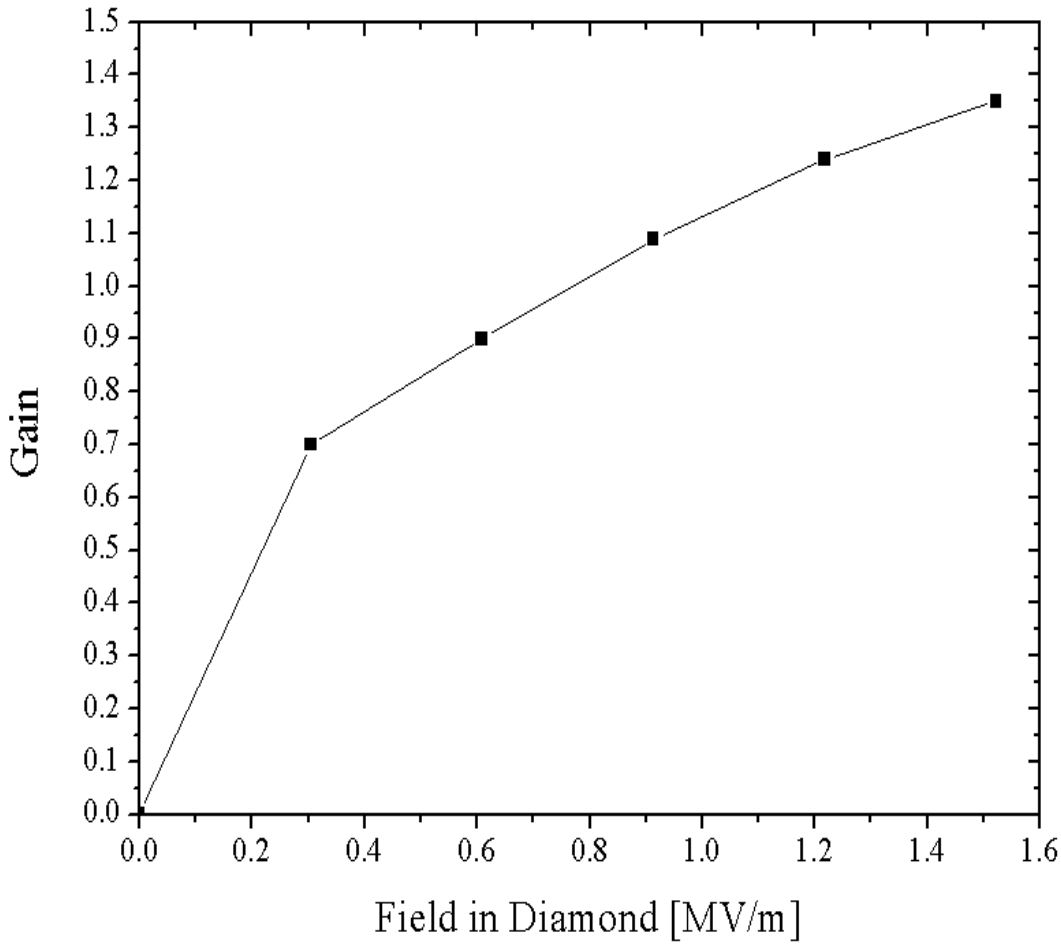


A vacuum gap in between the copper anode and the diamond surface, and the termination of this surface is changed to hydrogen instead of metal coating.

- **DC voltage**
- **Pulsed beam**

DC beam or long pulse emission measurements♪

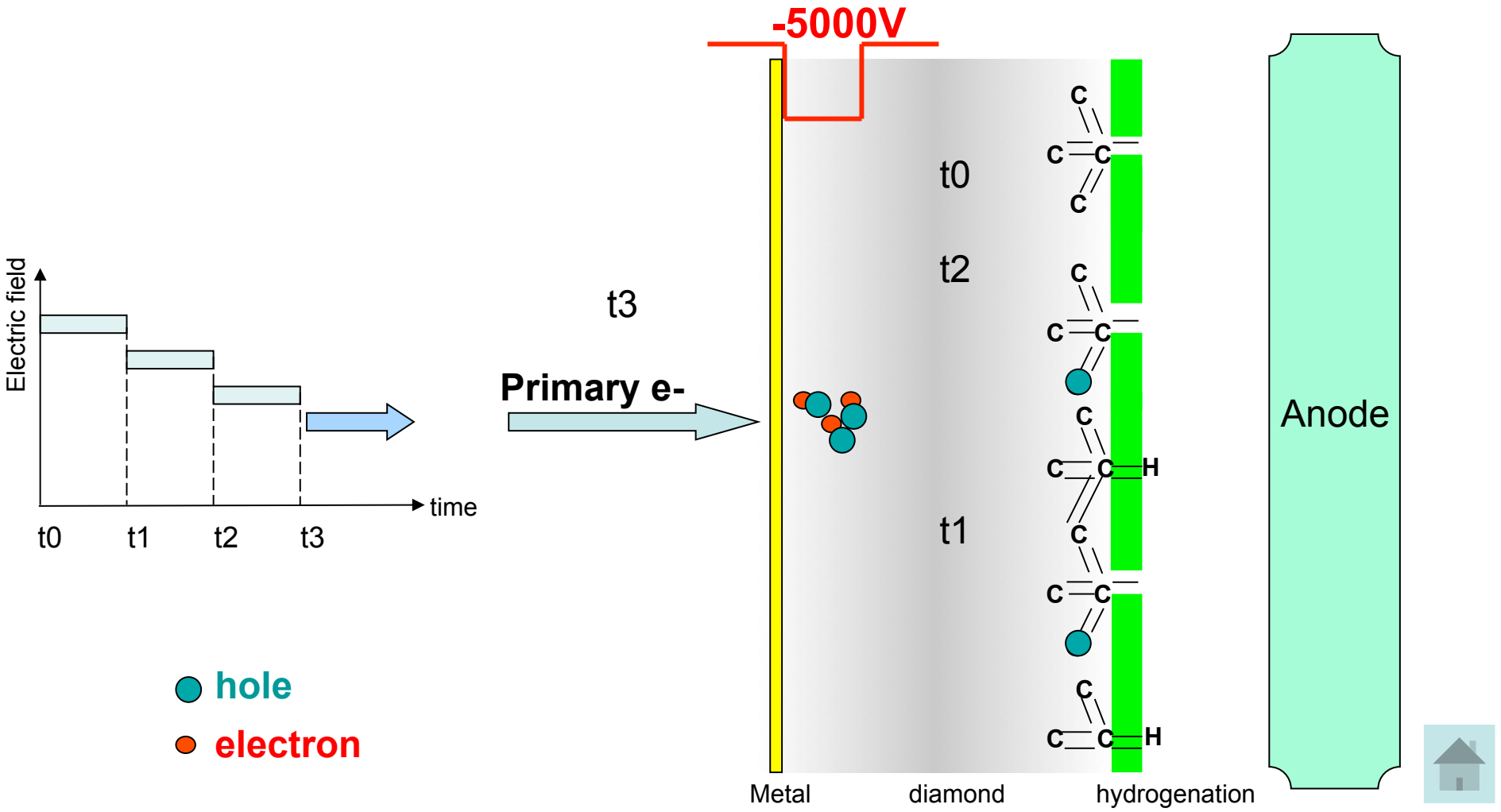
Trapping of the electrons?♪



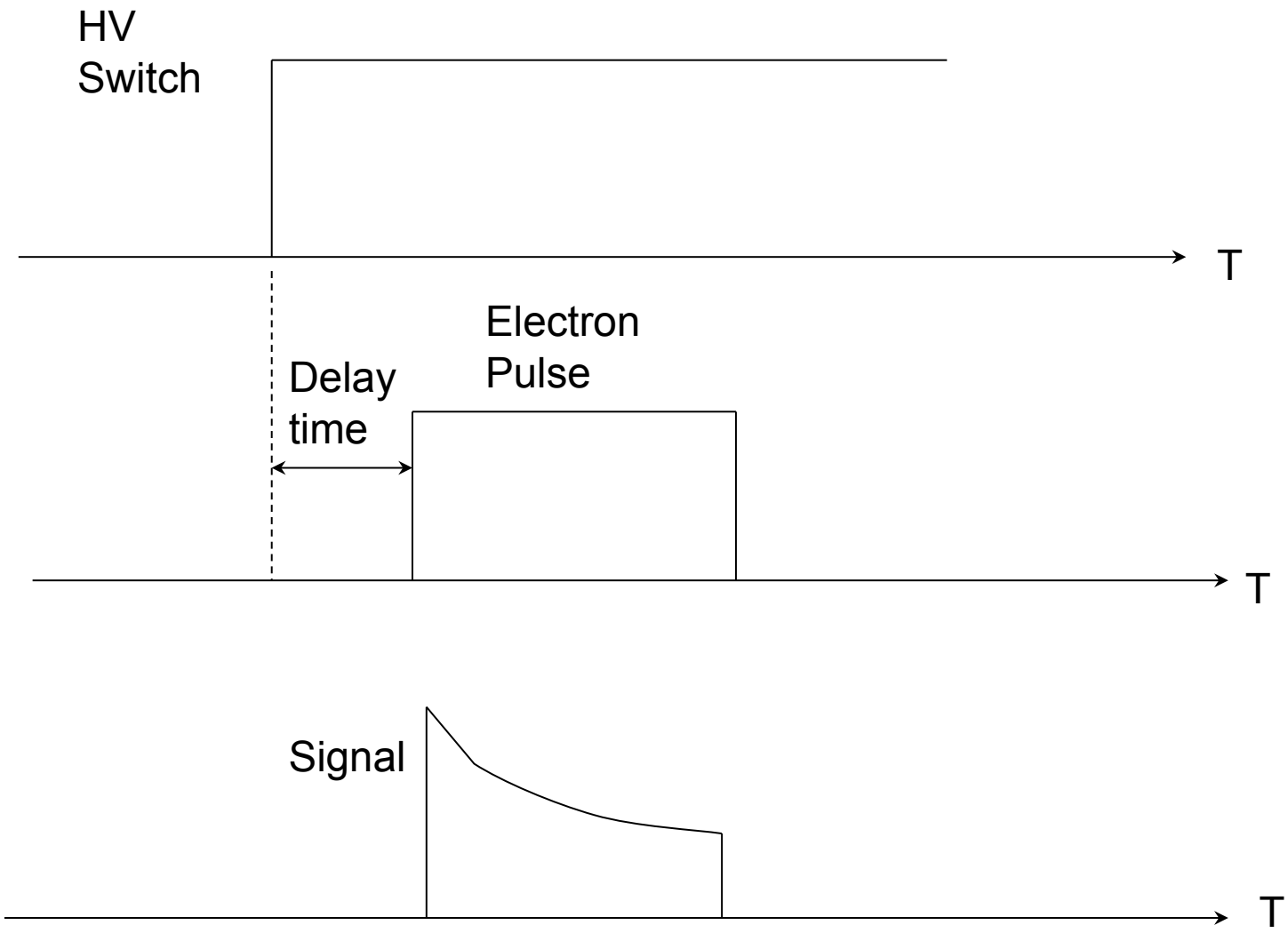
Possible trapping mechanics♪

- The hydrogenation is not good enough
  - Improve the hydrogenation system
  - Use [110] orientation diamond
  - …
- Bulk trapping due to impurity and lattice dislocations
- And…

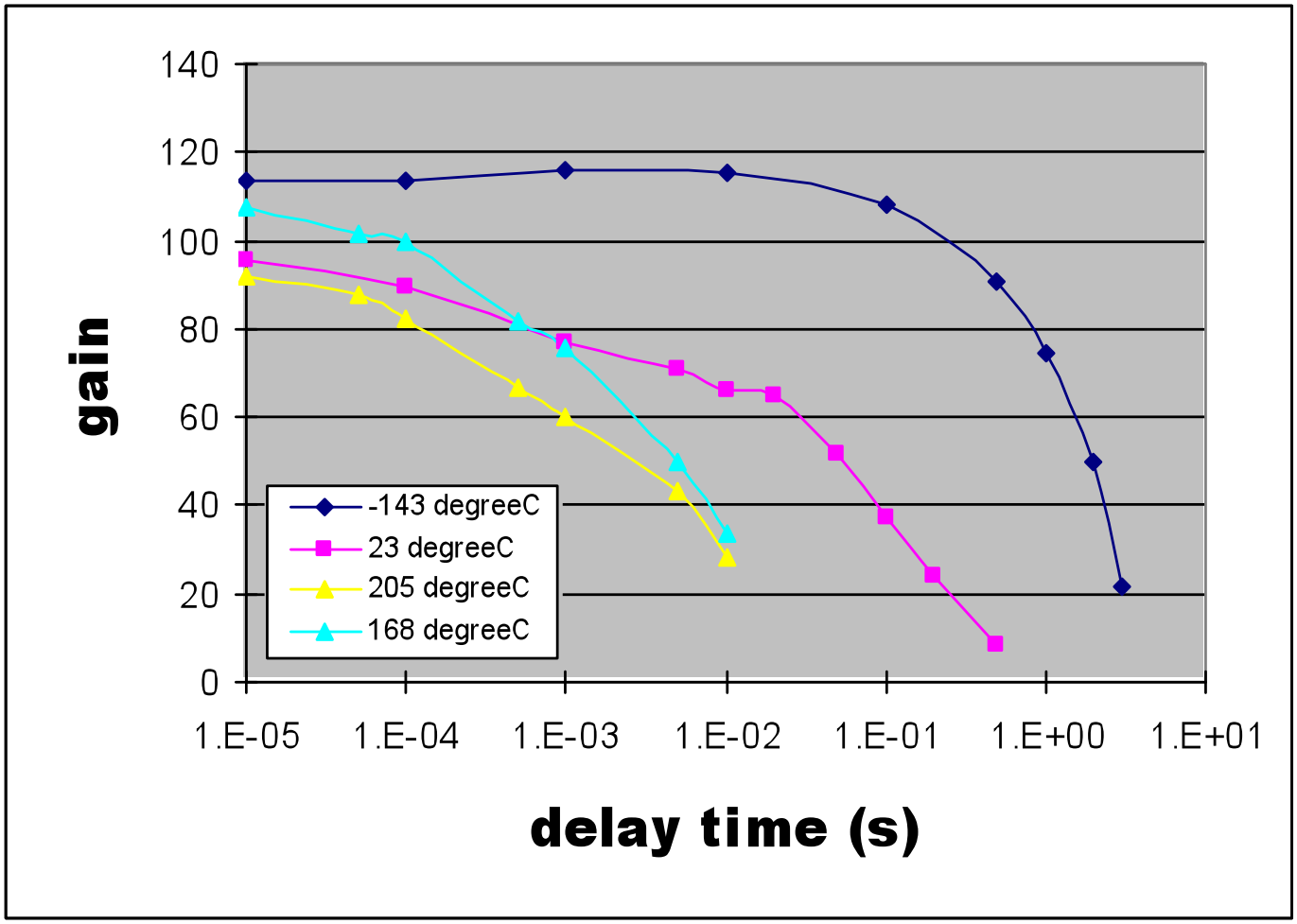
Possible mechanism of electron trapping and field shielding in diamond



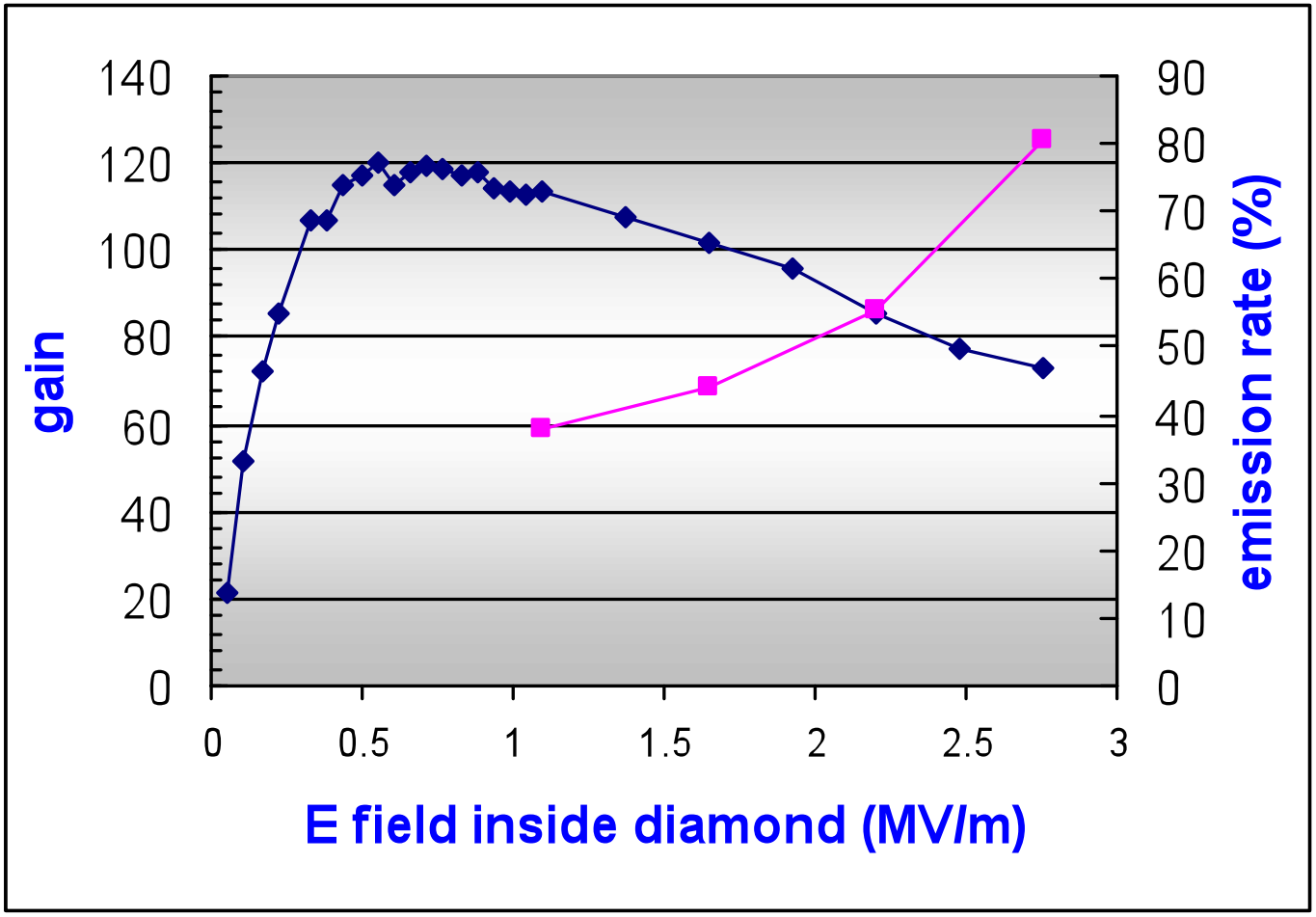
Testing circuit♪



High voltage is fixed at -500V

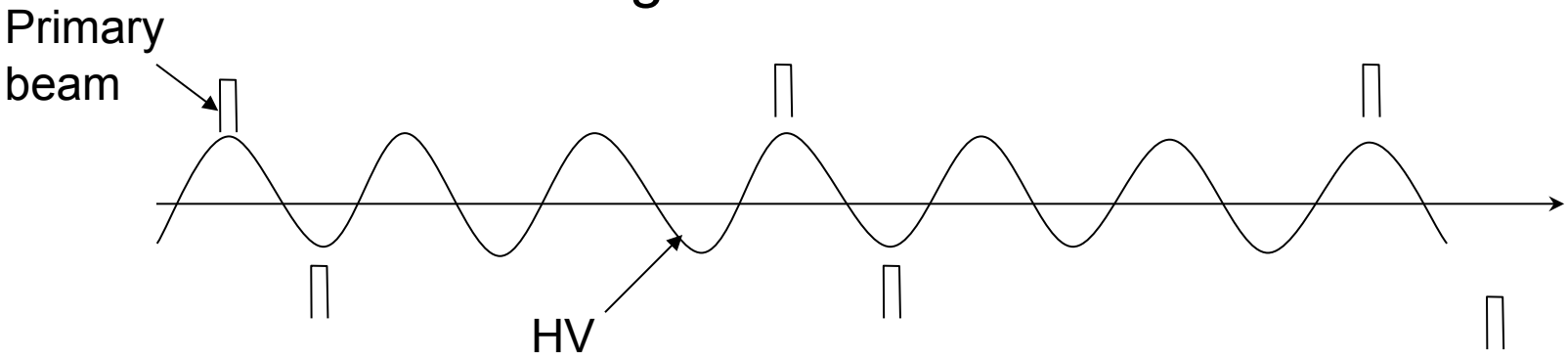


Estimation of the emission rate at beginning of the pulse

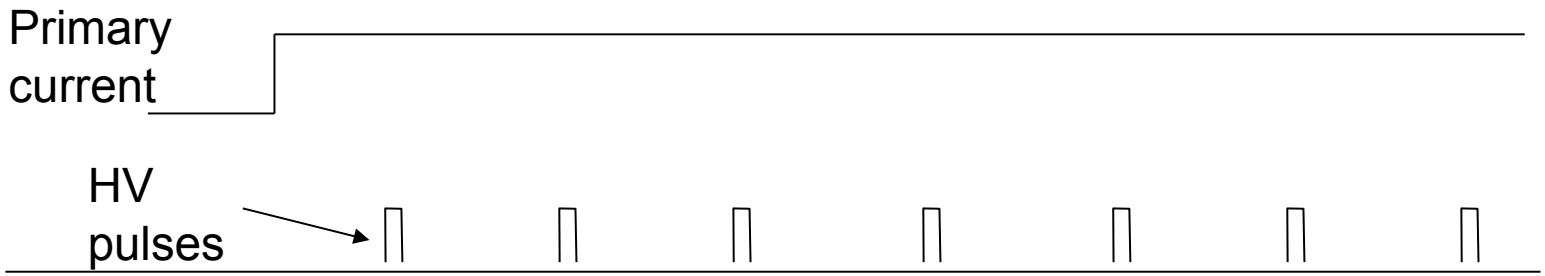


See directly the emission of the beam

- Use alternating field and high frequency beam to increase the average current of the emitted beam.

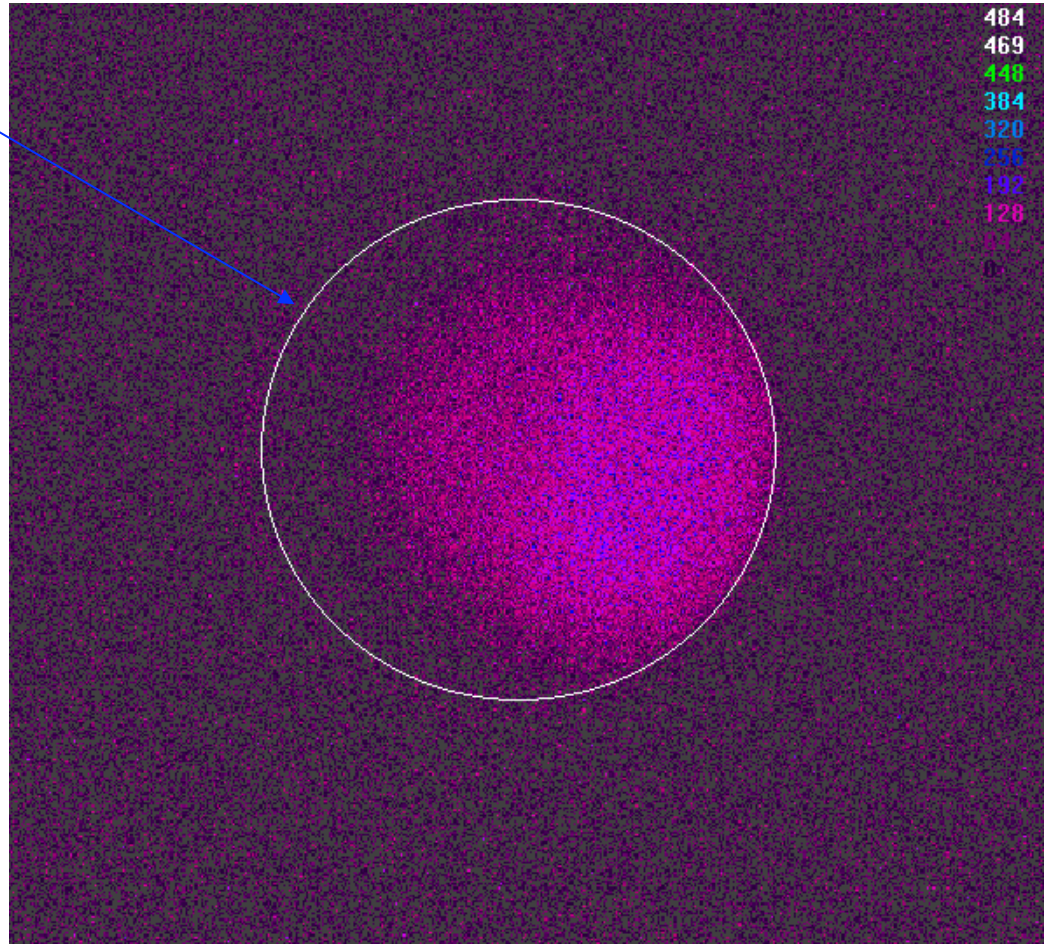


- Use DC electron beam but pulsed HV on electrodes



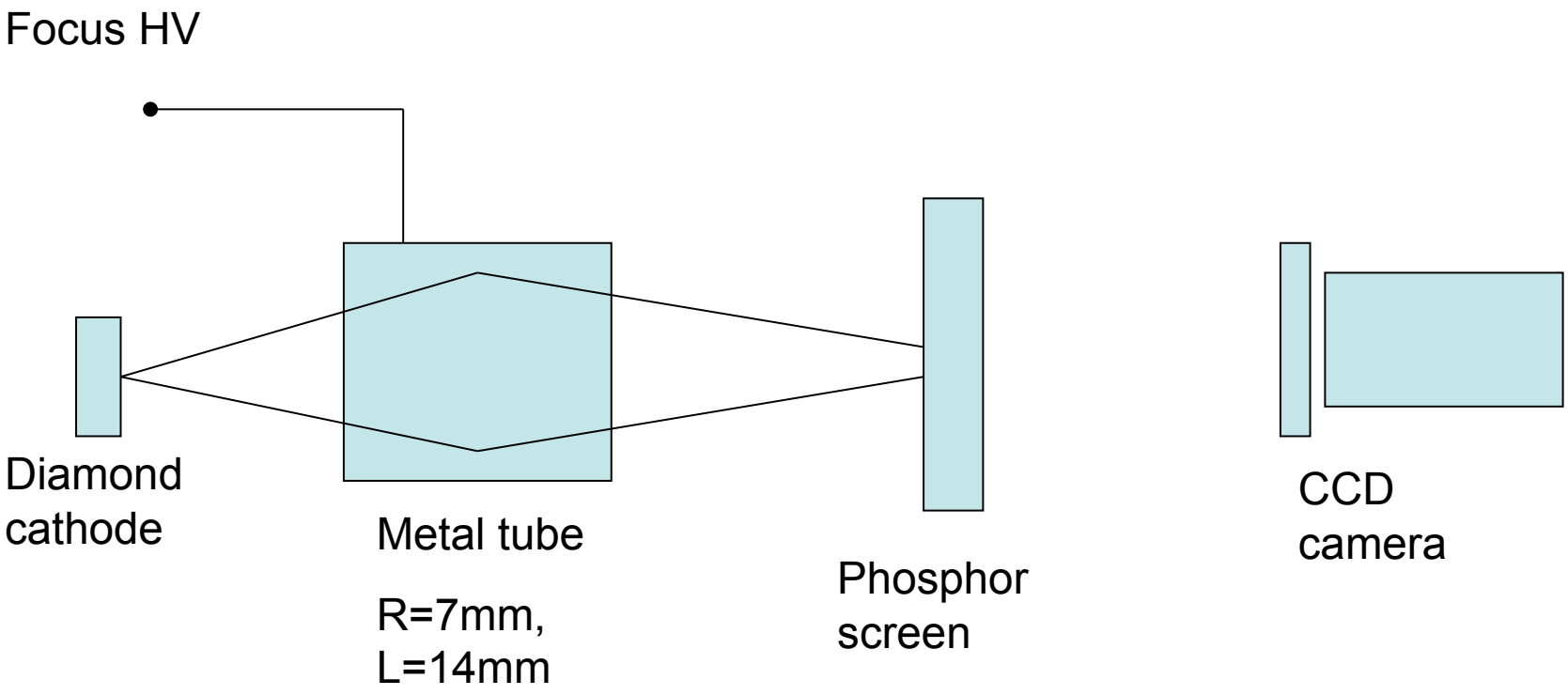
First observed beam from DAP

Phosphor screen size ~Φ22mm

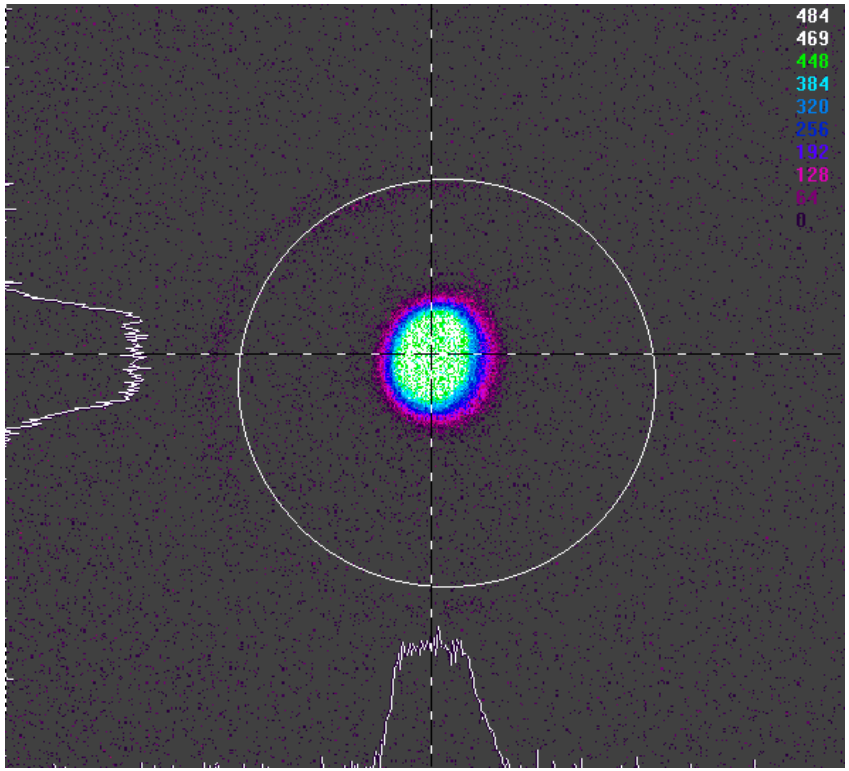


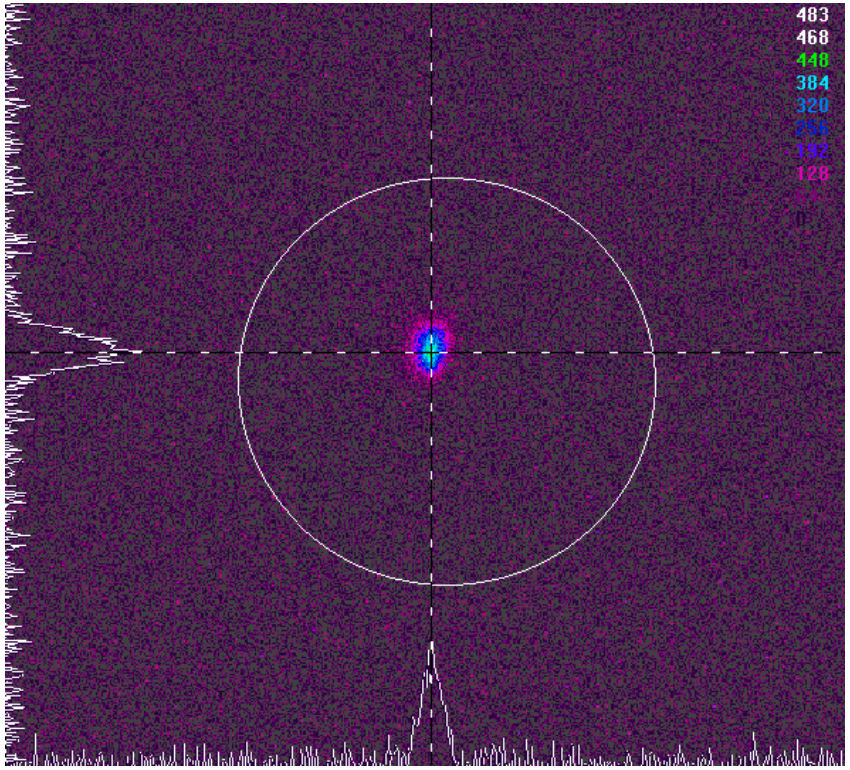
- Primary current: ~300nA.
- Spot: 0.5mm
- HV: 3kV
- Repetition frequency: 1kHz
- Duty cycle: 10^{-3}

Electric focusing



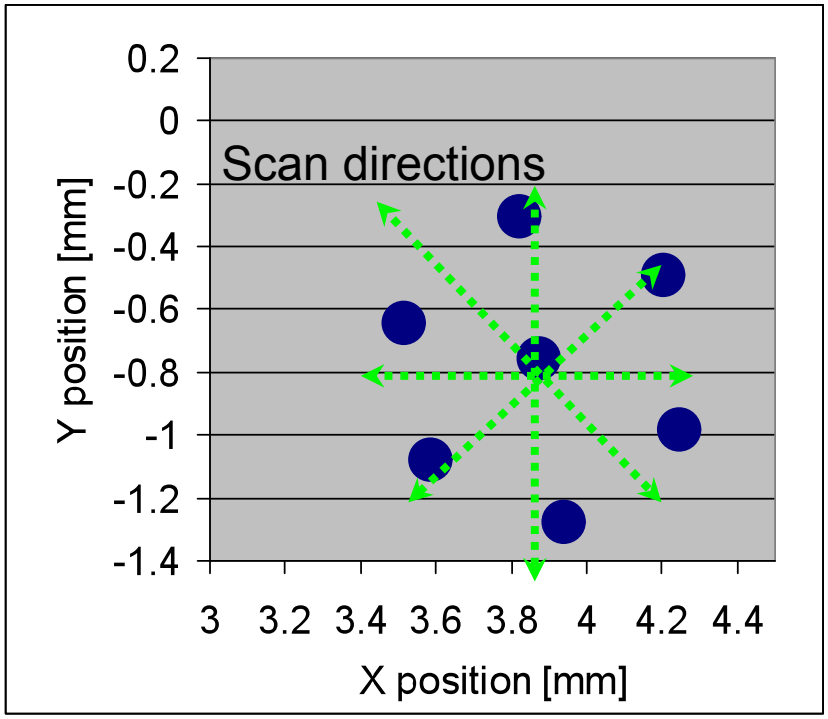
After focusing



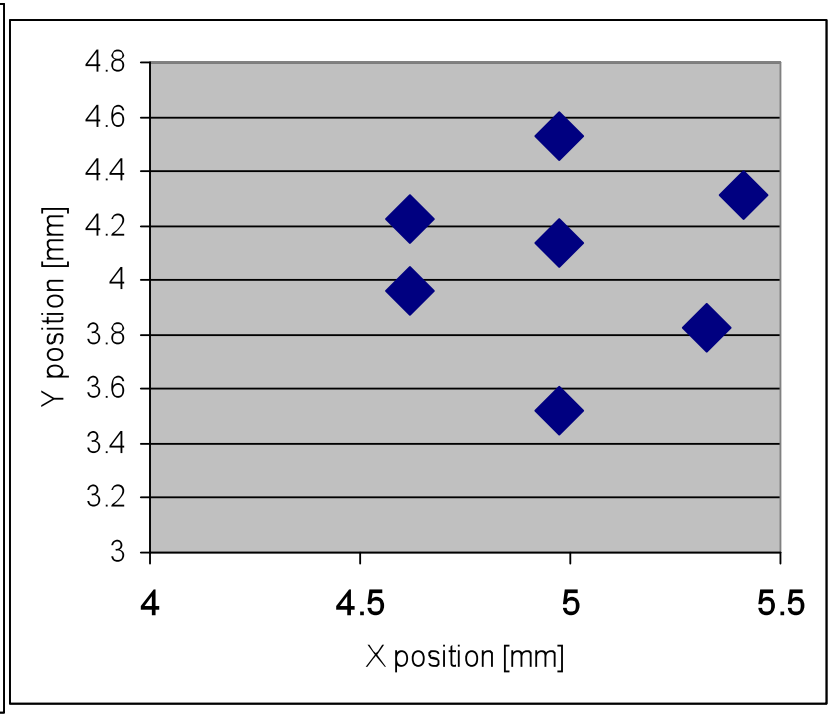


- The diamond was exposed to air during the installing of the focus tube
- The smallest size of the spot on screen is ~Φ1.2mm

Hole pattern on anode and the primary electron beam scan directions

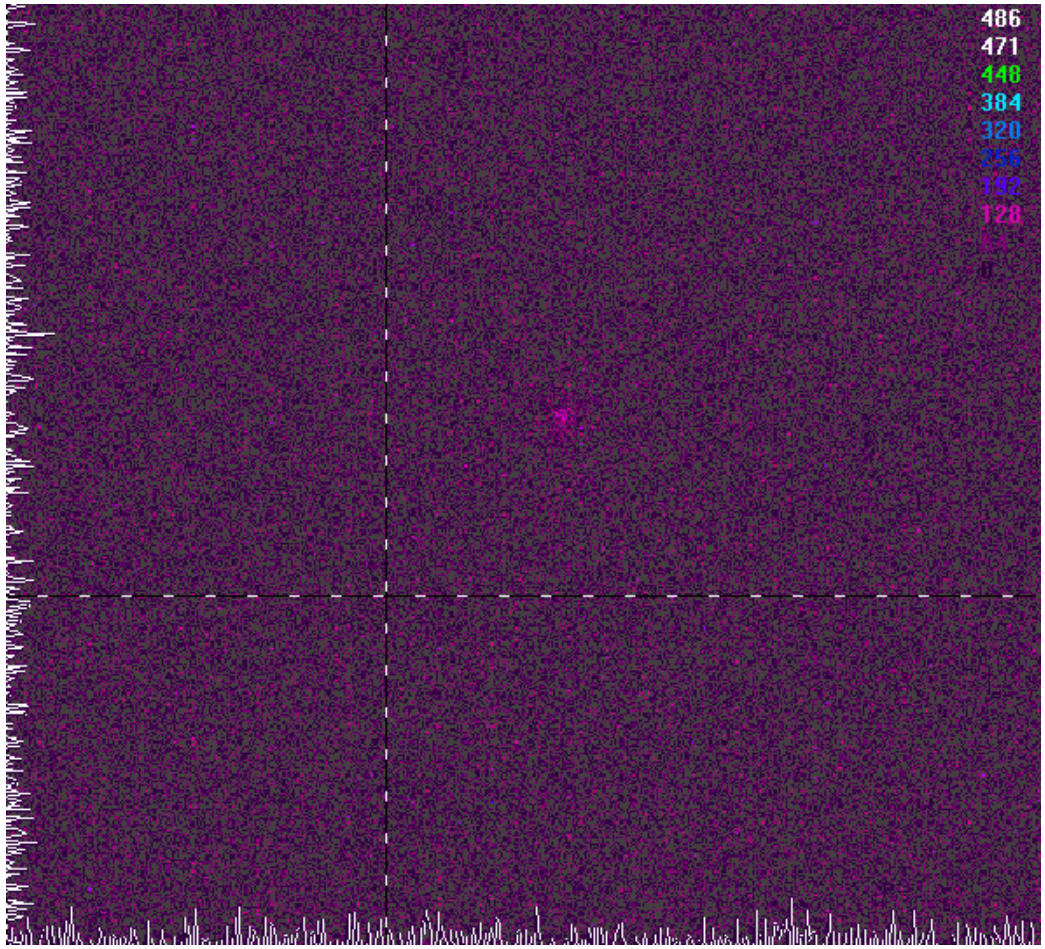


Hole pattern determined by the gun deflection settings

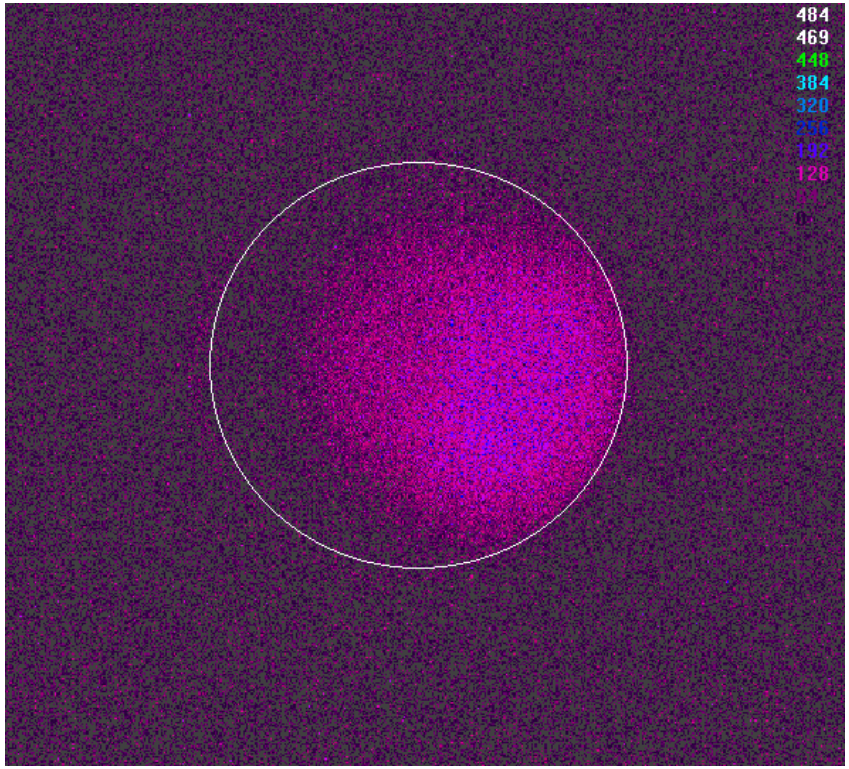


Hole pattern measured on the phosphor screen

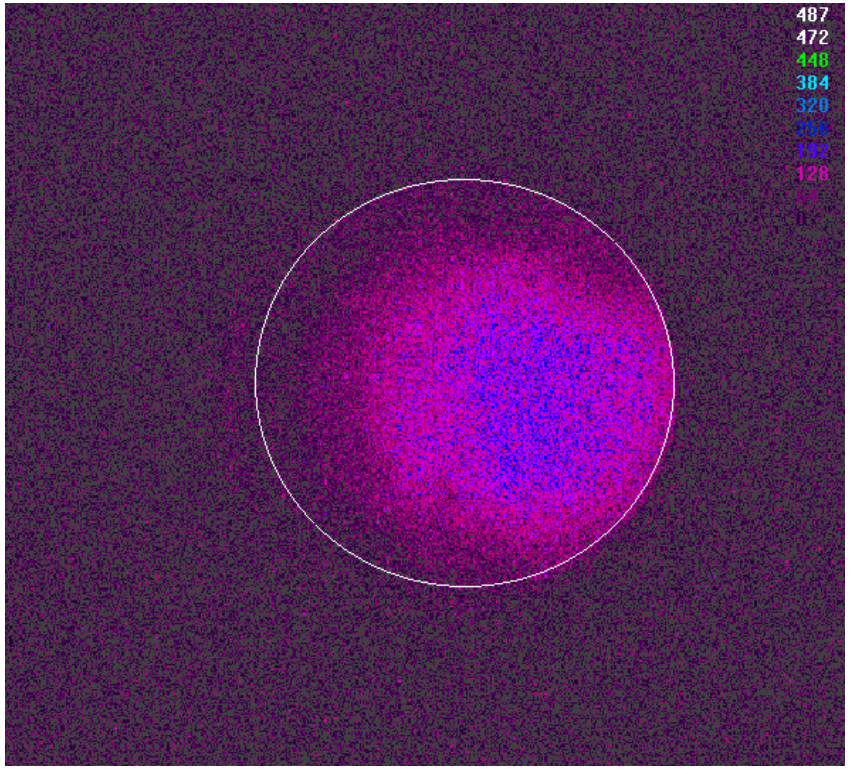
The horizontal scan images



Temperature effect



Room temperature



Liquid nitrogen temperature

The emission at low temperature is qualitatively much better than that at room temperature.♪

Recent Plan

- Improve the circuit (HV switch, noise reduction)
- Temperature dependence measurement
- Current density variation measurement
- Emission current calibration (use a collector behind the anode)
- Lifetime measurement
- Hydrogenation effects

Future Plan

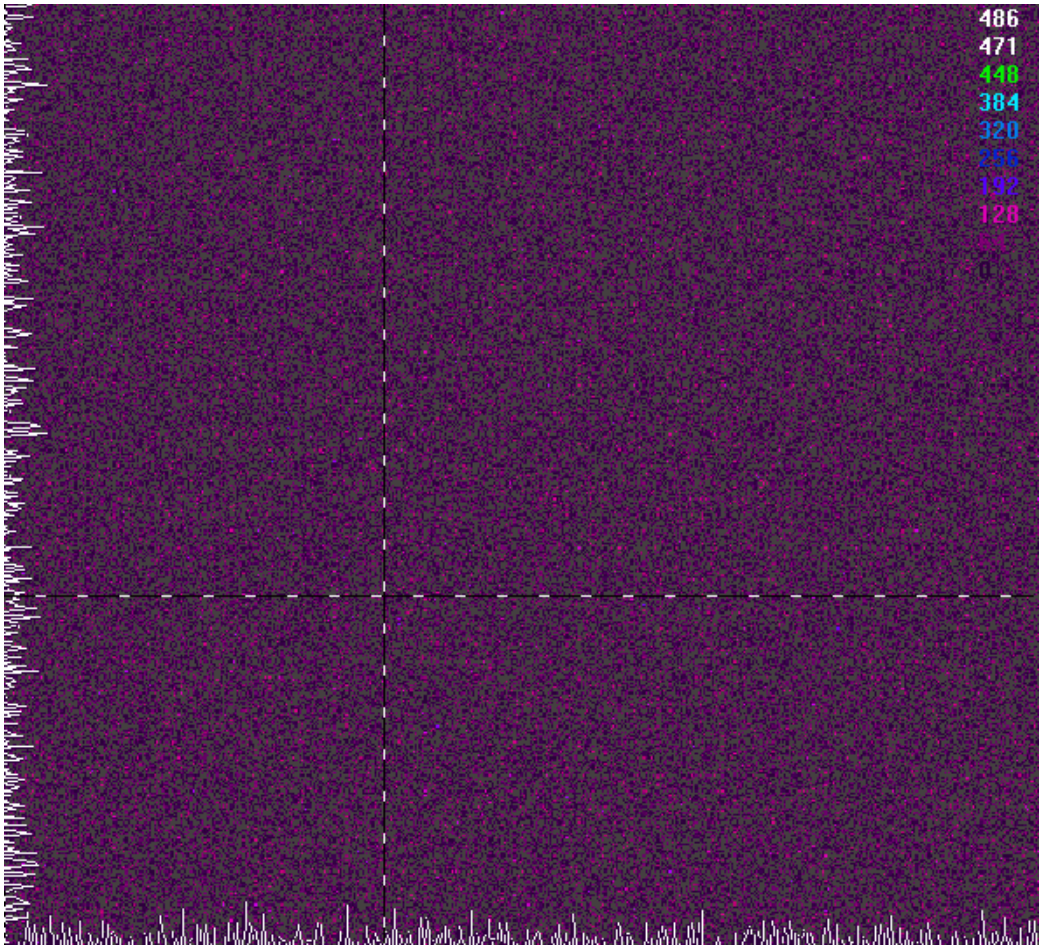
- Energy spread measurement
- Emittance measurement
- Room temperature RF gun test
- SRF cavity test
- …

Conclusion

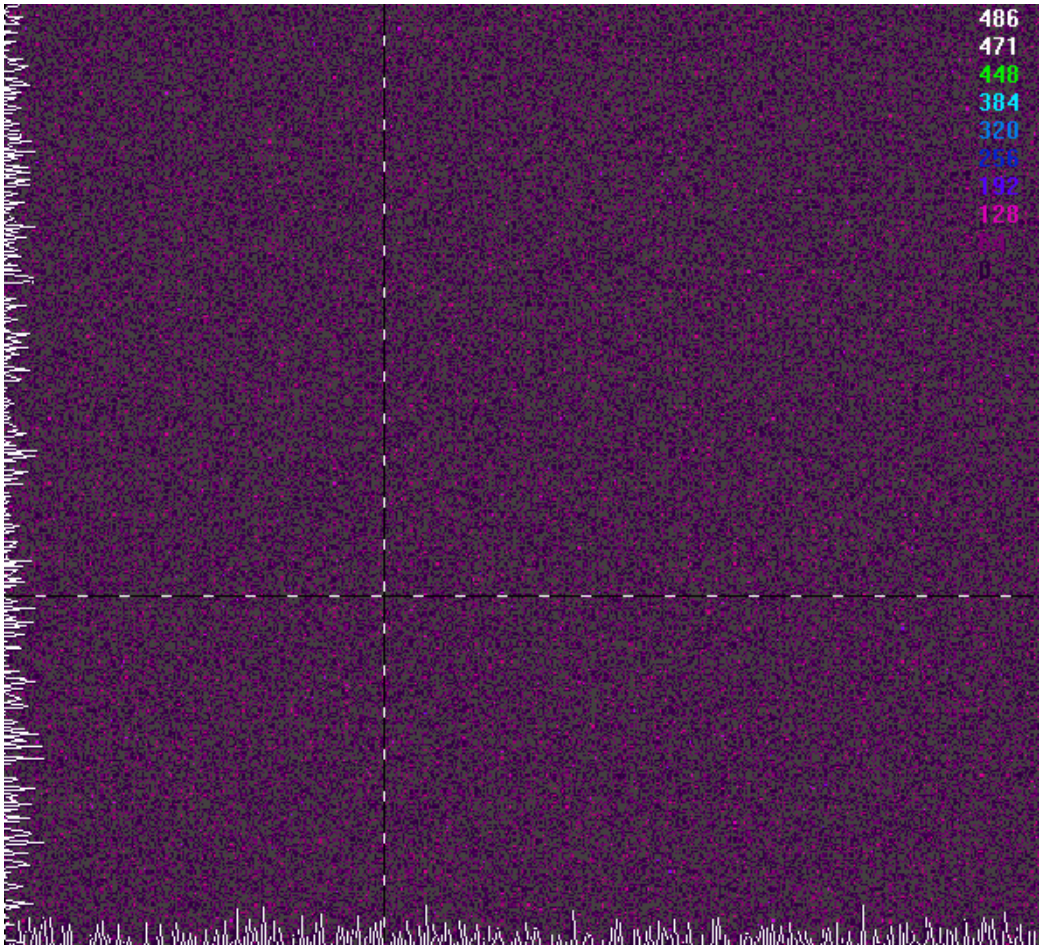
- We’ve seen the electron emission from the diamond amplified photo-cathode the first time on a phosphor screen.
- More measurements on the DAP become realistic now.

Supplementary

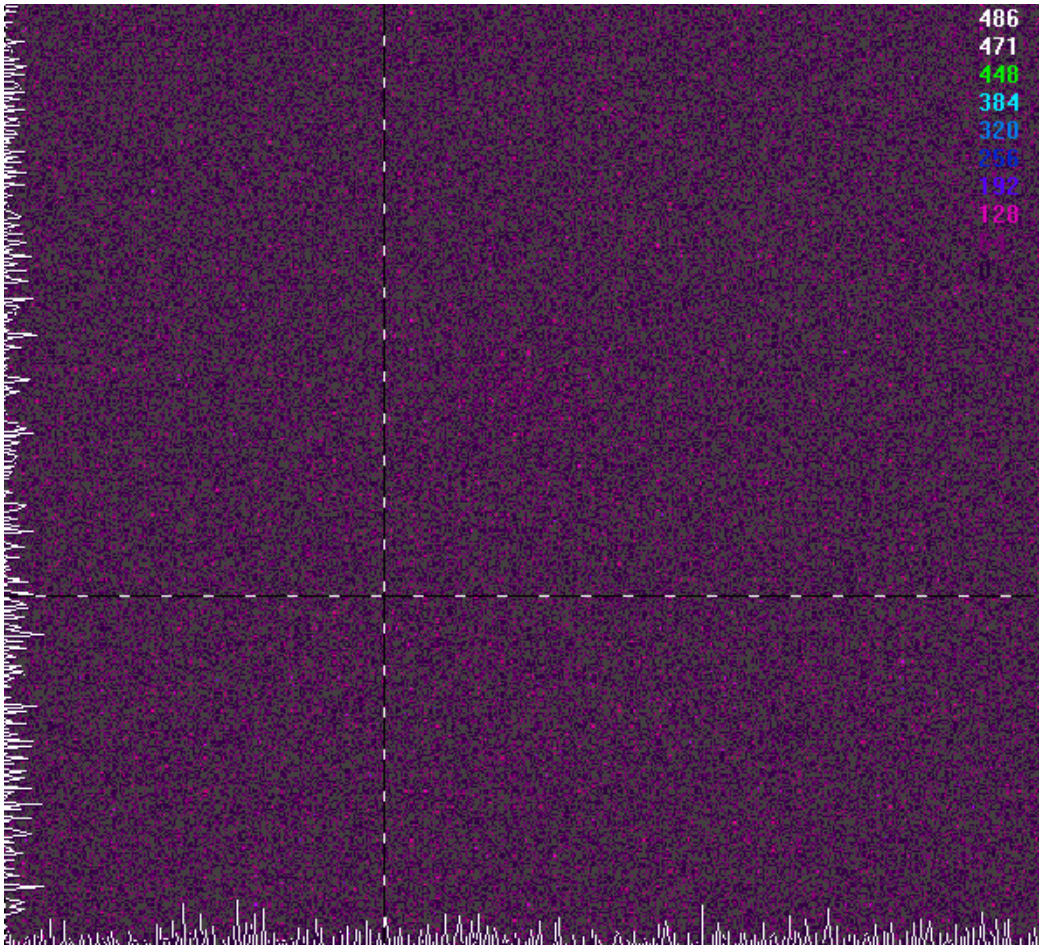
The vertical scan images



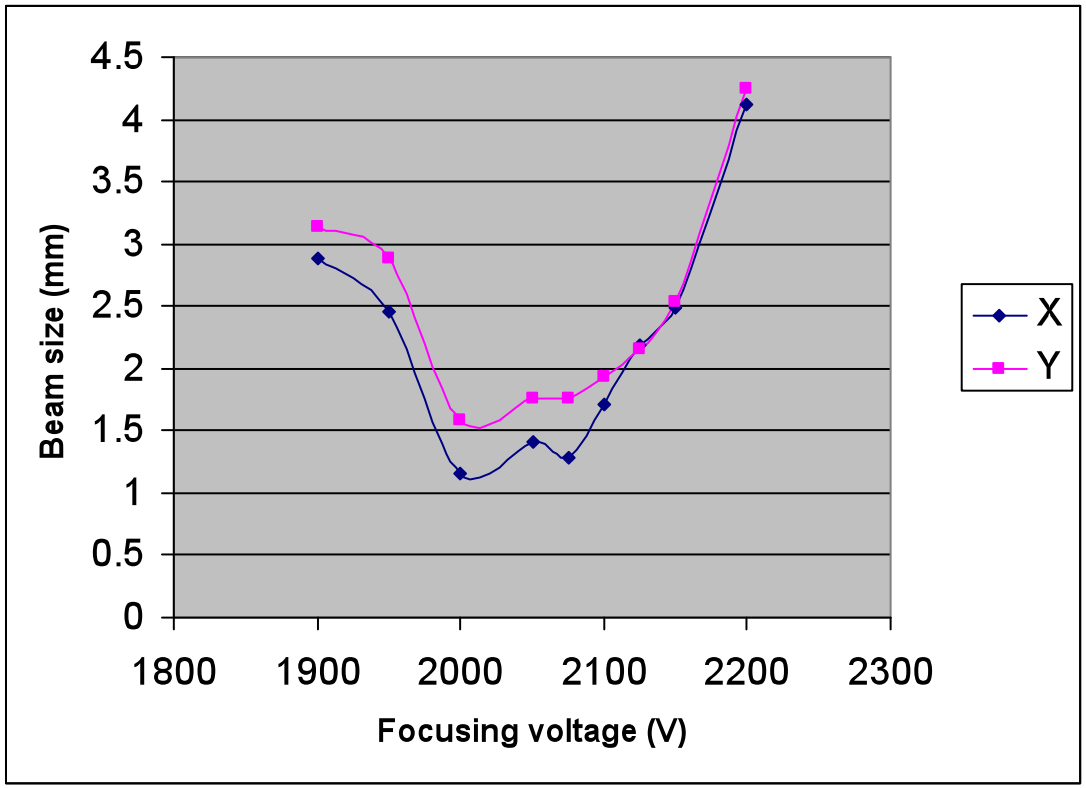
The diagonal #1 scan images

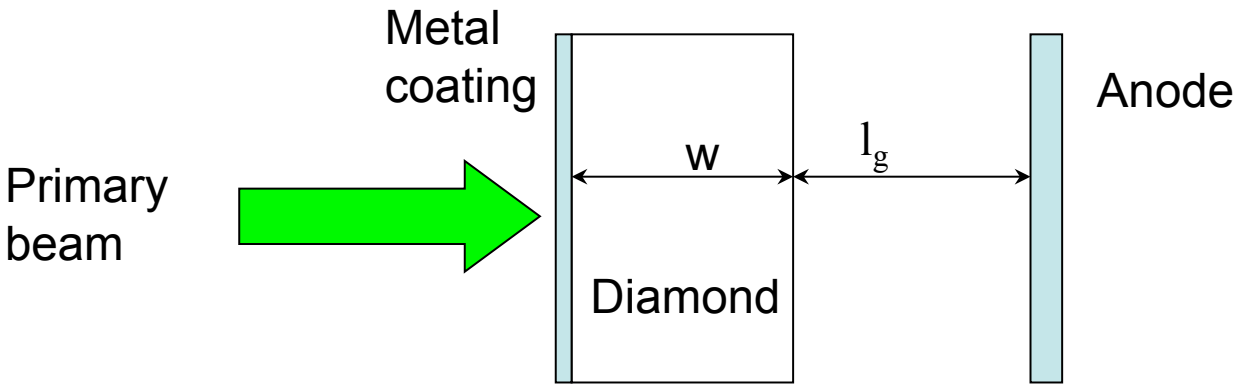


The diagonal #2 scan images



Focusing vs. spot size





Assume 2nd electron emission rate $x \equiv \frac{N_{emitted}}{N_{total}}$

(1) In case of full emission (x=100%), measured emission gain, G_m equals to transmission gain, G_t (measured from previous transmission experimental result)

(2) In case of all electrons are trapped (x=0%), measured gain,

$$G_m = G_t \frac{w}{w + 5.6 \times l_g} \approx G_t / 6$$ (capacitive coupling effect)

(3) Partial emission, we could estimate the emission rate x by:

$$G_t * x + (1 - x) * \frac{G_t}{6} = G_m \quad \Rightarrow \quad x = \frac{6}{5} * (\frac{G_m}{G_t}) - \frac{1}{5}$$