Development of a 500 kV DC Gun with Narrow Gap

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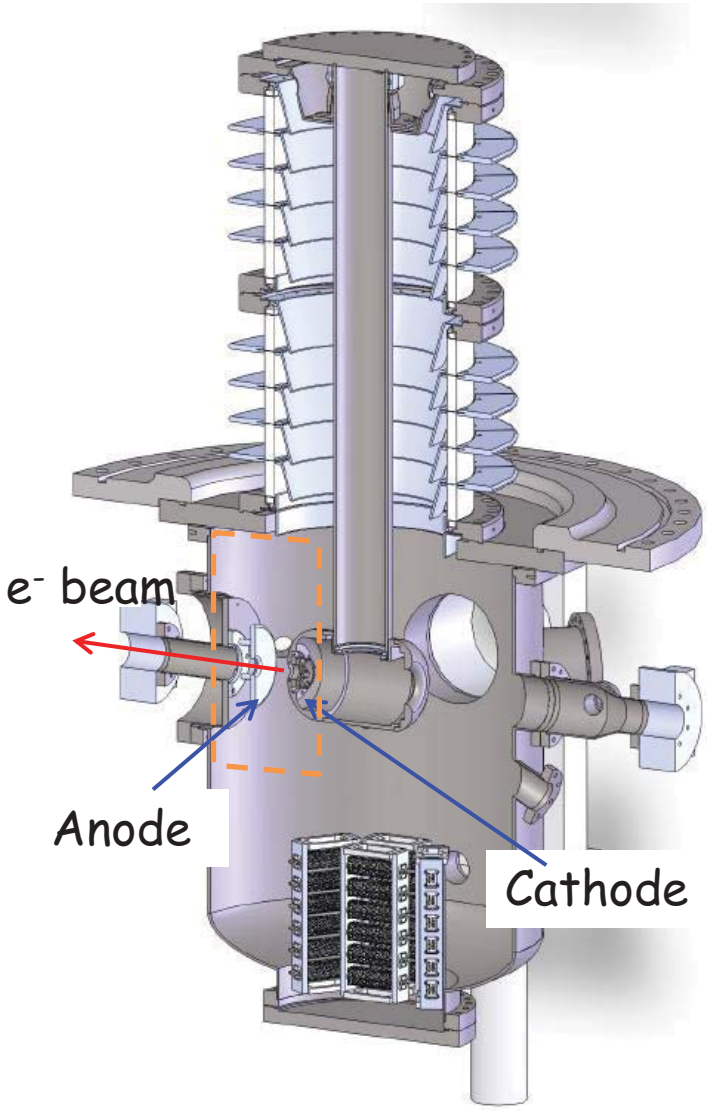
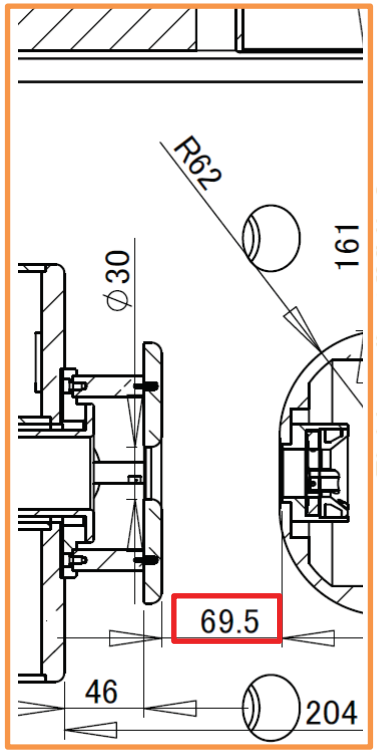
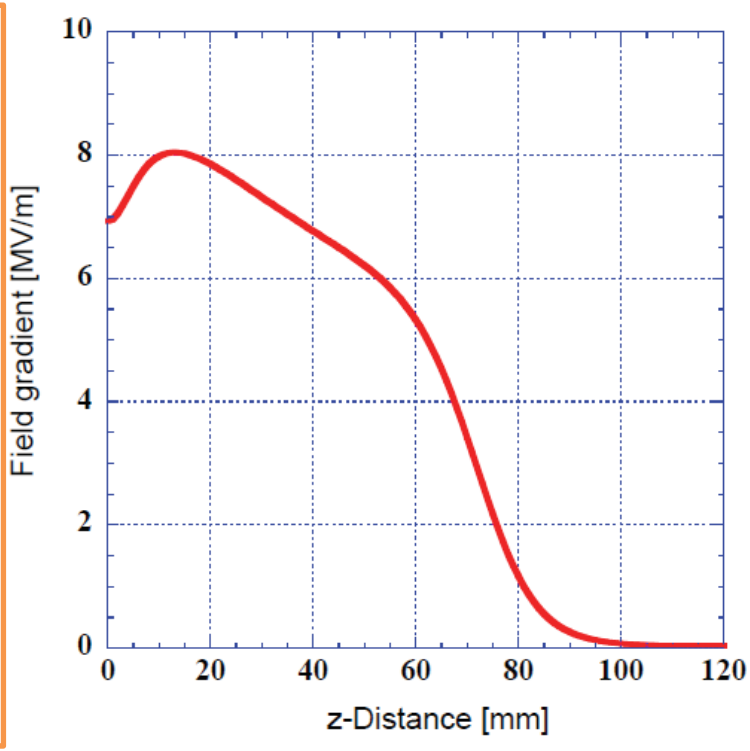
Outline

- Introduction
  - Gun basic configuration
  - Extreme high vacuum systems & baking
- HV test
  - FE problem
  - Conditioning & HV holding test
  - Model of trip voltage increase
- Photocathode preparation & installation
  - Cathodes simultaneous activation system
  - FE problem
- Summary

70 mm Gap 500 kV DC gun (2nd 500 kV gun) @KEK





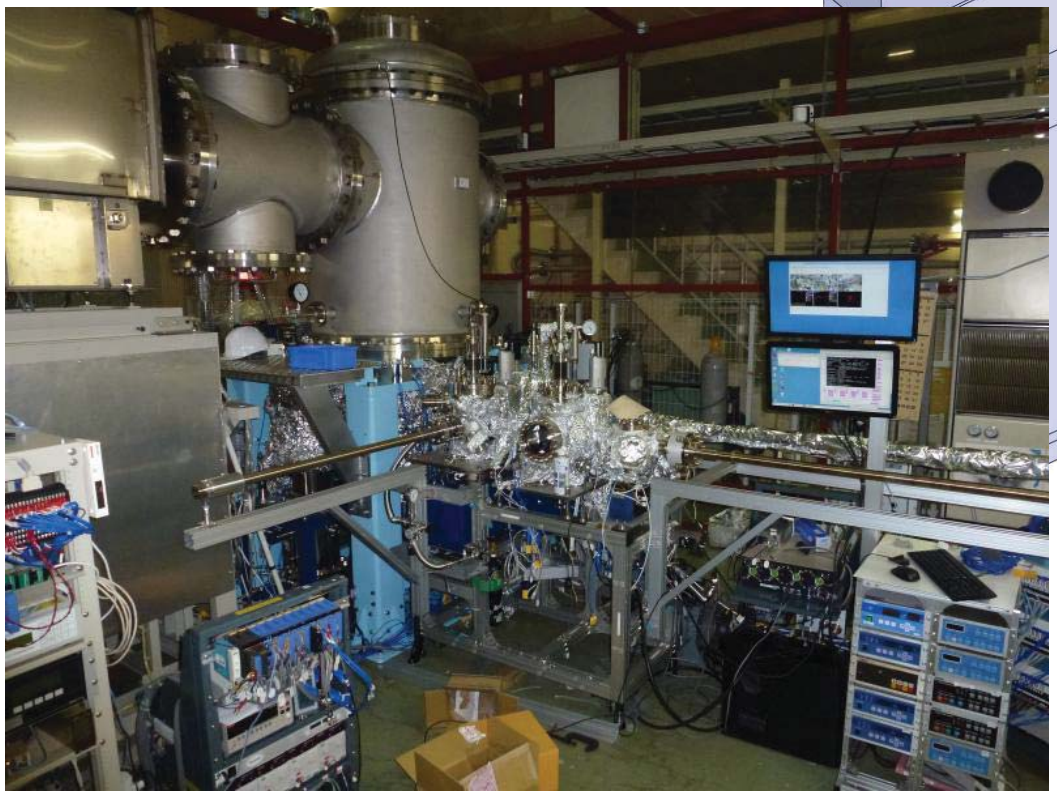


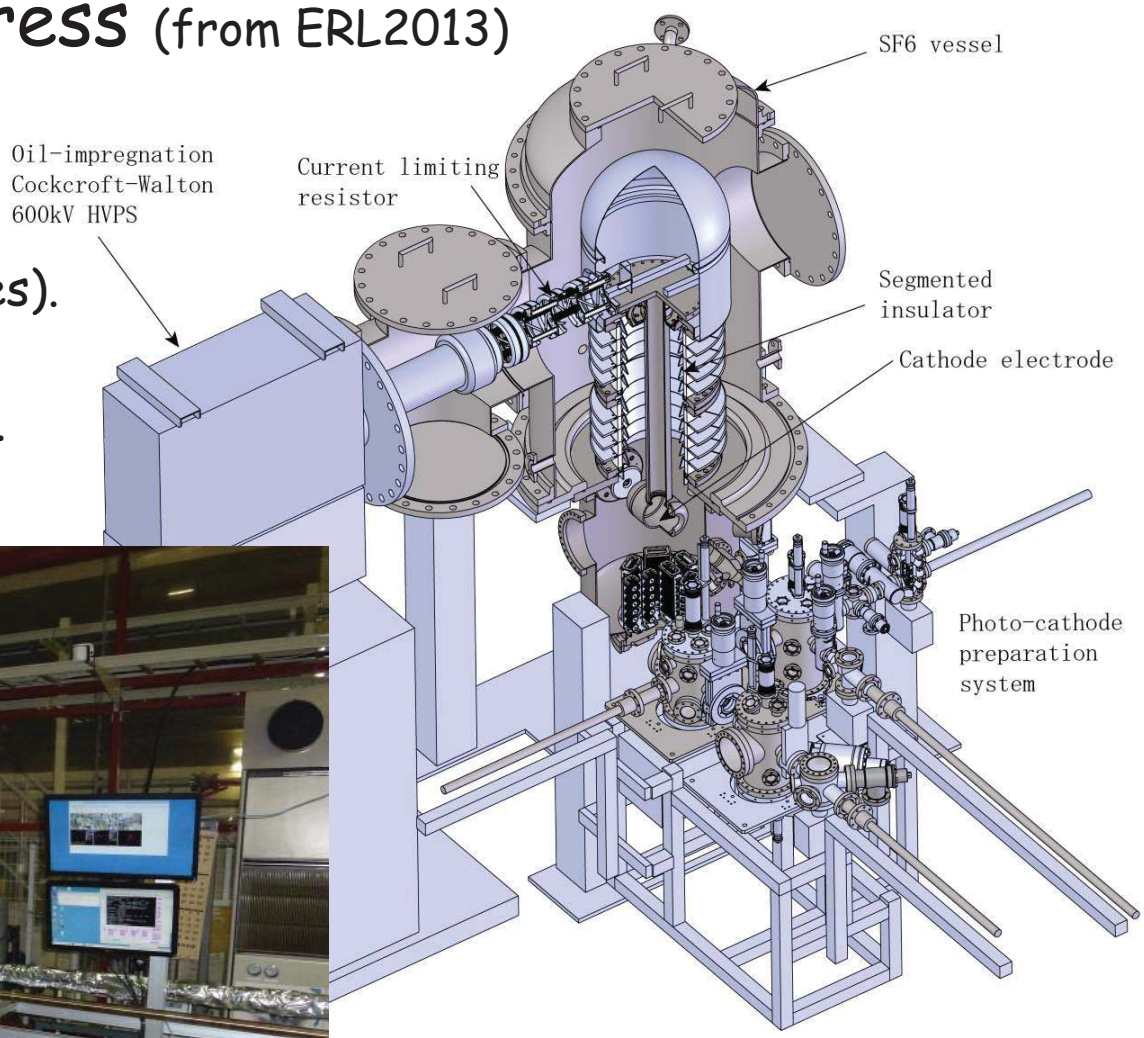
$$\epsilon_n \propto \sqrt{q \cdot \frac{k_B T}{E_{\mathrm{cath}}}}$$

- ✓ 6.9 MV/m @ photocathode center (=E_{cath})
- ✓ 11.0 MV/m @ cathode ball surface

Last 2 years progress (from ERL2013)

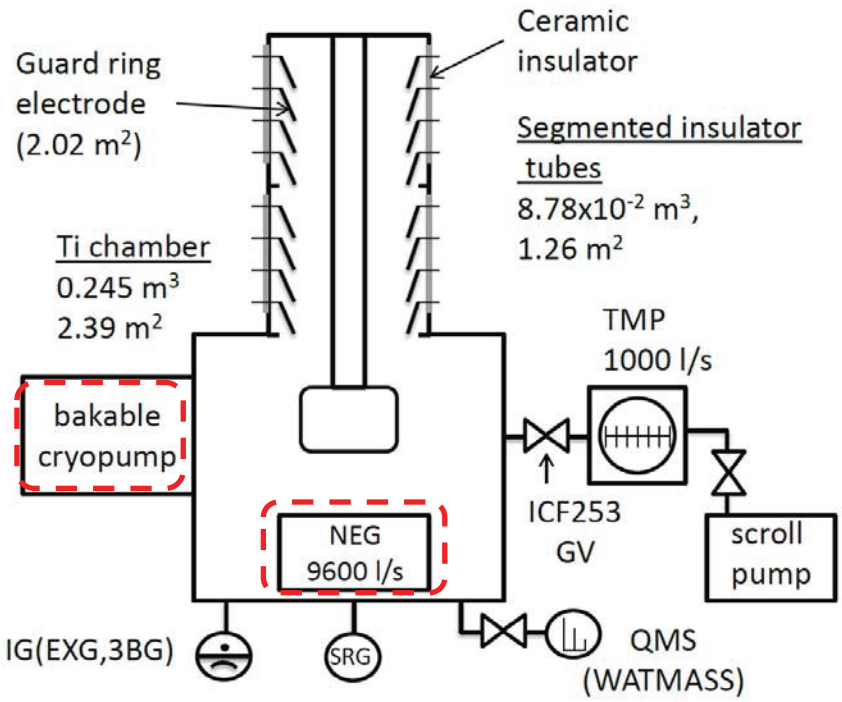
- ✓Baking with main pump system.
- ✓HV conditioning in XHV (4 times).
  2014/May, /Jul, /Aug, 2015/Jan.
- ✓Beam transport & Dump set up.

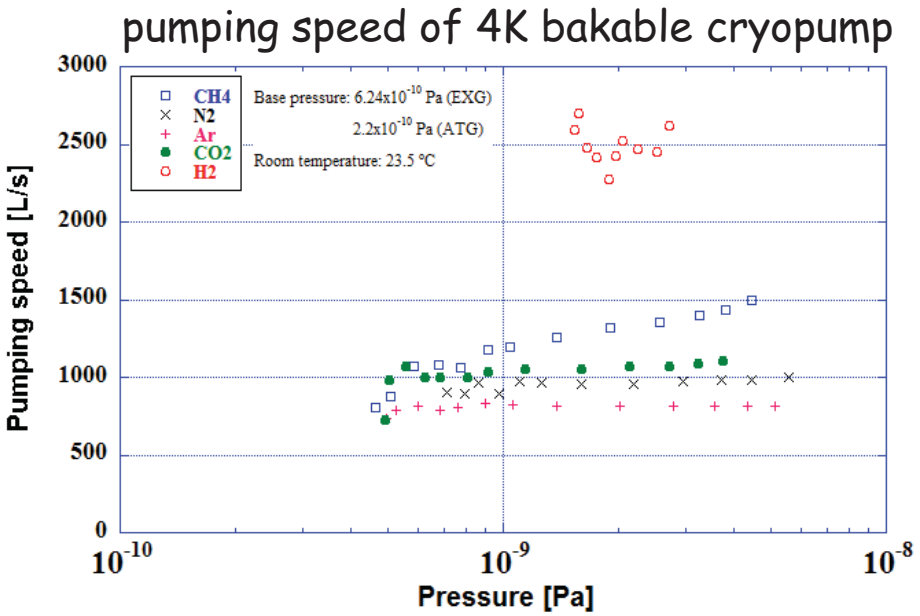




- ✓Demonstrated 3 cathodes simultaneous activation.
- ✓Connected cathode preparation system to the gun.

Main pump installation (2014/Mar)





Main pump composition

1. Non Evaporable Getter (NEG)
   D400-2 x 24 = **9600 L/s (H_2)**
   = **4320 L/s (CO)**
   (catalog value)

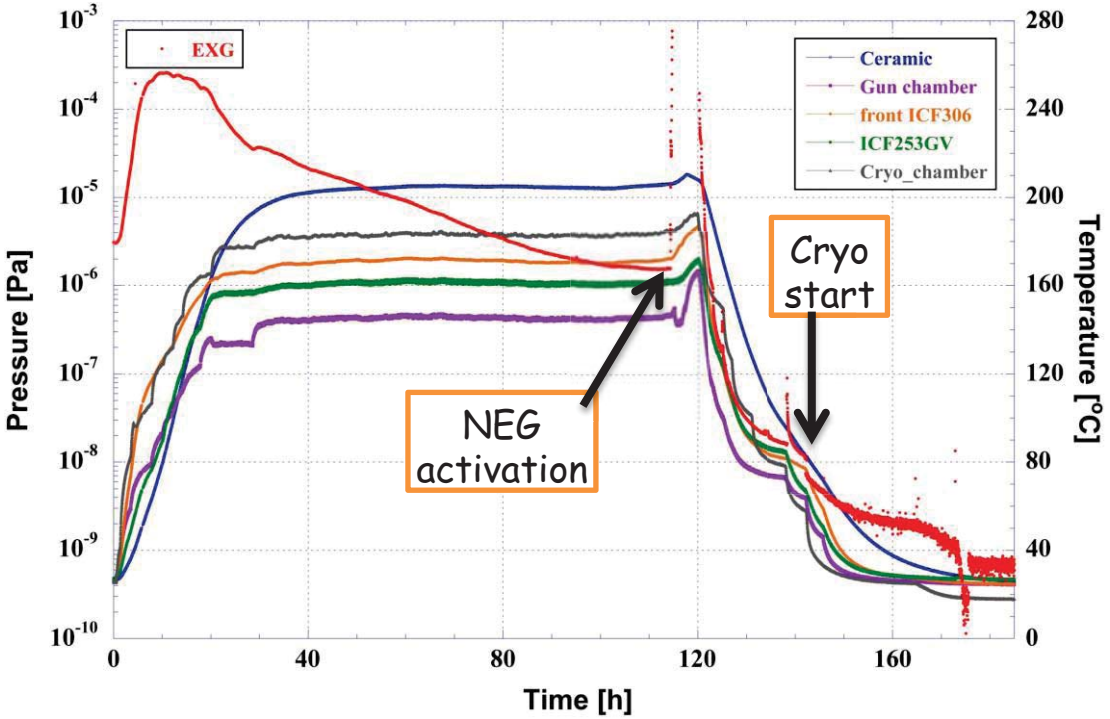
2. 4K bakable cryopump

~800 L/s (Ar), ~1000 L/s (N_2,CO_2), ~1200 L/s (CH_4) (measured values@1x10⁻⁹ Pa)

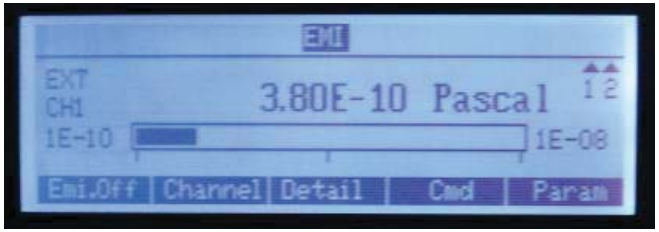
NEG pump set

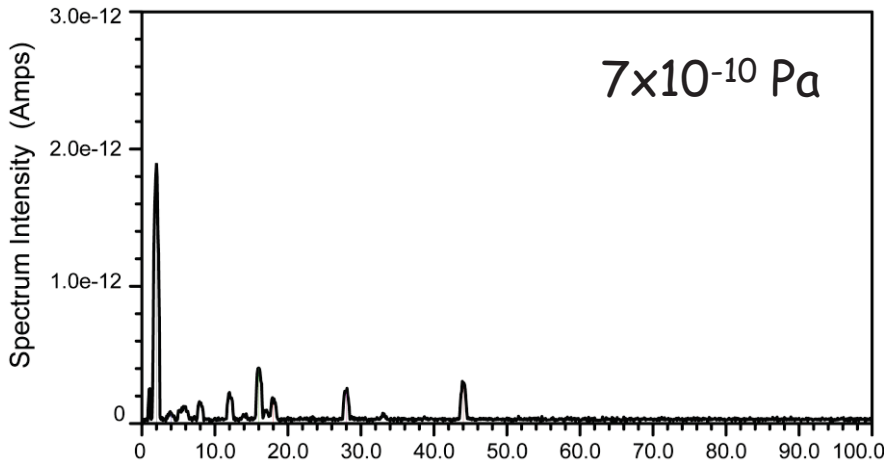
4K bakable cryopump

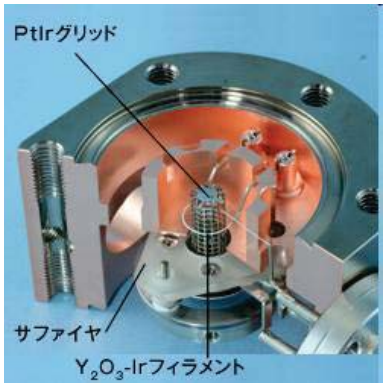
Baking & RGA spectrum in XHV (2014/Mar~Apr)



3B Gauge



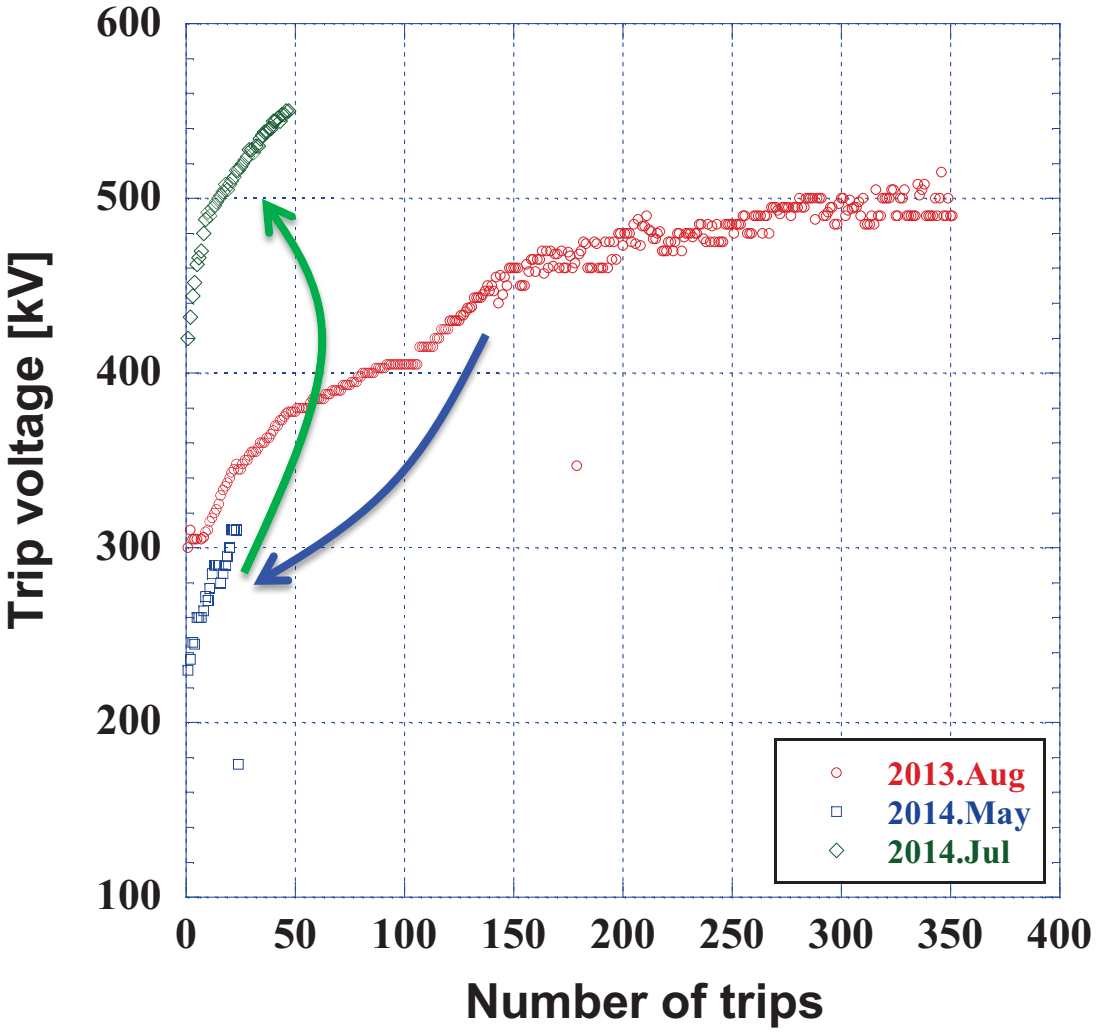




Special RGA ion source for XHV

http://www.vaclab.co.jp/product04.html

HV conditioning history (2013/Aug ~ 2014/Jul)



2013/Aug. HV Conditioning
(w/o main pump system)

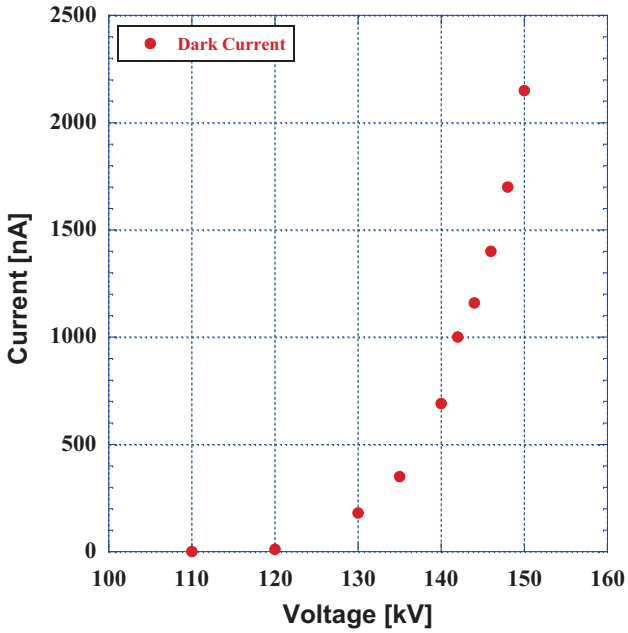
Main pump installation & baking.
XHV (~4x10^{-10} Pa) achieved.

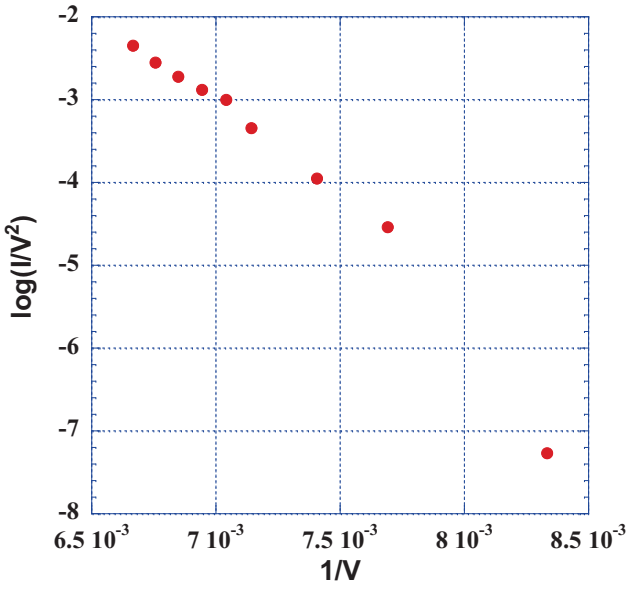
2014/May HV Conditioning
(FE source was generated after 24 trips)

Removed electrode & eliminated dust on the cathode electrode.
Baking & rebuilt HV setup.

2014/Jul. HV Conditioning
(reached 550 kV after 48 trips)

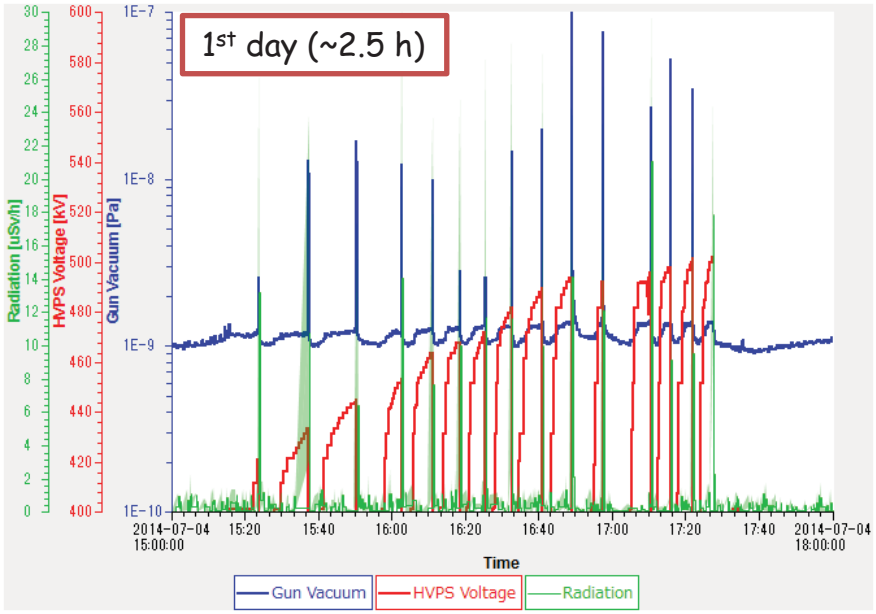
Field emission from a dust (2014/May~Jun)

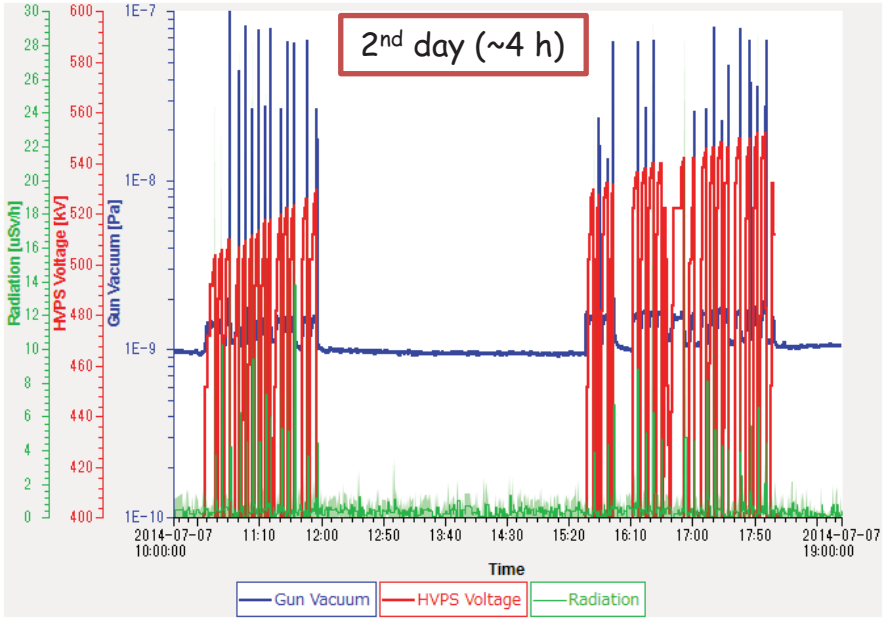


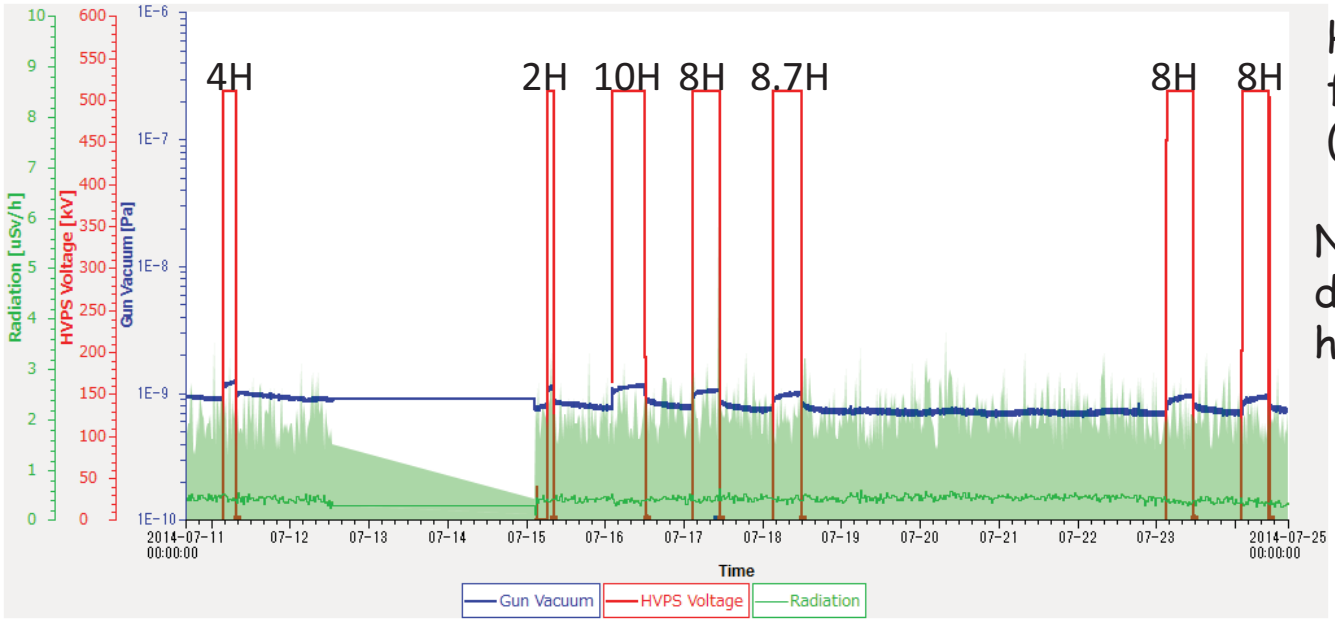


The dust was easily vanished by blowing ionized air.
Finally, the electrode was cleaned by wiping lint free cloth. (with ethanol& dry cloth)

HV conditioning & holding test (2014/Jul)



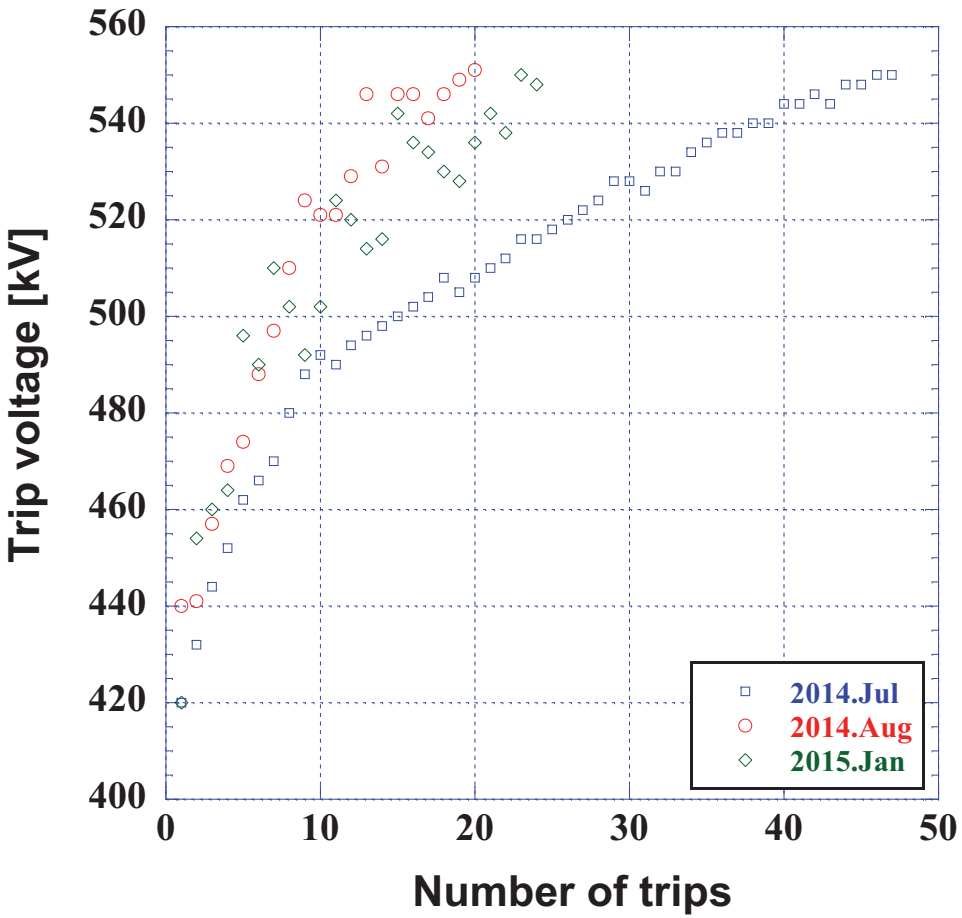




HV conditioning was finished in a short time (~7 hours).

No breakdown appeared during 50 hours 500 kV-holding test.

HV conditioning repeatability (2014/Jul ~ 2015/Jan)



2014/Jul. HV Conditioning
(reached 550 kV after 48 trips)

~3 weeks shutdown
~1 week for XHV establish

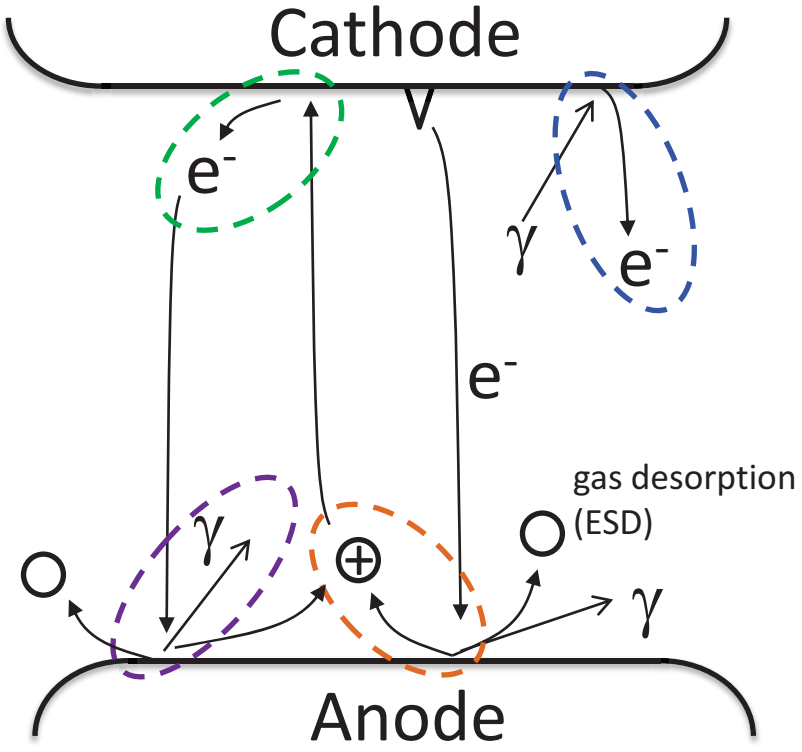
2014/Aug. HV Conditioning
(reached 550 kV after 20 trips)

~3.5 months shutdown
~1 week for XHV establish

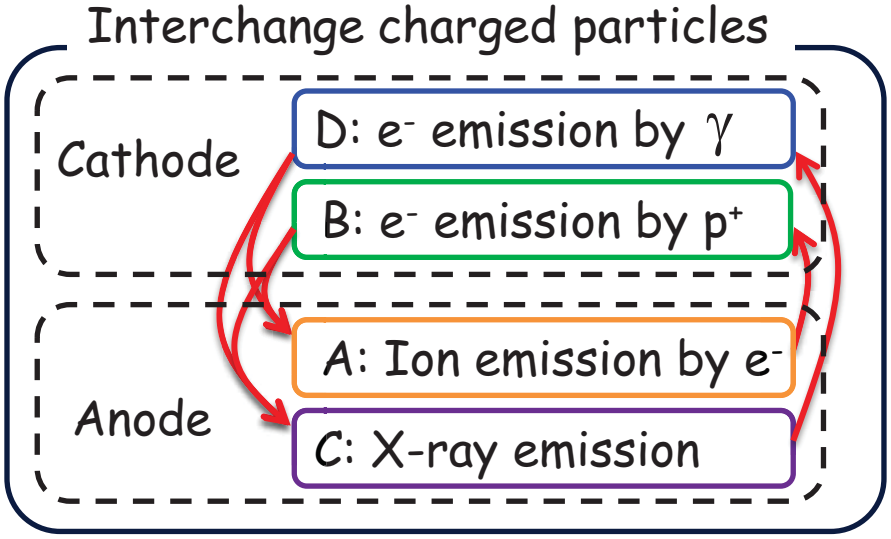
2015/Jan. HV Conditioning
(reached 550 kV after 23 trips)

Almost trip events were hardly detected emission current (≤1 nA) just before trip happened. Almost trip voltage increased continuously as if the trip voltage was memorized. How we can explain this ?

Breakdown process in vacuum gap



In case of ...
* DC bias in UHV.
* small dark current condition.
(a small seeding for breakdown process)



Four essential coefficients (A~D)

A: Electron induced ion emission
B: Ion induced electron emission
C: Photons produced by a electron
D: Electron produced by a photon

J.G.Trump & R.J. van de Graaff, J. Appl. Phys. 18, (1947) 327

$\underline{avg(A*B+C*D)>1}$

Discharging & Vacuum trip.

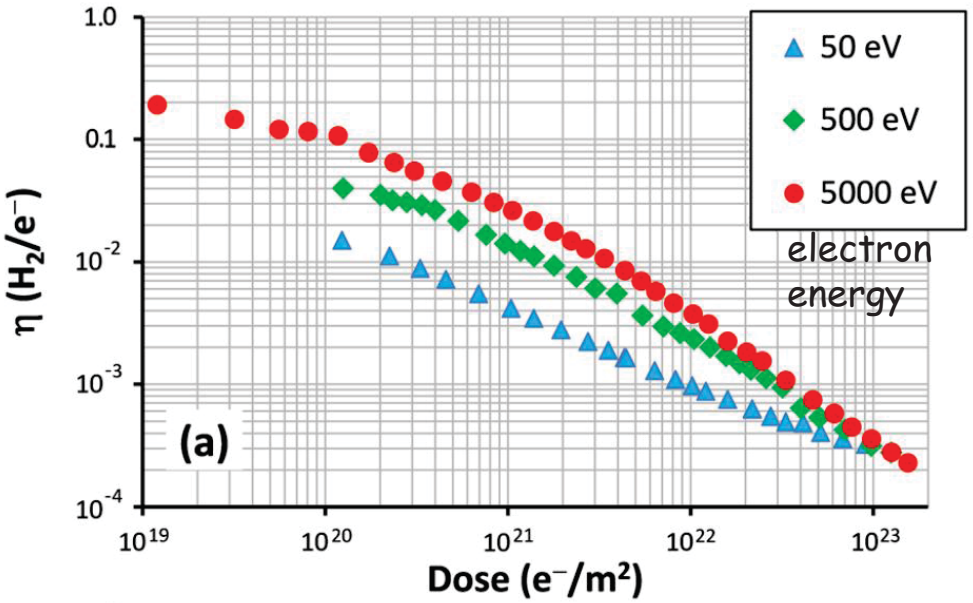
$\underline{avg(A*B+C*D)<1}$

Finished discharge phenomenon

Model of trip voltage memory phenomenon

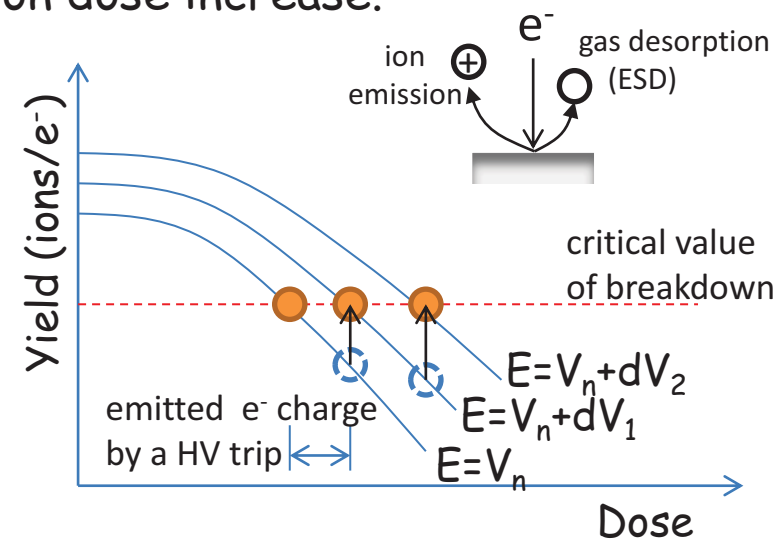
Electron induced ion (H^+,H_2^+,etc.) emission is probably related electron stimulated desorption (ESD) phenomenon.
ESD yield is decrease drastically by electron dose increase.

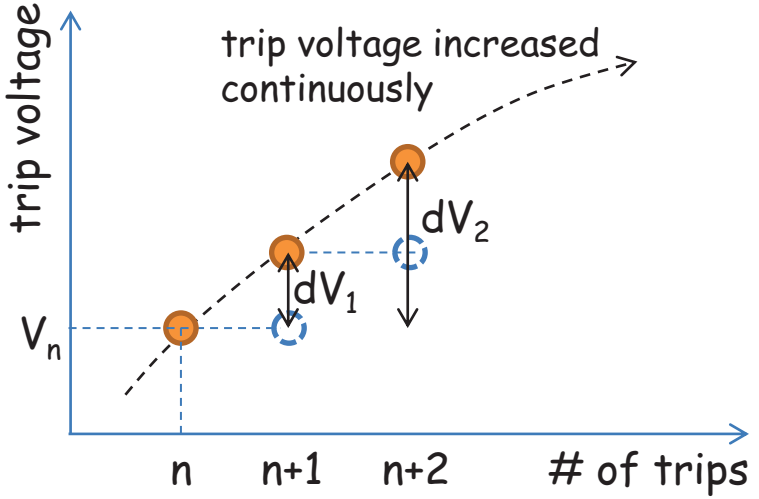
Hydrogen desorption from SUS316L



Oleg B.Malyshev et al., J.Vac.Sci.Technol.A 31 (2013) 031601

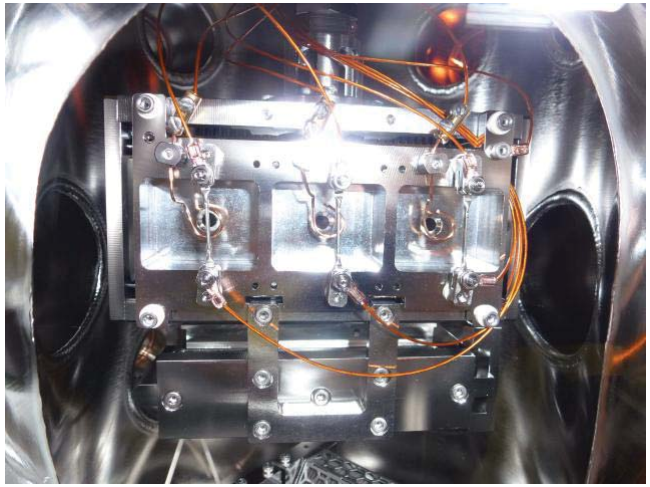
✓ ESD property of anode surface may give a important hint to know a limitation of breakdown voltage.





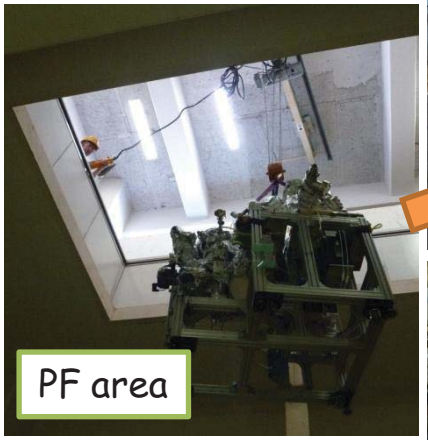
Cathode preparation system

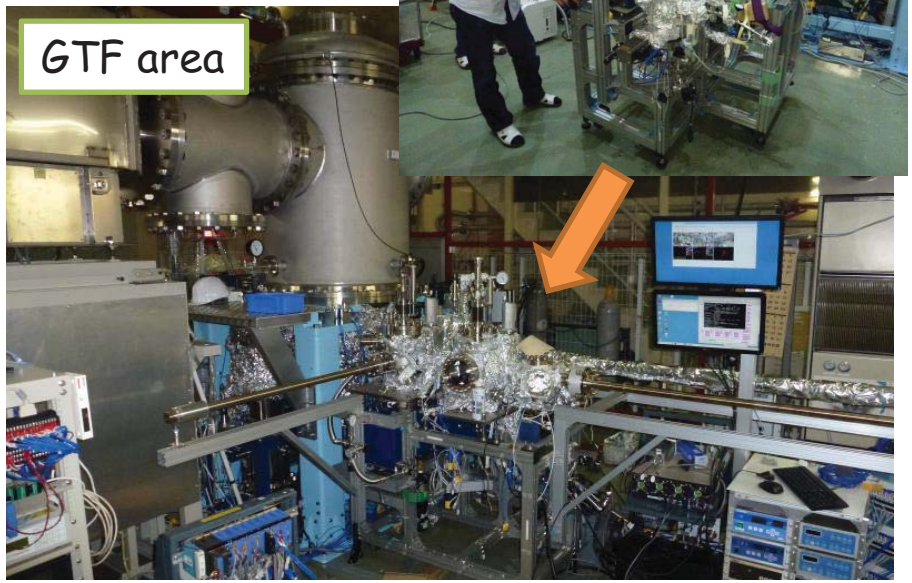
Three cathodes simultaneous activation (QE:6~10%) were successful. (2014/Sep.)



Inside view of activation chamber

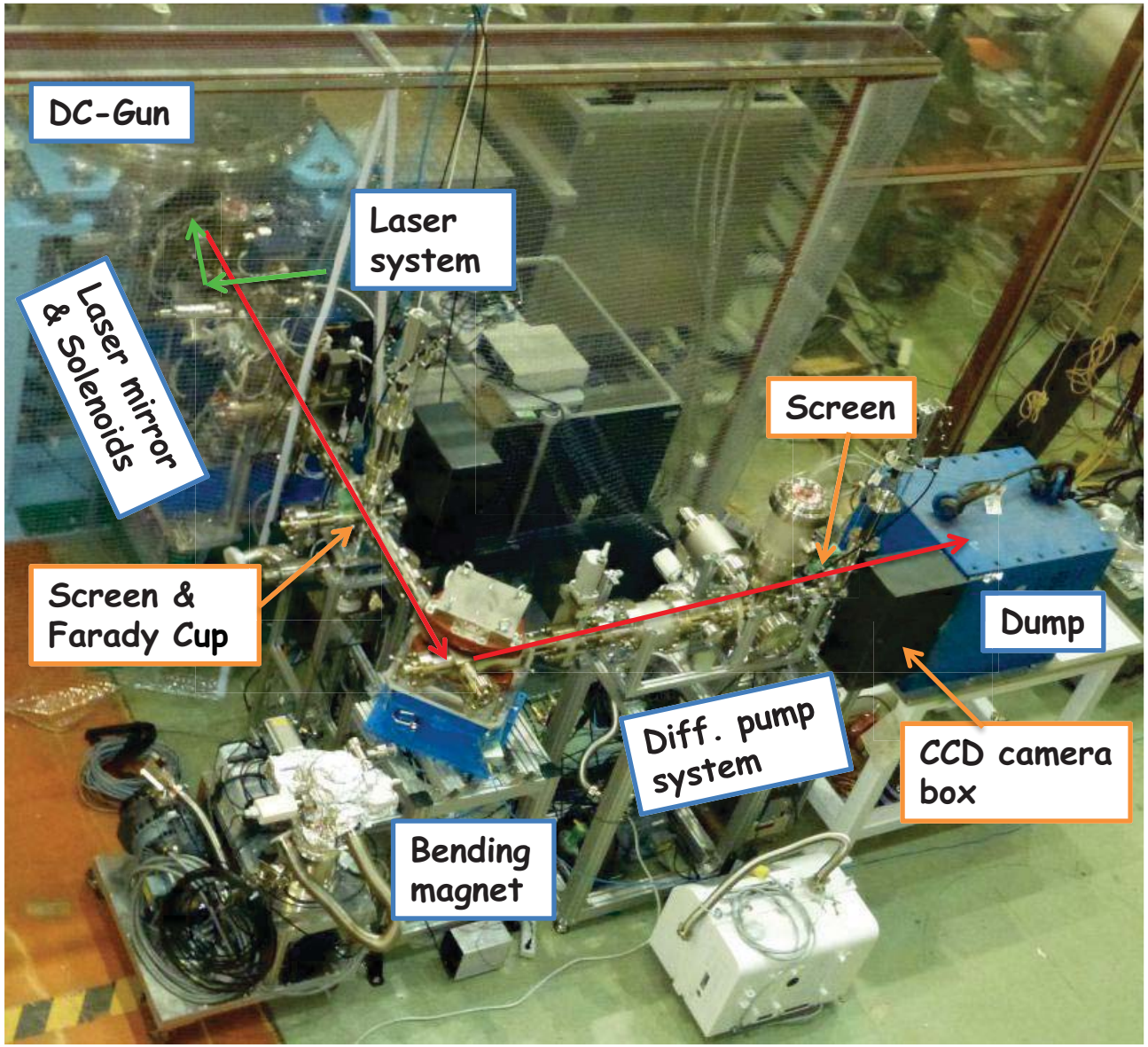
Last cathodes-activation was done in 2015/Jan. and transported to the storage chamber.
~2 months storage cathode was still alive.

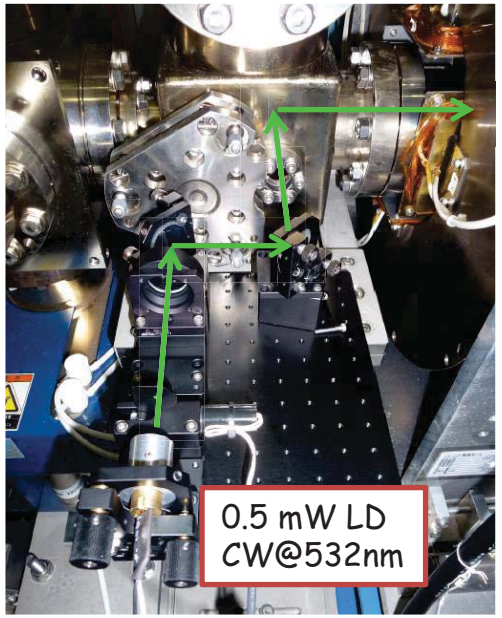




The prep. system was moved 2014/Oct.
Reconstruct & connected to the gun 2014/Nov~Dec.

Beam Transport & Dump section

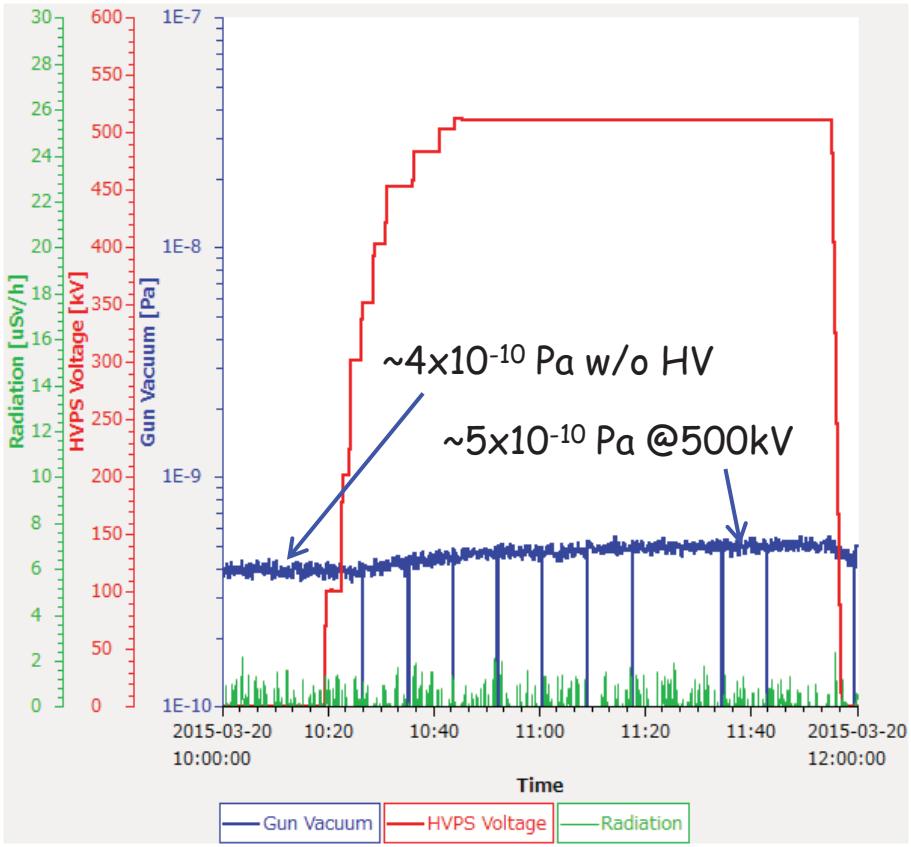




Laser system

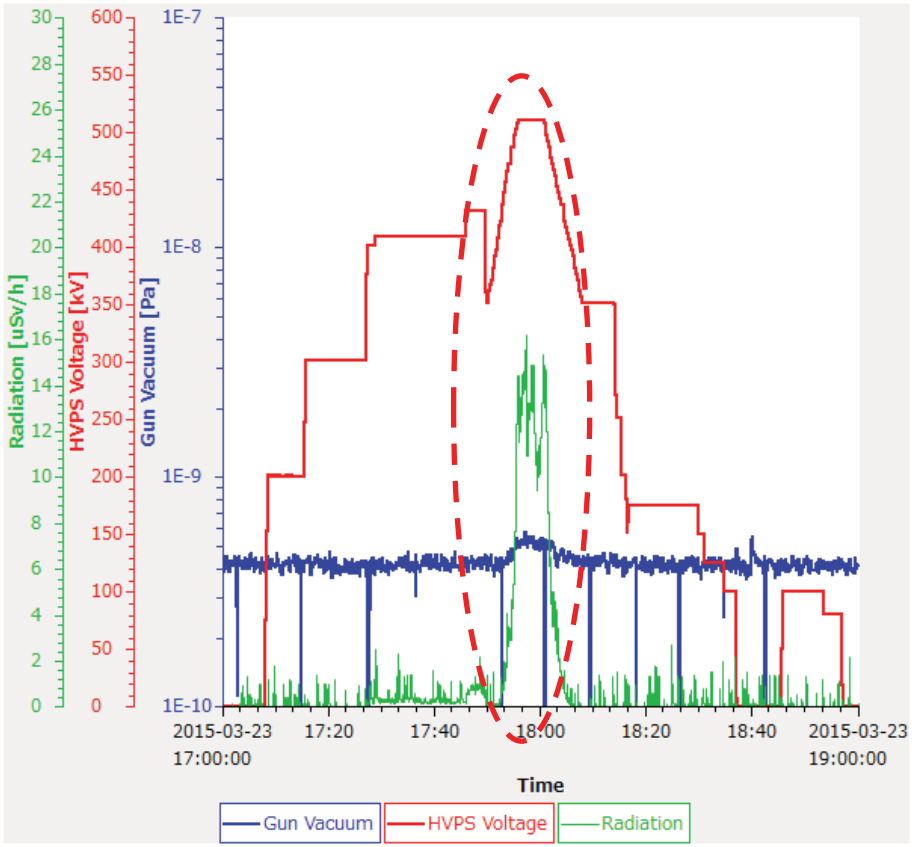
YAG screen

Field emission problem by cathode installation



Before photocathode installation (Equipped with SUS dummy puck)

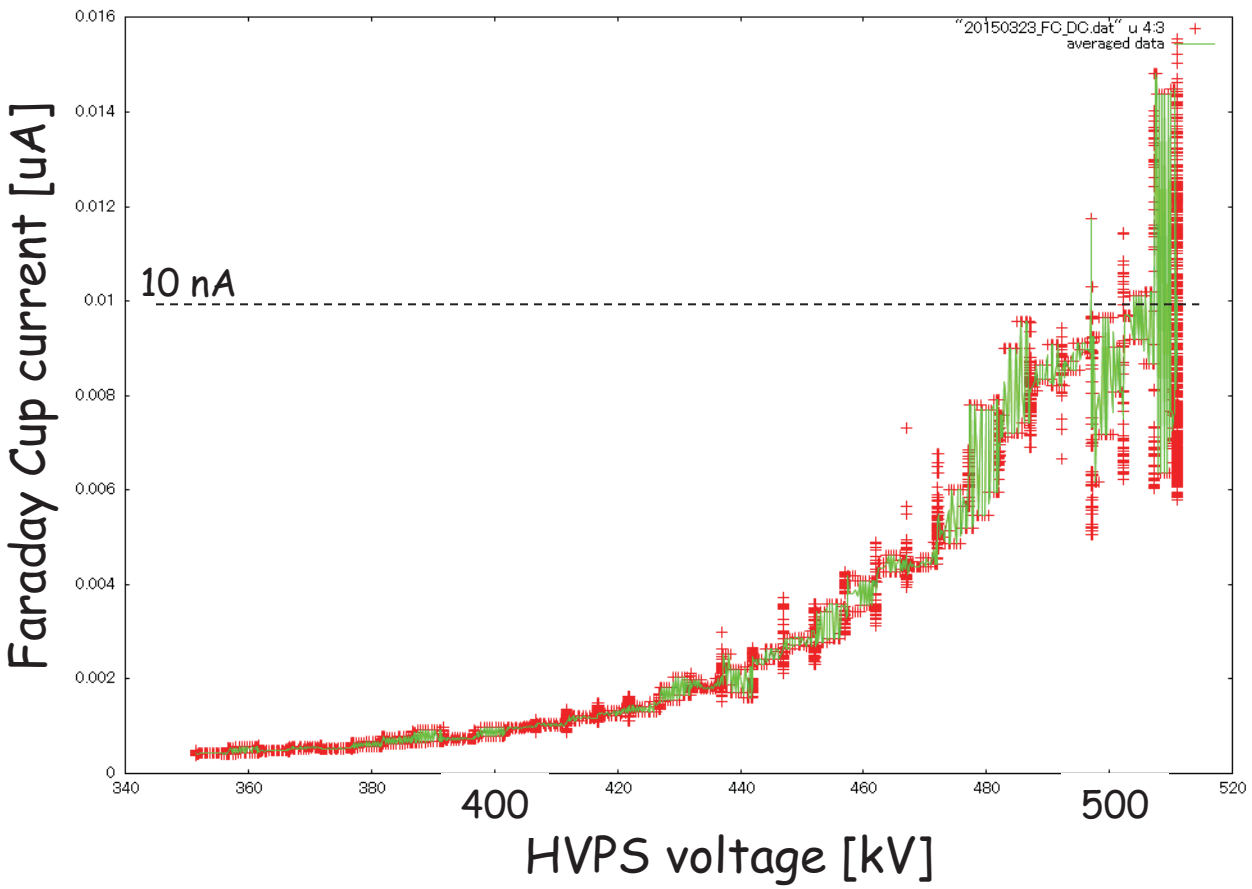
Only BG level radiation, dark current (<1 nA) were detected under a 500 kV condition.

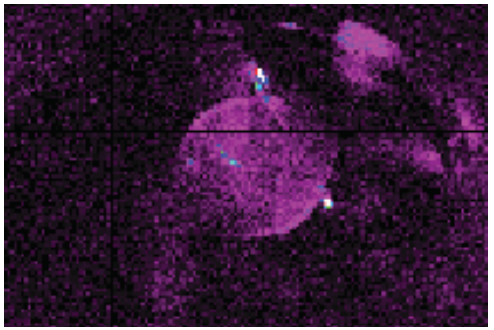


After activated photocathode installation (Bulk GaAs)

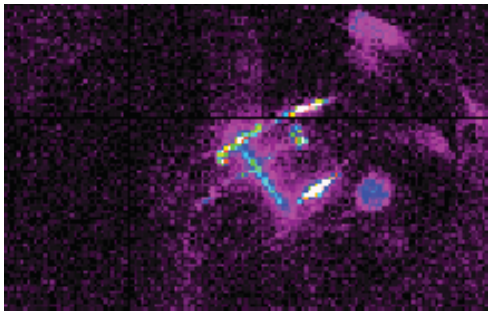
About 15 uSv/h radiation, ~4 nA dark current to anode electrode were detected under a 500 kV condition.

Dark current beam profile (w/o laser irradiation)

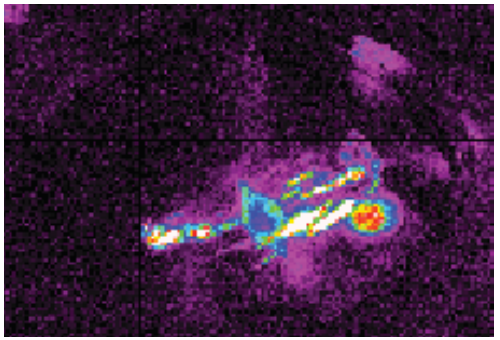




350 kV



400 kV



450 kV

Photoemission by stray light of ion gauge was exist. (<0.5 nA)

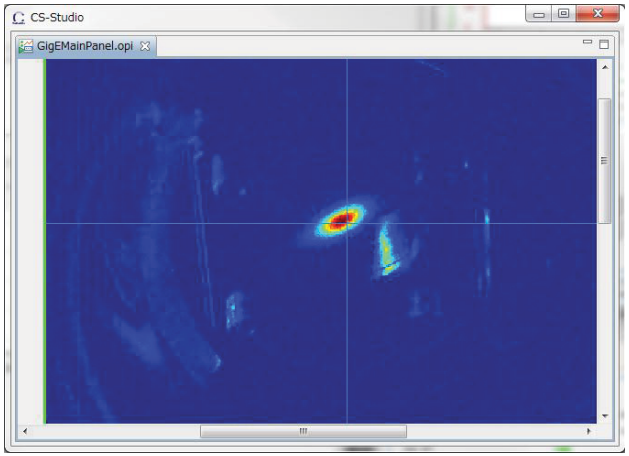
Some field emitters exist near the photocathode. Field emission current was increased over 400 kV.

Summary

- Extreme high vacuum was established by NEG & bakable cryopump.
- HV conditioning up to 550 kV & 50 hours holding test of 500 kV were successful.
  - Fortunately, FE problem was solved by easy way.
- A model of trip voltage memory mechanism was proposed.
- Cathode preparation system was constructed.
  - Three cathodes simultaneous activation was successful.
  - ~2 months storage cathode was alive.
- Unfortunately, FE problem was come back by a cathode installation.
  - Investigations of FE source & the point at issue are underway.

Now & Feature plan

- 400 keV beam study is just started.
- Preparations for mA class high current cw-beam operation are underway.
  - Radiation shield
  - Water cooled beam dump
  - Fast interlock system



400 keV beam profile near the dump (with laser irradiation)

Acknowledgement

H. Iijima for construction beam transport & dump line and many wiring works.
T. Michikawa, S. Nagahashi, R. Takai and T. Obina for making a lot of IOC programs and many advices about devices control.
F. Watanabe for advice of XHV measurements.