# Status of 200keV Gun for ILC

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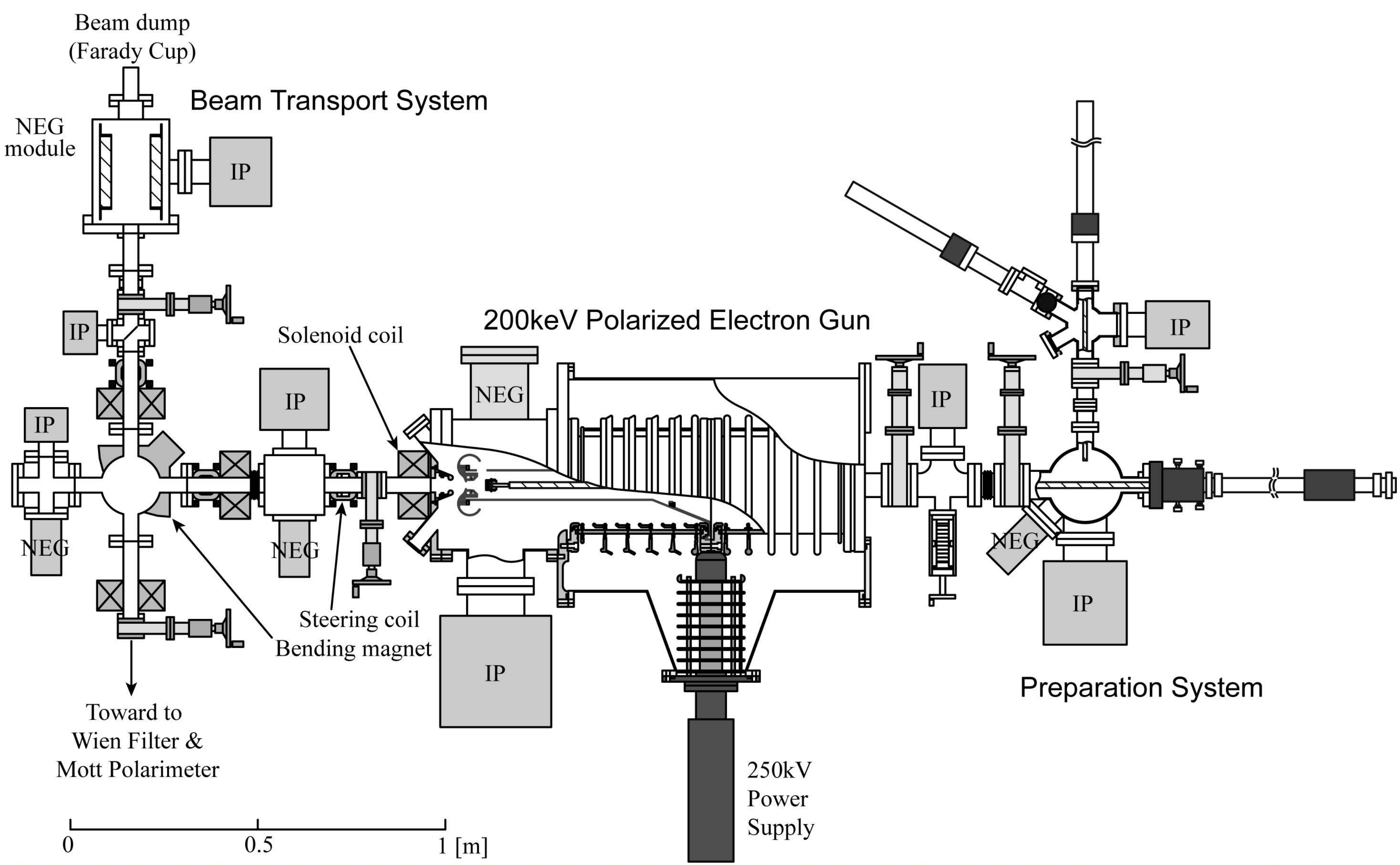
# Summary

- Nagoya 200kV gun satisfies basic requirements of ILC gun.
- High voltage 200kV operation with Mo-Ti electrodes open the possibility of higher peak current operation;
  - **Shorter initial bunch length (<0.5ns)**
  - **Simplified bunching section.**
  - **Less energy spread.**
- R&D of 500kV gun can be a common effort for ERL and ILC injectors.

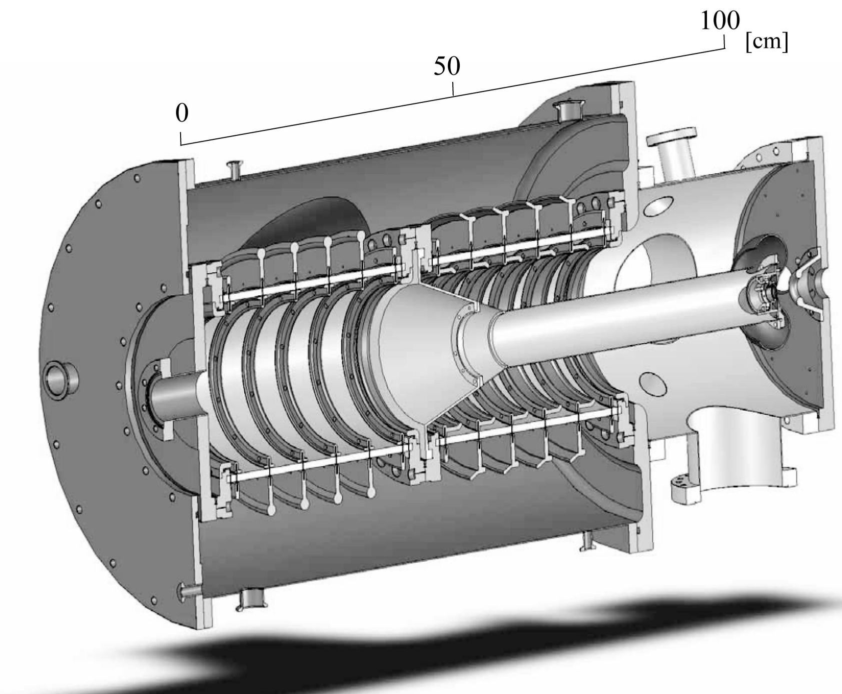
# Outline

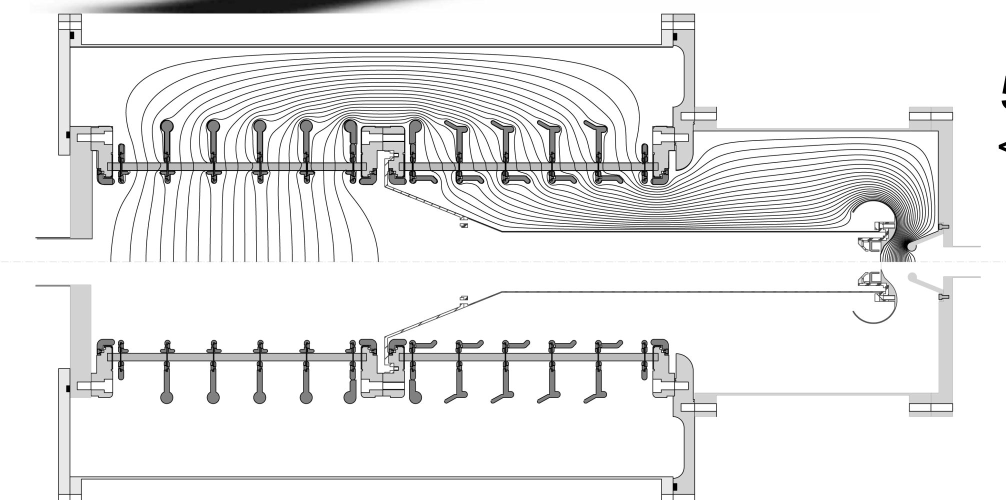
- ▶200kV Gun system at Nagoya University.
- ▶High voltage conditioning of the Mo-Ti electrode.
- ▶Dark- and 50μA operational Lifetime measurement.
- ▶Nano-second bunch generation.
- ▶Summary and Future.

# 200keV Polarized electron source at Nagoya University



# 200keV gun basic performance



Base pressure: $2\times10^{-9}$ Pa
200  baking for >100 hours
360 L/s IP, 850 L/s NEG

Maximum field gradient (200kV):
7.8MV/m (Cathode)
3.0MV/m (Photocathode)

<u>Electrode</u>

Cathode: Molybdenum (>99.6%)
Anode: Titanium (JIS-grad 2)
Finishing: electro-buff polishing

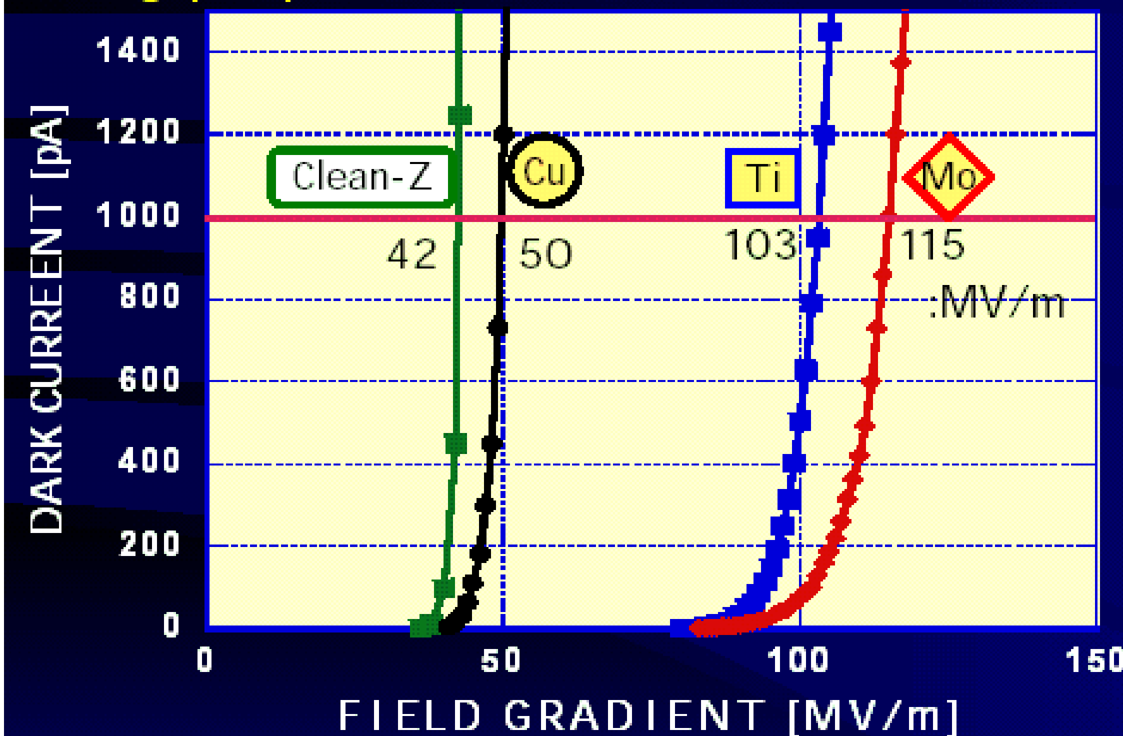
<u>Ceramic</u>

Dividing five segments w/ guard rings.
(to avoid field concentration)
500MΩ connection  for each
<0.3MV/m for each segment at the junctions

# Dark Current EXPRMNT

Nagoya & KEK

gap separation=0.5mm    Vac : ~1e-9 Pa




Materials & Finishing

Clean-Z (Re-Melted SUS316L)
Electro-buff polishing

Copper (OFHC)
precision diamond machining
( no polishing )

Pure Ti (JIS grade-2)
Only buff polishing

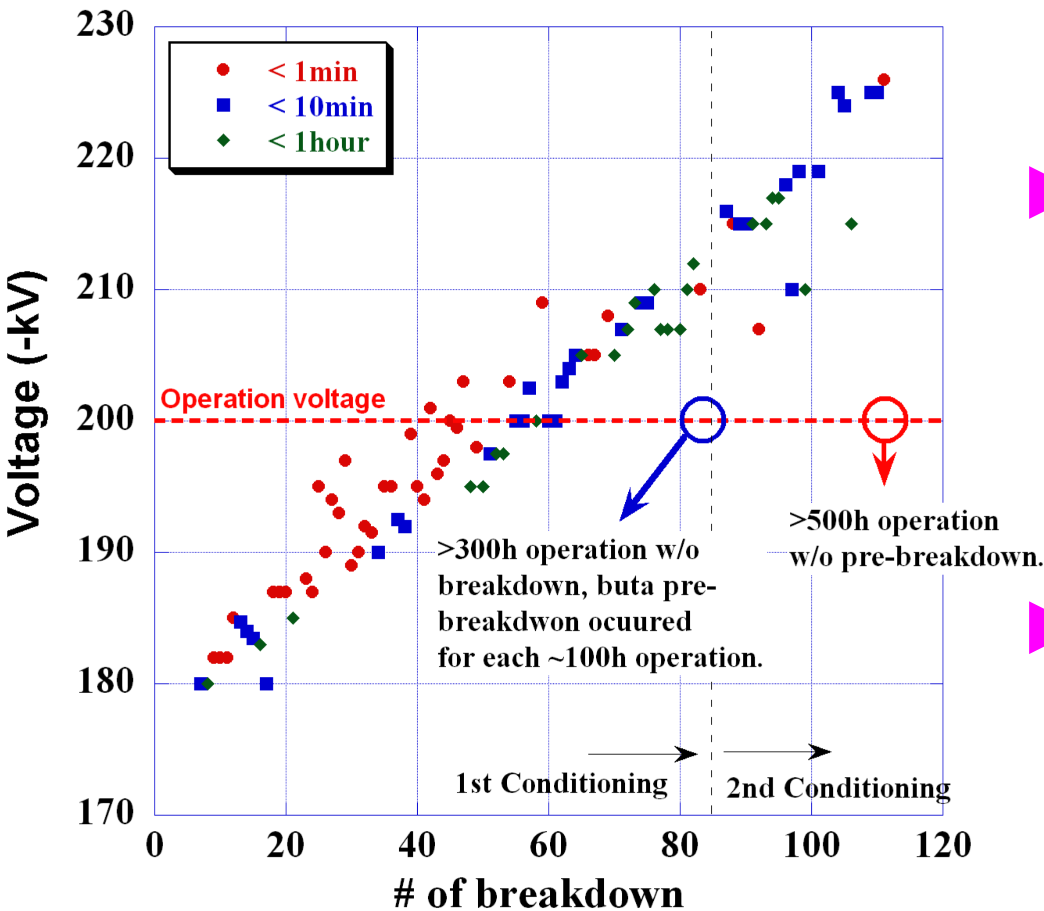
Pure Mo (poly-crystal 5N)
Only diamond buff polishing

A point to note ...

Only 7mm$^2$ area exposed maximum field gradient.

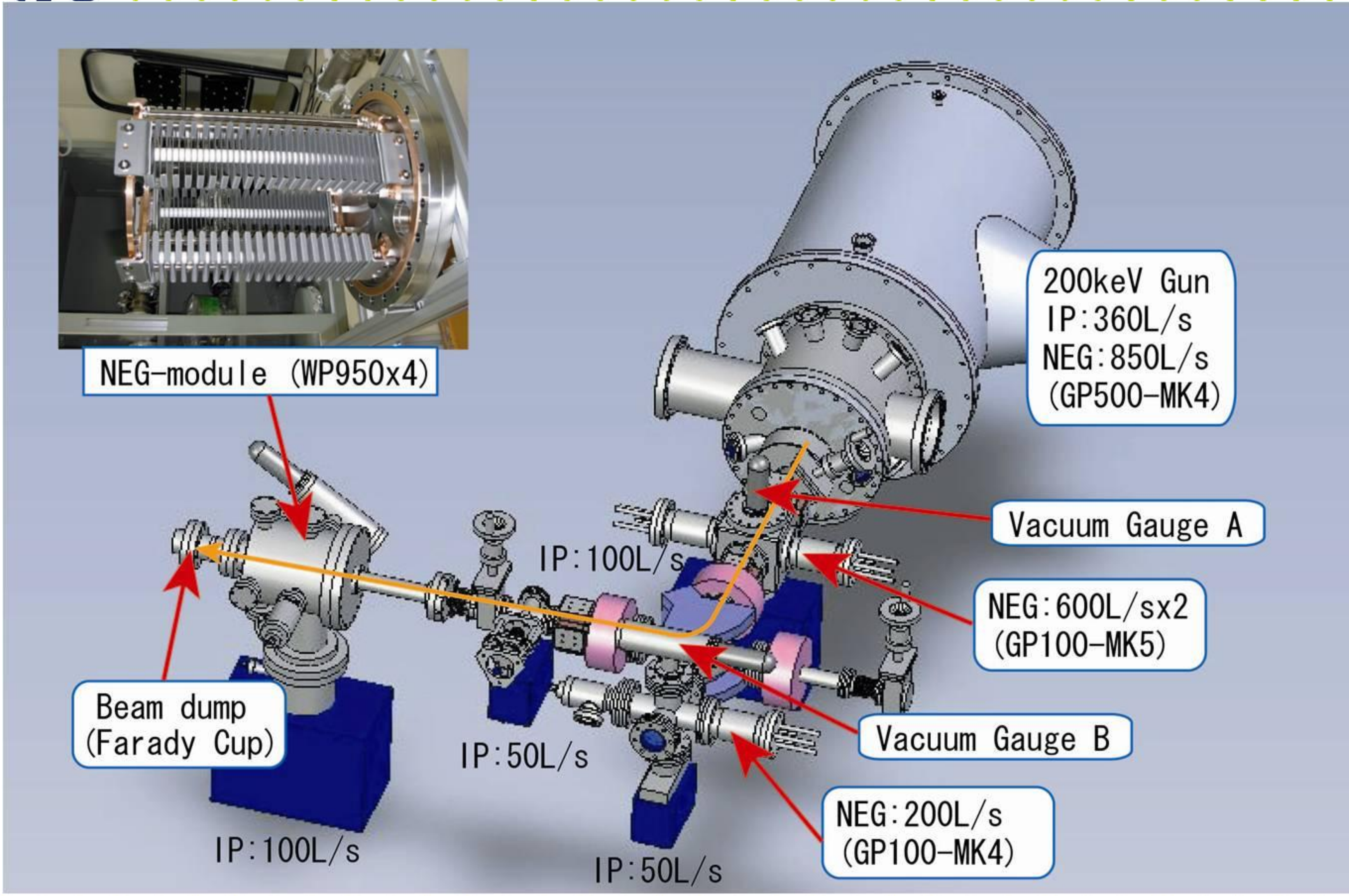
ILCWS2005, Snowmass

# Mo-Ti Electrode conditioning




- Electrode conditioning was done in UHV condition.
- 215kVconditioning: No breakdowns occurred for >300 hrs, but pre-breakdown gives a crucial damage.
- 225kV conditioning: No pre-breakdown occurred > 500 hrs. Stable operation.

# Beam transport & Vacuum system

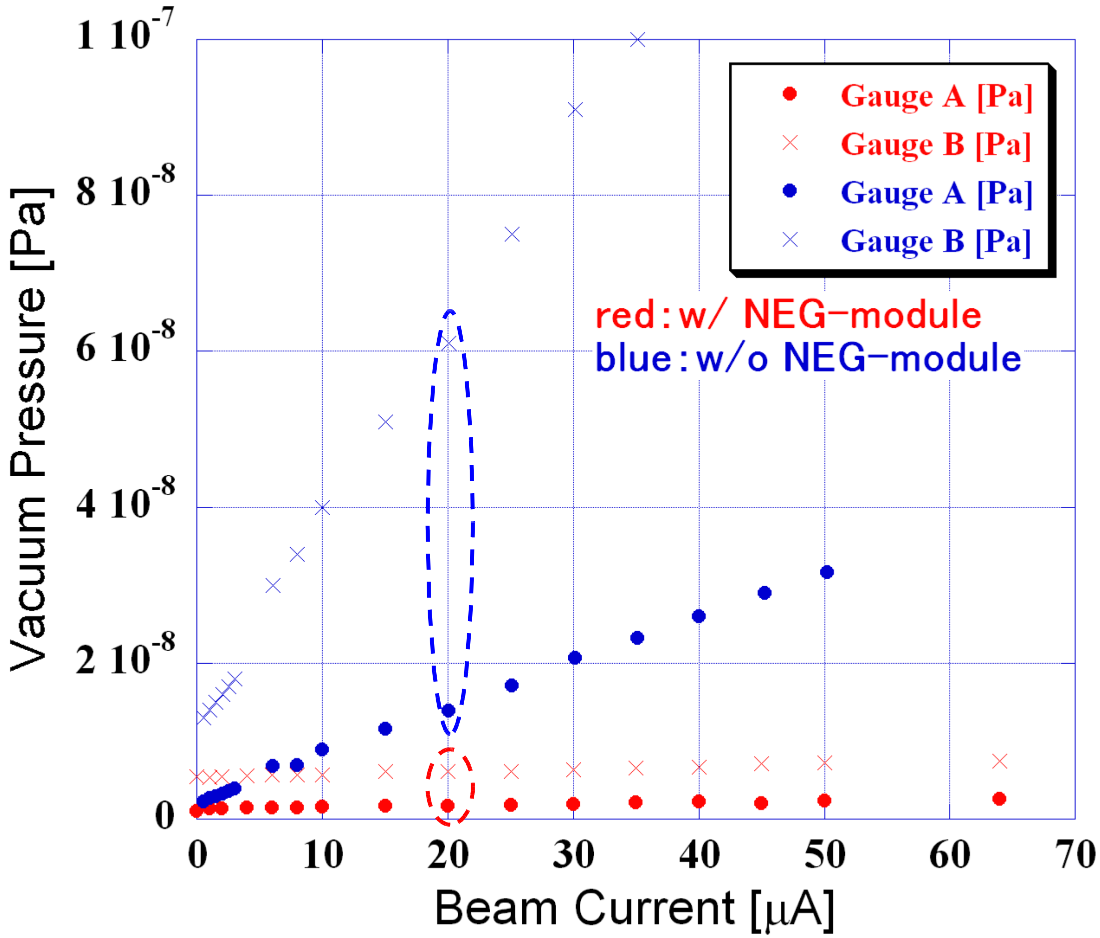


# Life Time

- Even the low dark current between gun electrode, the operational life time has been shorter than expected.
- Out-gas from the down stream, i.e. beam dump and beam loss during the transport, is suspicious.
  - **NEG pumping at the beam dump.**
  - **QE damage mapping.**

**Faraday Cup**

# NEG-module Beam dump



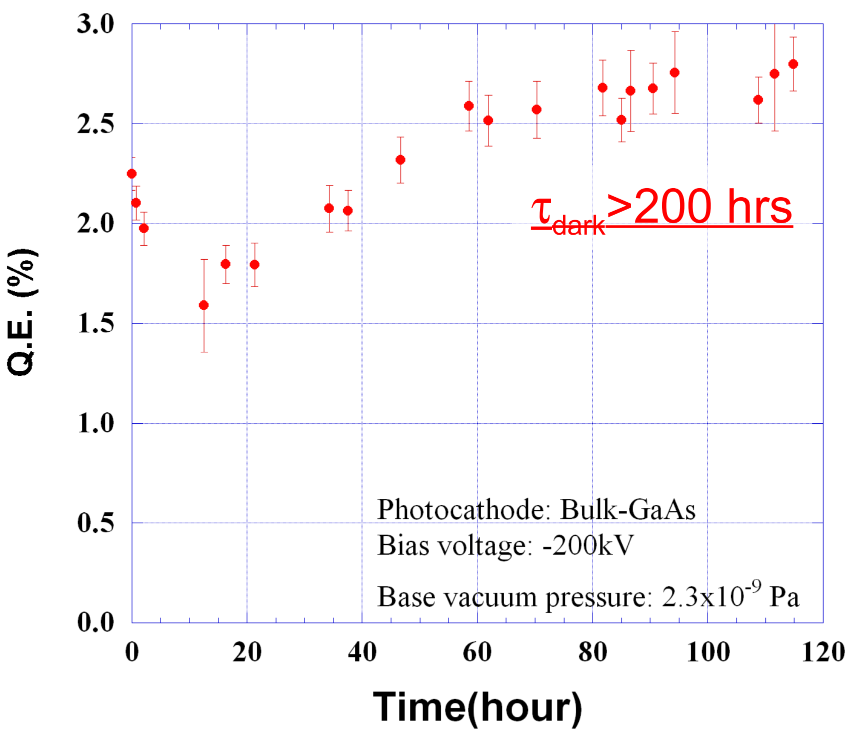

<u>Beam dump vacuum system</u>
IP: 100 L/s
NEG: 1720 L/s
(WP950x4:Saes getters)
Base pressure: $5 \times 10^{-9}$ Pa
(measured by NIG)

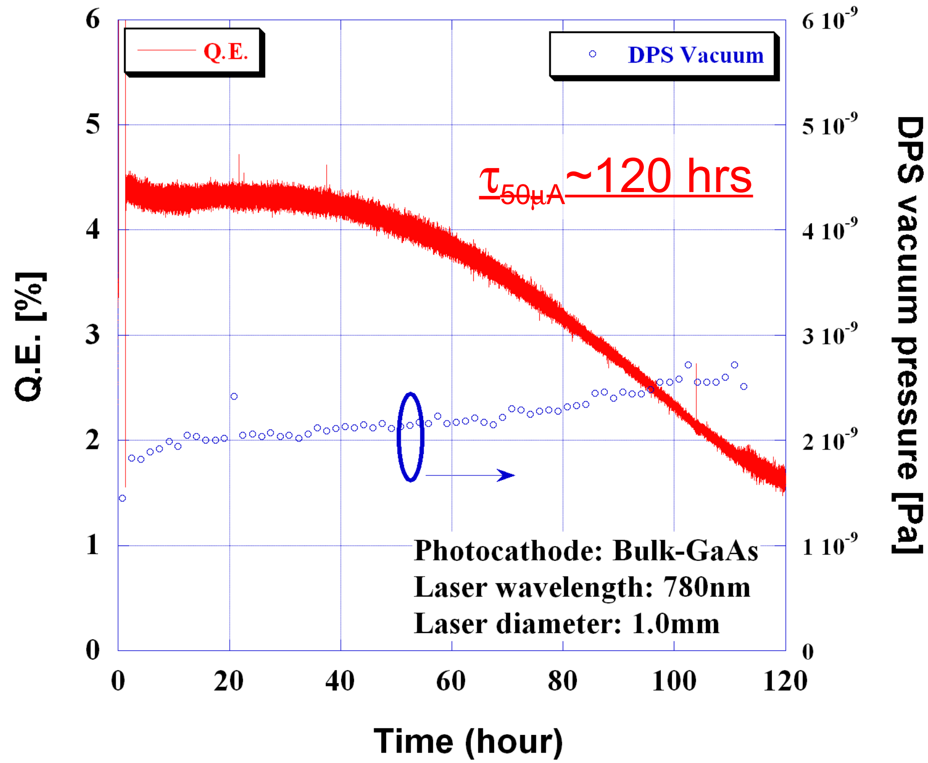
<u>Operational Lifetime</u>

(Last year)
w/o NEG-module dump
~25 hours @20μA

(This year)
w/ NEG-module dump
>100 hours @20μA

# Dark & Operational Lifetime




<u>Photocathode</u>: Bulk-GaAs

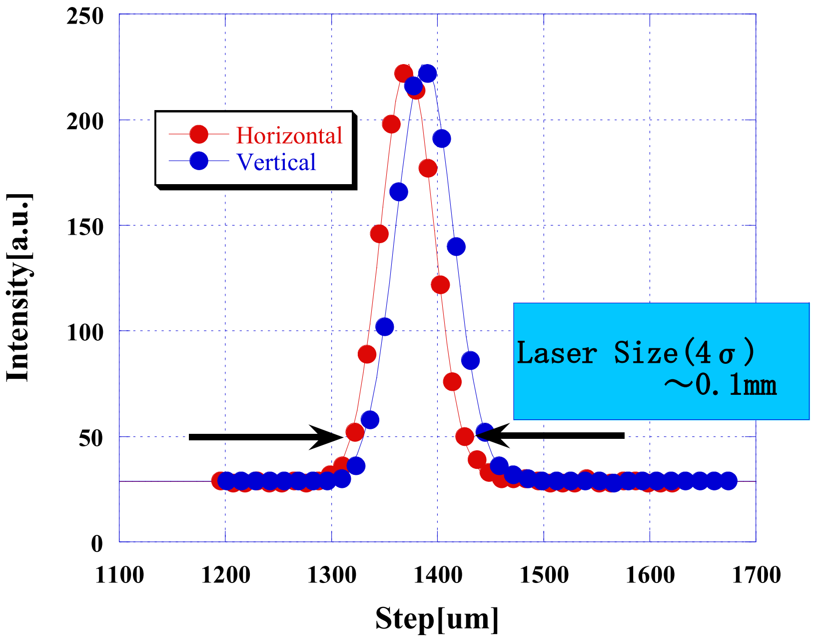
<u>Dark-Lifetime measurement</u>

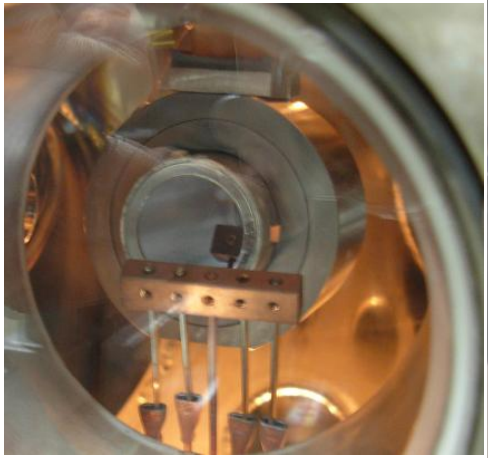
Pbase: 2.3x10$^{-9}$Pa, Vbias: -200kV, Idarkt: <1nA

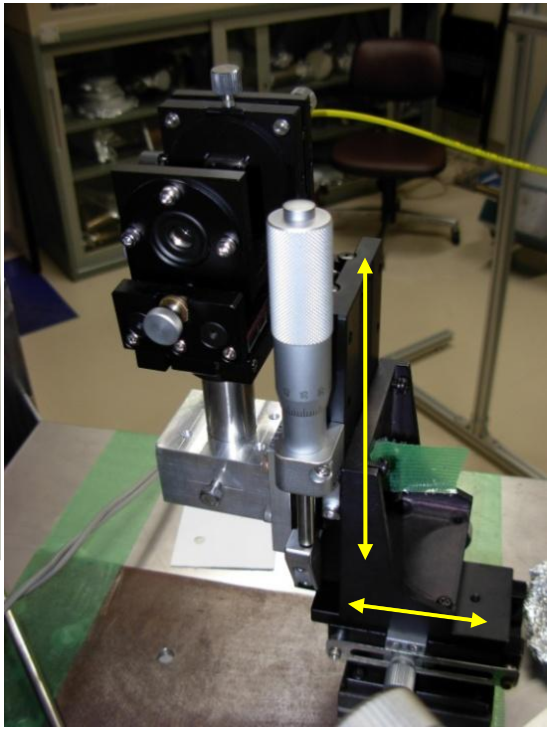
<u>Operational-Lifetime measurement</u>

Laser dia. $\phi$1mm, I=50$\mu$A, Beam transport efficiency >96%

# 2D-Q.E. Mapping for damage study

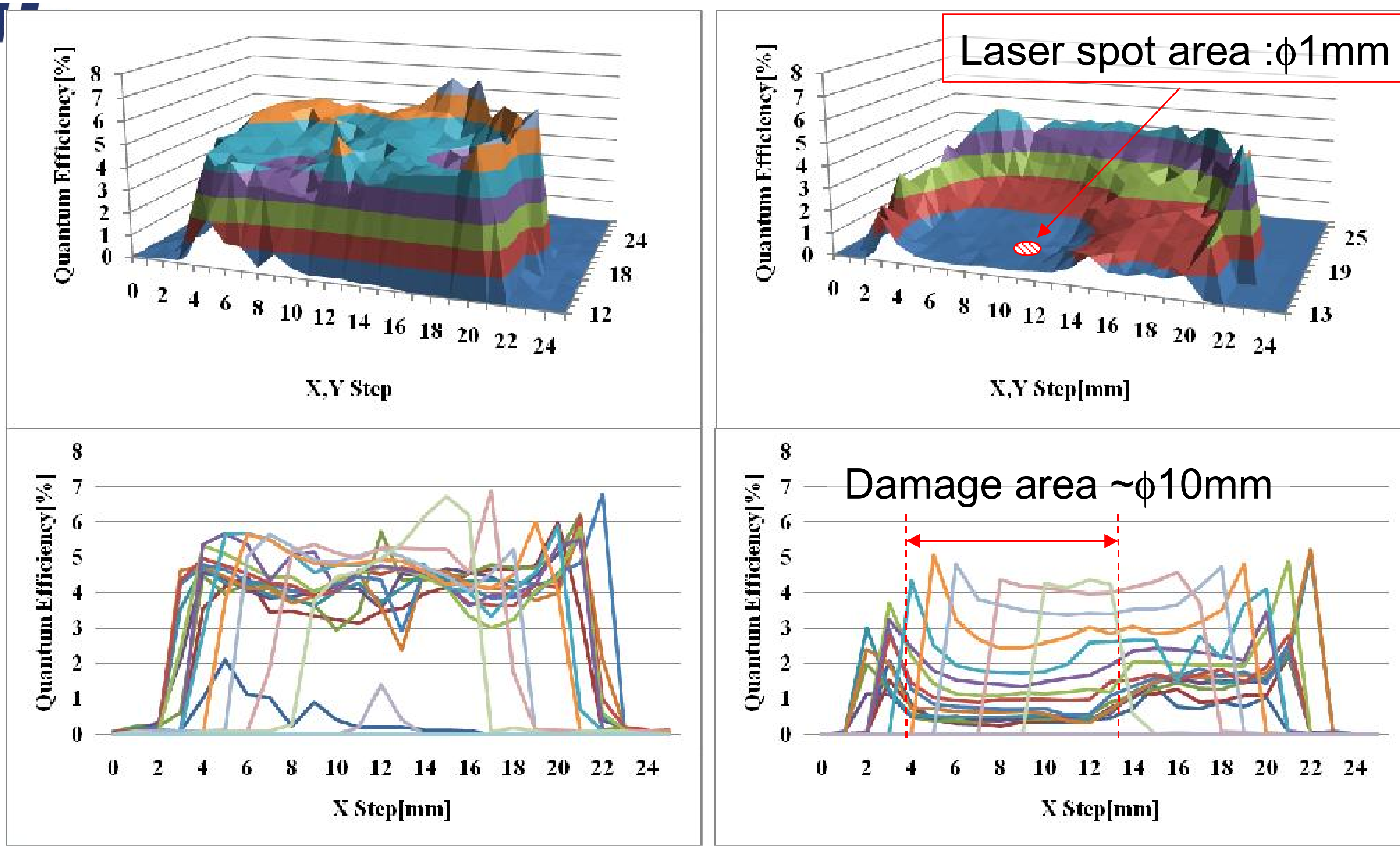




- ▶ Laser diameter is 0.1mm @PC. The 2D QE scan was done by 1mm step.
- ▶ Laser power was controlled to be ~100nA photocurrent emission to minimize QE decreasing.

# Result of 2D-QE measurement

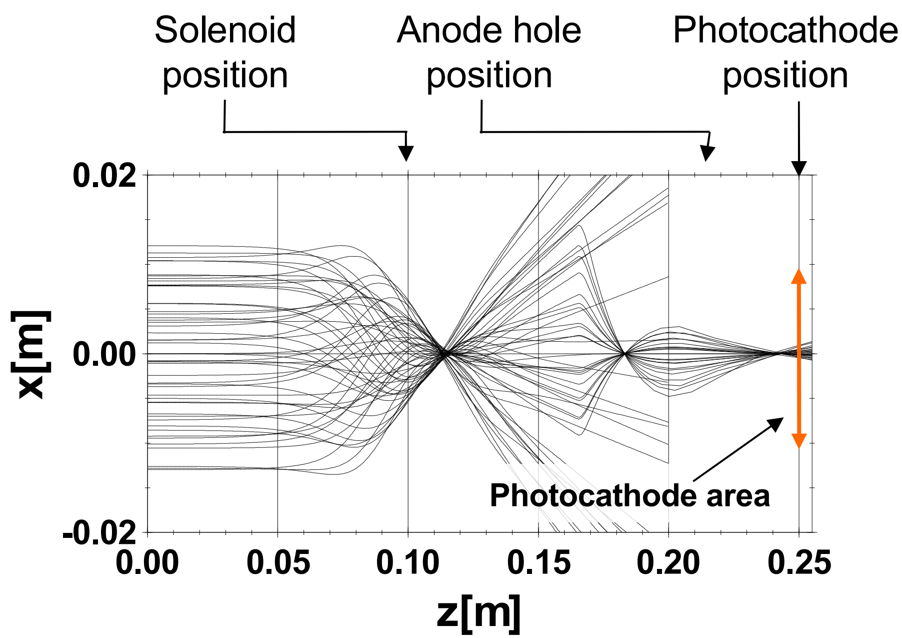



Before operation
(immediately after NEA act.)

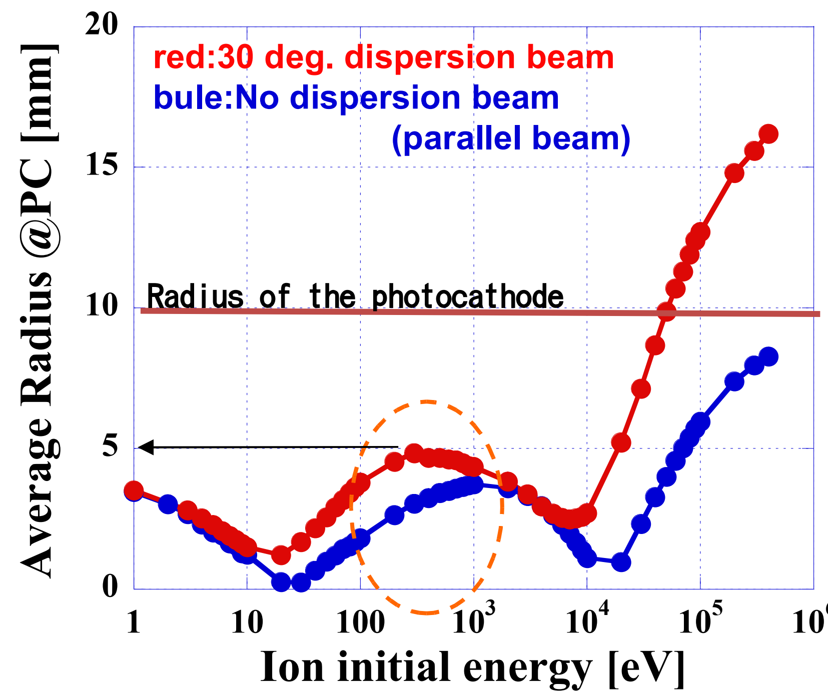
After 50 μA operation

Damage area is larger than the laser spot area. The damage is not caused by ion generated between the electrode gap.

# Backward ion from the transport line




GPT simulation: Ion (proton) beam trajectories to the photocathode. (parallel beam with 10eV beam energy)

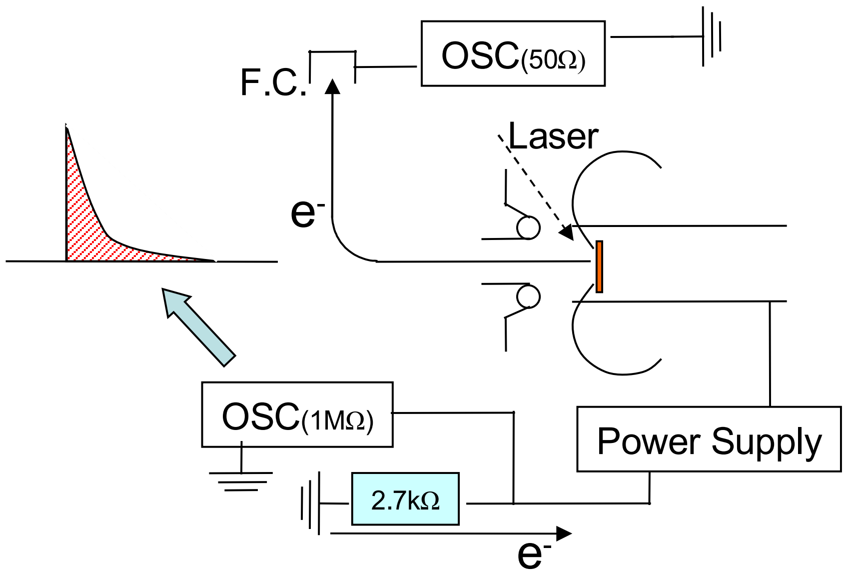


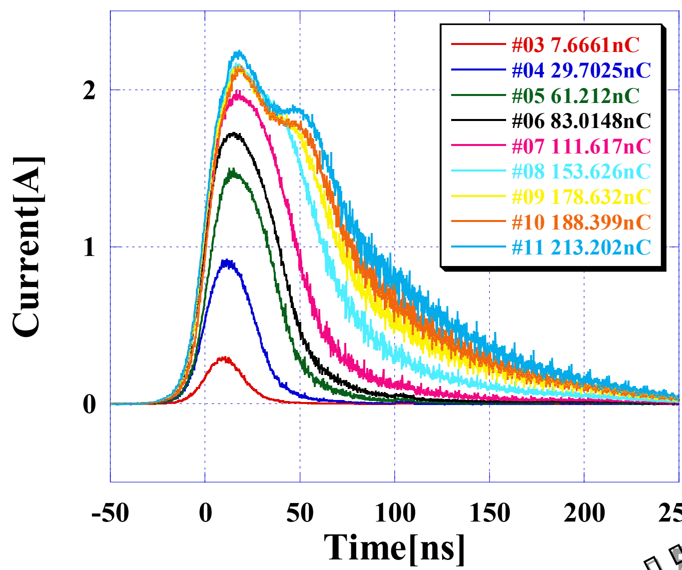
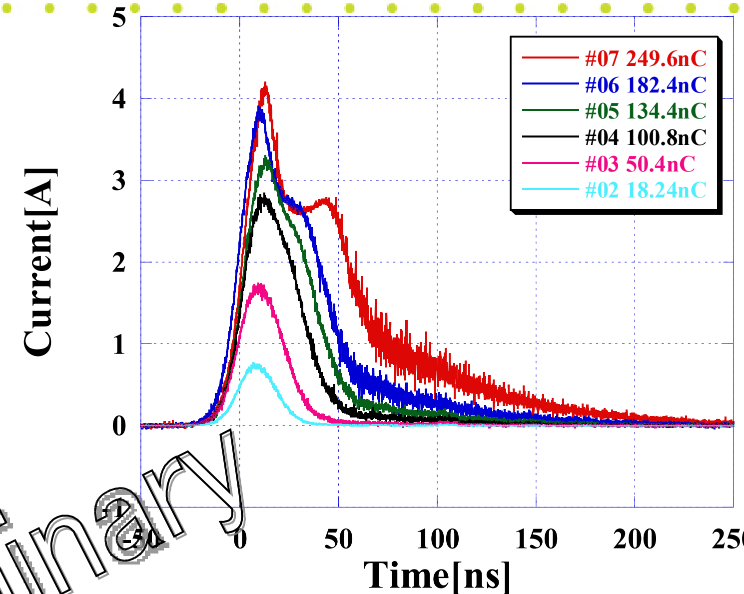
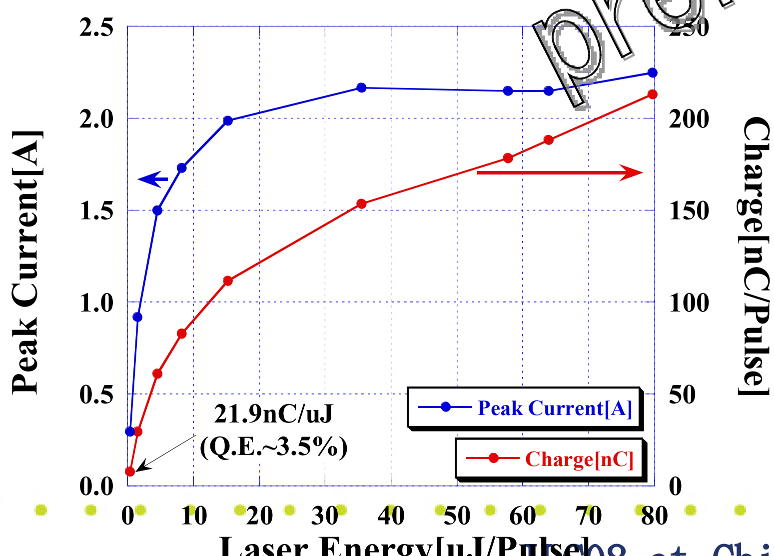
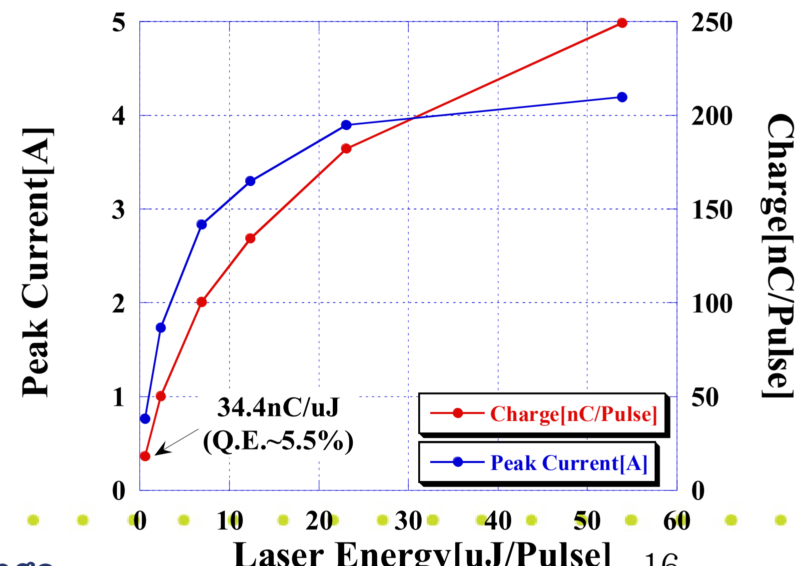

The main energy of the ion that generated by 100keV electron beam collision to the wall is several tens ~ hundreds eV.

The damage area is consistent to the ion spot from the transmission line.
QE damage can be cured by reducing beam loss in the transport.

# Nano-second high bunch charge

- Purpose: Demonstrate the high peak current (space charge limited) of the 200kV gun ~20A.
- Cathode: ϕ23mm, Bulk-GaAs (Zn dope density: $3.2 \times 10^{19}$ /cm$^3$)
- Laser: Spot size: ϕ13mm, Wavelength：780nm, Pulse width: 20ns (FWHM), Pulse repetition：10Hz.
- Bunch charge was measured by 2.7k Ohm resistor.
- Bunch shape was measured by Faraday cup.



| | QE~3.5% | QE~5.5% |
|---|---|---|
| $e^-$ beam shape |  |  |
| Peak current & Total charge |  |  |



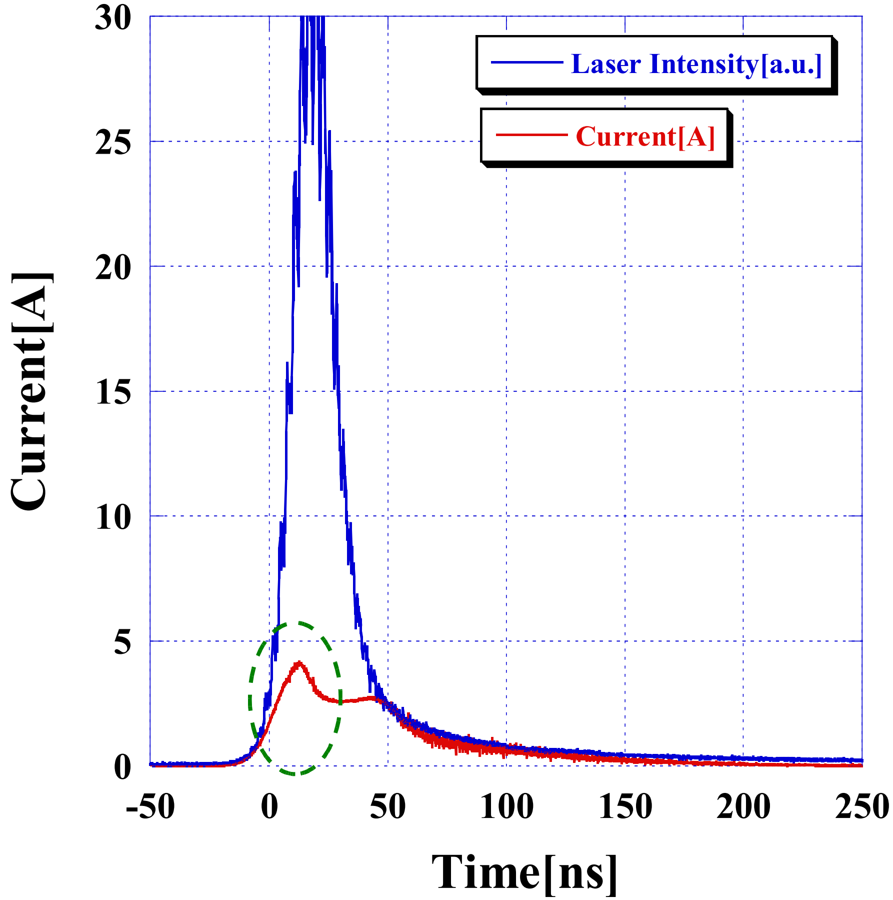






preliminary

# Ns bunch charge summary




- A clear suppression on the emission current by photo-voltage effect (surface charge limit) on bulk-GaAs is observed.
- Space charge limit will be studied with the super-lattice cathode with high Zn doping.

# Summary

- High voltage conditioning of the Mo-Ti electrodes resulted stable 200kV operation.
- Dark- and 50μA operational Lifetime were measured: $\tau_{dark}$ >200hr, $\tau_{50\mu A}$ ~120hr. It can be improved by a better beam transport.
- The space charge limit was not detected by bulk-GaAs. The measurement will be made with the super-lattice cathode.

# Future prospects

- R&D for 500kV gun for Compact ERL (ERL prototype) has been started as a collaboration of KEK, JAEA, Nagoya, Tokyo, and Hiroshima.
- ERL injector is also NEA-GaAs based photo-gun, but with tougher conditions: 100mA average current, super-low emittance, etc.
- It is a reasonable thought, that we continue this R&D as a common effort; ILC gun is based on the latest technology available at that moment.