

Preparation of Cs-Te Photo- cathodes at KEK

Nobuhiro Terunuma

KEK

*Workshop on High QE Photocathodes for RF Guns,
INFN, Milan, Italy 10/4-6/2006*

RF Guns at KEK

ATF (Cs-Te)

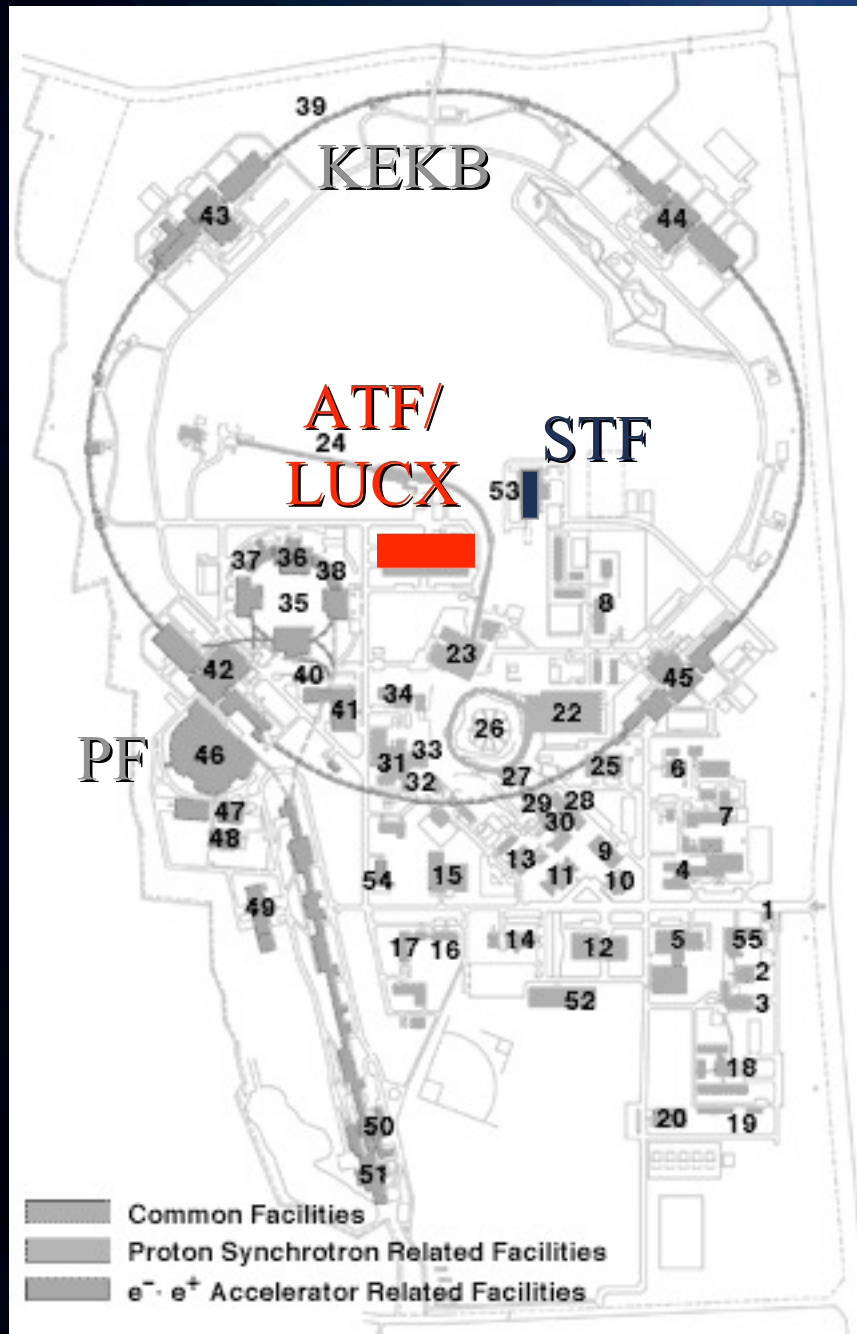
S-band, Modified BNL-IV
 $\sim 2 \times 10^{10}$ electrons/bunch
1~20 bunches/pulse

LUCX (Cs-Te)

S-band, Modified BNL-IV
 $\sim 2 \times 10^{10}$ electrons/bunch
100 bunches/pulse

STF

Planning..., L-band, Cs-Te?

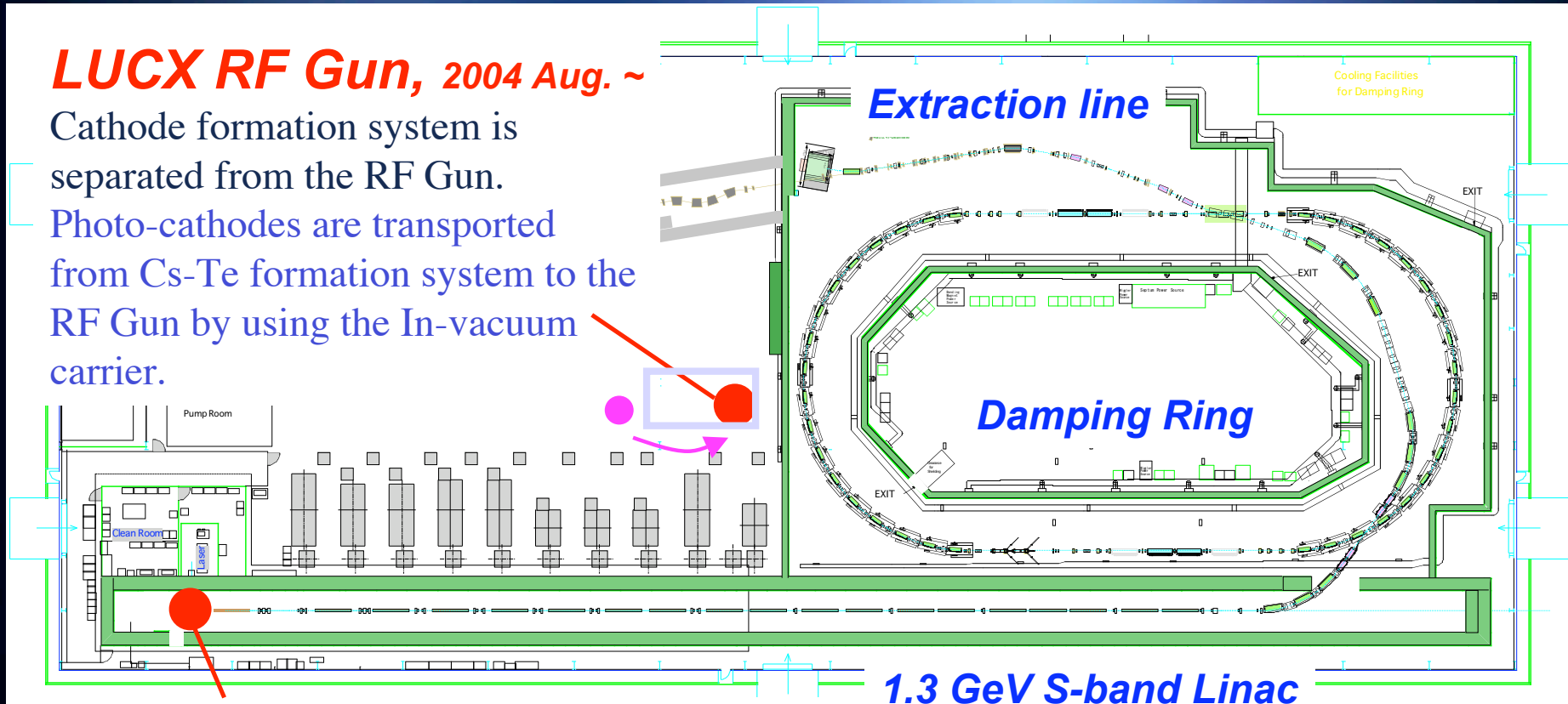


Photocathode RF Guns at ATF

LUCX RF Gun, 2004 Aug. ~

Cathode formation system is separated from the RF Gun.

Photo-cathodes are transported from Cs-Te formation system to the RF Gun by using the In-vacuum carrier.



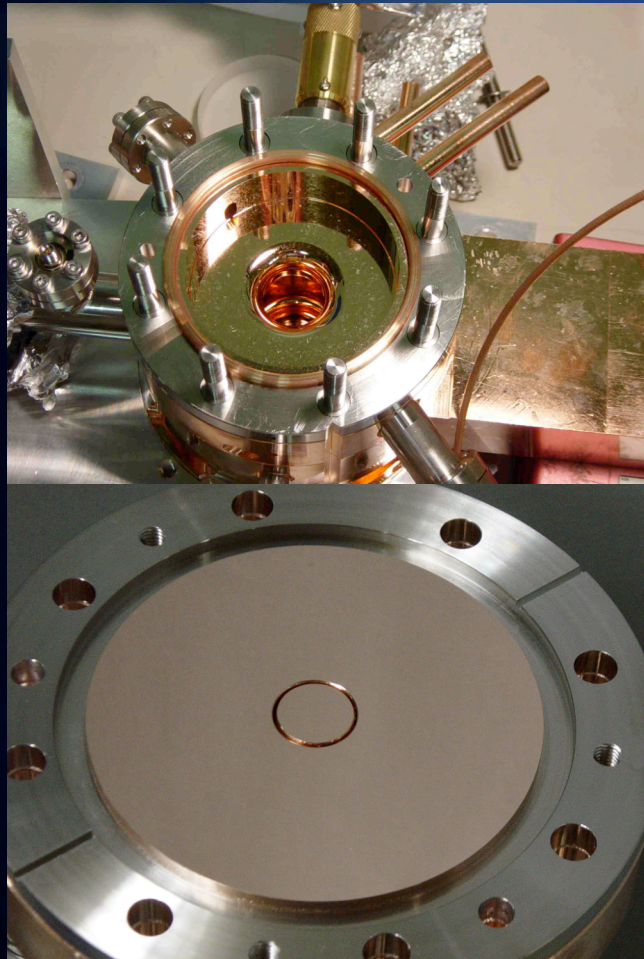
ATF RF Gun, 2002 Sep.~

Cs-Te formation system is a part of the RF Gun vacuum system.

Photocathode is transported through the vacuum pipes by using the coupling rods.

RF Gun for Cs-Te photocathode

Modified BNL type IV: 1.6 cell, 2856 MHz



Cathode Guide

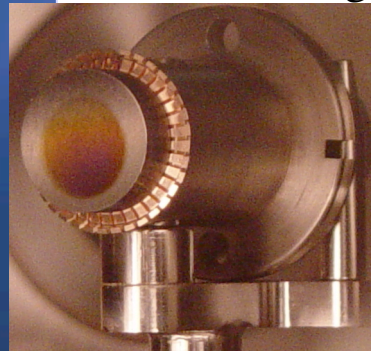
Cathode Plug

End plate

Beam

Laser
266nm

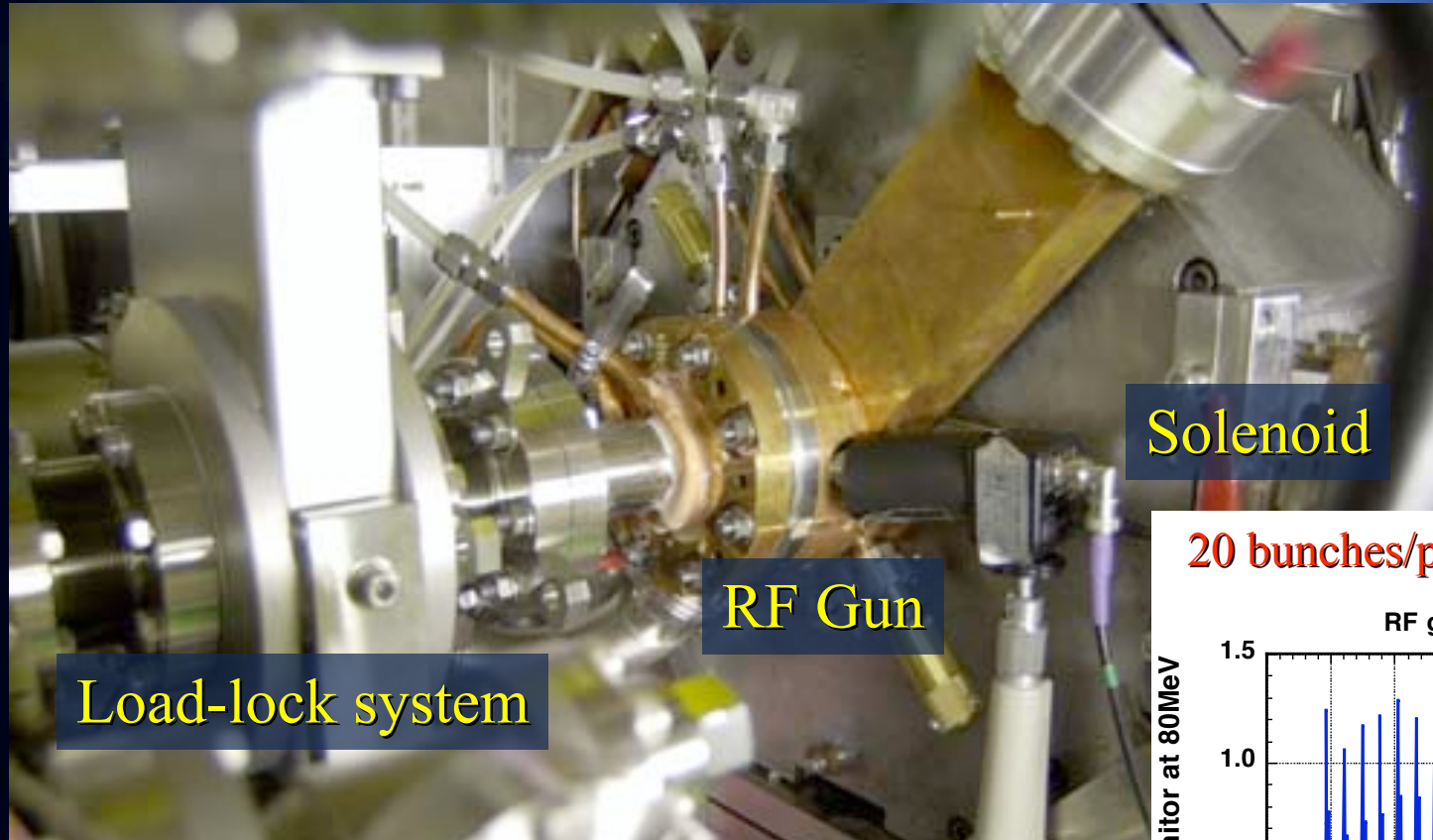
50mm



CERN-style contactor
between the plug and the
end plate of cavity

Cavity was fabricated by KEK with the ultra-fine diamond turning developed for X-band accelerating structure.

ATF RF Gun

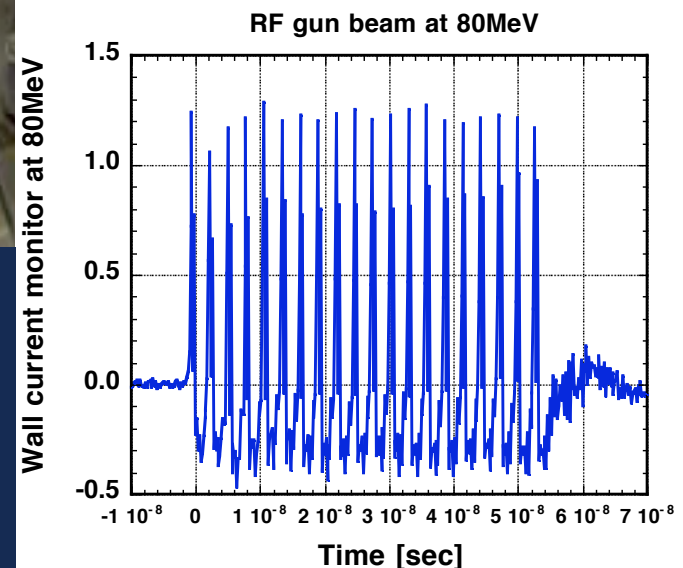


Load-lock system

Solenoid

RF Gun

20 bunches/pulse, 2.8ns Spacing

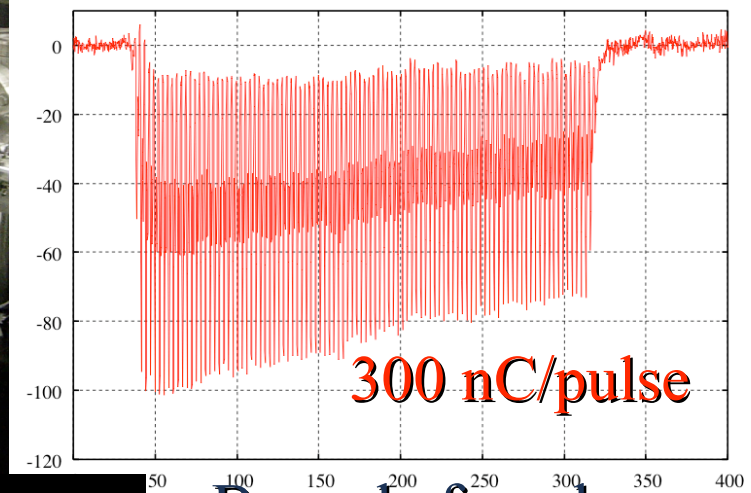
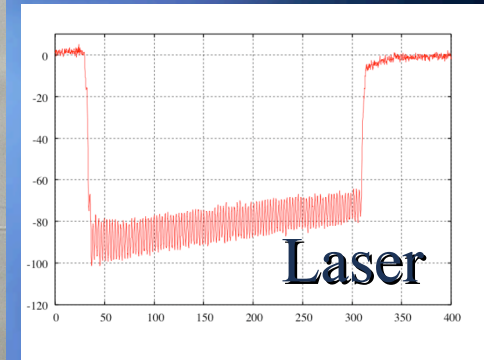
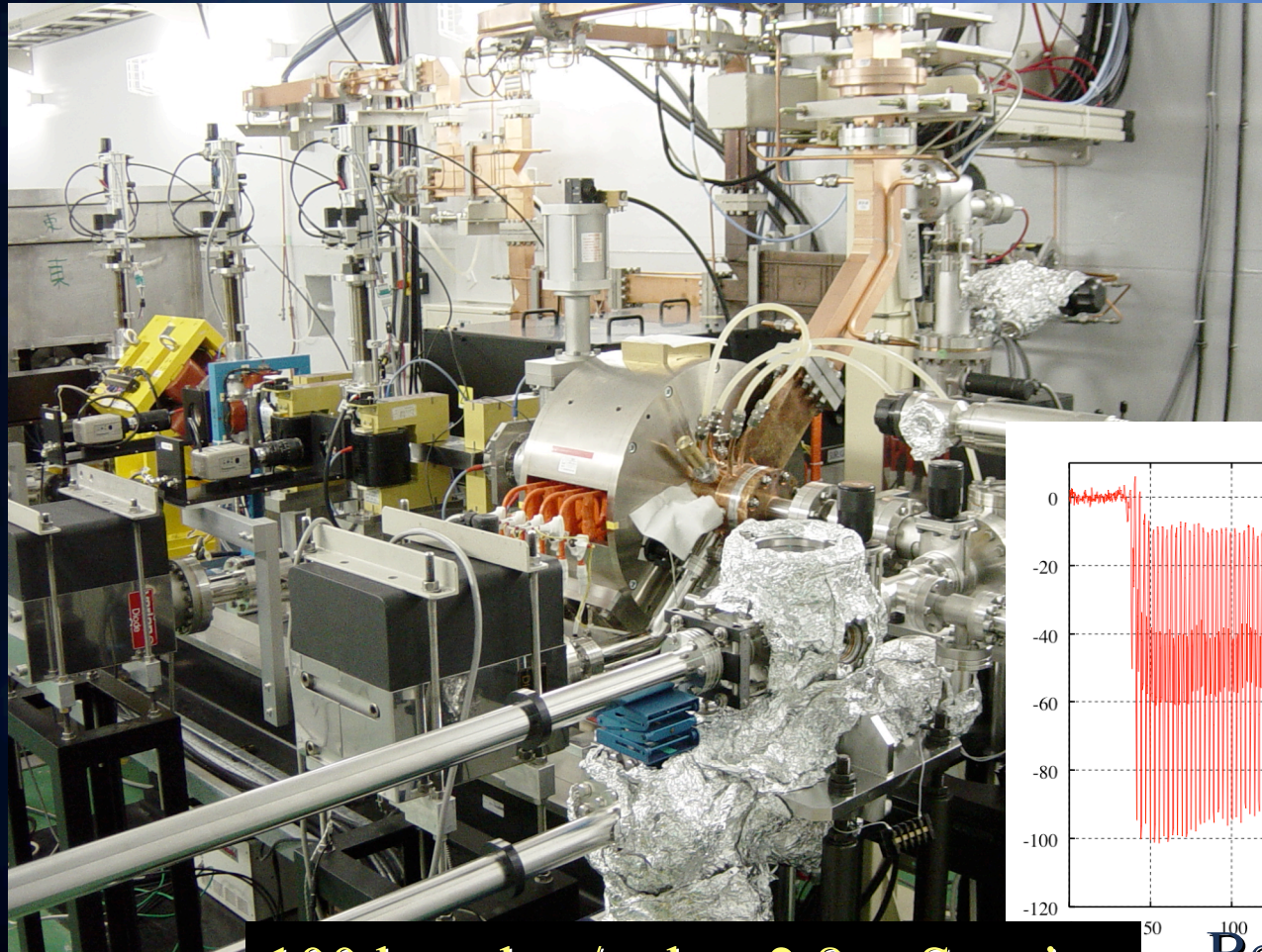


*High quality Multi-bunch beam
is generated.*

1 ~ 20 bunches/pulse, 2.8ns spacing

$\sim 2 \times 10^{10}$ electrons/bunch

RF Gun Test Bench (RFGTB->LUCX)



100 bunches/pulse, 2.8ns Spacing

Beam before dump

History of RF Guns in KEK

- 2001 Sep Checked the possibility of e- source by using the used RF Gun with Cu cathode.
- 2002 Spring Design the Cs-Te system
Fabricate the RF Gun in KEK machine shop
- 2002 Sep Installation of RF Gun and Cs-Te cathode on Cu.
- 2002 Oct Decided to keep the RF Gun for ATF operation.
- 2002 Nov Changed to the Mo substrate
- 2003 Jan Laser, Head-on injection
- 2004 Aug Fabricate the RFGTB system
Start the 100 bunch/pulse generation at RFGTB
- 2006 Aug RFGTB upgrade -> LUCX
- 2006 Oct Fabricate new Cs-Te RF gun for Waseda Univ.

Requirement for the ATF RF-gun system

Improve the beam quality by changing the thermionic gun to the RF gun. RF gun should be fit the space for the bunching system.

Multi-bunch electron beam for ATF

1~20 bunches/pulse, 2.8 ns spacing (357 MHz)

1×10^{10} electrons/bunch (nominal), 3×10^{10} (max.)

ATF laser system prepared for RF Gun

1~20 bunches/pulse; 266 nm, 357MHz

1 uJ/bunch in 2002, Now ~3 uJ/bunch(typical)

$1 \times 10^{10} e^- \sim 1\%(Q.E.) \times 1 \mu J(Laser)$

Higher QE photocathode ~1% --> Cs-Te

ATF cathode system behind the RF-Gun

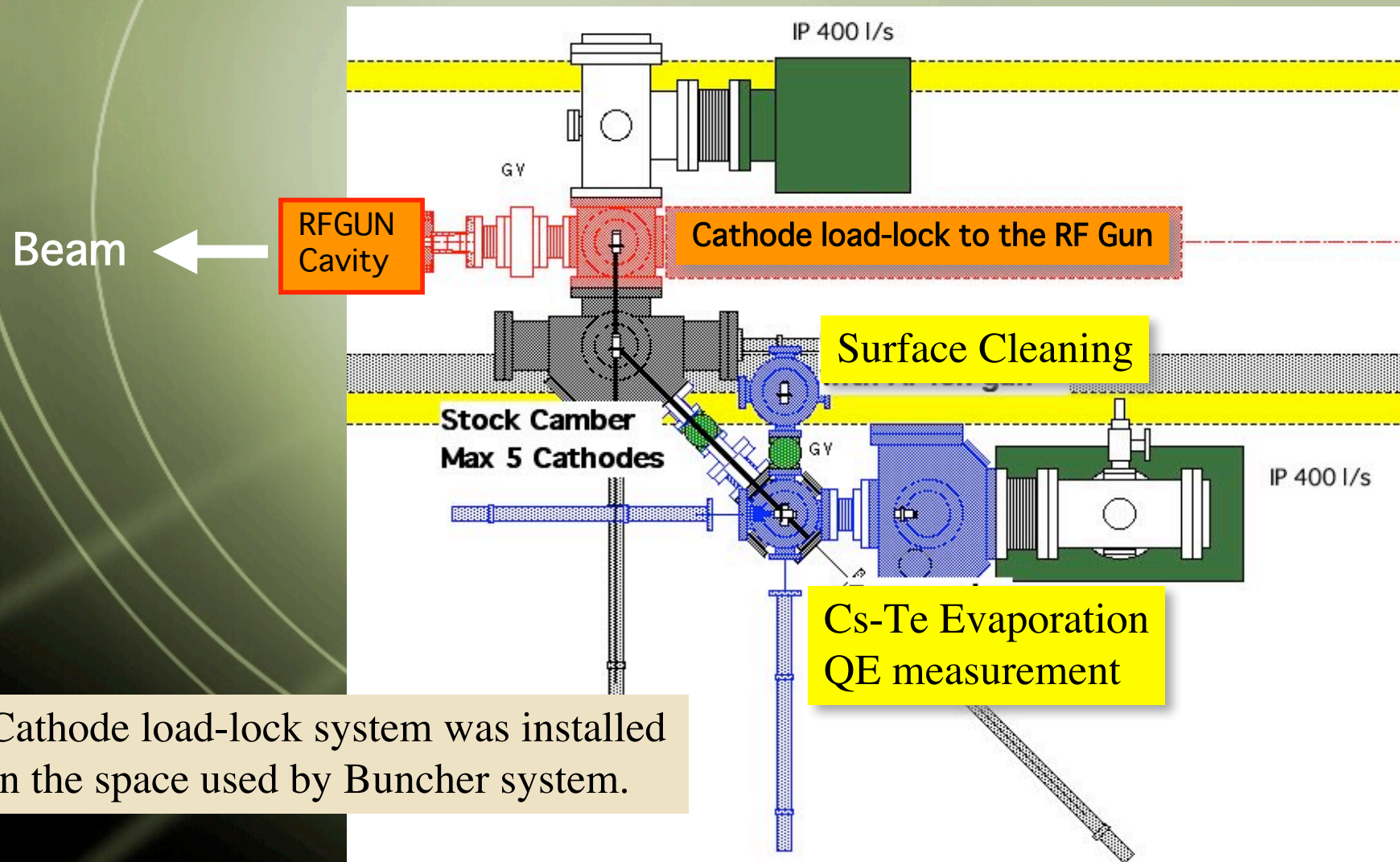
Advantages

- No vacuum works during the transportation.
Minimize the possibility of Oxidation for QE.
- Quick transport between the preparation device and the RF gun.
- Can measure the QE with a same system for preparation.
without the RF, Shottkey effect
- Can increase the QE by adding Cs quickly.

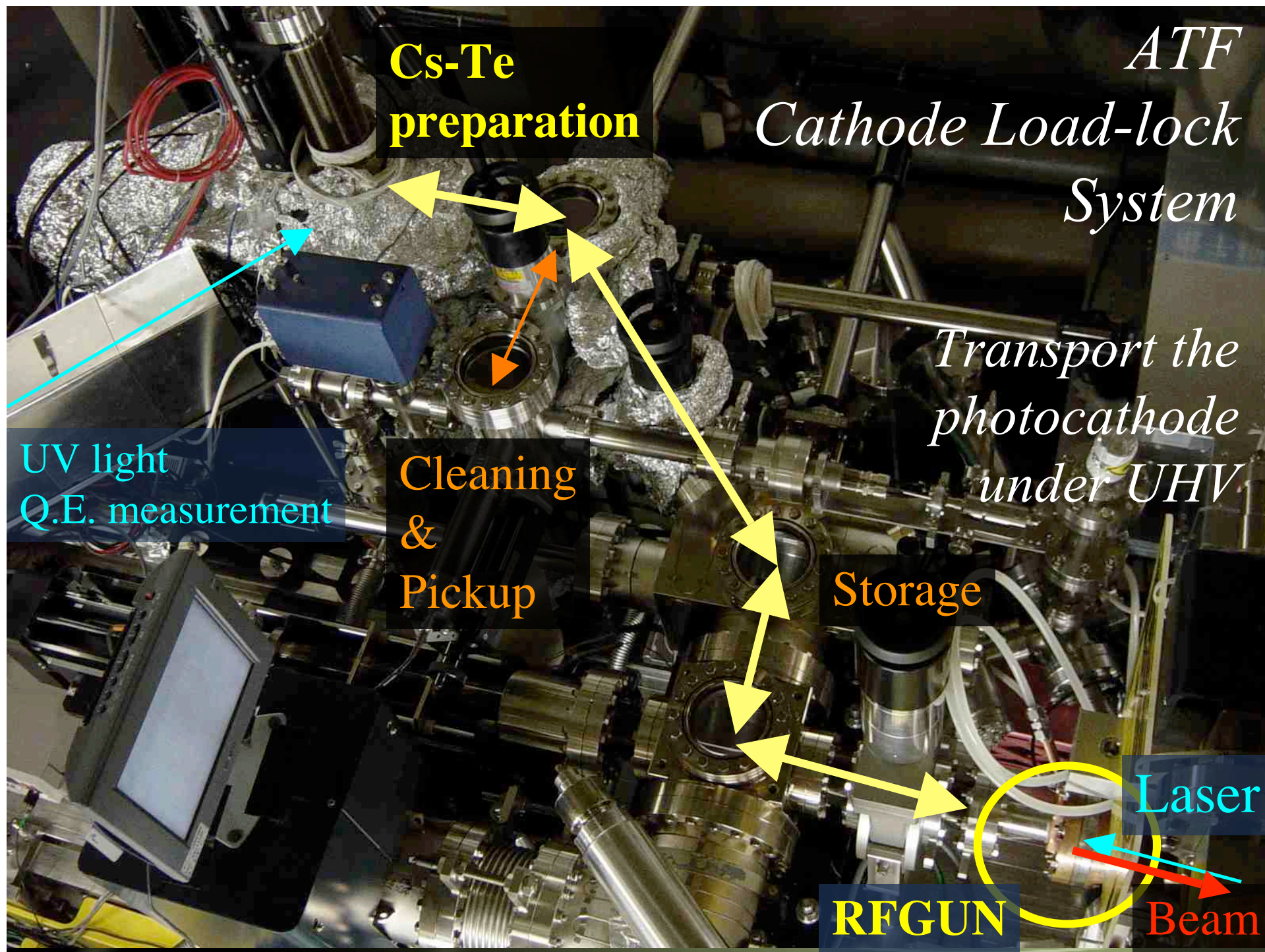
Disadvantages

- No R&D work during the ATF operation.
Use RFGTB/LUCX system for R&D.

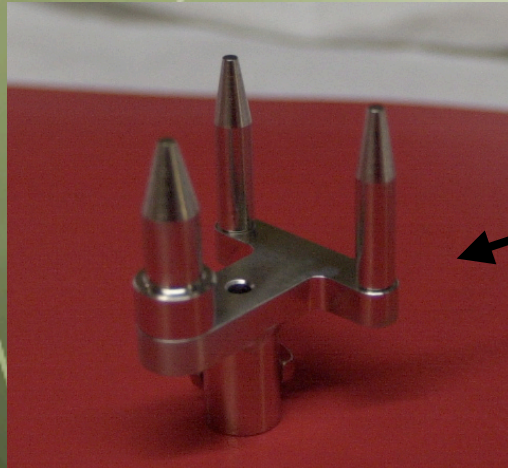
ATF Cathode Load-lock System



Cathode load-lock system was installed in the space used by Buncher system.

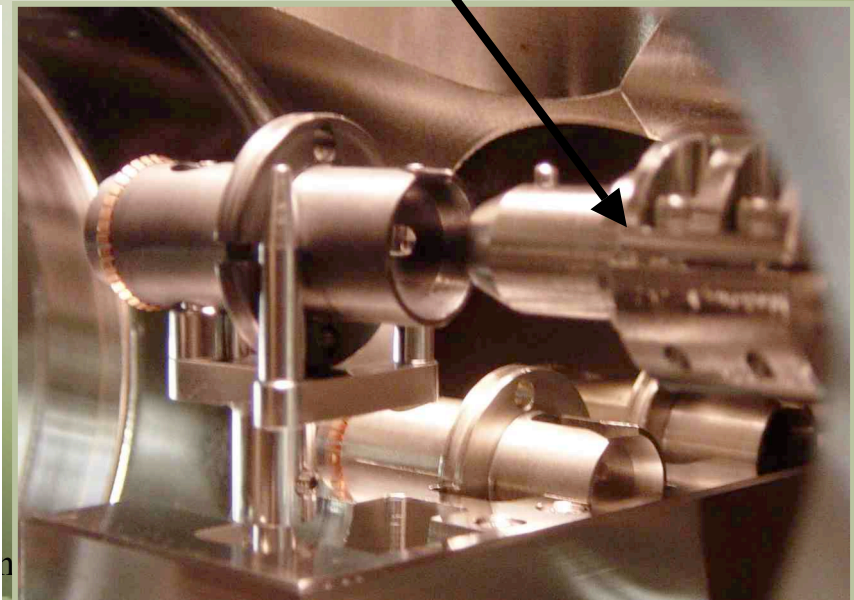
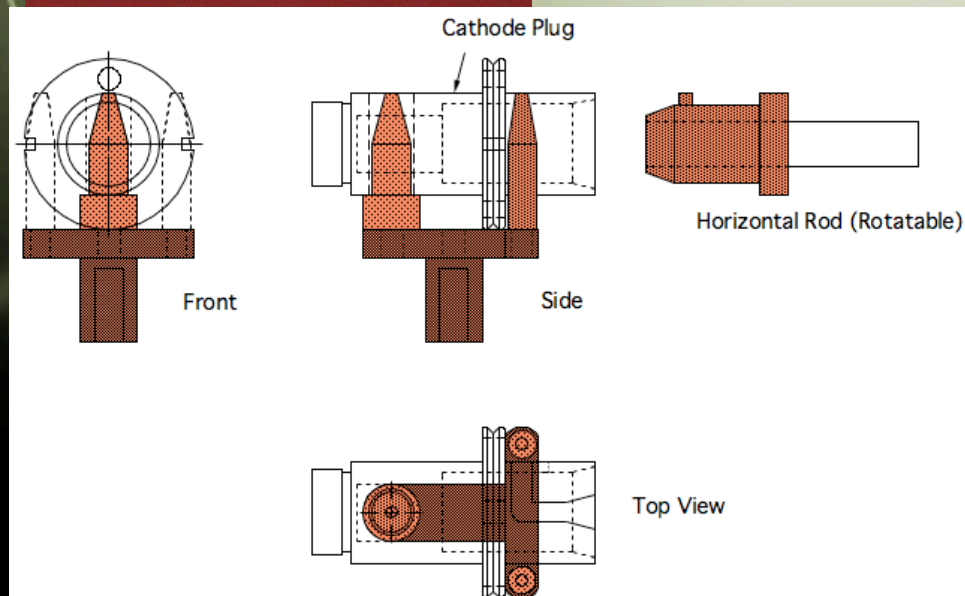


Transportation of plugs in the ATF photocathode system



Plug mount for vertical rods
Up/down and rotation

Horizontal rod
Rotate to lock the cathode plug



Preparation of the Cs-Te photocathode

Step 1: Surface cleaning of the cathode plug

Argon-ion source is used to cleanup/sputter the surface of new cathode plug. It also used to remove the previous Cs-Te layer on the plug.

Step 2: Te evaporation

Te is coated on the substrate about several nm thickness. Amount of Te is controlled by monitoring the thickness on the sensor located at the equivalent distance.

Step3 : Cs evaporation

Cs dispenser is used to put Cs on/into the Te layer. Amount of Cs is controlled by monitoring the quantum efficiency.

Cathode substrate; Cu or Mo



Cu plugs were used in Sep./Oct. of 2002, during the commissioning of

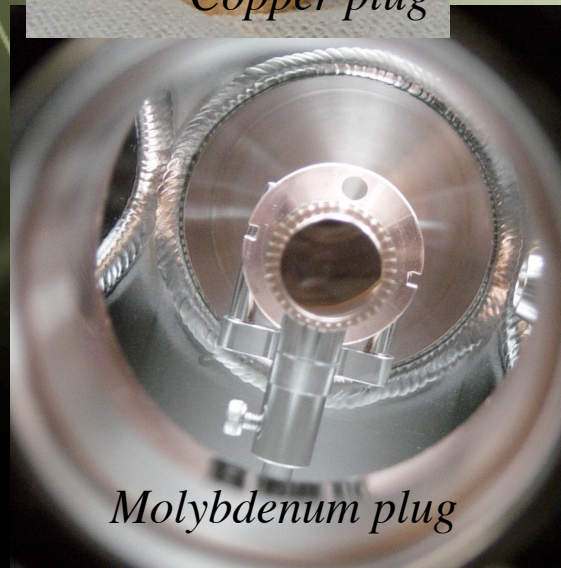
- ATF RF gun,
- photocathode preparation system.

Manufacturer should have an experience of machining the Molybdenum.

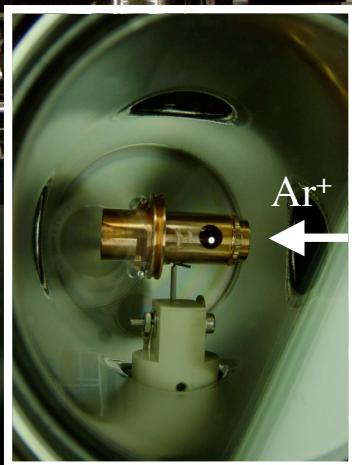
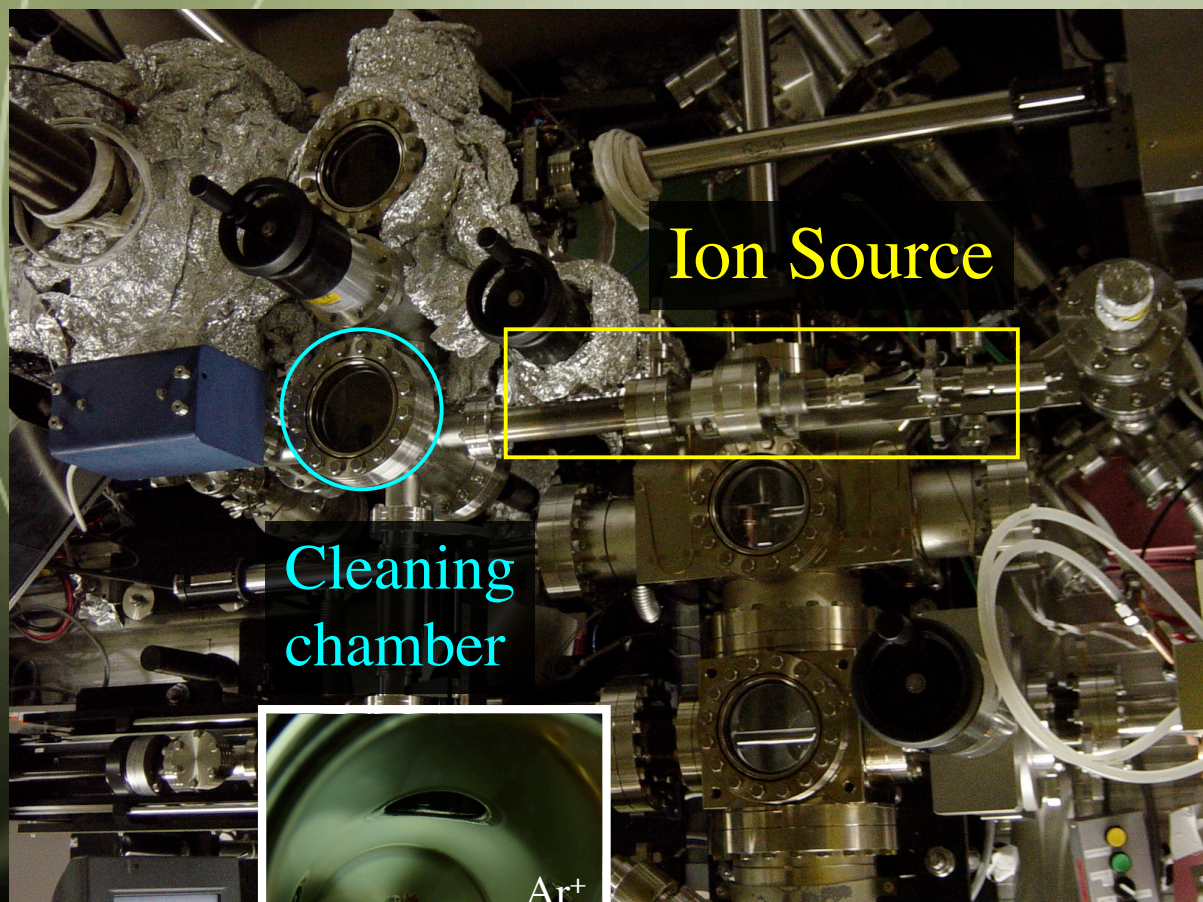
After that,...

Mo plugs are used since Nov. of 2002.

- Surface is polished as mirror.
- Ultrasonic cleaning by Ethanol/Acetone after the machining.
- No other chemical treatment is applied.



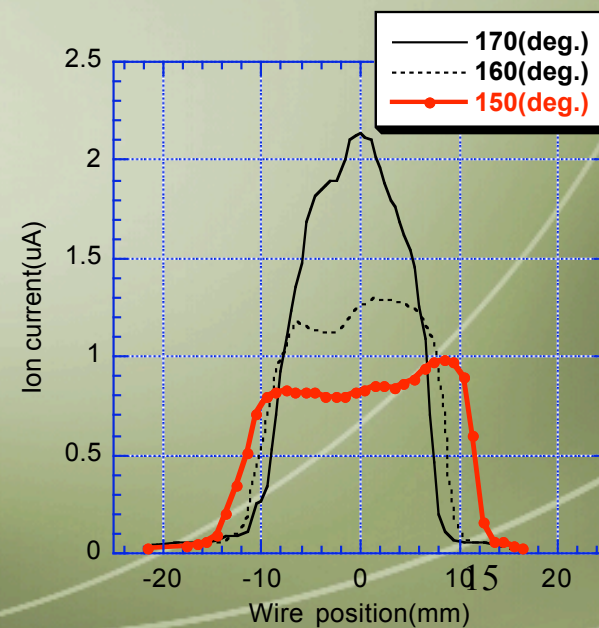
Cleaning of the plug surface



**Ar⁺ ion
bombardment**

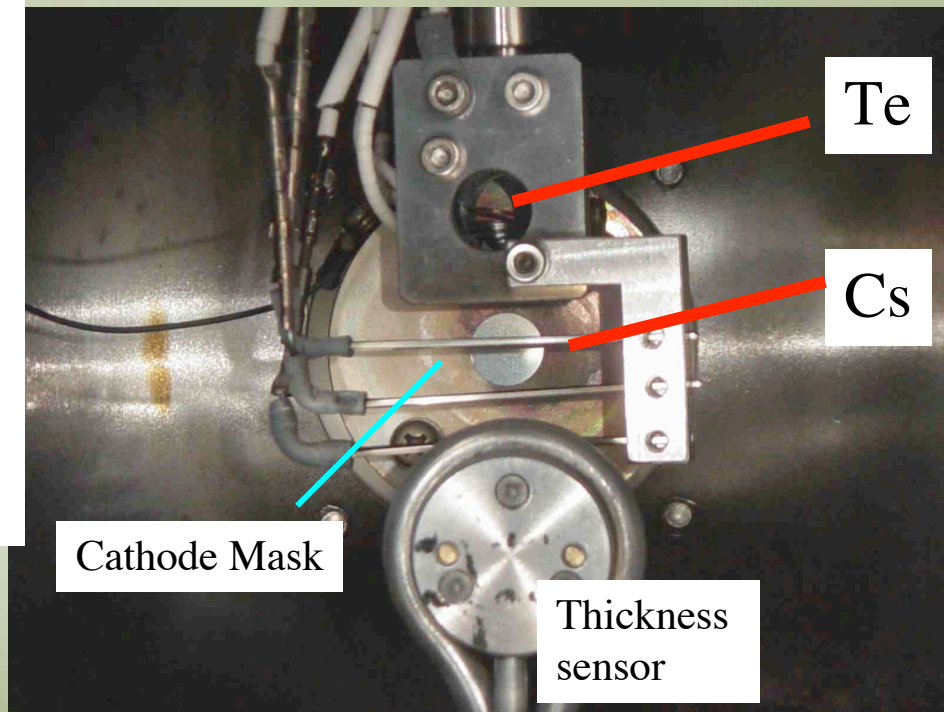
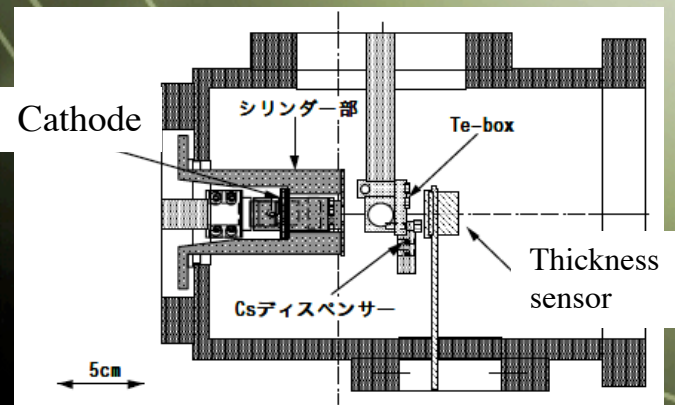
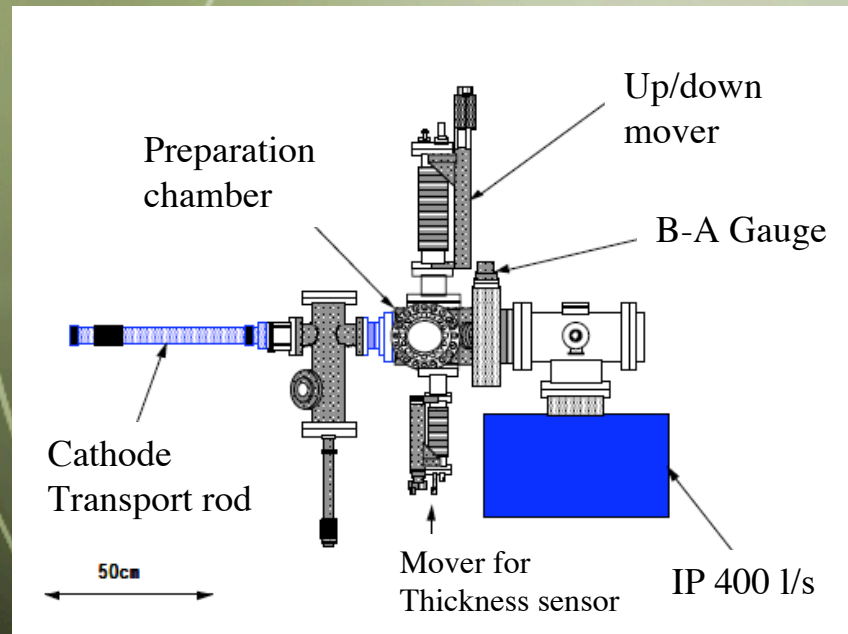
For
New/used cathodes,

Sputter depth ~50nm .



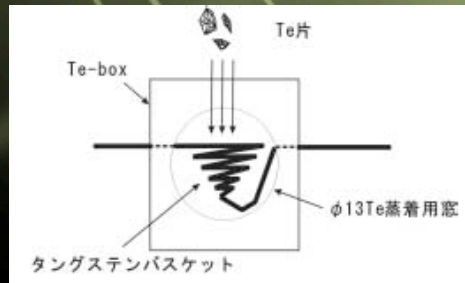
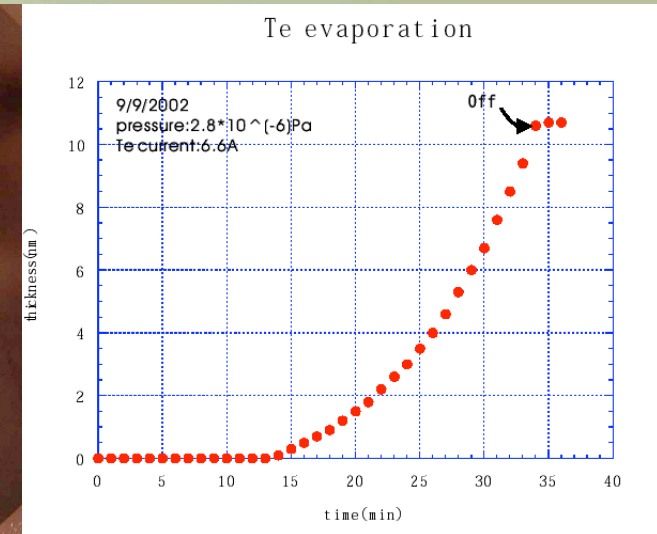
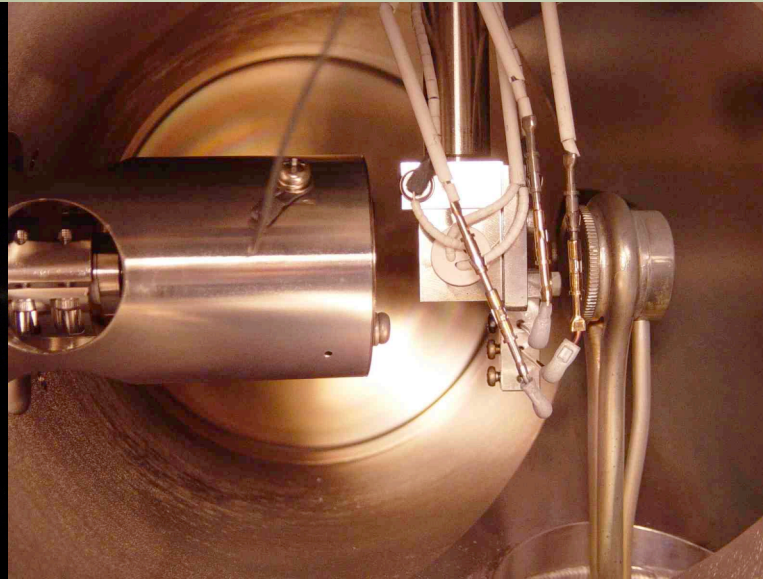
WSHQE, INFN, Milan 10/4-6/2006

Cs-Te sources



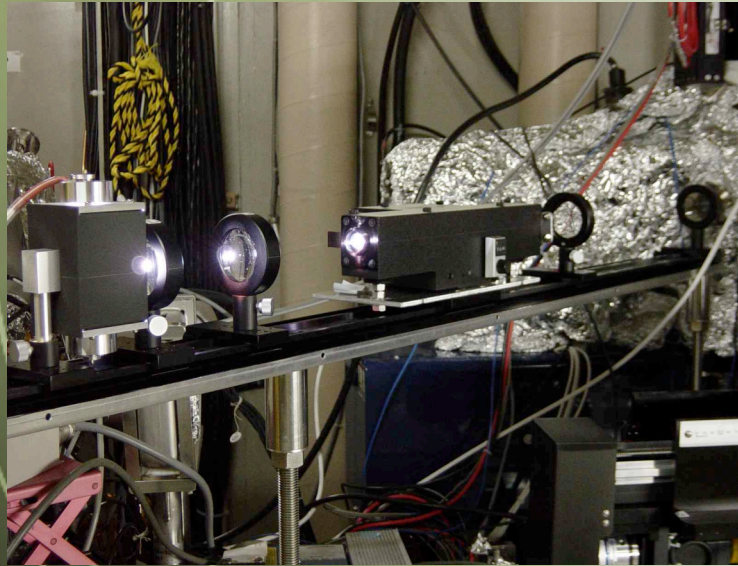
Up/down mover is used to select Te or Cs.
It cyclically moves to get a better uniformity.

Evaporation of Tellurium



Te is heated by a Tungsten filament.
We can control the Te thickness by monitoring the thickness coated on the sensor placed at equivalent distance.

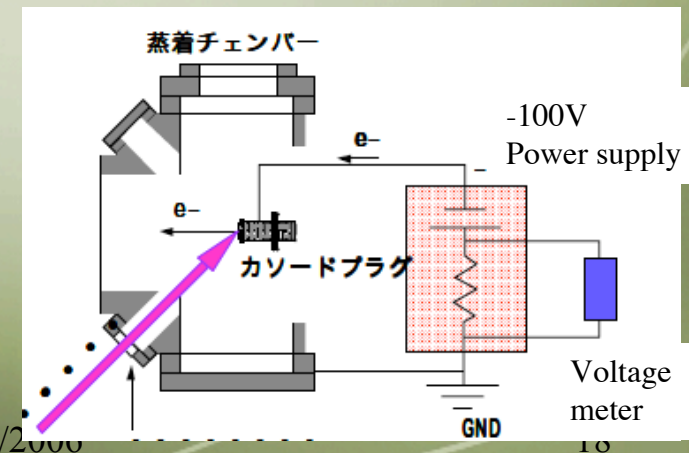
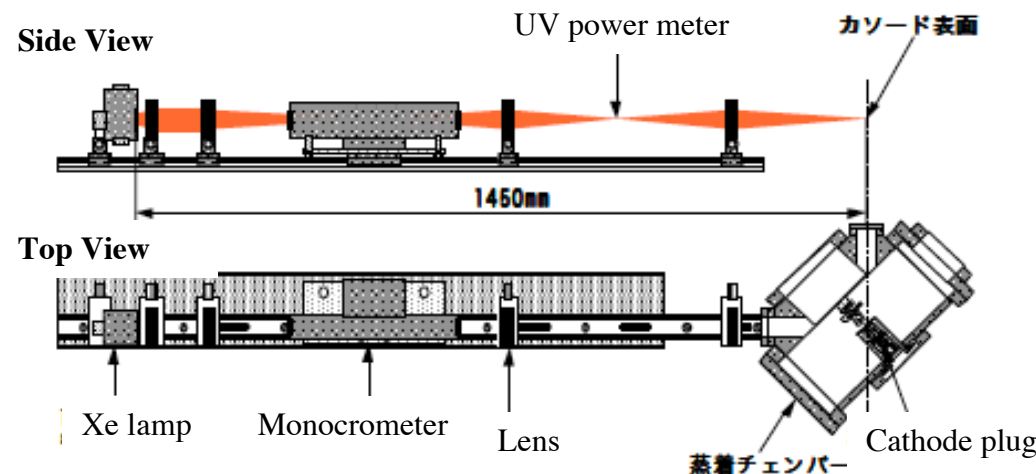
Measurement of $Q.E.$



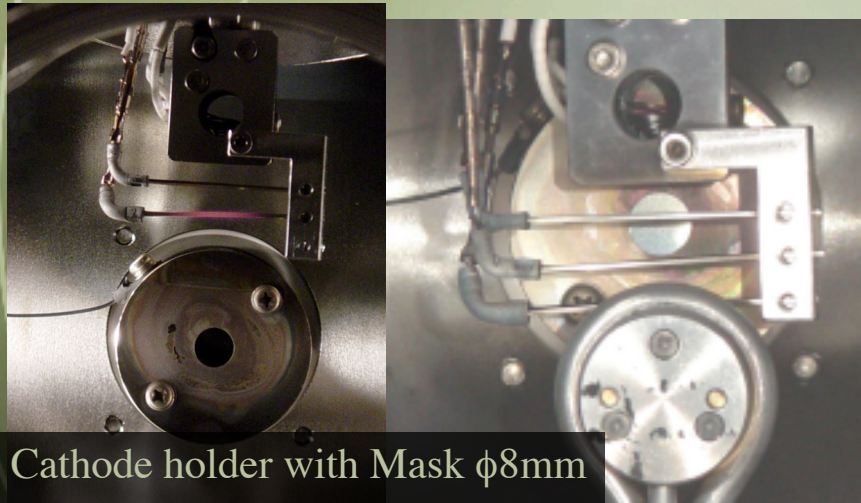
We can measure the QE of photo-cathode at the preparation chamber.

Xe lamp with monochromator selects the UV light $\sim 266\text{nm}$.

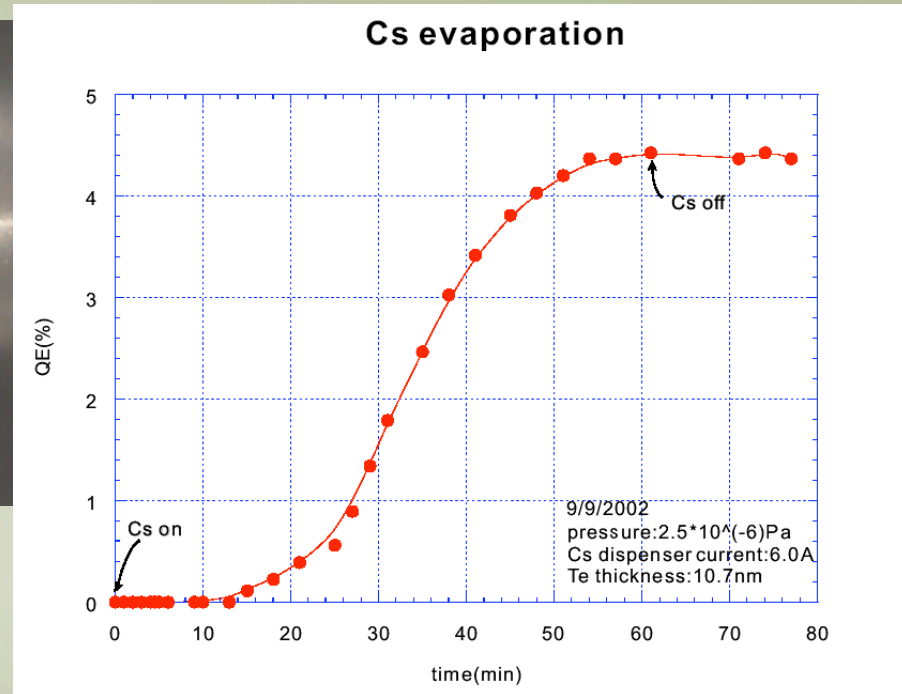
Measure the photo-emission current by monitoring the drop of voltage on the cathode.



Evaporation of Caesium

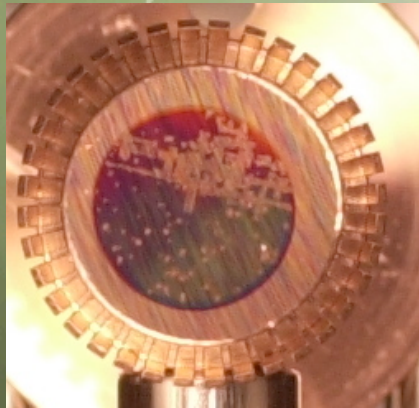


Cs Dispenser by SAES Getters Co.

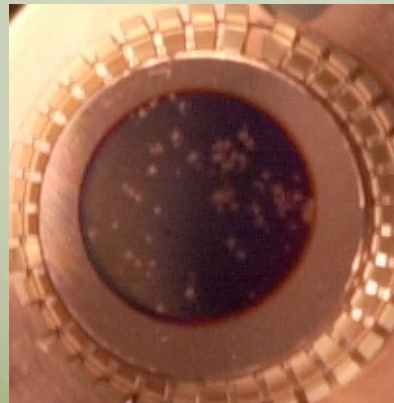


Cs is evaporated on the Te layer .
Amount of Cs is controlled by
monitoring the Q.E. with Xe-lamp
system.

Cu plugs after the Beam Test



Cu#1



Cu#2

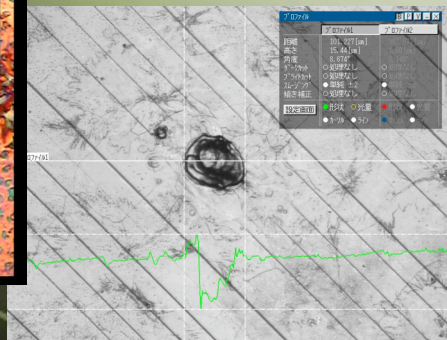
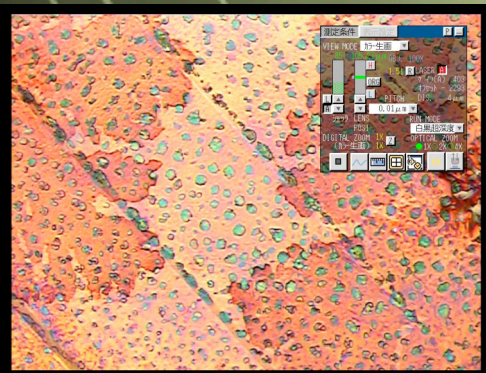
Two cathode plugs were used for Sep./Oct. operation in 2002.

Cu#1 cathode (left):

Used under the RFGun aging and the initial laser tuning.
Many RF breakdowns.

Cu#2 cathode (right)

Used stable laser operation.



Damage by RF breakdowns

Typical spot size

Width 100 μm

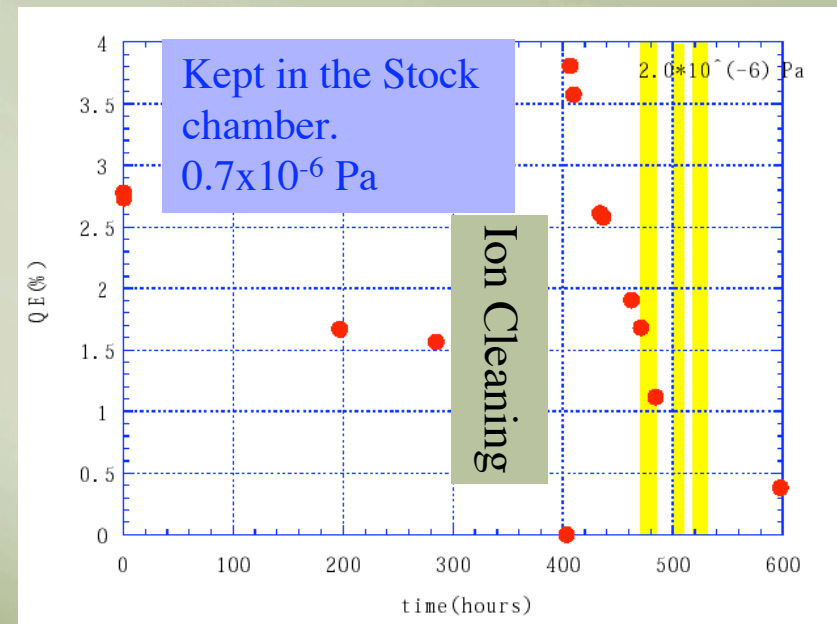
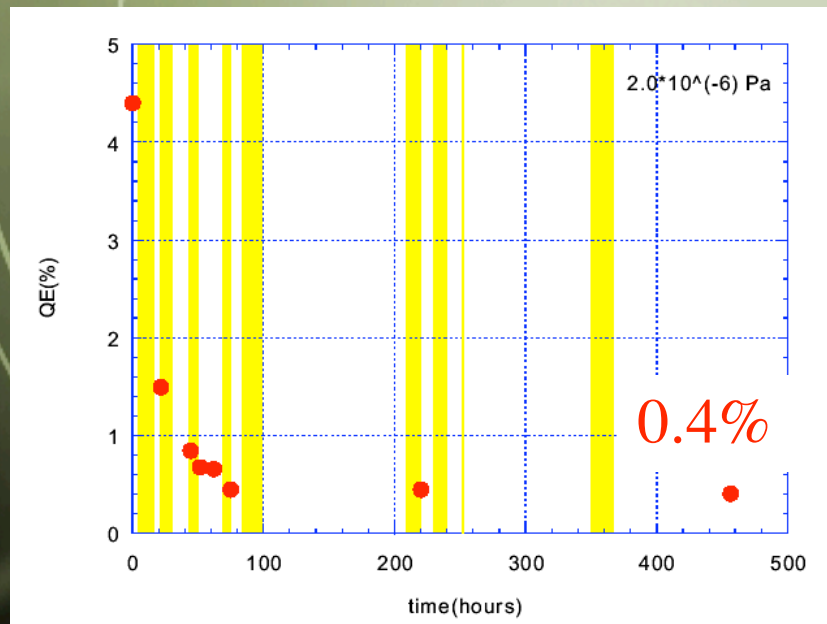
Depth 15 μm

Q.E. of Cs-Te on Cu, with RF

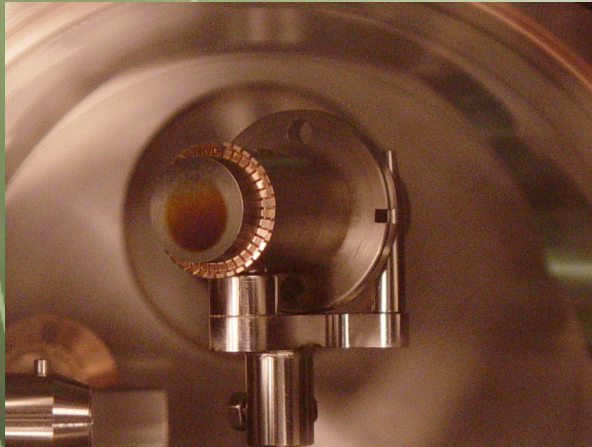
Cu#1, 2002

Yellow area: RF on
 1.3×10^{-6} Pa at RFGUN

Cu#2, 2002

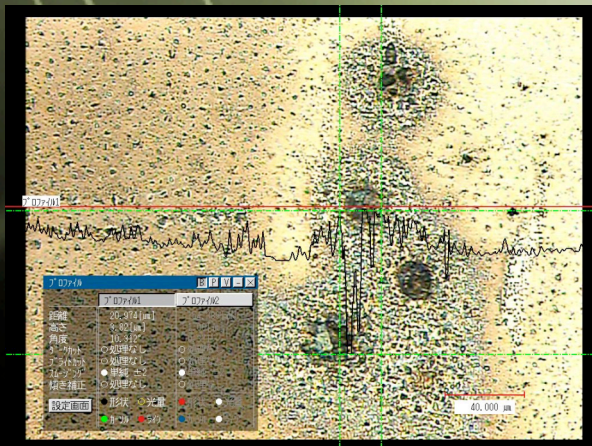


Mo plugs



Two plugs were tested in Nov. 2002. Their surface were polished as mirrors.

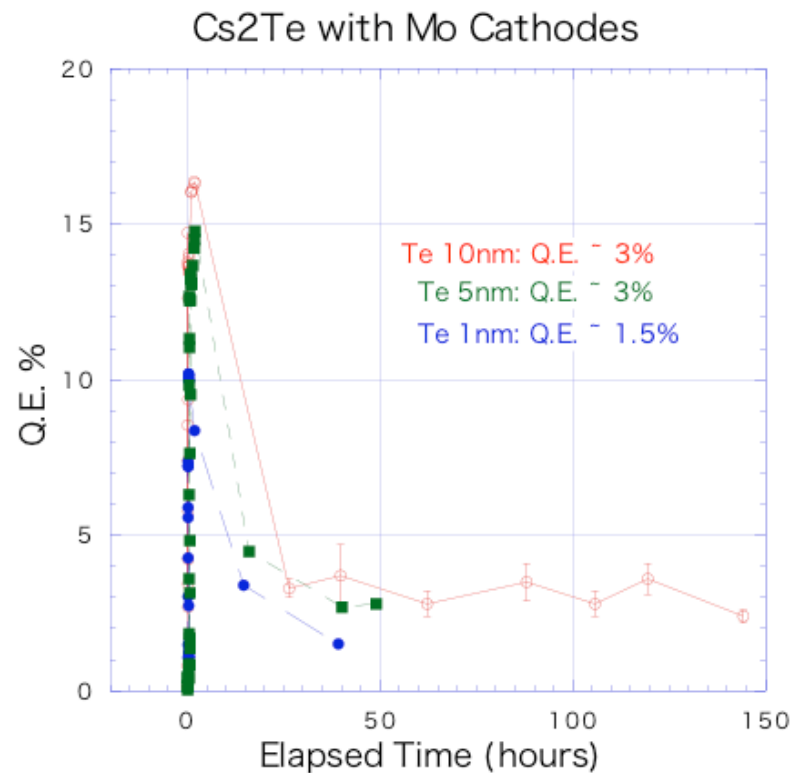
Smaller damages compare to the copper plugs were found after the beam generation.



Typical spot size was
Width 20 μm ,
Depth 4 μm .

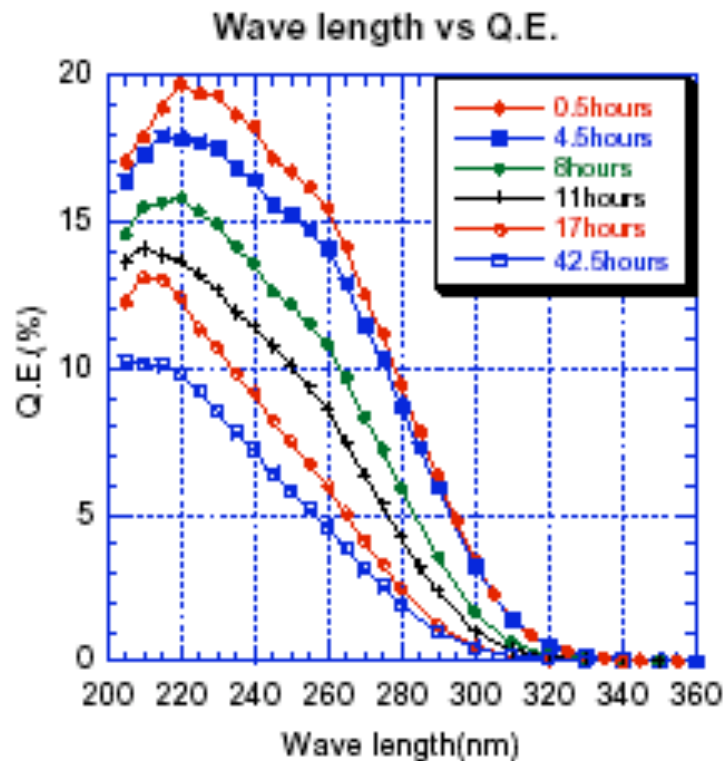
We are using Mo plugs for ATF operation.
No copper plugs were used since 2003.

Q.E. of Cs-Te on Molybdenum



- ⊕ **Q.E. just after the cathode preparation exceeds 15%.**
- ⊕ **Q.E. was dropped quickly under the RF operation.**
- ⊕ **It shows stable Q.E. after the RF operation.**
- ⊕ **Cs-Te photocathode on Molybdenum shows the higher Q.E. (~3%) than that on Copper (~0.4%).**

Wavelength dependency



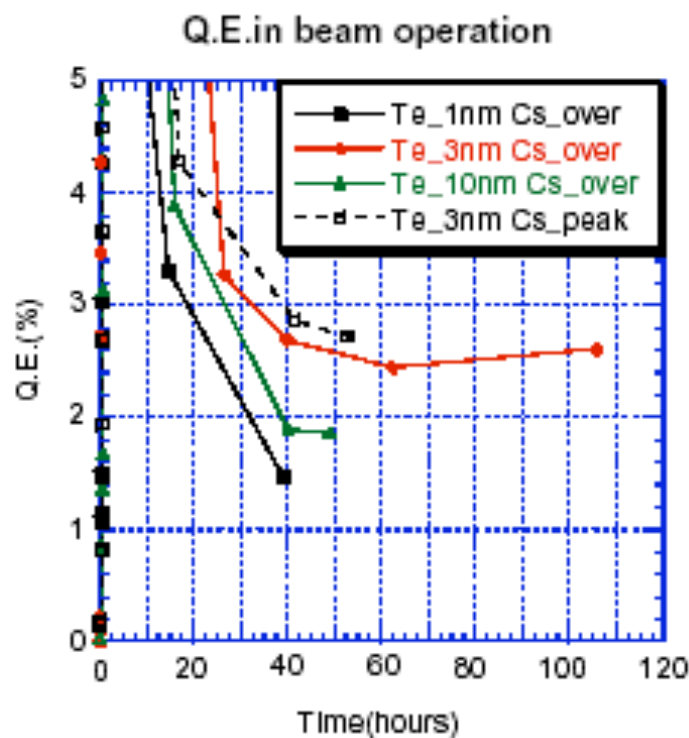
Q.E. dropping was measured at all wavelength.

Peak of Q.E. seems to be shifted to the shorter wave length.

It suggests the electron affinity is changing;

Effect of Oxidation?

Te thickness dependency

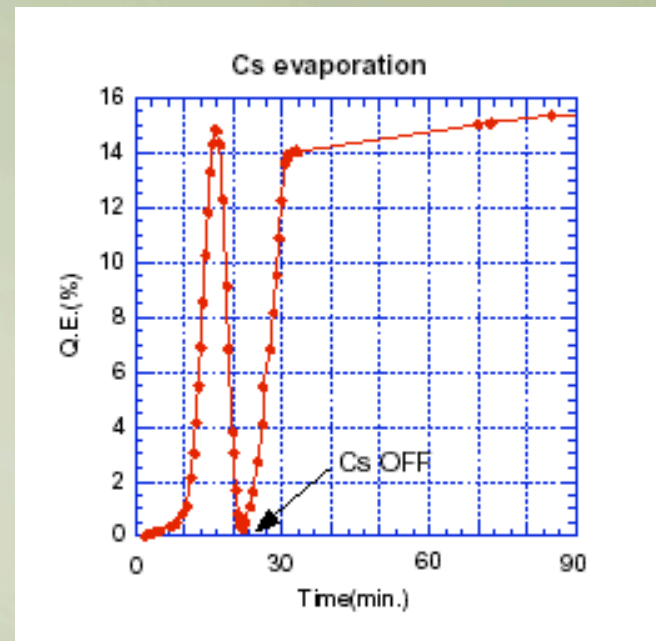
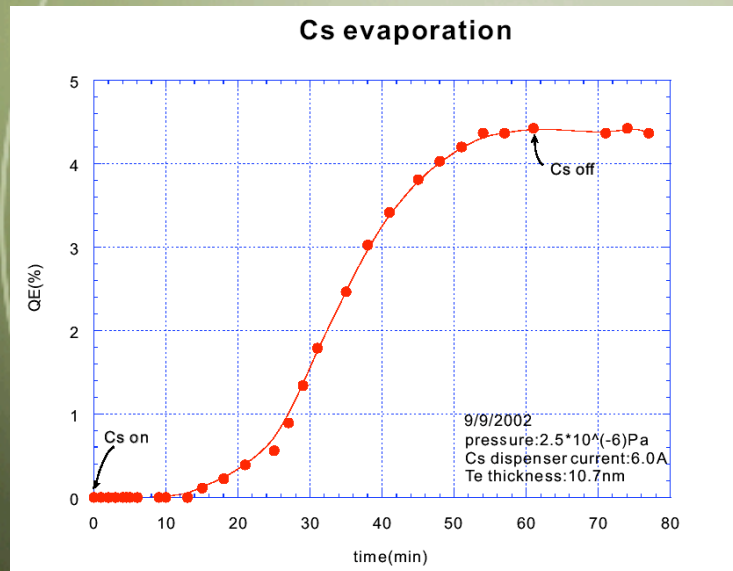


We have not enough samples to understand the thickness dependency of Tellurium for QE.

Results in 2003 showed better QE for the 3 nm sample after RF operations.

About 3 to 5 nm of Te are used for the ATF operation.

QE during the Cs evaporation



Slow doping shows the well formed Cs-Te cathode. Fast doping makes a Cs-rich surface at a moment and QE drops quickly. QE is recovered after Cs is diffusing into the Te layer.

Adding Cs or Te&Cs on the used Cs-Te cathode

1. Two samples were used for long period of ATF operation. One of them had experiences of adding Cs or Te&Cs on the used layer without the Ar cleaning.
2. When we added both Te and Cs, QE was well recovered as 0.4% -> 6.7%.
3. On the other hand, when we added only Cs, QE was recovered much smaller as 0.3% -> 1.2%.

Will be shown at the session for Operations.

Summary

KEK-ATF uses the Cs-Te photocathode RF gun for the electron source. We also have another RF gun for the LUCX experiment.

Photocathode preparation was done by using the ATF system.

Quantum efficiency obtained after the preparation of new cathode exceeds more than 15%.

Adding Cs or Te&Cs recovers QE of used cathode.

R&D by ATF system is limited by ATF operation. LUCX system will be used for R&D and training of new members.