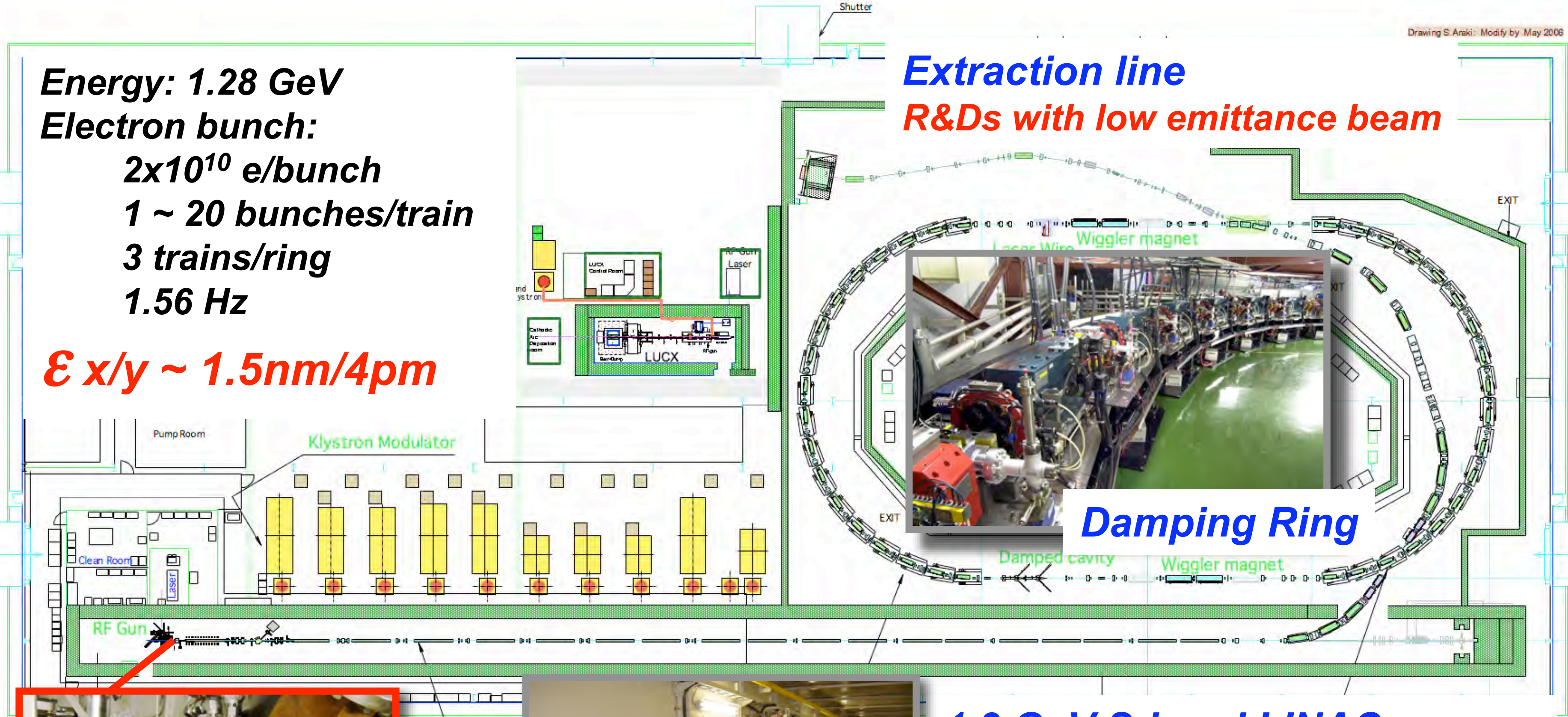
Operation of Cs-Te photocathode with ATF RF gun

Nobuhiro Terunuma
KEK

KEK-ATF for ILC R&D

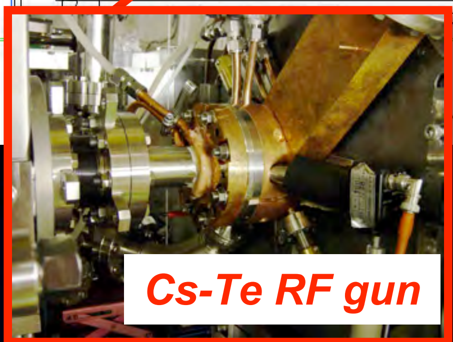
Energy: 1.28 GeV
Electron bunch:
- *$2\text{x}10^{10}$ e/bunch*
- *1 ~ 20 bunches/train*
- *3 trains/ring*
- *1.56 Hz*

ε x/y ~ 1.5nm/4pm



Extraction line
R&Ds with low emittance beam

Damping Ring



Cs-Te RF gun

1.3 GeV S-band LINAC
with Δf ECS for multi-bunch beam

Laser system for ATF RF Gun

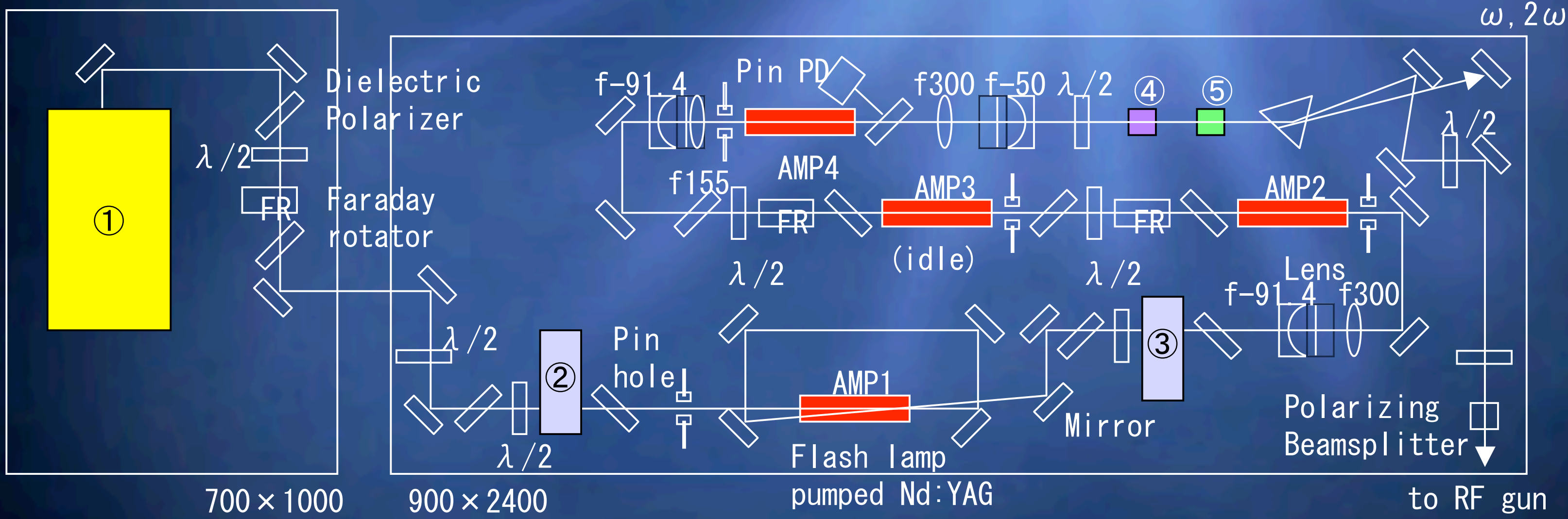
① Mode-locked-laser
Nd:YVO_4,1064nm,357MHz, 410mW(CW)
Pulse length : 7.2ps(FWHM)
Timing jitter : < 0.5ps(rms)

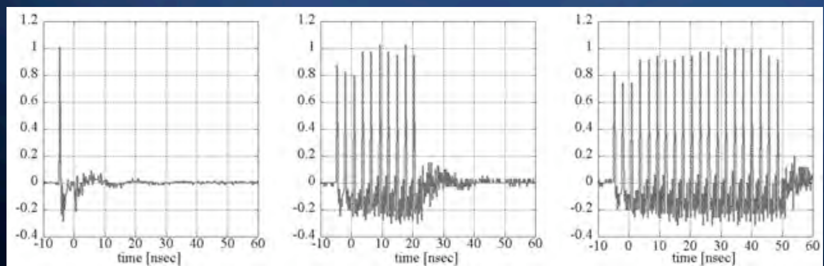
②Pockels cell
Rise&Fall time : < 3nsec

③Fast Pockels cell
Rise time : < 1nsec

④ SHG
CASIX, β-BBO
6×6×6mm

⑤ FHG
CASIX,β-BBO
6×6×6mm

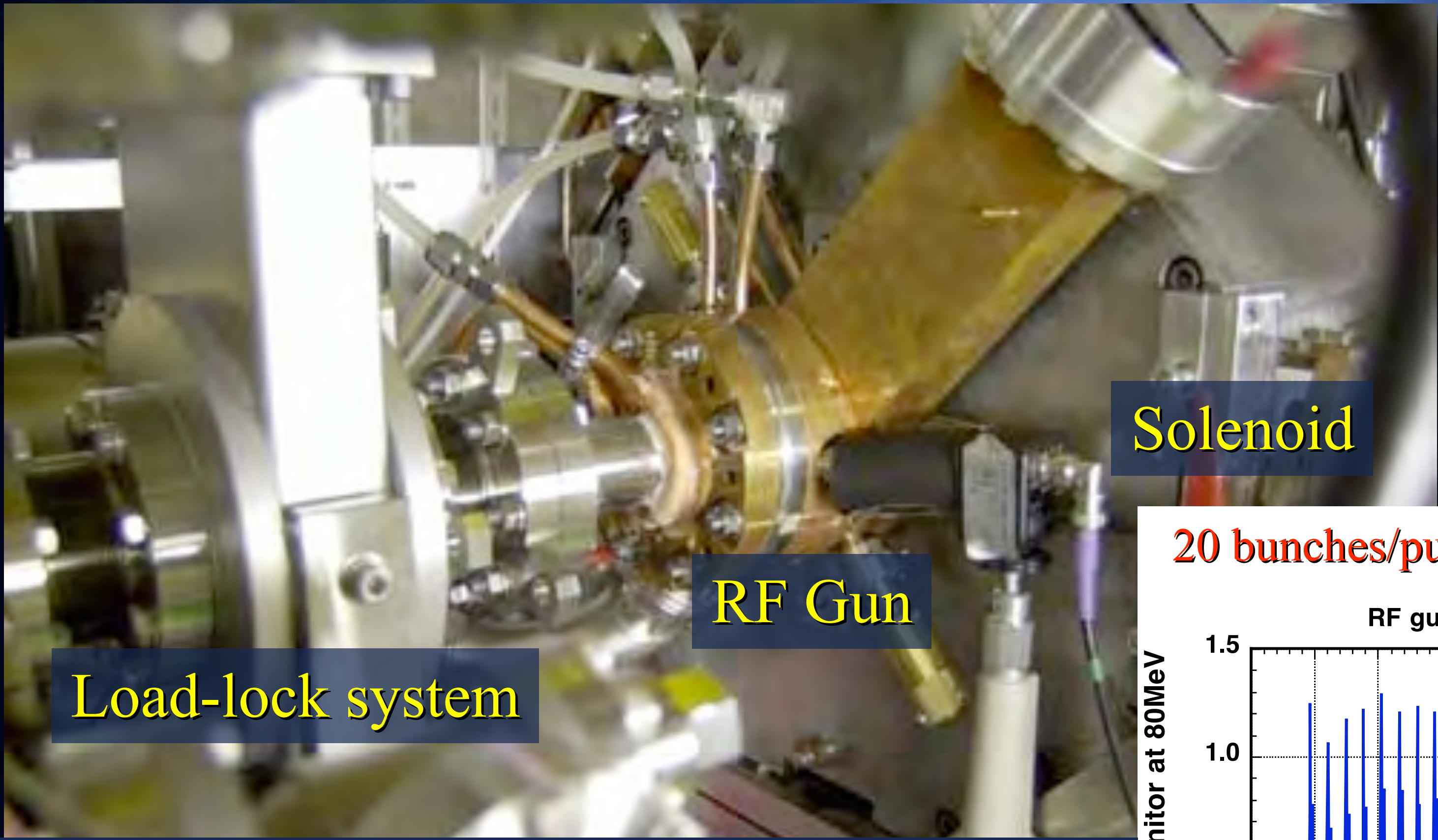




Beam structure at the end of ATF injector

Output UV 266 nm
Pulse length: 12ps(FWHM)
Power: ~3μJ/bunch (1uJ in 2002)
1~20 bunches/pulse

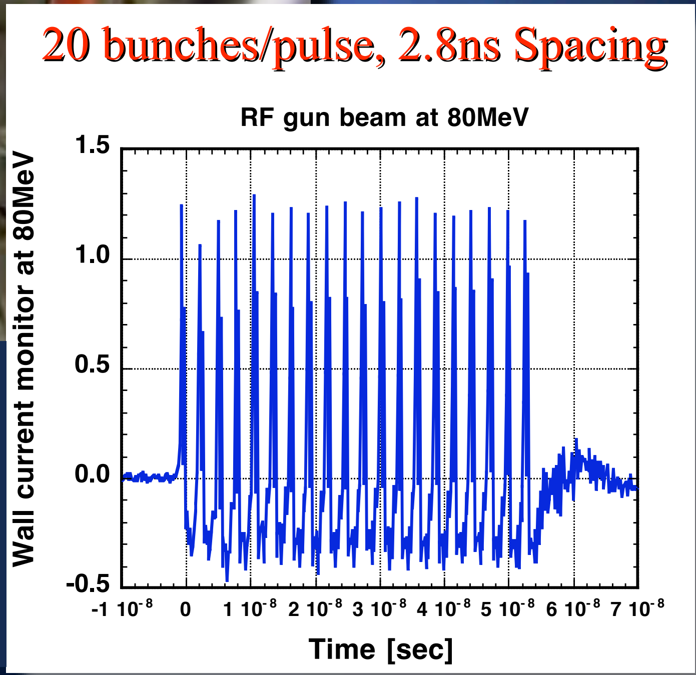
ATF RF Gun



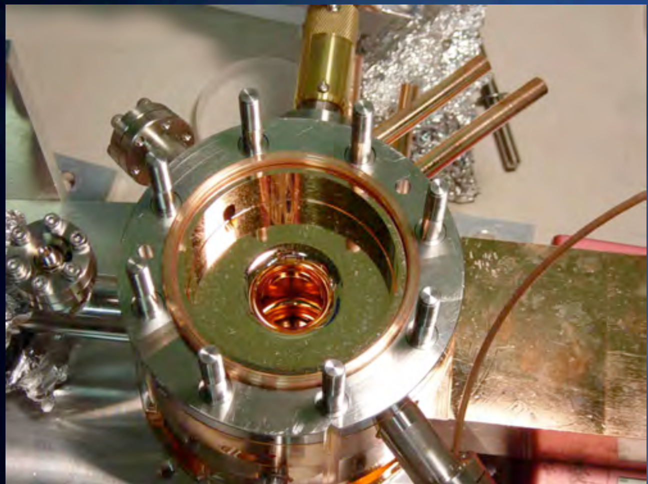
High quality Multi-bunch beam is generated.

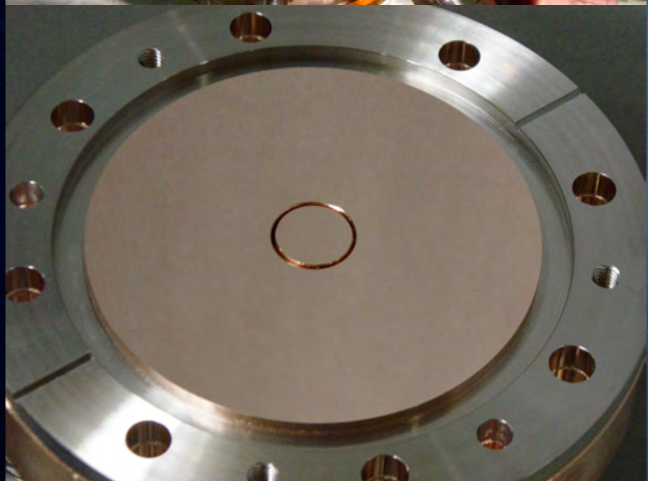
1 ~ 20 bunches/pulse, 2.8ns spacing

~ 2 x 10^{10} electrons/bunch

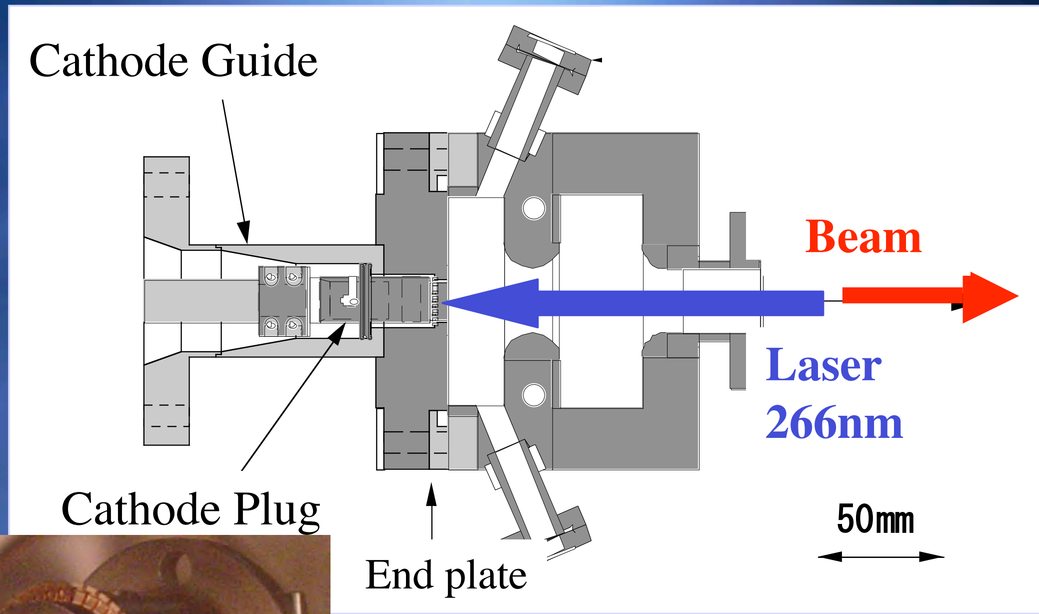


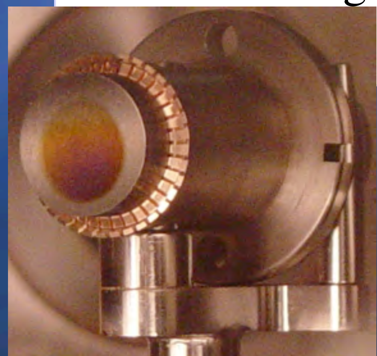
RF Gun for Cs-Te photocathode

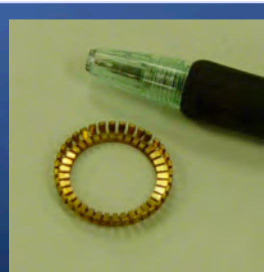




Modified BNL type IV: 1.6 cell, 2856 MHz



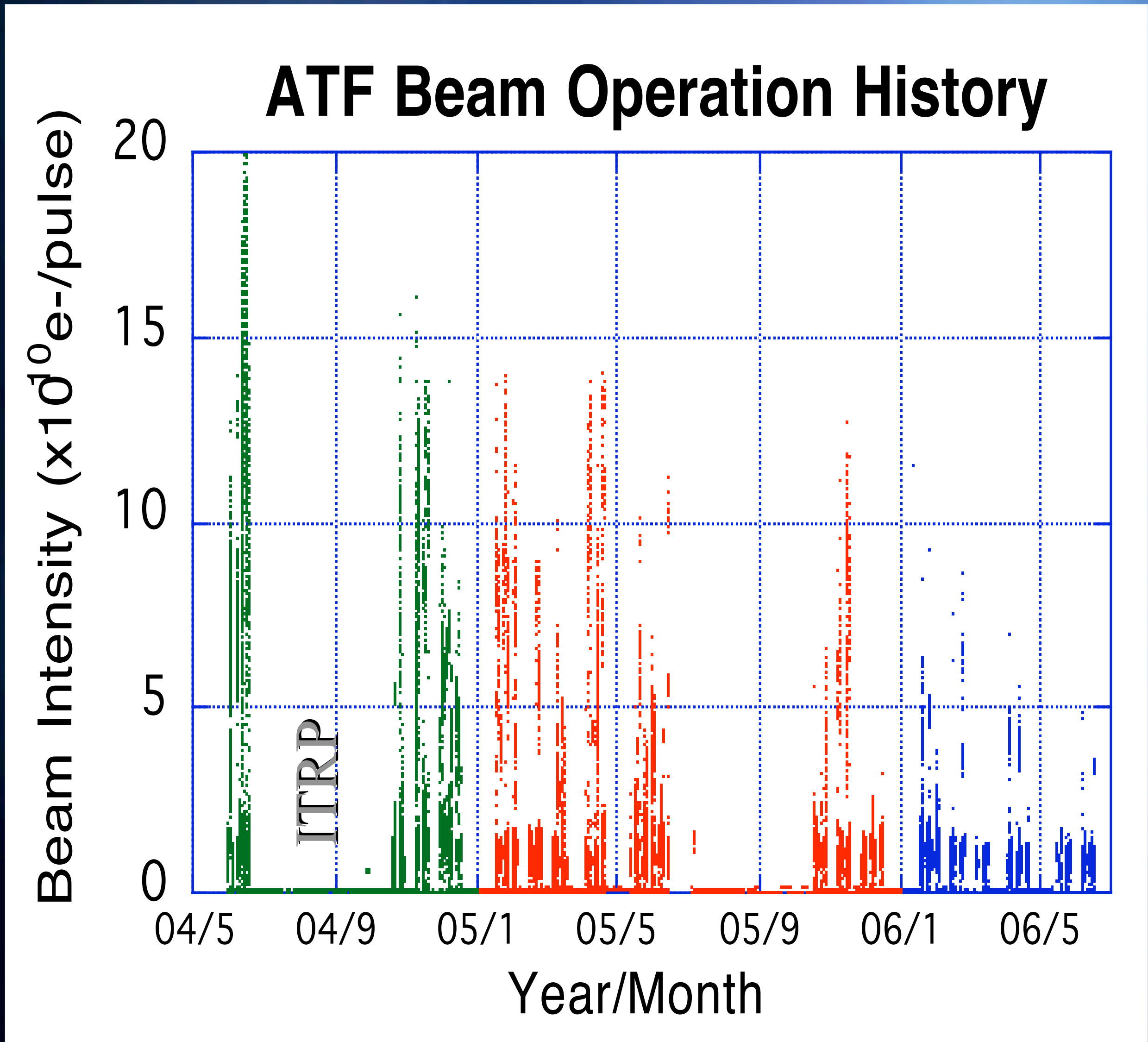




CERN-style contactor between the plug and the end plate of cavity

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

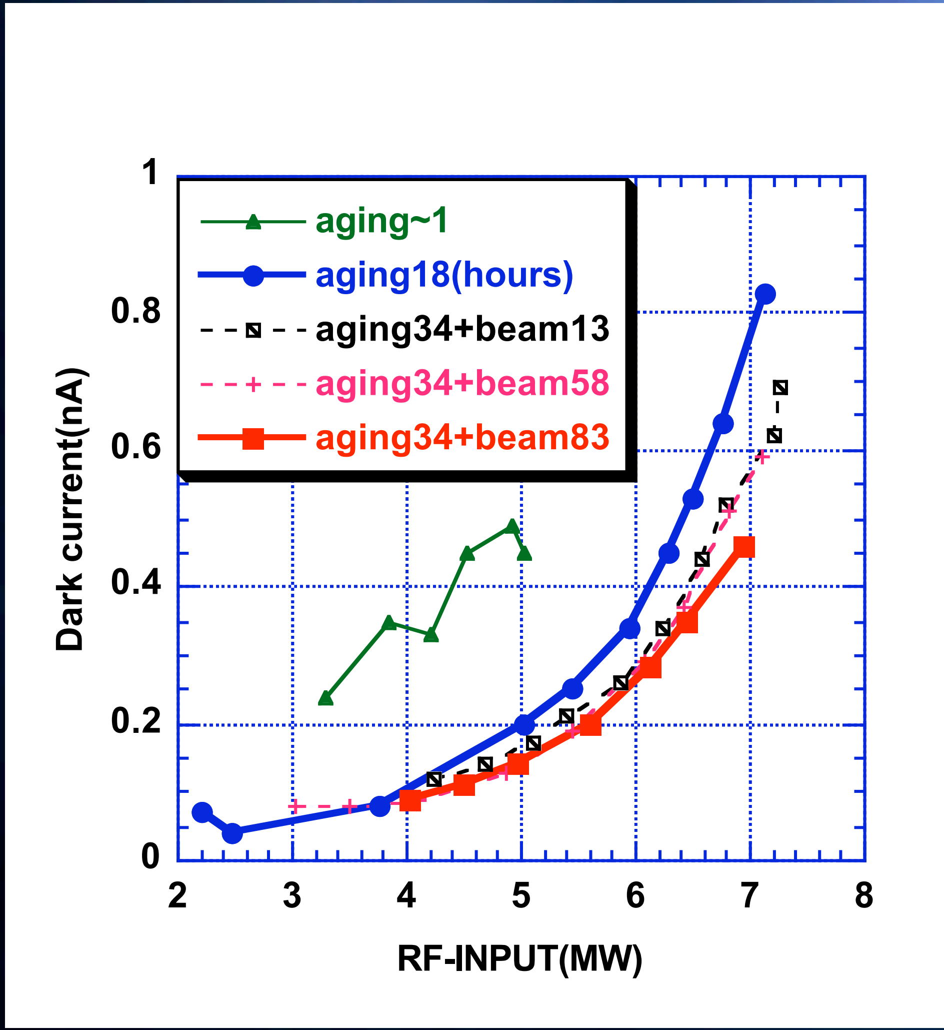
Recent Beam History by Cs-Te RF Gun for ATF operation



Multi-bunch Operation

Single bunch operation

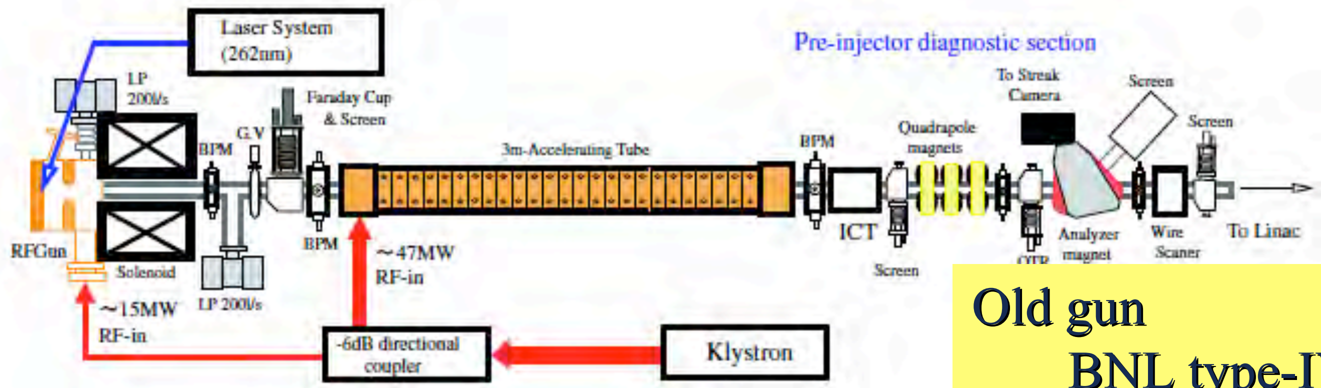
Dark Current of ATF RF Gun



Measured in 2002, commissioning of the ATF RF Gun.

Aging means no beam generation (no lasers), it is a RF processing of the RF-Gun cavity.

Dark Current 2001/2002



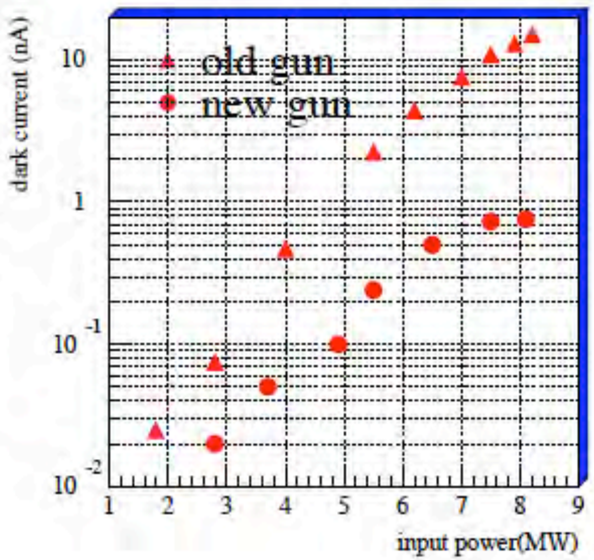


Figure 2: Dark current from the gun cavity as function of input RF (1.6 μs duration and 12.5 Hz reputation). The current gun is shown as "new gun".

Old gun

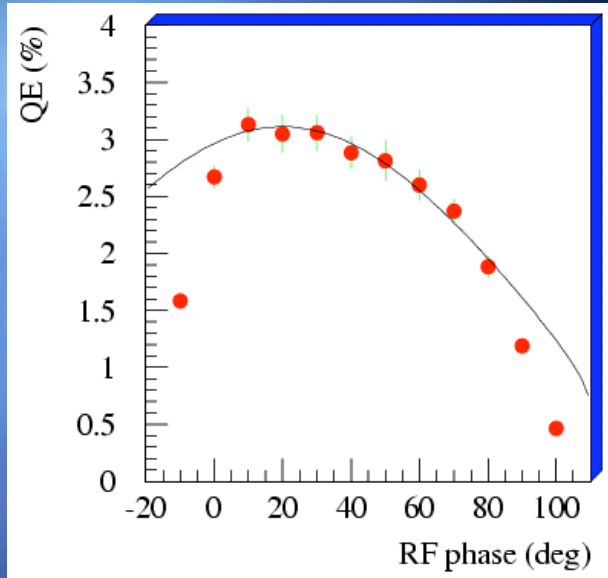
- BNL type-IV, Cu cathode
- Tested in 2001
- manufactured by Sumitomo Heavy Industry

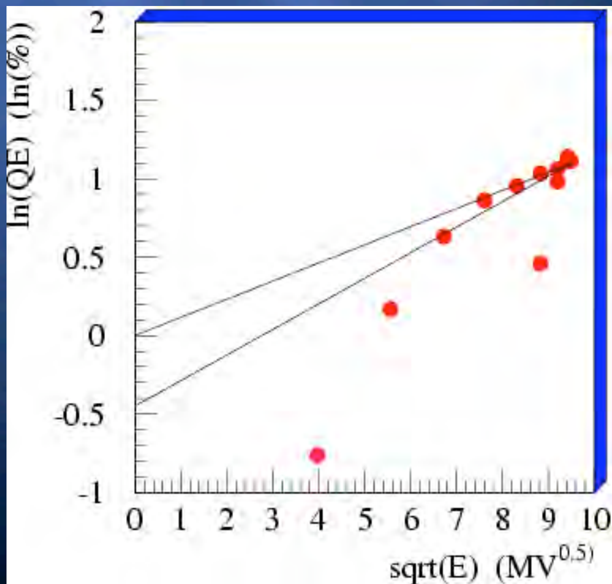
New gun

- BNL type IV modified for Cs-Te cathode
- Used since 2002
- Manufactured by KEK with the ultra-fine diamond turning.

QE in operation

- QE in operation (with a strong surface field ~ 90 MV/m) was evaluated by using the Faraday Cup.
- QE was up to 3 %, although QE in a low field was ~1%. That can be explained as Shottky effect.
- QE was decreased at the end phase, where the transmission from the gun becomes low.





Emittance

- Normalized emittance was measured by Q-scan method at the downstream of the injector, where the beam energy is 80 MeV.
- The beam size was measured by W-wire scanner.
- The expected beam spot at the cathode is 1.2mm in FWHM.

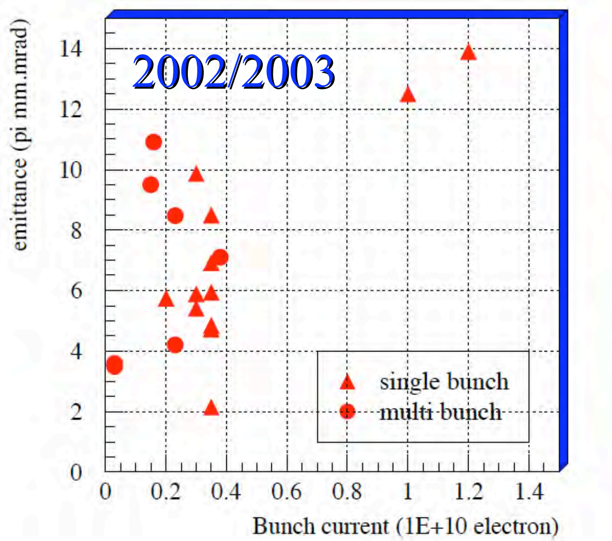
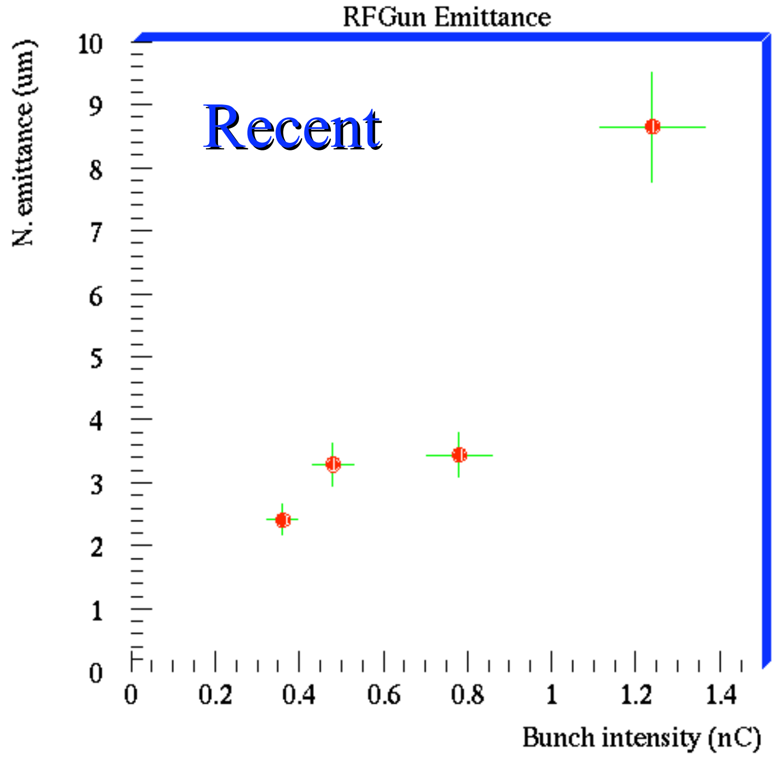
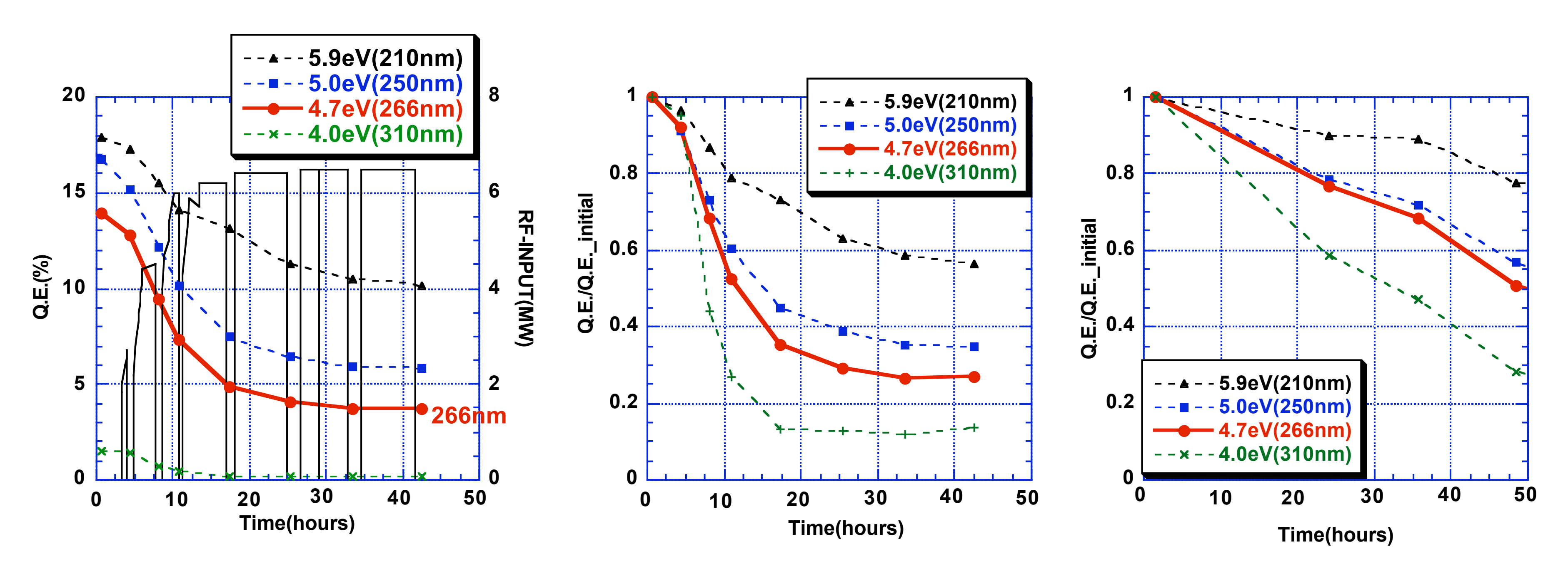


Figure 4: Beam emittance data are plotted as function of bunch current. The triangle and circle symbol show the single- and multi-bunch data respectively.



Drop of the quantum efficiency under the RF field



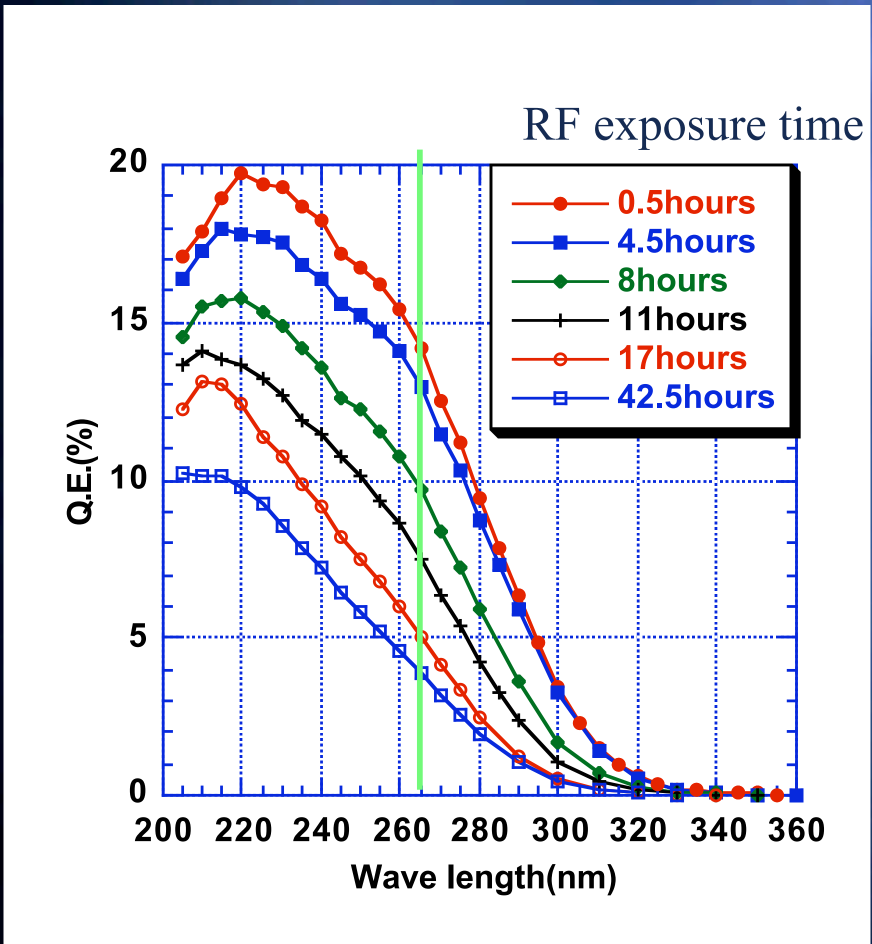
With RF(normalized) WithoutRF(normalized)

Initial QE is sufficiently high ~ 15 %.

It drops quickly when we apply the RF field.

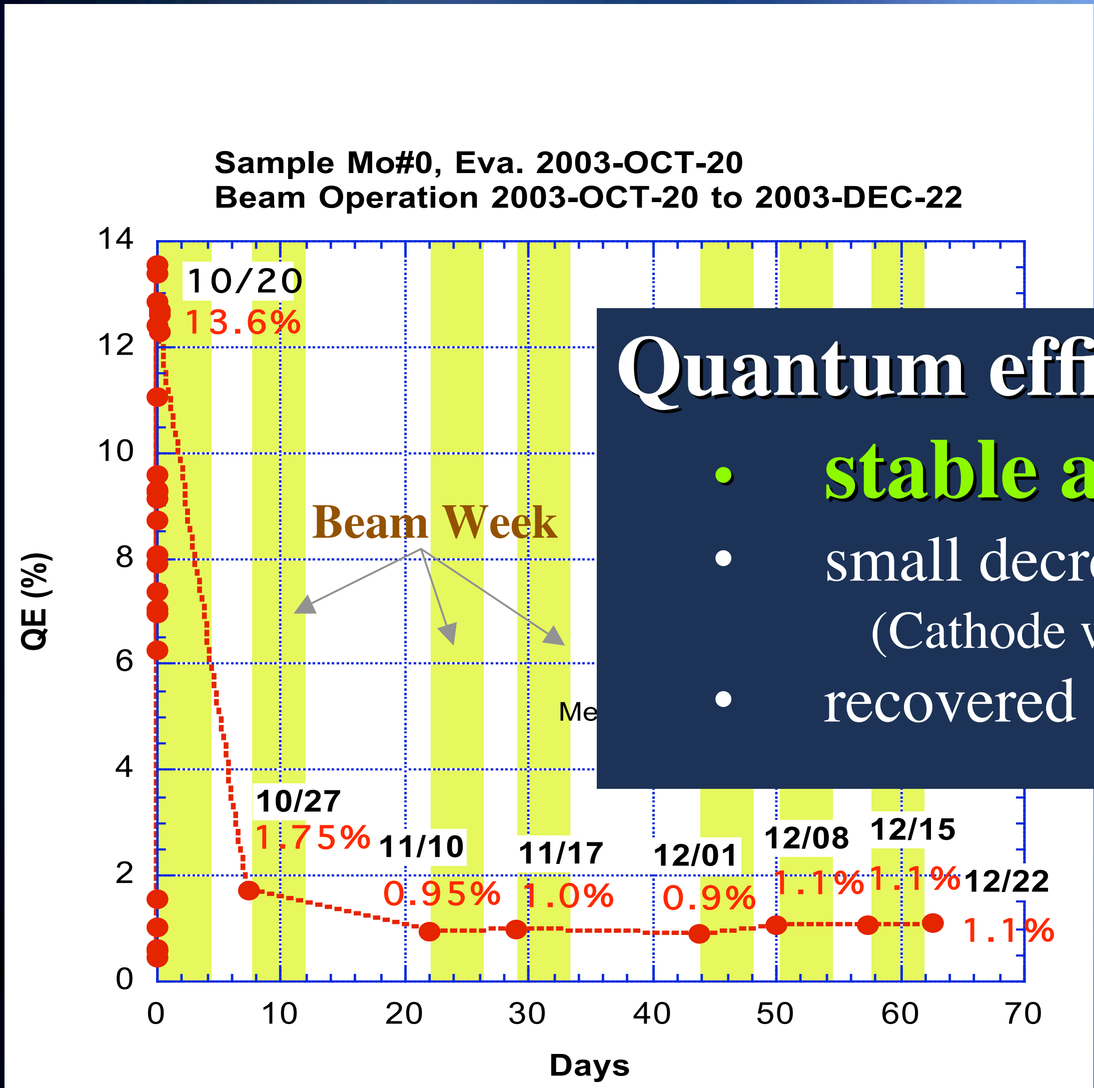
All QE measurements were done by moving the photocathode from the RF gun to the Cs-Te preparation chamber.

Wavelength dependency



- Decrease of QE was measured in all wavelength.
- ATF laser is 266 nm.
- Peak of the QE is shifted to shorter wavelength.

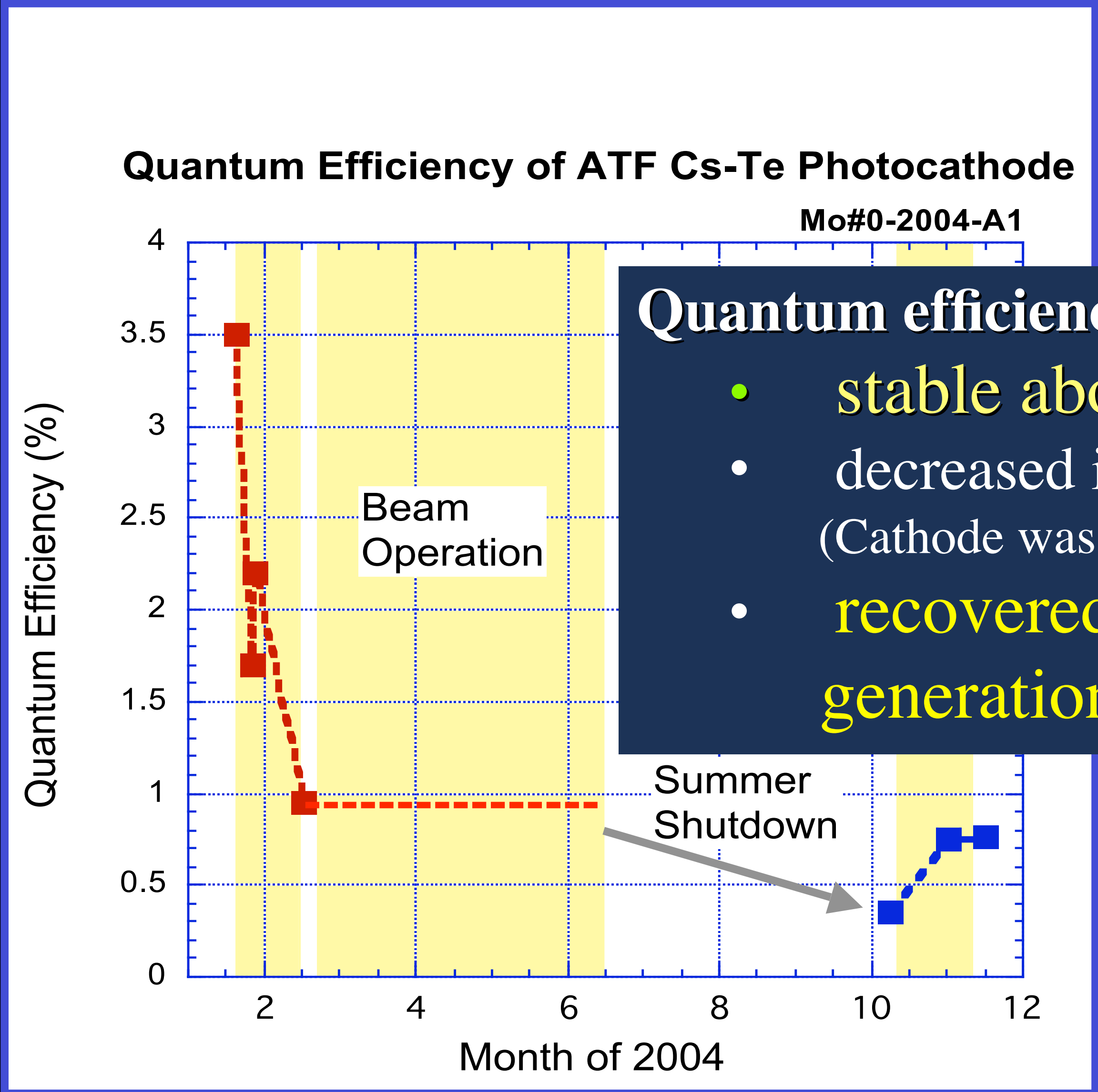
Two months history of the quantum efficiency under the ATF operation



Quantum efficiency is …

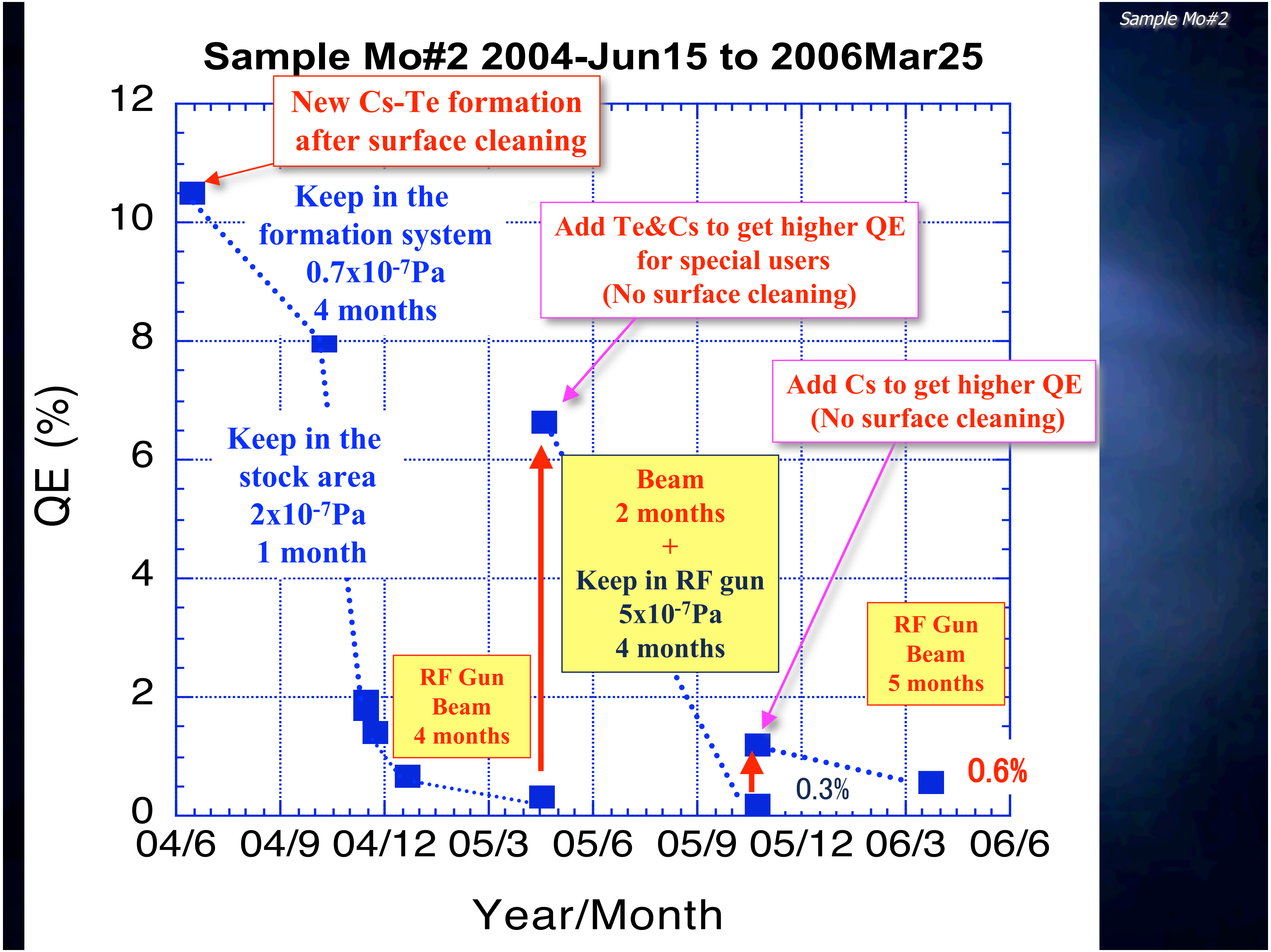
- **stable about 1%.**
- small decrease in the shutdown week?
  (Cathode was stored in the RF gun. 5×10^{-7} Pa)
- recovered after the beam generation?

ATF beam operation: Half Year



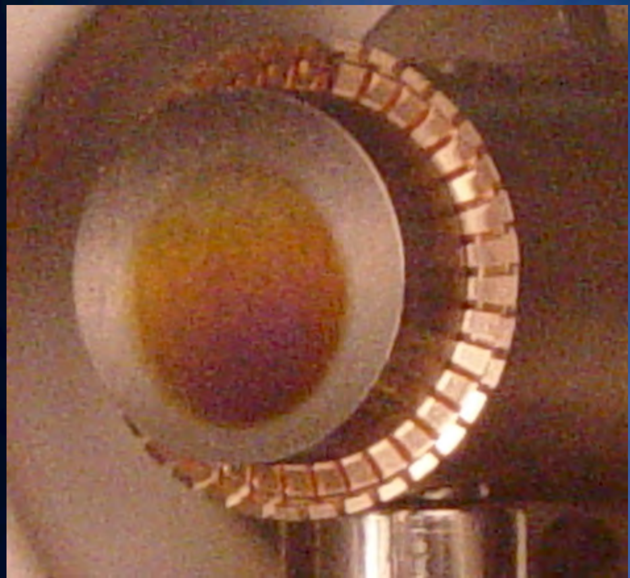
Quantum efficiency is …

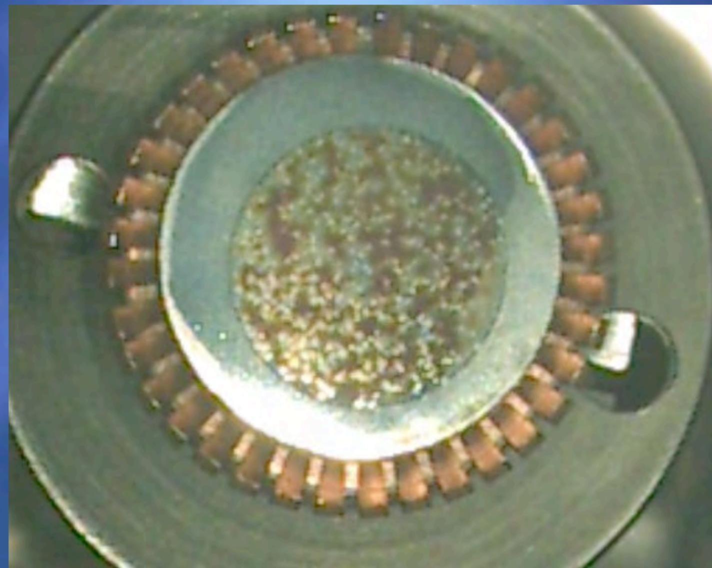
- stable about 1%.
- decreased in the summer shutdown.
  (Cathode was stored in the RF gun. 5×10^{-7} Pa)
- recovered after the beam generation.



Sample Mo#2
Sample Mo#2 2004-Jun15 to 2006Mar25
New Cs-Te formation after surface cleaning
Keep in the formation system 0.7x10-7Pa 4 months
Add Te&Cs to get higher QE for special users (No surface cleaning)
Add Cs to get higher QE (No surface cleaning)
Keep in the stock area 2x10-7Pa 1 month
Beam 2 months + Keep in RF gun 5x10-7Pa 4 months
RF Gun Beam 4 months
RF Gun Beam 5 months
0.3%
0.6%
QE (%)
Year/Month
0
2
4
6
8
10
12
04/6
04/9
04/12
05/3
05/6
05/9
05/12
06/3
06/6

Damages?





Just after the Cs-Te formation

After the half-year operation

- We did not see this pattern during the dropping of QE by RF operation.
- Why Q.E. was kept about 1% with this pattern?
- Can we keep a higher Q.E. if we minimize this change?

Summary

- RF Gun
  - We have used the RF gun with the Cs-Te photo-cathode about four years for the ATF operation.
  - It can supplies the electron beam about 1~2x10^{10} electrons/bunch and 1~20 bunches/pulse.
  - It works well to supply the electron beam for ATF programs.
- Cs-Te photocathode
  - QE just after formation reaches about 16 %.
  - It is decreased with the RF operation.
  - It reaches the stable level about 1%.

Cs-Te RF Guns manufactured by KEK

2002 July First RF Gun for ATF

2004 June Second RF Gun for RFGTB/LUCX

2006 Oct Third RF Gun for Waseda Univ.

End plate of the half cell will be brazed with the full cell.
That is no helicoflex connection. Half cell has four tuning pins. KEK supplies the Cs-Te photocathode.

Other institute are considering to use this RF gun.
Kyoto Univ., etc.