Stabilization of KEK-ATF RF gun

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for ATF collaboration

- Status of ATF RF-gun
- QE in operation
- Emission stabilization
- Summary and future

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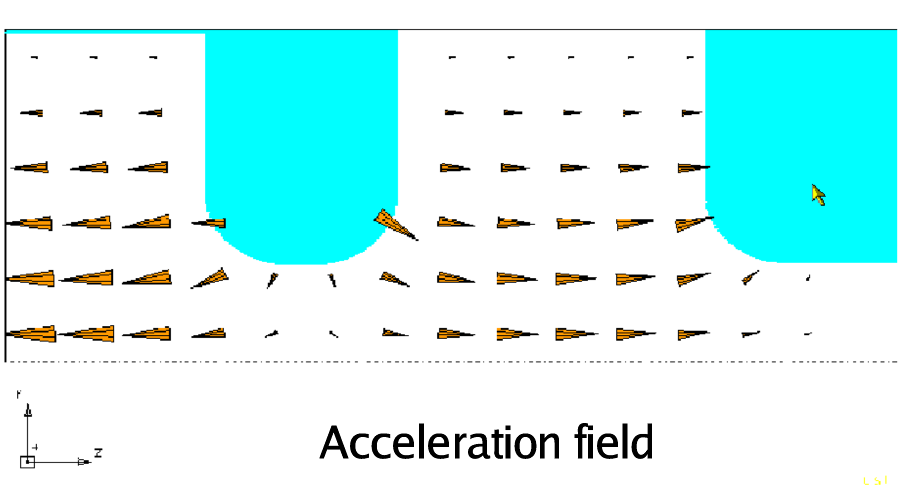
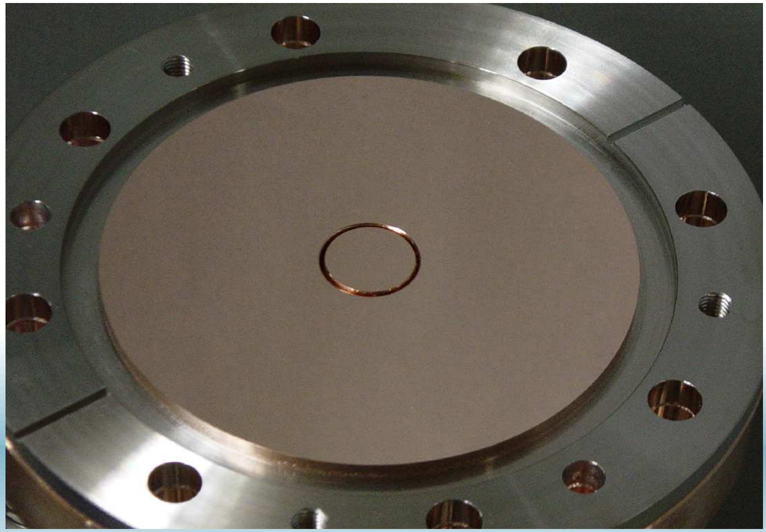
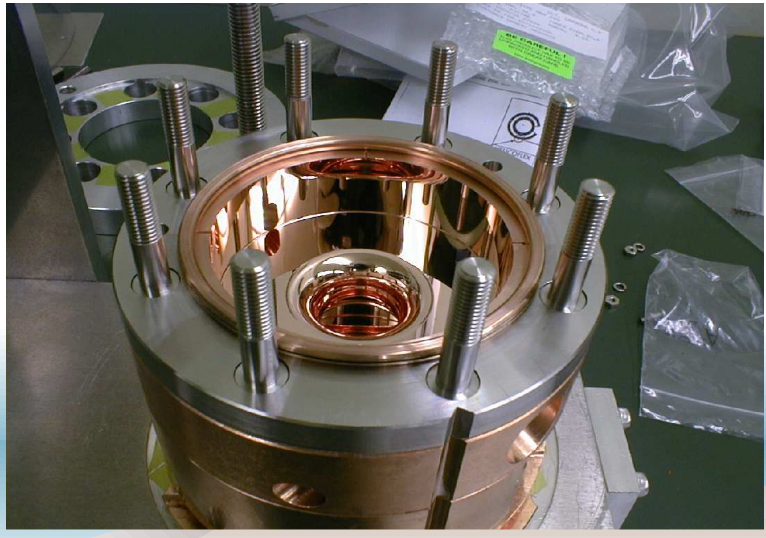
RF electron gun

- 1.6 cell BNL gun IV type.
- Pi mode acceleration.
- Cs_2Te cathode.



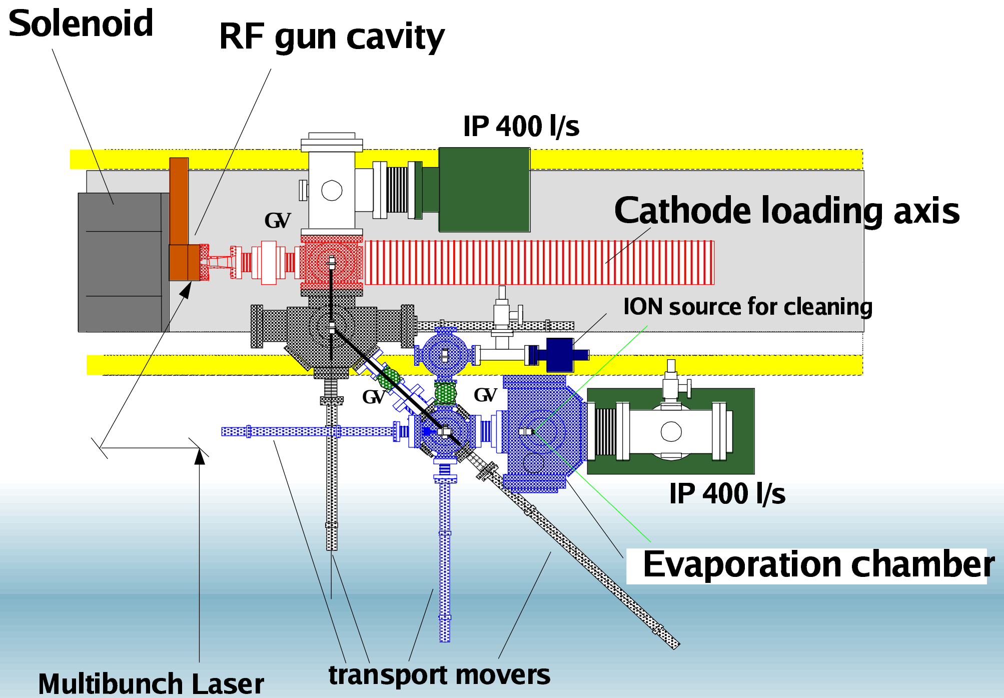
Acceleration field

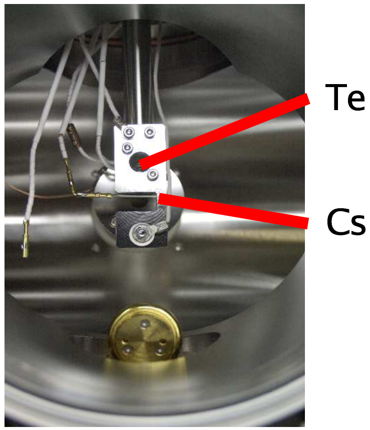




Cathode evaporation system

- CsTe cathode is formed by evaporation on Mo plug.
- QE was measured by illuminating UV light from Xe lump.
- The cathode is transported to the gun cavity in the load-lock chamber.





Evaporation System

Cathode Plug (Cu)

MB Laser Block Diagram

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

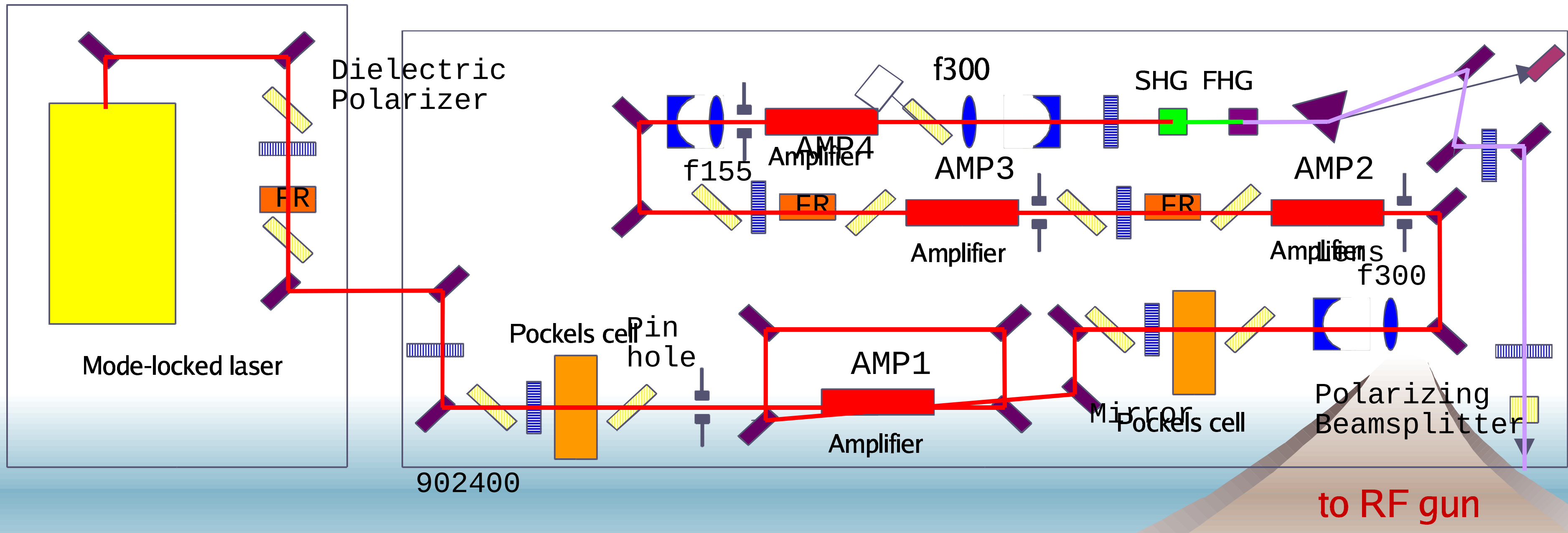
Pockels cell
KD*P crystal
7kV maximum
Rise&Fall time <3nsec

Fast Pockels cell
3.4kV maximum
Rise time : < 1nsec
Double Pockels Cell

SHG
CASIX, β-BBO
6×6×6mm

FHG
CASIX,β-BBO
6×6×6mm

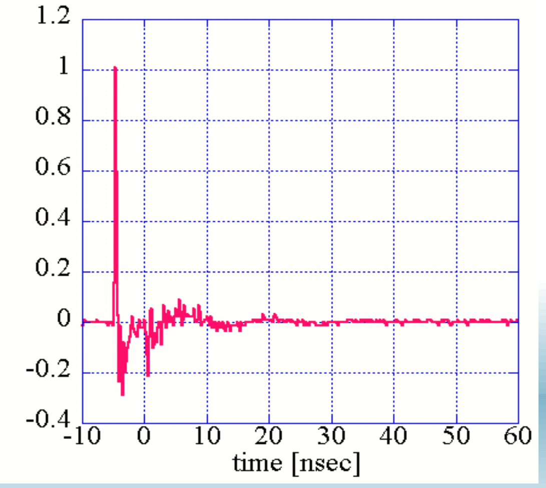
UV light:
12ps(FWHM)
1μJ/pulse



Pulse Clipping

- 357 MHz mode-lock laser generates continuous pulse train with 2.8 ns spacing.
- A part of the train is clipped out to make the multi-bunch (1 – 20) beam by the Pockels cells.
- The clipped pulse-train is amplified and converted to UV light.
- By shifting the clipping timing, any number of pulse from 1 to 20 can be obtained.

1



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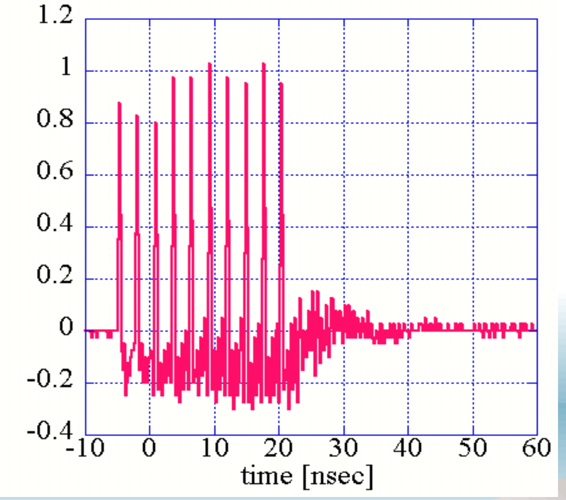

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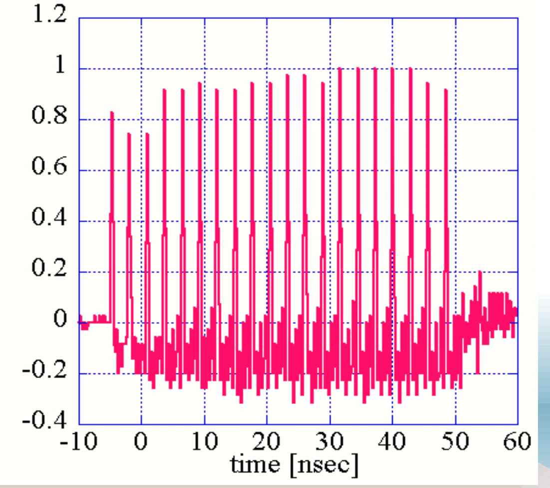
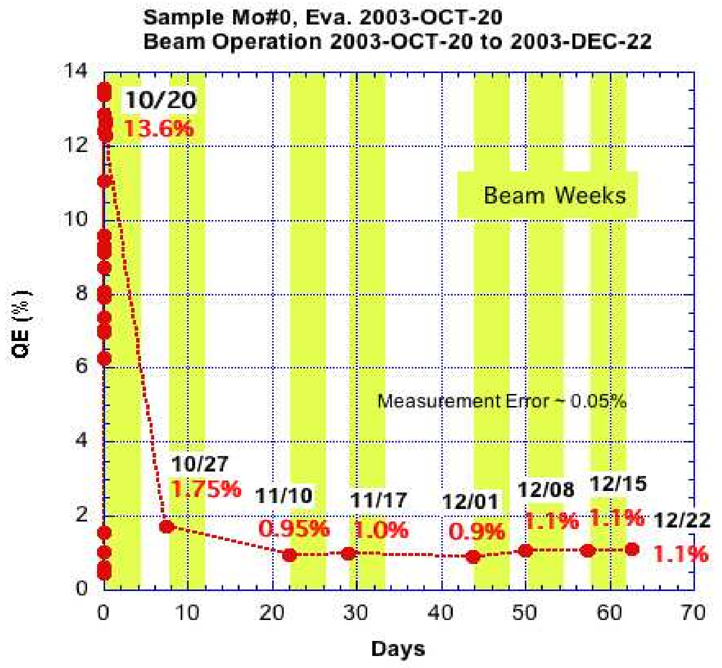


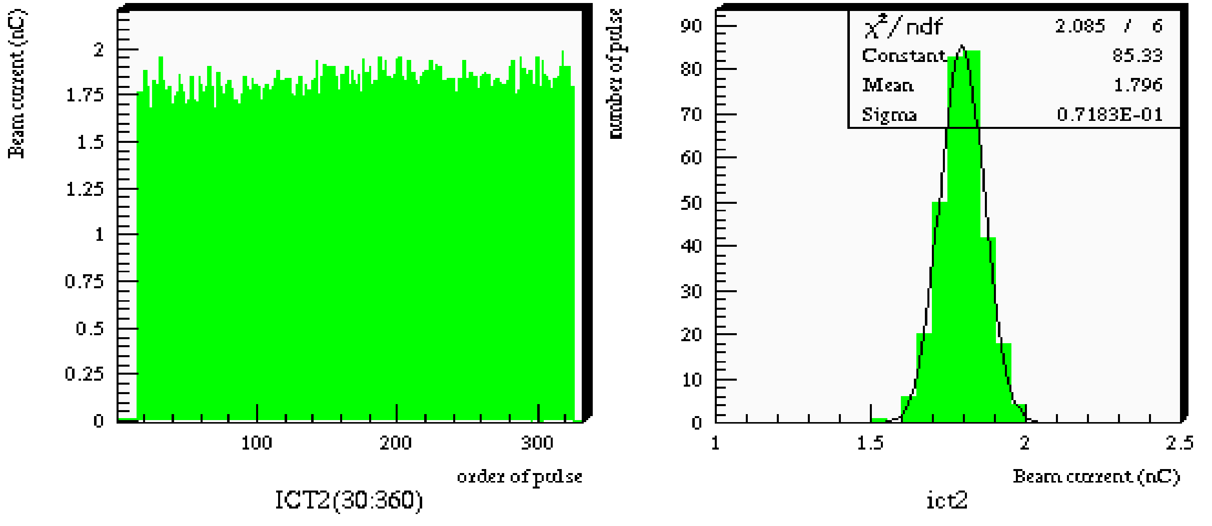
Status

- QE that was initially more than 10% was decreased rapidly and then kept around 1%.
- The emission did not change at least two months.
- Beam intensity : **0.1-3.0x10[10] electron/bunch**
- Bunch number : **1-20**



Status (2)

- Normalized emittance : **2-20 pi mm.mrad**
- Bunch length : **6.4 ~ 7.9 ps (sigma)**
- Energy spread : **ΔE/E = 1.0-3% (FWHM)**
- Intensity flatness in a train **: 5 - 20% p-to-p**
- Intensity fluctuation (pulse by pulse) **: 5~10%**
- Injection efficiency **: can be 100%**



QE in Operation

- Because QE is a function of the surface field, QE in operation is different from that at low surface field.
- QE in operation was extracted by observing the emission by varying the laser power.
- QE data were extrapolated toward zero surface field to compare that at zero surface field.

A Simple Model

Assuming Fermi-Dirac statistics and Shottky effect, emission from a photo-cathode

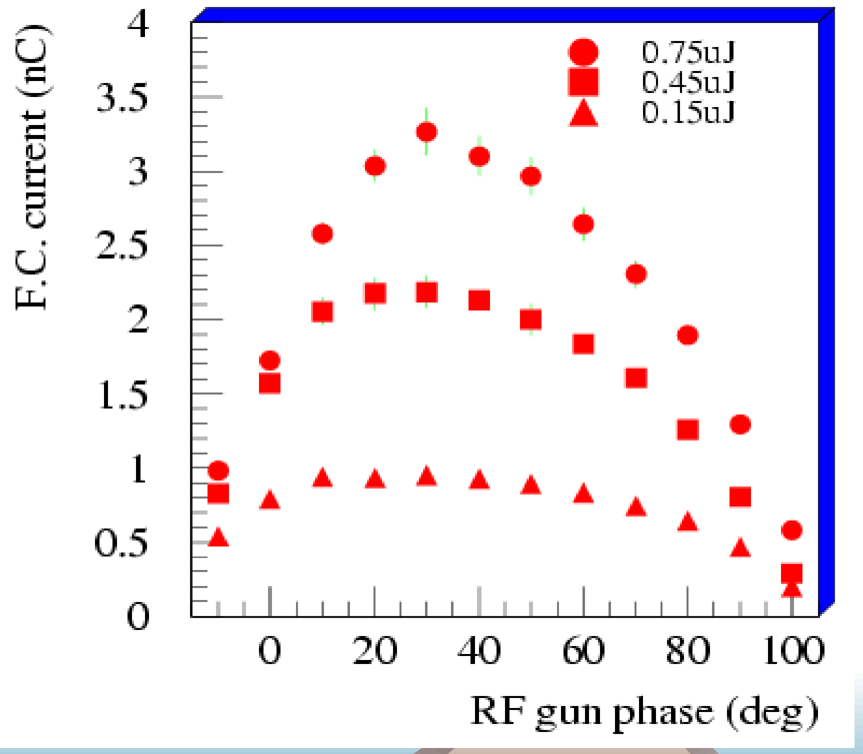
$$J = AT^2 \exp\left(\frac{h\nu - \phi_0 + \sqrt{e\beta E/4\pi\epsilon_0}}{kT}\right)$$

leads QE as function of the surface field;

$$QE(E) = QE_0 \exp\left(\frac{\sqrt{e\beta E/4\pi\epsilon_0}}{kT}\right)$$

Emission Vs RF Phase

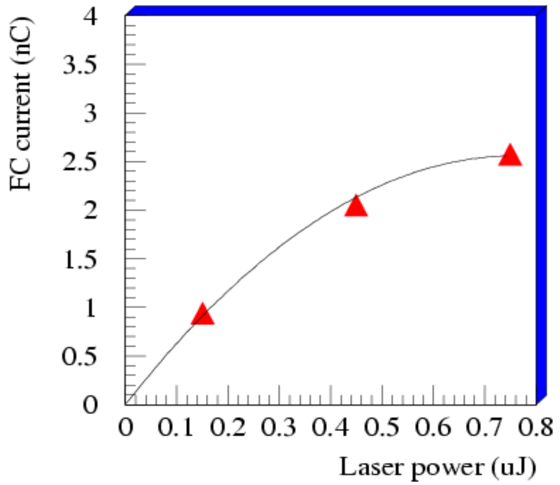
- Emission was measured by FC.
- Solenoid strength was optimized to maximized the emission for each point.
- The emission was measured for different laser power, 0.75, 0.45, 0.15 μJ.

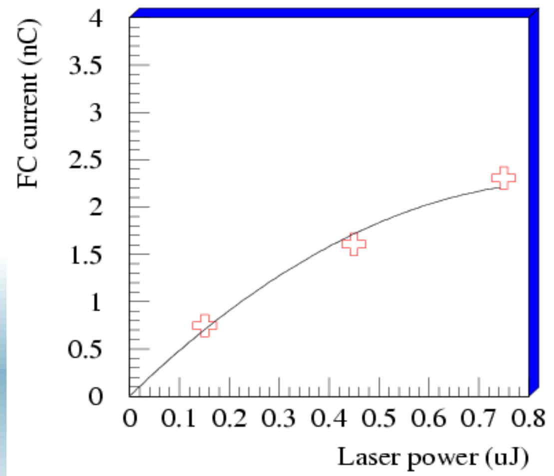


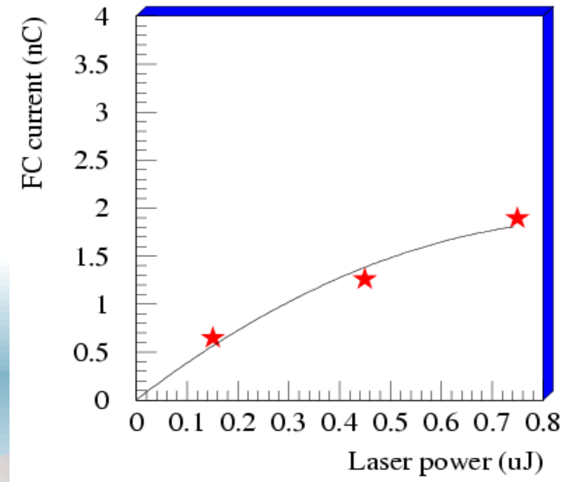
QE Extraction

- QE is defined as a ratio of numbers of illuminated photons and emitted electrons.
- The emission is however saturated by the surface and space charge limitation effects.
- QE at zero emission can be defined with its derivative as

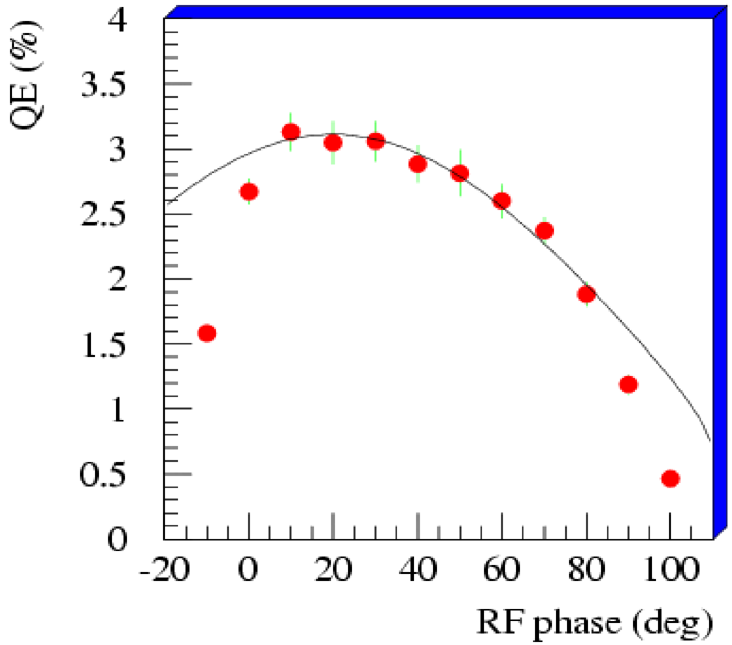
$$QE(0)[\%] = \frac{123.8}{\lambda[nm]} \left. \frac{\partial I[nC]}{\partial P[\mu J]} \right|_{I=0}$$

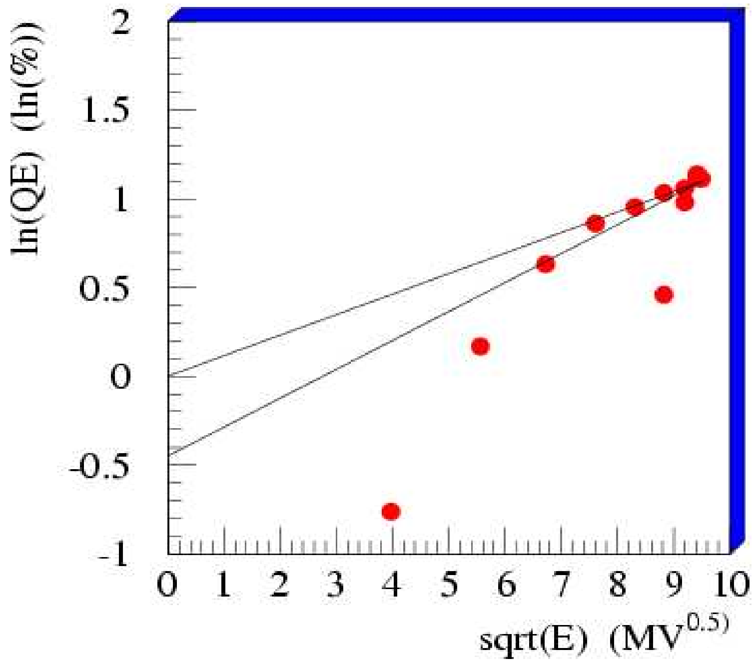






QE vs. Surface Field





1) QE at zero surface field : 0.64 +- 0.16 % that is not consistent to 1.0%.
2) A part of beam might be lost during the acceleration at the low field phase.

Surface Chrage Limitation

- The emission from a photo-cathode is a function of the surface field as shown.
- The surface field is modified by a space charge near of the cathode surface.
- The emission is then surpressed by the localized space charge.
- The emission current will be saturated with a space charge that vanishes the surface field.

Formalism

Assuming a thin charge distribution and a purely perpendicular surface field on a cathode, the deceleration field E_{dec} by the space charge is expressed

$$E_{dec} = \frac{Q}{2\pi s_x^2}$$

where Q is tatal charge, s_x is beam radius. If the field is balanced to the acceleration field E_{acc}, the maximum extracted charge Q_{max} is

$$Q_{max} = 2\pi\sigma_x^2\varepsilon_0 E(t)$$

Emission stabilization

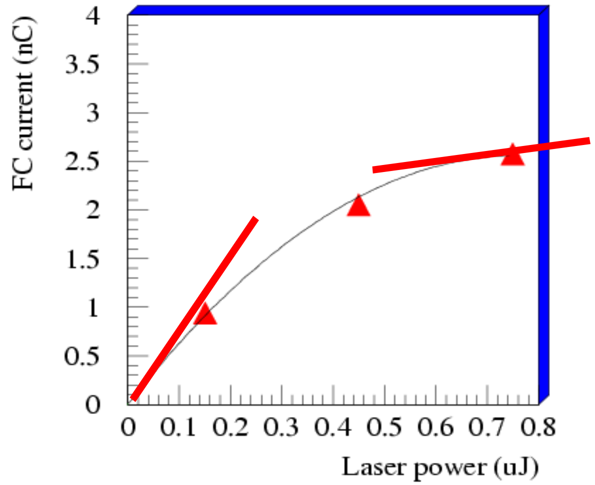
The maximum current is expressed with the practical units

$$Q_{max}[nC] = \frac{E_{acc}[MV/m]\sigma_x^2[mm]}{18}$$

By putting typical parameters of 100MV/m field and 0.5mm radius, the saturated emission becomes 1.4nC. The emission will be insensitive to the laser power in such condition.

Emission stabilization

- The emission can be stabilized by the saturation effect with the surface charge.
- To implement this method, we have to control the spot size and flatness of the laser light well.
- Even with a distorted laser spot, this mechanism can be used to compensate the intensity fluctuation due to the laser power jitter.
- This effect has been observed already in a real operation.



Summary

- CsTe RF gun in KEK-ATF is stably operated.
- By varying the laser power, QE in operation was measured. It was up to 3.0%.
- The surface field dependence of QE may be distorted by the transmission efficiency to FC.
- The significant surface charge limitation effect was observed. This effect potentially stabilizes the emission with a precise laser control.

Summary(2)

- Even with the current condition, the fluctuation due to the laser power jitter is compensated.
- A set of micro lends array will be introduced as a intensity homogenizer.
- Real time laser power and profile monitors are planned.