Summary of recent photocathode studies

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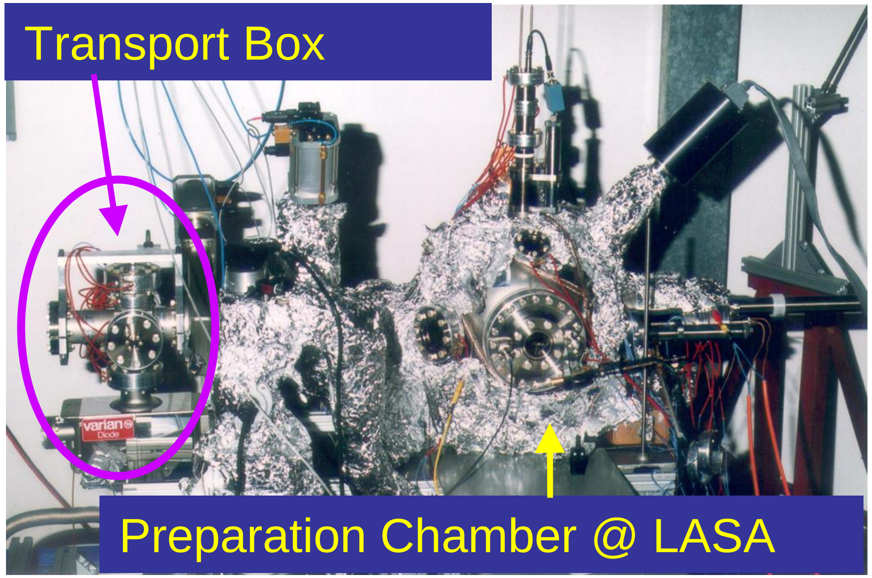
FLASH seminar November 17th, 2009

Outlook

- Cs_2Te photocathodes
- Pulsed QE measurements
  - laser transmission
  - measurements
- Cathode life time
- Dark current investigations
- Summary and conclusion

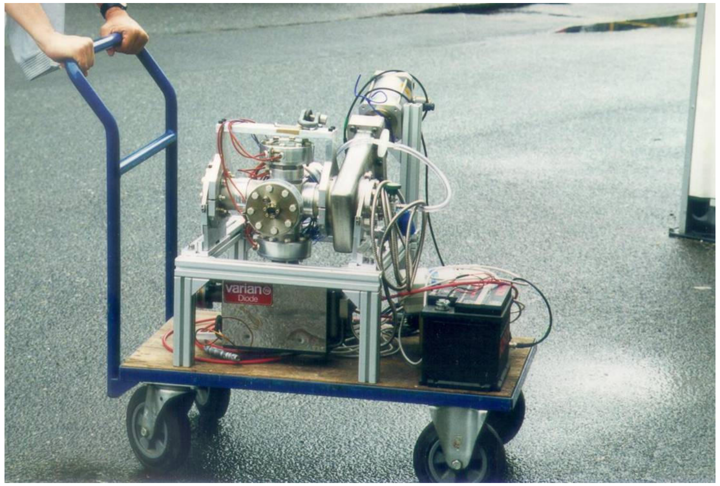
Cs_2Te photocathodes

Cs_2Te photocathodes for FLASH prepared at INFN-Milano, LASA, Italy



- UHV Vacuum System - base pressure 10^{-10} mbar
- 6 sources slot available
- Te sources out of 99.9999 % pure element
- Cs sources from SAES®
- High pressure Hg lamp and interference filter for online monitoring of QE during production
- Masking system
- 5 x UHV transport box

After preparation transport to FLASH or PITZ under UHV conditions



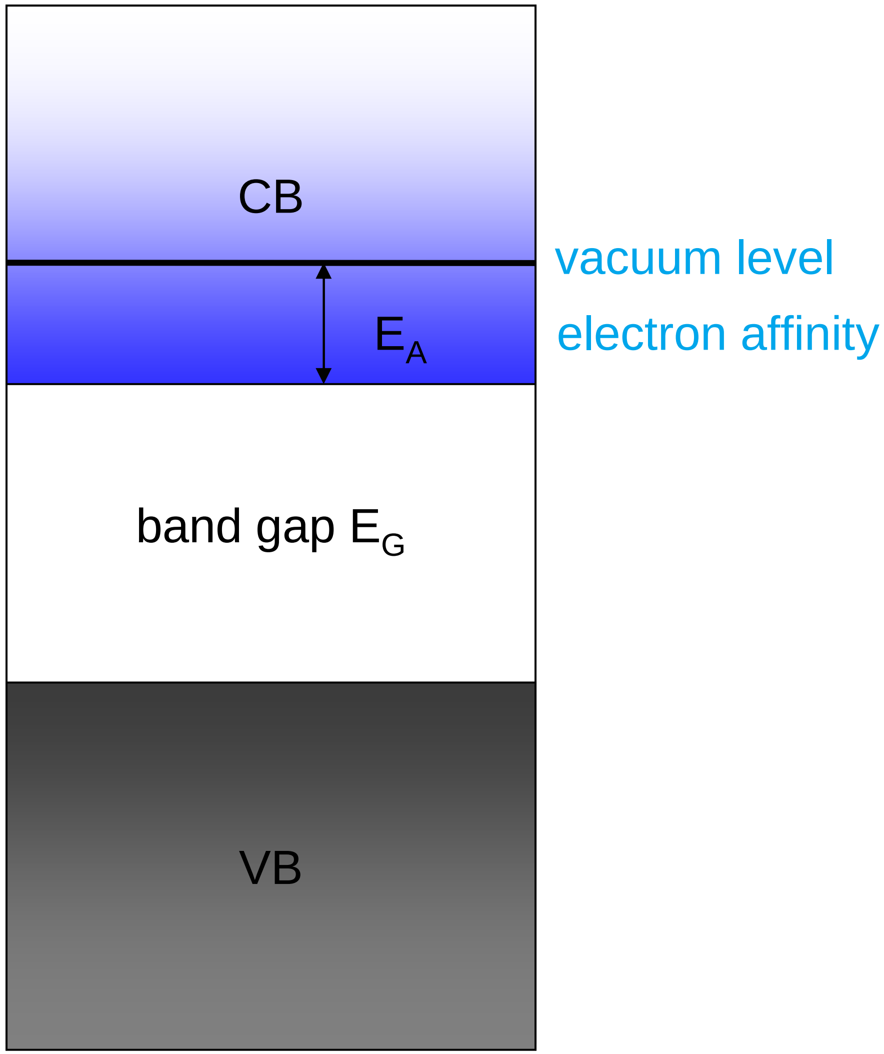
Cs_2Te photocathodes

Cs_2Te photocathodes
- semiconductor
- band gap E_G = 3.3 eV
- positive electron affinity E_A = 0.2 eV

+ ability to release high peak current electron bunches
+ high QE
+ stabe under RF operation
+ response time ~ 1 ps

- need UHV ($\leq 10^{-9}$ mbar)
- UV laser needed

For DESY:
active area 5 mm
thickness controlled by Te amount (no co-evaporation), standard 10 nm Te

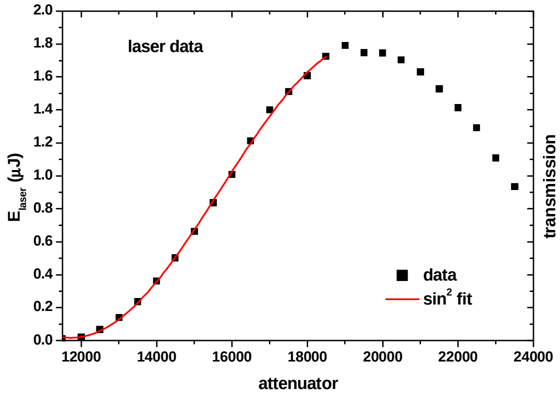


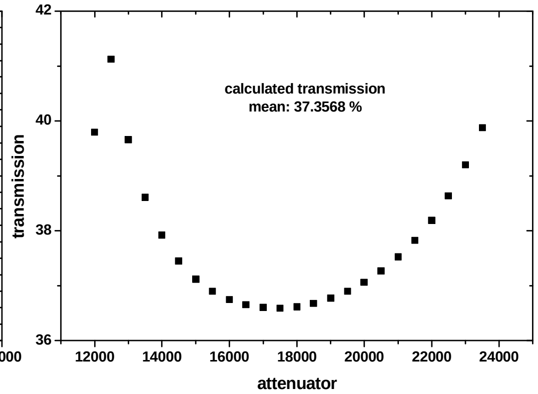
QE measurements

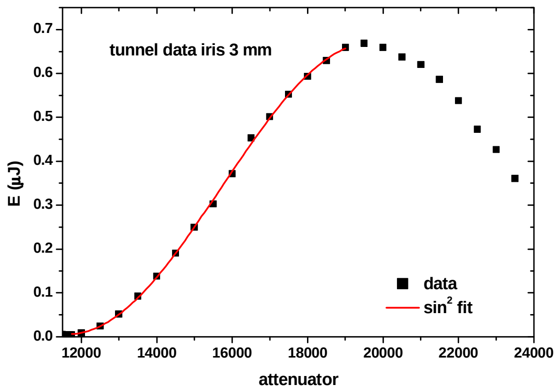
FLASH
Free-Electron Laser in Hamburg

For the pulsed QE measurements the laser energy at the cathode has to be determined

- laser energy measured with joulemeter (Molectron J-5)
- laser energy measured on laser table and in laser hut as function of the attenuator
- transmission of view port (92 %) taken into account
- reflectivity of vacuum mirror (90 %) accounted for
- fitted by sin² to evaluate transmission (half-wave plate/polarizer attenuator)







iris 3 mm
2009-03-15

iris	date	transmission
1mm	2009-01-17	5.4 %
2 mm	2009-01-17	12.39 %
3 mm	2009-01-17	21.7 %
1 mm	2009-03-15	12.0 %
2 mm	2009-03-15	26.4 %
3 mm	2009-03-15	37.6 %
1 mm	2009-04-27	18.04 %
2 mm	2009-04-27	37.7 %
3 mm	2009-04-27	48.35 %
1 mm	2009-07-13	16.0 %
2 mm	2009-07-13	33.5 %
3 mm	2009-07-13	47.1 %

QE measurements

QE measurement
- **charge measured with toroid T1**
- **laser energy measured in laser hut**
- **automated procedure for measuring charge vs. laser energy dependence**

$$QE = \frac{n_{el}}{n_{ph}}$$

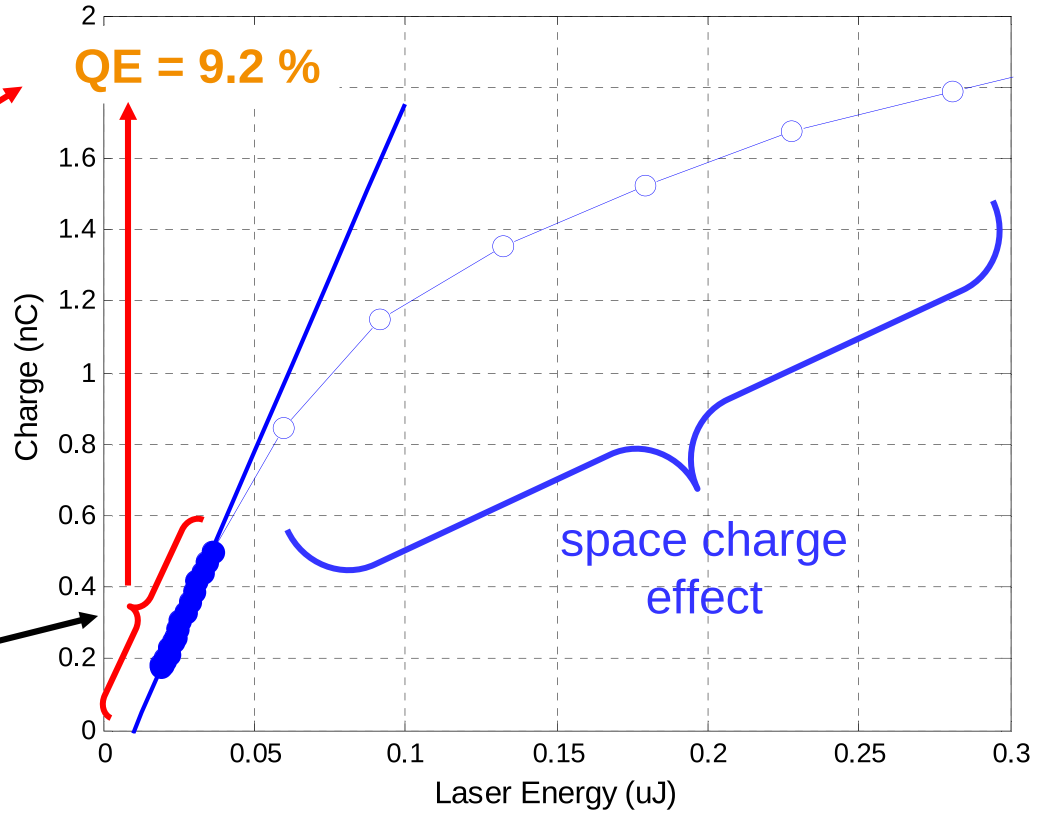
$$QE[\%] = 100 \frac{Q[C] E_{ph}[eV]}{E_{cath}[J]}$$

$$QE[\%] \approx 0.5 \frac{Q[nC]}{E_{cath}[\mu J]}$$

@ 262 nm

example of QE measurement at FLASH cathode #77.2 2009-04-27

P_{for} = 3.8 MW phase 38 deg w.r.t. zero crossing , iris = 2 mm

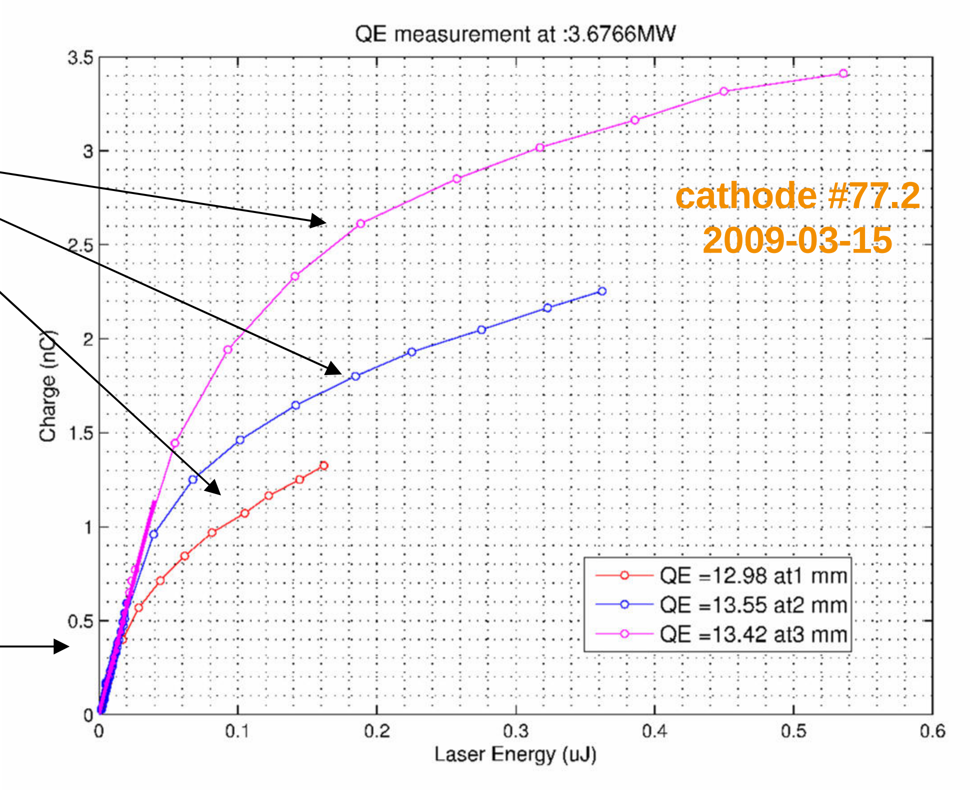


charge trend at low charge fitted

QE measurements

Charge versus laser energy obtained for different laser diameters at the cathode, accelerating field constant.

In the space charge affected regime the extracted charge depends on the laser spot size.



The slope of the linear part in the low energy region is independent from the spot size since here the emission is not effected by space charge.

QE – vs. field

RF data analysis – QE enhancement

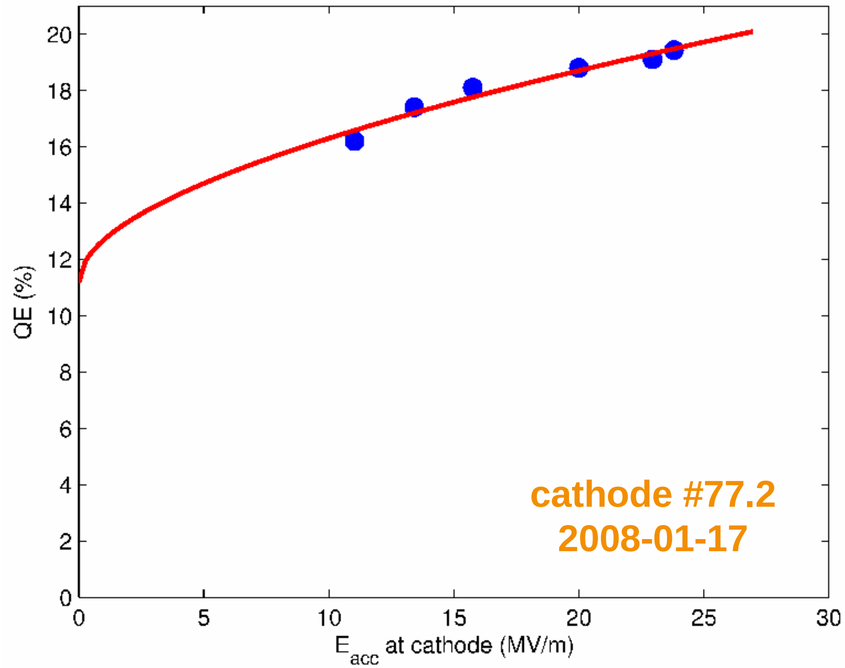
- QE @ given acc. gradient E and phase ϕ
- with a given laser energy without space charge

$$QE = A \cdot \left[h\nu - (E_G + E_A) + q_e \cdot \sqrt{\frac{q_e \cdot \beta \cdot E \cdot \sin(\phi)}{4 \cdot \pi \cdot \varepsilon}} \right]^m$$

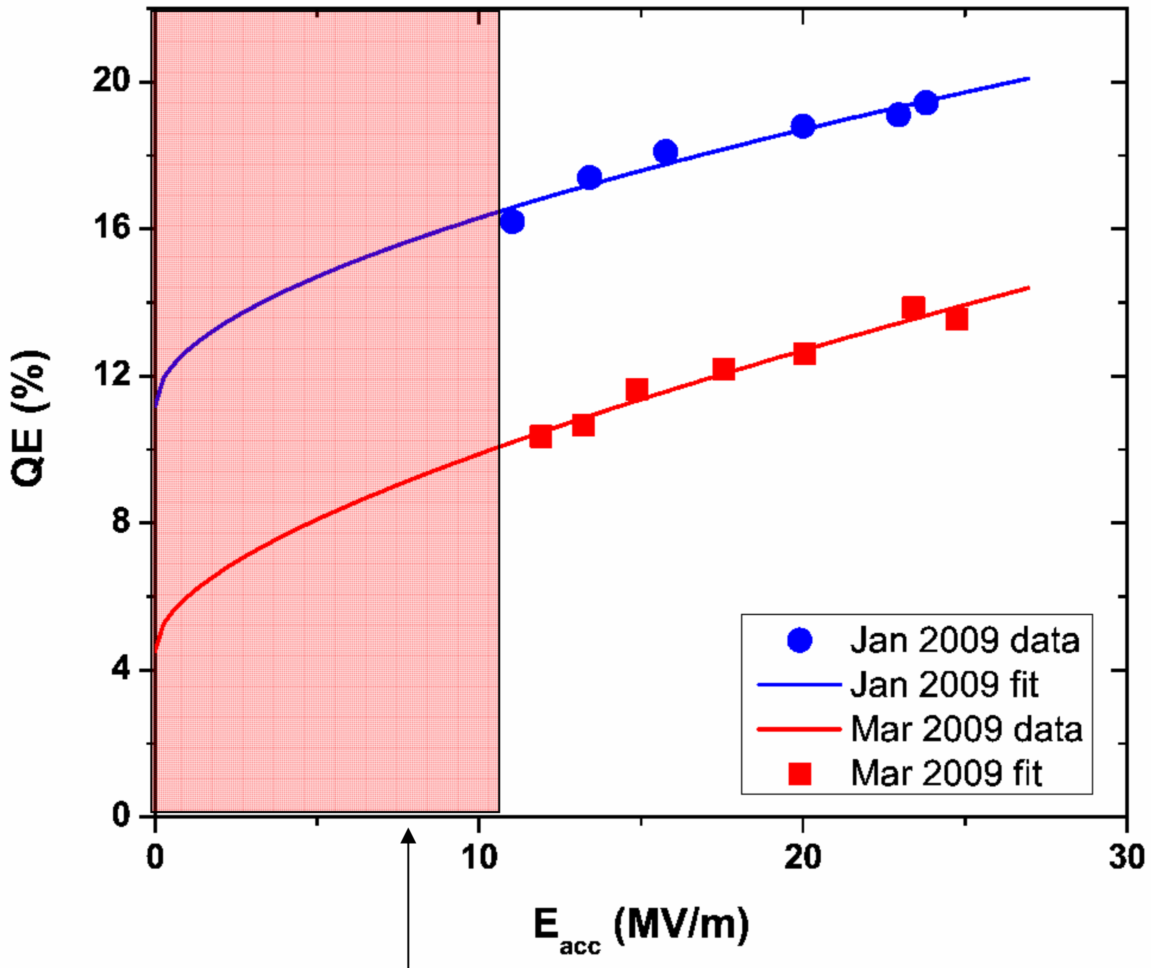
where E is the accelerating field, ϕ is the phase RF/laser, β is the geometric enhancing factor

From the fit of QE versus electric field at the cathode one gets information about the work function and the geometric enhancement factor.

$E_G + E_A$ = 3.5 eV
β = 4.7
QE @ zero field = 11.2 %



QE – vs. field



measurements impossible

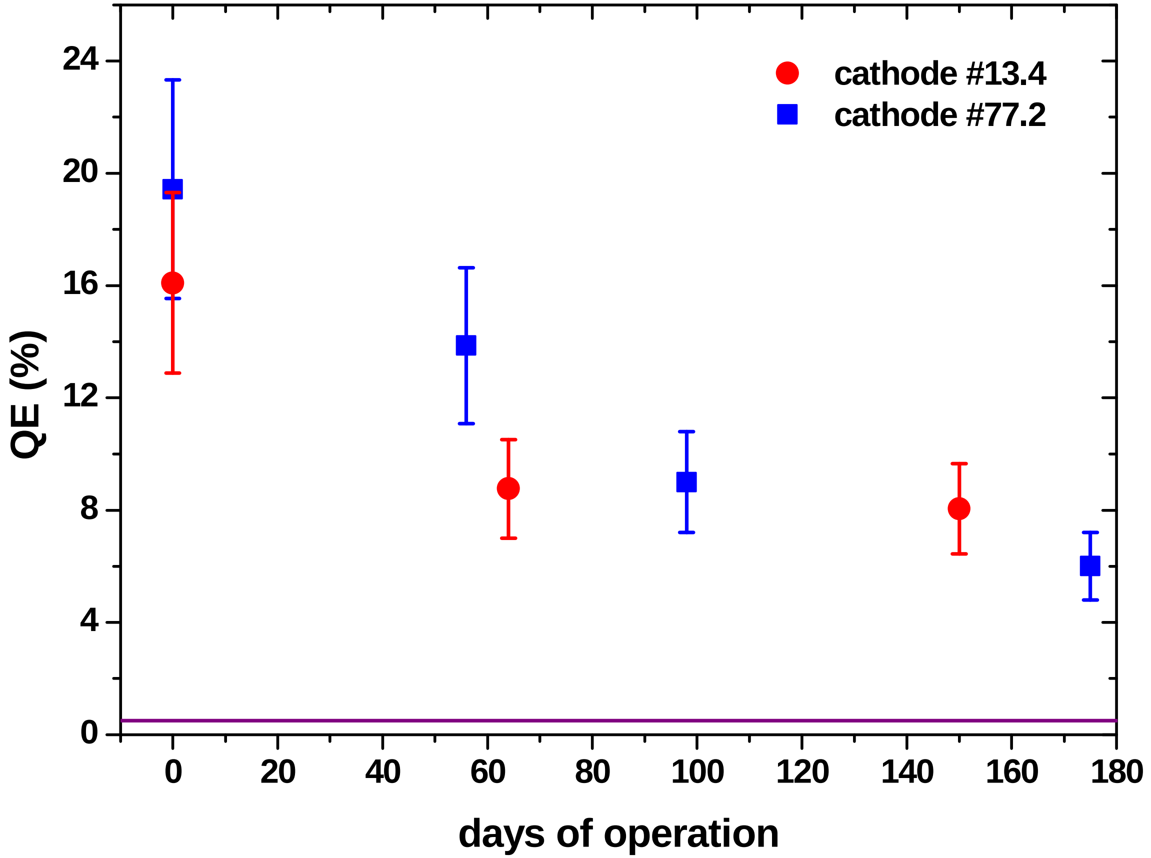
cathode #77.2 2009-01-17
QE @ zero gradient = 11.2 %
$W = E_G+E_A = 3.5$ eV
$\beta = 4.7$

56 days of operation

cathode #77.2 2009-03-15
QE @ zero gradient = 4.5 %
$W = E_G+E_A = 3.8$ eV
β= 12.7

→ QE decreased
→ E_G+E_A increased
→ field enhancement increased

Cathode life time

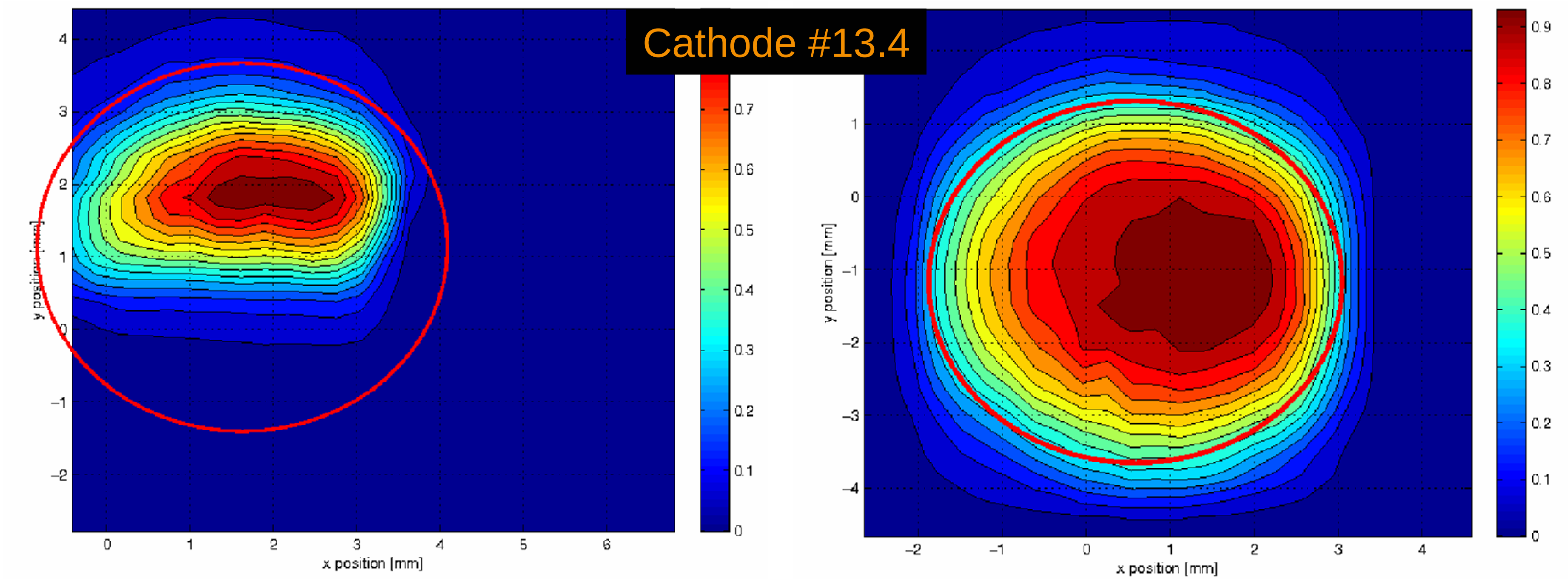


For the actual operation mode of FLASH, there are NO life time problems.
Cathode changes have not been motivated by low QE!
Since summer 2008 only 3 cathodes have been used
(#13.4, #77.2, and #53.2)!

open question: life time for long pulse train operation

QE maps

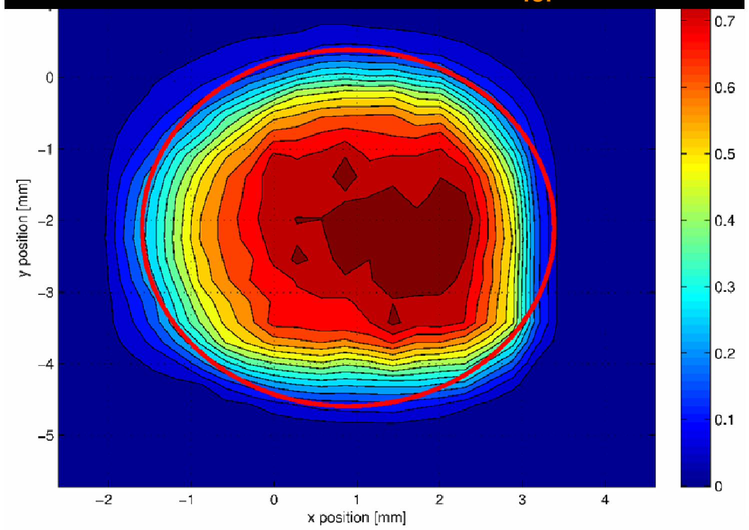
Laser with smallest possible spot size (0.26 mm) is moved over the cathode and the extracted charge is measured with the toroid T1. The aim of this studies is to get an idea of how homogeneously the charge is extracted from the cathode.
In addition the QE map is used to center the laser on the cathode for operation.



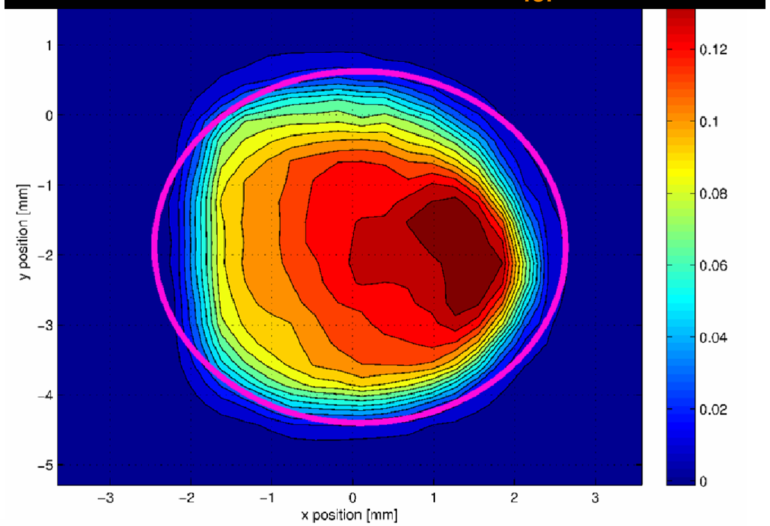
QE maps before and after realignment of the laser to the cathode.
Red circle represents the 5 mm photo emissive Cs_2Te film.

QE maps

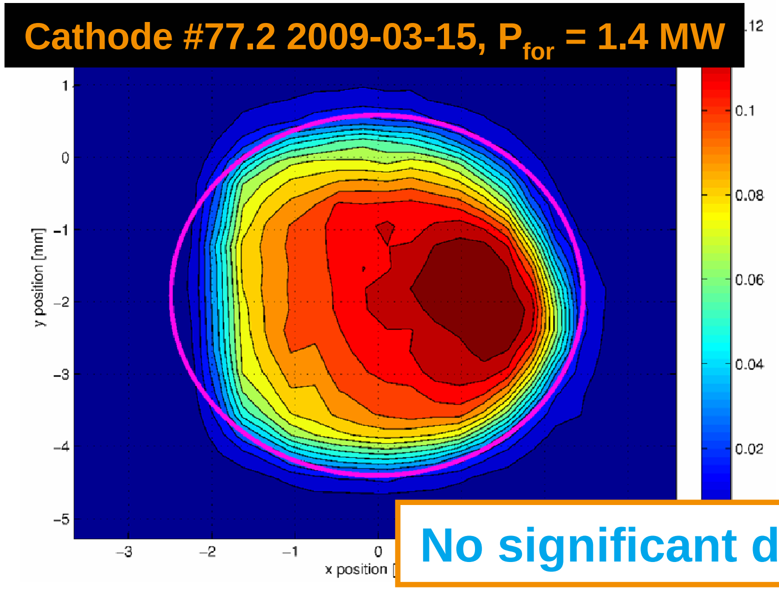
Cathode #77.2 2009-01-17, P_{for} = 3.4 MW



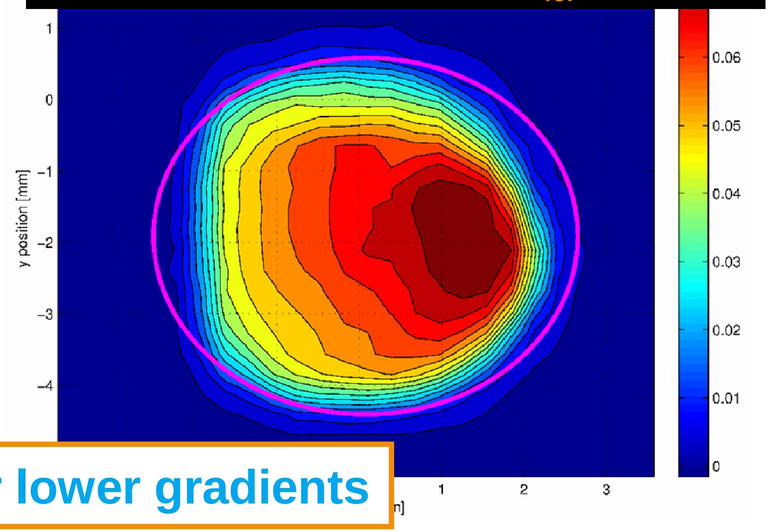
Cathode #77.2 2009-03-13, P_{for} = 3.85 MW



Cathode #77.2 2009-03-15, P_{for} = 1.4 MW



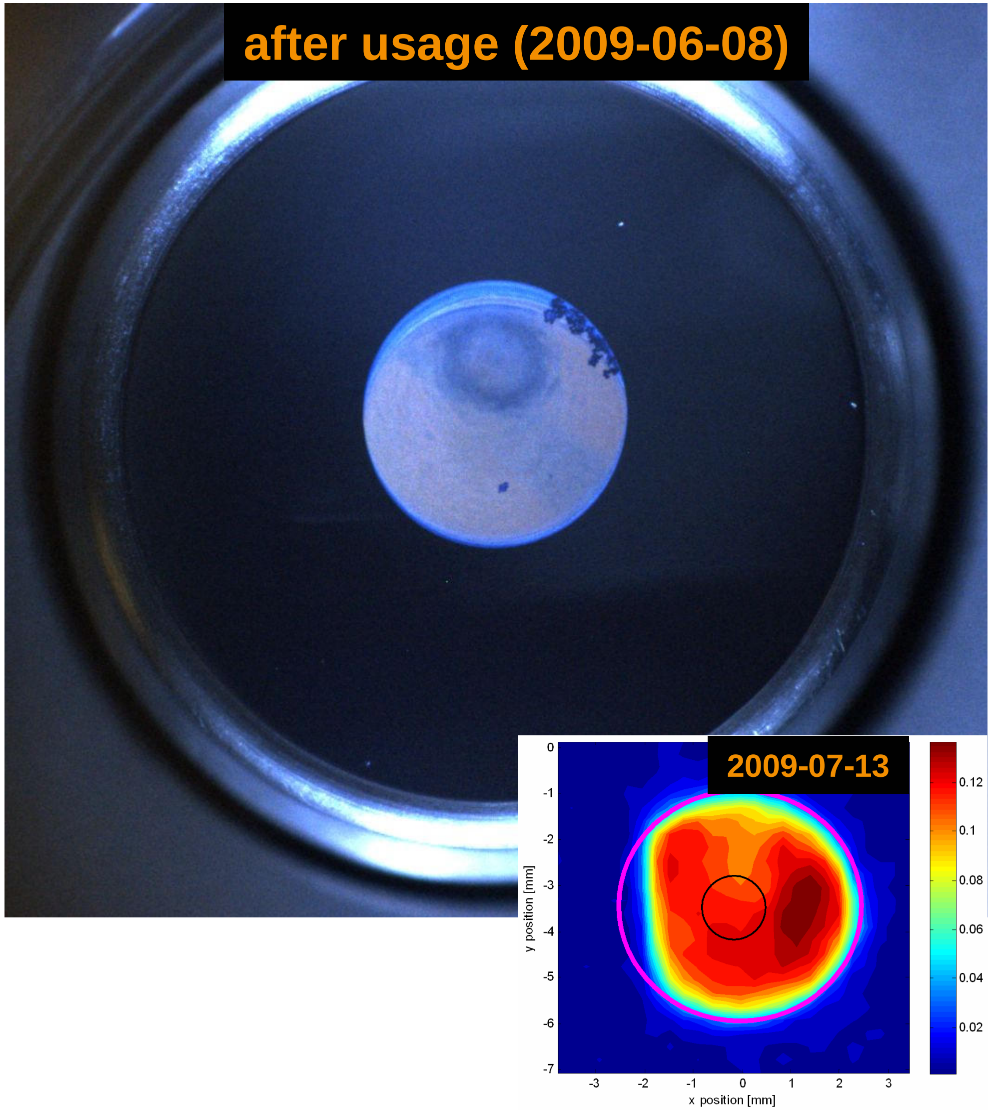
Cathode #77.2 2009-03-15, P_{for} = 0.9 MW



No significant differences for lower gradients

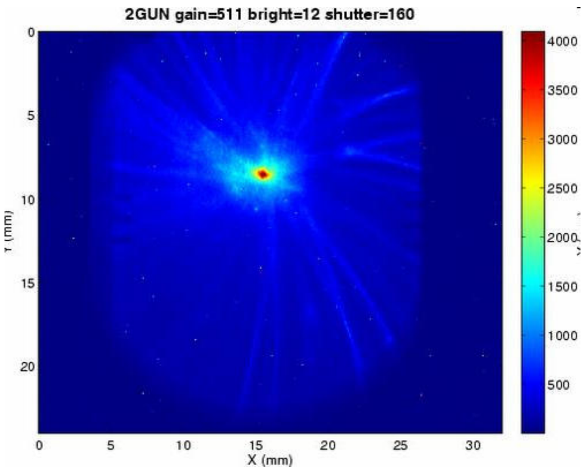
Optical inspection

cathode #77.2



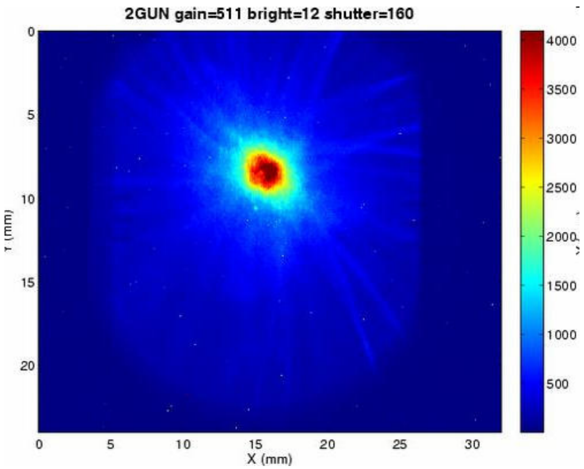
Dark current

cathode #77.2



Pfor=3.94 MW
rf length 400 μs
solenoid 305 A
bucking -22.8 A

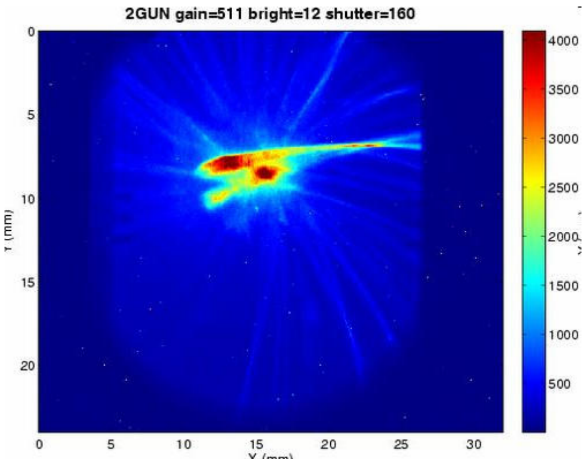
dc level 480 μA



Pfor=3.94 MW
rf length 400 μs
solenoid 250 A
bucking -22.8 A

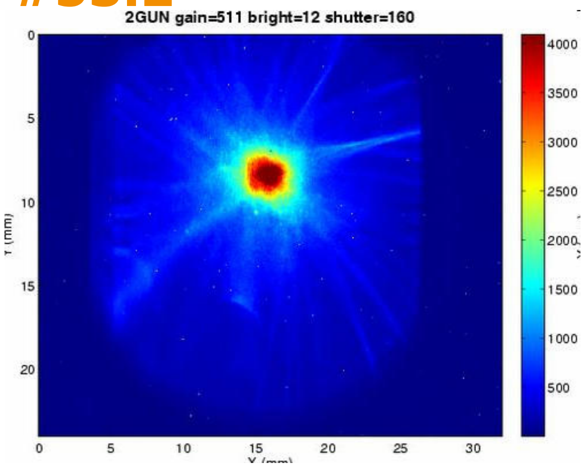
dc level 400 μA

cathode #53.2



Pfor=3.94 MW
rf length 400 μs
solenoid 305 A
bucking -22.8 A

dc level 500 μA



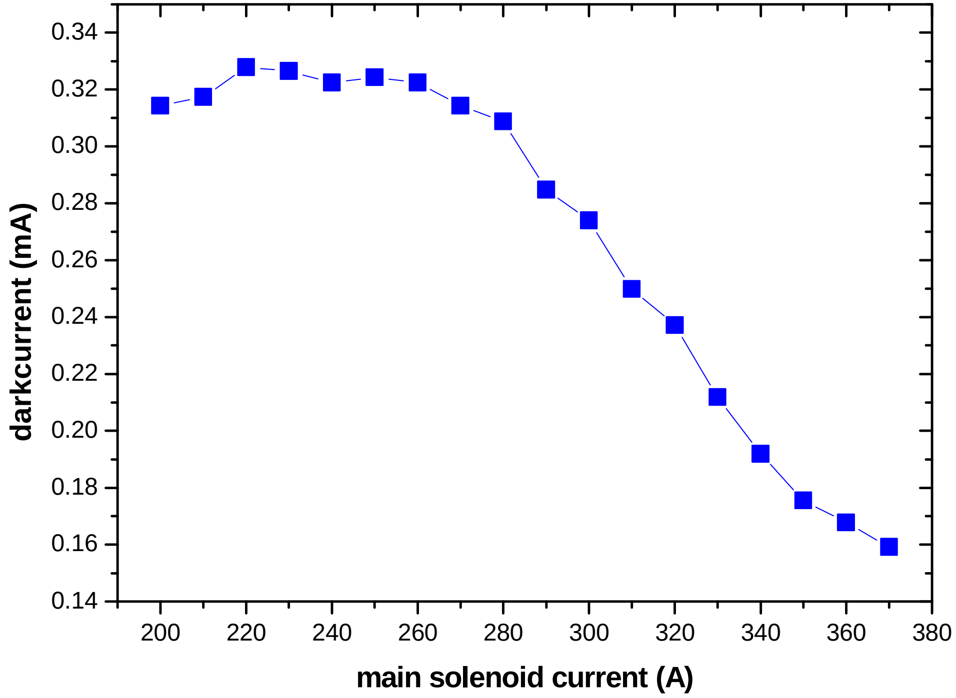
Pfor=3.94 MW
rf length 400 μs
solenoid 250 A
bucking -22.8 A

dc level 500 μA

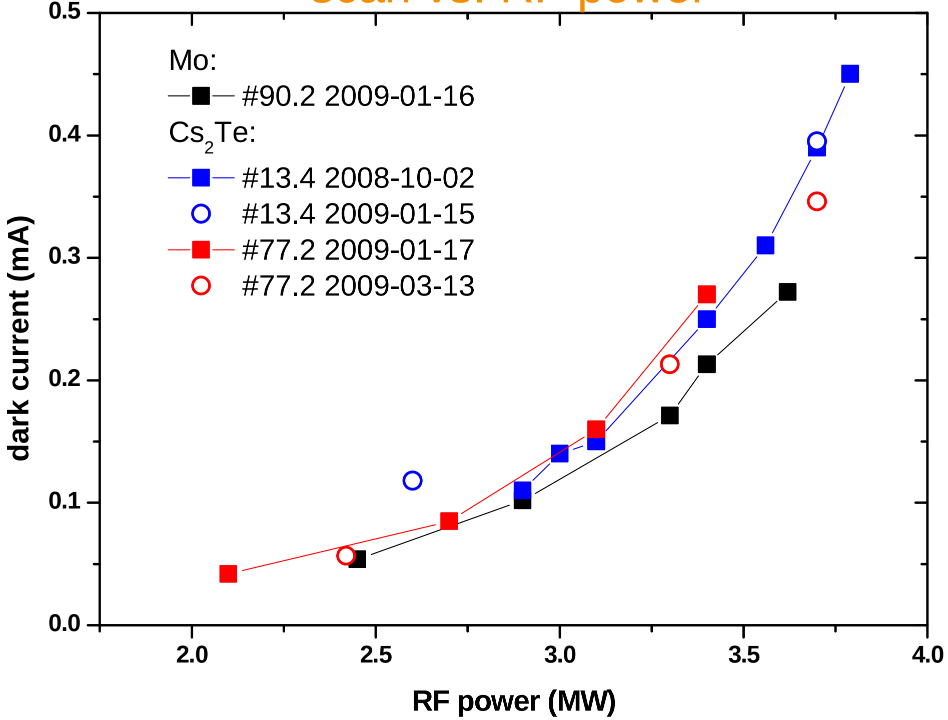
In general dc hard to measure!! The hot spots for #53.2 go from left to right while increasing the solenoid field

Dark current

Dark current vs. main solenoid current

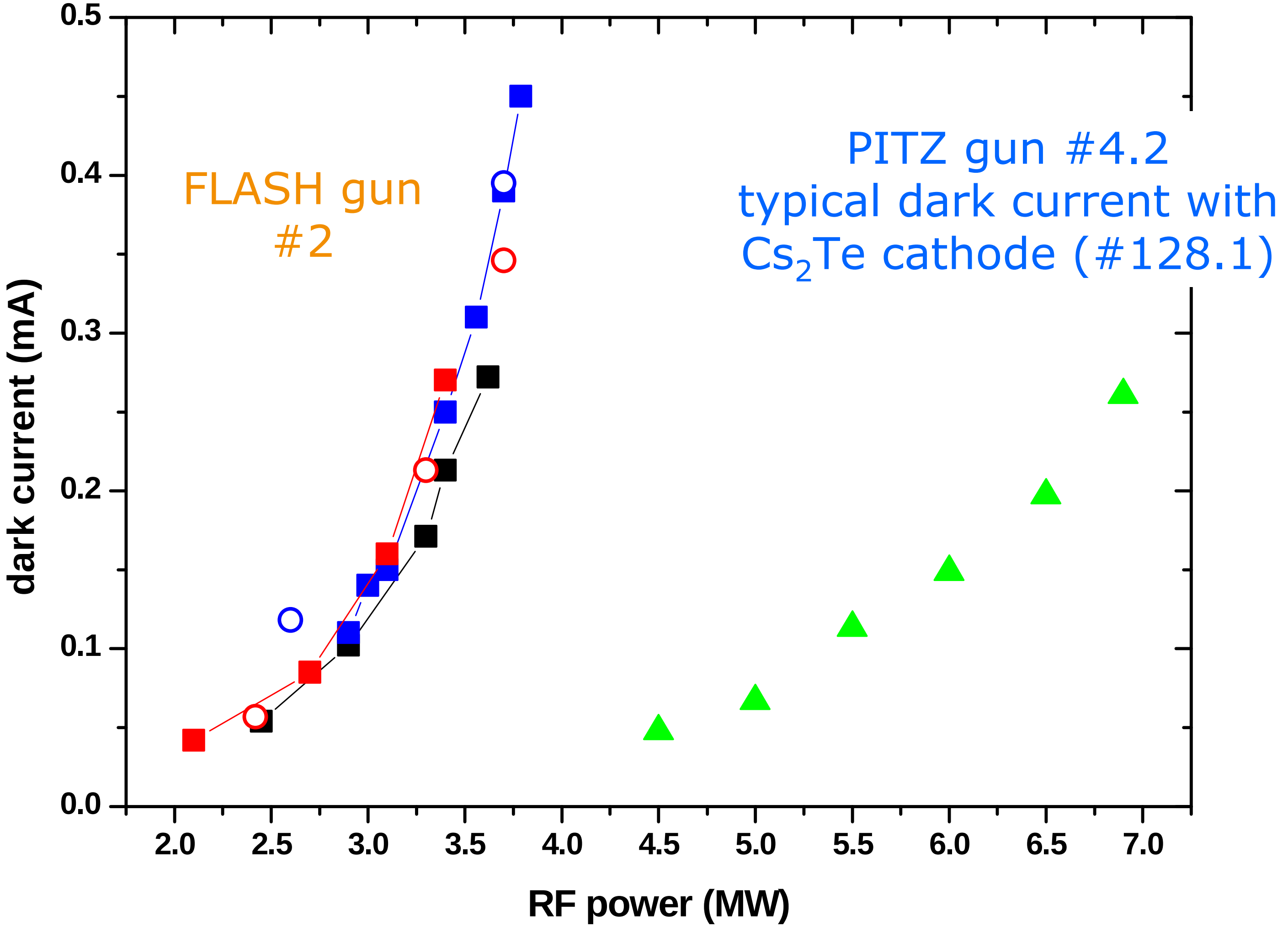


Max. dark current from solenoid scan vs. RF power



- **Dark current constantly high and only acceptable if no problem with the cathode**
- **In addition caused by ageing of the gun full scans have been impossible (vacuum interlocks)**

Dark current



Gun 4.2 will be mounted at FLASH January 2010

Summary and Conclusion

- Results from last beam times presented
  - Laser beam line transmission (from January until July 2009)
  - pulsed QE
    - Measurements and analysis
    - Evolution over time
    - Life time
  - QE maps
- More studies needed for further understanding the QE behaviour under influence of RF field
- More studies needed after long pulse train operation

- Dark current issues
  - dc images
  - dc vs. main solenoid scans
  - dc for different RF power