INVESTIGATIONS ON THE INCREASED LIFETIME OF PHOTOCATHODES AT FLASH AND PITZ.

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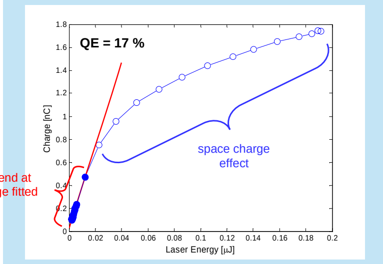
Introduction

The operation of Cs_2Te photocathodes requires a drive laser with a wavelength in the UV. The quantum efficiency has to be high in order to keep the average laser power in a reasonable regime for high duty cycle operation. Usually starting from about 10 % the QE degenerates during operation in RF-guns. If the QE is below 0.5 % the end of the cathodes lifetime is reached. In 2006 and 2007 an unexpected decrease of the lifetime was observed. Investigations by means of x-ray photoelectron spectroscopy (XPS) on cathodes operated at FLASH and PITZ showed that the photoemissive film was destroyed by contamination with fluorine [1]. After removal of Teflon washers and improved vacuum conditions the cathode lifetime increased in both photoinjectors.

Photocathodes

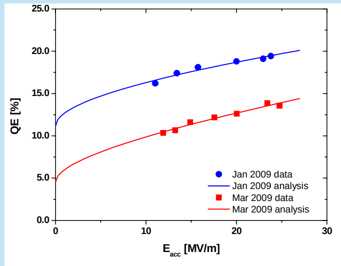
The Cs_2Te photocathodes used at PITZ and DESY are prepared at INFN – Milano, LASA [2]. After fabrication the QE dependency on the photon wavelength (spectral response) is measured by means of applying interference band pass filters to the cw output of an Hg-lamp. From the spectral response the QE at the drive laser wavelength (λ=262 nm for FLASH and λ=257 nm for PITZ) are extrapolated. Until now an average of 8.5 % is obtained for λ=262 nm [3] .
For each prepared cathode the relevant data like reflectivity of the Mo surface, QE after production, operation times, and measurements in the RF-guns of FLASH and PITZ are summarized in an online accessible database [3].
After production the cathodes are stored in a transport box under UHV environment with a base pressure in the low 10^{-10} mbar. This allows the shipment of cathodes to FLASH or PITZ, conserving the QE over months. At the photoinjectors the transport boxes are connected to the RF-gun load-lock cathode system [4].

QE measurements

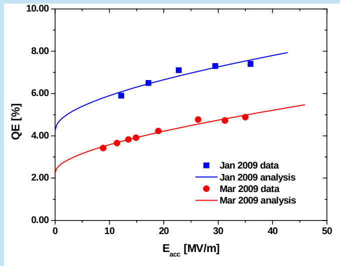


Charge vs. Laser energy for cathode 77.2 directly after insertion; P_{for} = 3.8 MW, phase +38 deg w.r.t zero crossing.

QE dependence on accelerating field



QE vs. E_{acc} for cathode #77.2 obtained at FLASH January 2009 (blue) and March 2009 (red).



QE vs. E_{acc} for cathode #128.1 obtained at PITZ January 2009 (blue) and March 2009 (red).

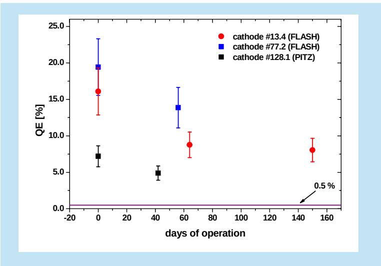
$$QE = A\cdot\left(E_{ph}-\left(E_G+E_A\right)+q_e\sqrt{\frac{q_e\beta E_{acc}}{4\pi\varepsilon_0\varepsilon_r}}\right)^m$$

- E_{ph} photon energy
- E_g band gap
- E_a electron affinity
- q_e elementary charge
- β microscopic field enhancement factor
- E_0 dielectric constant of vacuum
- ε_r dielectric constant of Cs_2Te (set to 1 giving an upper limit for β)
- m for simplicity set to 2

FLASH	days of operation	E_g+E_a	β
#77.2	0	3.5 eV	4.7
#77.2	56	3.8 eV	12.7

PITZ	days of operation	E_g+E_a	β
#128.1	0	3.9 eV	1.9
#128.1	42	4.1 eV	2.6

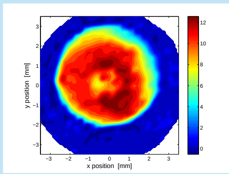
Lifetime



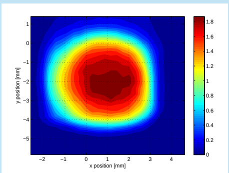
QE vs. days of operation for two cathodes used at FLASH and one at PITZ; P_{for} = 3.8 MW, phase +38 deg w.r.t zero crossing.

After improving the vacuum environment the cathode lifetime increased considerably. Since then, **no cathode has been changed because of a low QE**.

Cathode uniformity



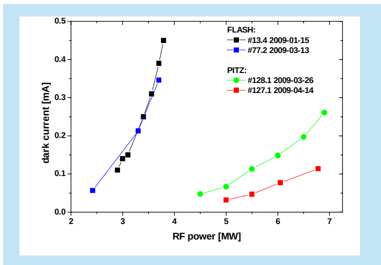
QE-map of cathode #128.1 measured at PITZ after 56 days of operation, P_{for} = 7 MW.



QE-map of cathode #13.4 measured at FLASH after 150 days of operation, P_{for} = 7 MW.

At PITZ a much faster change in the homogeneity of photoelectron emission is observed.

Dark current



Dark current as function of RF-power for two Cs_2Te cathodes from FLASH and two from PITZ. Data are maximal dark currents obtained by scanning the main solenoid field.

FLASH
> no dependence on cathode
> dark current dominated by gun body
> confirmed by optical investigations of gun back plane in 2008 [5]

PITZ
> an order of magnitude less dark current
> dark current strongly depends on cathodes
> field emission from gun 4.2 small even at 7 MW RF-power [6]

During the winter 2009 upgrade we plan to exchange the current FLASH RF-gun with gun 4.2 from PITZ. This will decrease the dark current transported through the FLASH linac by an order of magnitude.

Summary and Outlook

One crucial issue of operating Cs_2Te photocathodes as electron sources in high gradient RF-guns is the lifetime. An improved vacuum environment yields improved lifetimes at FLASH of several months and at several weeks at PITZ. This result is important especially for the future European XFEL, operating as a user facility like FLASH but with gradients at the cathode comparable to PITZ.
We plan to exchange the RF-gun at FLASH during the winter 2009 upgrade with the PITZ gun 4.2. This will reduce the dark current transported through the FLASH linac by an order of magnitude.

References

[1] S. Lederer et al., "XPS studies of Cs_2Te photocathodes", Proc. FEL 07, Novosibirsk, Russia, 26-31 Aug 2007, pp 457.
[2] D. Sertore et al., "Review of the production process of TTF and PITZ photocathodes", Proc. PAC 05, Knoxville, Tennessee, 16-20 May 2005, pp 671.
[3] http://wwwlasa.infn.it/ttfcathodes/
[4] P. Michelato et al., "High Quantum Efficiency Photocathode Preparation System For TTF Injector II", TESLA FEL-Report 1999-07, pp 39.
[5] S. Schreiber et al., "Cathode Issues At The FLASH Photoinjector", Proc. FEL 08, Gyeongju, Korea, 24-29 August 2008.
[6] S. Rimjaem et al., "Tuning And Conditioning Of A New High Gradient Gun Cavity At PITZ", Proc. EPAC 08, Genoa, Italy, 23-27 June 2008, pp 244.