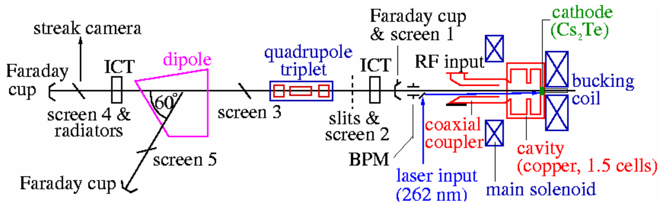
RF Gun and Cathode Operation at PITZ

In collaboration with: BESSY Berlin, INFN-LASA Milano, INR Troitsk, INRNE Sofia, MBI Berlin, TU Darmstadt, YERPHI Yerevan

Goals and Current Layout of the Photo Injector Test Facility at DESY Zeuthen, PITZ

- test facility for FELs like TTF2-FEL and XFEL
  - ⇒ **very small transverse emittance (~1 µm @ 1 nC)**
  - ⇒ stability, short bunches, small energy spread
- extensive R&D on RF guns in parallel to TTF operation
- compare detailed experimental results with simulations:
  - ⇒ benchmark theoretical understanding of photo injectors
- test and optimize new developments (laser, cavities, cathodes, beam diagnostics)



Achievements on RF Conditioning

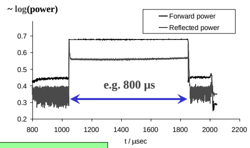
RF frequency: 1.3 GHz

maximum RF power in the gun:

- rf pulse lenght: 900 µs
- repetition rate: 10 Hz
- gradient: ~42 MV/m at the cathode

duty cycle: 0.9 %

average RF power: 27 kW

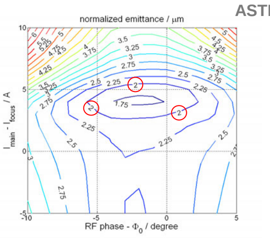


fulfills complete TTF2-FEL RF parameter requirements !

next: attack XFEL goals (60MV/m, ≤ 650 µs, 10 Hz)

Electron Beam Transverse Emittance

ASTRA Simulation:

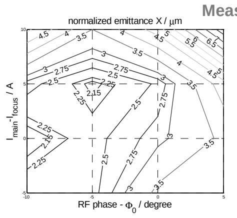


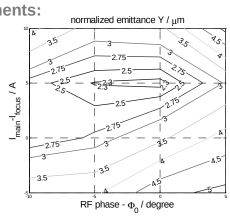
simulation conditions here:

- charge: 1 nC
- laser profiles:
  - longitudinal: 20 ps FWHM, 5 ps rise/fall time
  - transverse: $\sigma_{x,y}$ = 0.6 mm homogeneous
- gradient at cathode: 42 MV/m

If transverse laser shape is Gaussian (same $\sigma_{x,y}$): ⇒ min. emittance ~ 5 µm

Measurements:

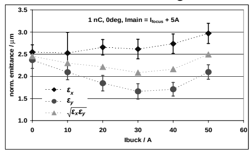




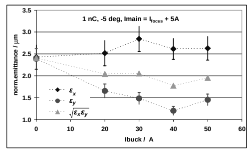
~2.5 µm for ~1 nC have been obtained by different shifts on different days reliably !

better than the TTF2-FEL start-up requirements on beam quality !

If the bucking coil is turned on further improvement can be obtained:

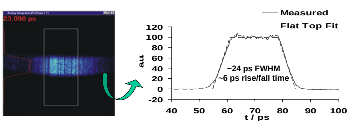


ε_n ~ 2.0 µm

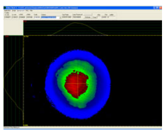


Measured Photo Cathode Laser Beam Parameters

longitudinal: (measured at 524 nm)



transverse: (measured in UV at virtual cathode)

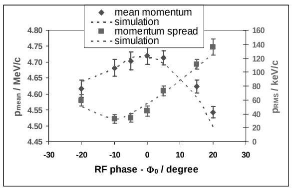


- variable (RMS 0.3 – 1.0 mm)
- diaphragm is imaged on cathode
- e.g.:

$\sigma_x = 0.52 \pm 0.02$ mm

$\sigma_y = 0.63 \pm 0.02$ mm

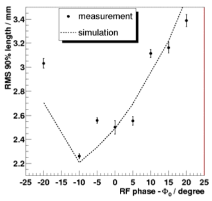
Electron Beam Longitudinal Phase Space



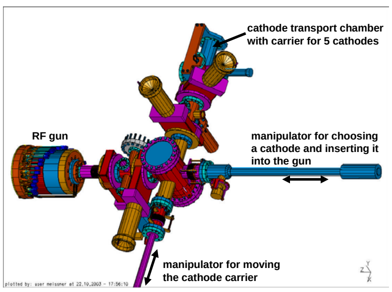
$p_{mean}^{max} = 4.73 \pm 0.03$ MeV/c

$p_{RMS}^{min} = 33 \pm 7$ keV/c

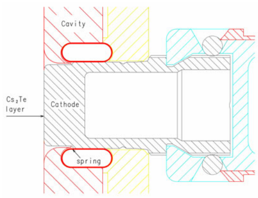
$\Delta z_{RMS\,90\%}^{min} = 2.25 \pm 0.05$ mm



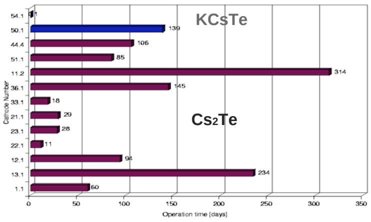
Cathode Exchange System



Cathode in the RF Gun



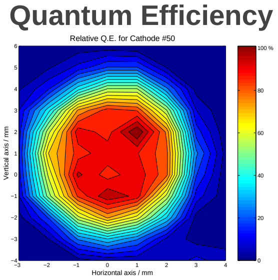
Operation Time Statistics



total operation time: 1263 d

mean operation time: 97 d

Homogeneity and Quantum Efficiency



- **homogeneity: within 10% in the active area** (laser spot size used for scanning: 0.5 mm rms)
- **QE: ~ 10% (after production)**
  - **→ 0.5 % (stable for month/years)**

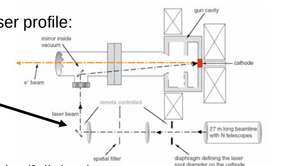
responsible author: Frank Stephan, DESY Zeuthen; Frank.Stephan@desy.de, Oct 2003

Towards the XFEL Requirements (1.4 µm @ undulator)

a) with improved homogeneity of transverse laser profile:

ε_n ≤ 2 µm @ 1 nC (see above)

How ? → upgrade laser beamline
When ? → spring 2004



b) with improved longitudinal laser profile (2 ps rise/fall time):

ε_n ~ 1.2 µm @ 1 nC (see below) **How ? → see laser poster, Ingo Will, MBI** **When ? → 2004 – 2006, funding ??**

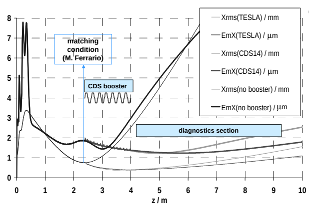
c) with all laser improvements, 60 MV/m on the cathode and booster cavity:

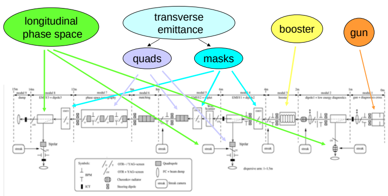
ε_n ~ 0.9 µm @ 1 nC (see poster on Injector III Concept)

How ? → more conditioning, may be better gun cooling
When ? → start 01/2004

PITZ 2: Further Scientific Program at PITZ

→ study emittance conservation and further improve electron beam quality





preliminary PITZ 2 layout