EXPERIMENTAL CHARACTERIZATION OF THE ELECTRON SOURCE AT THE PHOTO INJECTOR TEST FACILITY AT DESY ZEUTHEN

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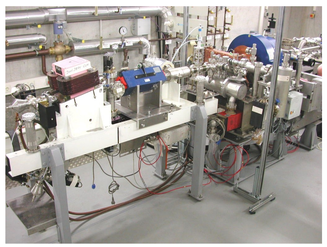

Abstract

The Photo Injector Test facility at DESY Zeuthen (PITZ) was built in order to study the production of high brightness electron beams, which are substantial for the successful operation of Free Electron Lasers (FEL) and linear colliders. The photoinjector at Zeuthen is based on a 1.5-cell L-band rf cavity with coaxial rf coupler equipped with emittance compensating solenoids, a laser capable to generate long pulse trains, an UHV photo cathode exchange system, and various diagnostics tools. The current goal of PITZ is a full characterization of the electron source, which will be installed at the TESLA Test Facility Free Electron Laser (TTF2-FEL) in autumn 2003. In the running periods before the gun is delivered to TTF2-FEL, the rf performance and the beam parameters will be measured in detail. The results presented in this contribution contain the measurements of dark current, driving laser parameters, beam charge, beam size along the facility, transverse emittance, momentum and momentum spread. The electron beam measurements will be presented in comparison with beam dynamics simulations.

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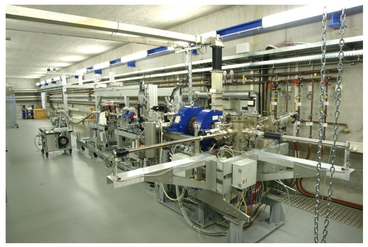
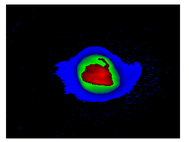
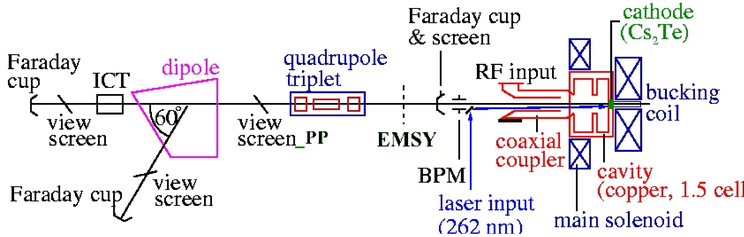


Schematic view of the gun and diagnostic sections

Beam spot at screen_PP
(view screen between quadrupole triplet and dipole)

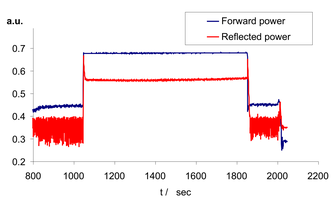




Achievements on RF commissioning

RF frequency: 1.3 GHz
Maximum average RF power in the gun:
- RF pulse length: 900 msec
- repetition rate 10 Hz
- gradient at photocathode ~ 40 MV/m
duty cycle 0.9%, averaged power in the cavity 27kW

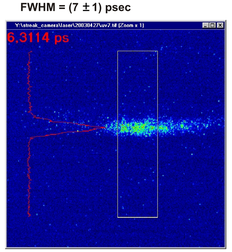
Typical long RF Pulse



Driving laser

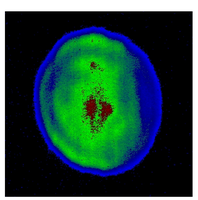
UV 262nm
Pulse train up to 800 sec
Rep.rate 1-5Hz

Laser pulse length measurement with streak camera.
FWHM = (7 ± 1) psec



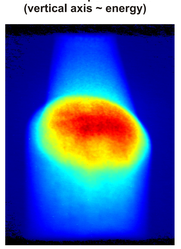
Transverse laser pulse profile measurement at virtual cathode, variable, e.g.

$_x$= (0.50 0.02) mm
$_y$= (0.67 0.01) mm

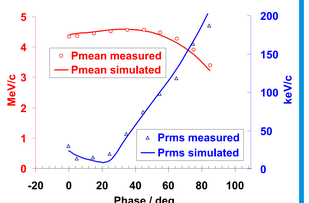


Longitudinal momentum measurements

Beam in dispersive arm (vertical axis ~ energy)

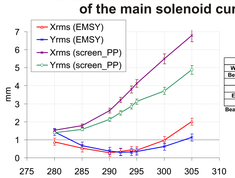


Longitudinal momentum and momentum spread as functions of RF phase
(Beam charge ~ 1nC)



Measurements of beam size

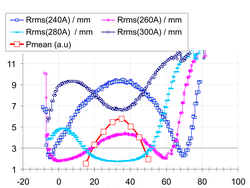
Beam transverse sizes as a function of the main solenoid current



	X	Y	
Waist at EMSY screen	0.27	0.31	mm
Beam size at screen_PP	2.62	2.5	mm
divergence	1.16	1.08	mrad
Energy	4.55	4.55	MeV
Estimated Norm.Emit	2.80	2.99	pi-mm-mrad
Error Norm.Emit	0.84	0.90	pi-mm-mrad

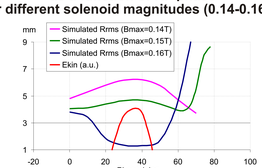
Beam Charge=0.1nC

Beam transverse sizes measured at screen_PP as a function of RF phase for different solenoid currents (240A-300A)



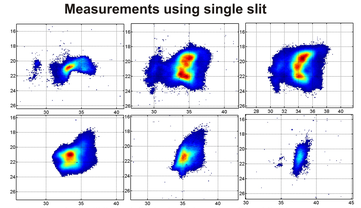
RF phase of maximal (minimal) beam transverse size corresponds to the phase with the maximum energy gain, in agreement with simulations

Simulated beam transverse sizes as a function of RF phase for different solenoid magnitudes (0.14-0.16T)



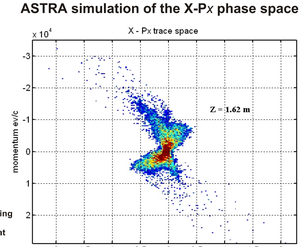
Measurements of beam transverse emittance

Measurements using single slit

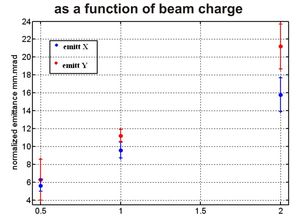


Scanning with a single slit through the horizontal cross section of the beam. The scanning step is 0.3 mm. The bunch charge: 0.66 nC. The mean momentum was measured to be 4.57 MeV/c. The current in the main solenoid: Imain=290 A. The X-RMS size of the beam at the position of slit (1.62 m after the photocathode) was measured directly as 0.38 0.01 mm. The measured normalized X-RMS emittance is 5.3 ± 0.7 -mm-mrad;
Y-RMS emittance is 4.7 ± 0.5 -mm-mrad.
Corresponding simulated normalized emittances: EmittanceX = 5.6 -mm-mrad;
EmittanceY = 4.5 -mm-mrad.

ASTRA simulation of the X-Px phase space

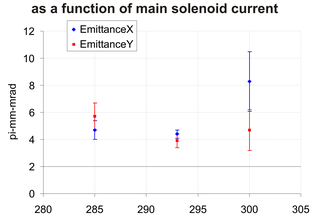


Transverse beam emittance as a function of beam charge



Measurement of the transverse emittance as a function of the bunch charge. For this measrement the single slit masks were used. At each charge the focusing current was adjusted so that the electron beam has a waist at the position of the slits.
Respectively the values of the focussing current are as follows:
1) *Imain (0.5 nC) = 292 A; 2) Imain (1.0 nC) = 290 A 3) Imain (2.0 nC) = 289 A*
Diaphragm 1.5 mm in laser beam line

Transverse beam emittance as a function of main solenoid current



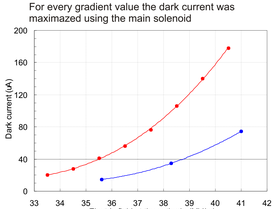
Transverse emittance as a function of the current of the main solenoid. The measurement were done at the following conditions:
Gun gradient = 40.0 MV/m;
Bunch charge = 0.5 nC;
Mean momentum = 4.55 MeV/c
Diaphragm 1.2 mm in laser beam line

Dark Current Measurements

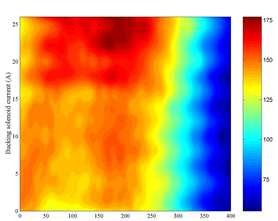
Main part of the dark current appears due to the Cs2Te cathode

Measured dark current as a function of accelerating gradient

For every gradient value the dark current was maximazed using the main solenoid



Contour plot of the measured dark current for the Cs2Te cathode as a function of the main solenoid and the bucking solenoid currents.

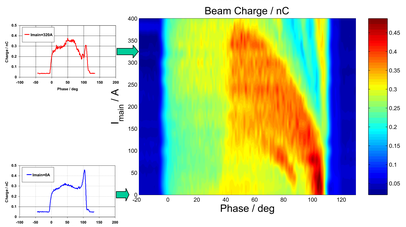


Phase Scan

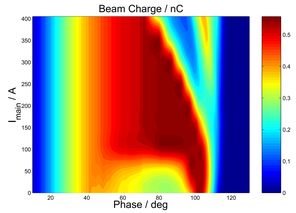
Beam charge measured by Faraday cup at Diag.Cross as a function of RF phase shows strong dependence on the main solenoid current

2D Phase scan - Beam charge as a function of RF phase and main solenoid current

Measurements
Beam Charge / nC



Simulations
Beam Charge / nC



According to simulations the cavity and beam line apertures play a significant role in the charge transport

Conclusions

The experimental characterization of the electron source at the photoinjector test facility at DESY Zeuthen is ongoing. Maximal averaged power of 27 kW in the gun with a duty cycle of 0.9% have been achieved. Detailed measurements of dark current, beam longitudinal momentum and transverse phase space have been