PITZ Optimization at SRF Gun Gradient.

M. Krasilnikov, P. Boonpornprasert, Y. Chen, G. Georgiev, J. Good, M. Gross, P. Huang, I. Isaev,
C. Koschitzki, S. Lal, X.-K. Li, O. Lishilin, G. Loisch, D. Melkumyan, R. Niemczyk, A. Oppelt, H. Qian,
H. Shaker, G. Shu, F. Stephan, G. Vashchenko, DESY, 15738 Zeuthen, Germany
M. Dohlus, E. Vogel, DESY, 22603 Hamburg, Germany

Abstract

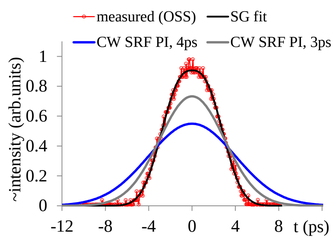
A continuous wave (CW) mode operation of the European XFEL is under studies for a future upgrade. A superconducting RF (SRF) CW gun is under experimental development at DESY in Hamburg. Beam dynamics simulations for this setup have been done assuming 100 pC bunch charge and a maximum electric field at the photocathode of 30-40 MV/m. Experimental studies for these parameters using a normal conducting RF gun have been performed at the Photo Injector Test facility at DESY in Zeuthen (PITZ) together with corresponding beam dynamics simulations. The beam transverse emittance was minimized by optimizing the main photo injector parameters in order to demonstrate the feasibility of generating electron beams with a beam quality required for successful CW operation of the European XFEL for conditions similar to the SRF gun setup.

Photocathode laser

Temporal profile

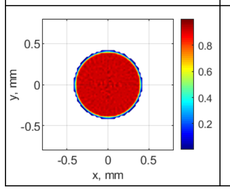
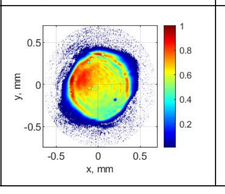
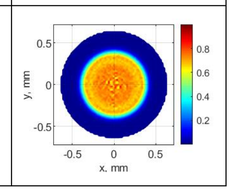
- **CW SRF PI simulations**: **Gaussian** temporal profile of **3 ps** and **4 ps** RMS
- **PITZ simulations**: **Gaussian 6 ps** FWHM (2.6 ps RMS)
- **PITZ experiment**: Gaussian pulses with ~6 ps FWHM, measured by cross-correlator (OSS – Optical Sampling System).

Super Gaussian fit of the measured profile
$SG \propto \exp\{-0.5 \cdot |t/2.6|^{2.59}\}$



Transverse distribution

Transverse shaping of the laser illuminating the photocathode is realized using variable aperture (the so-called Beam Shaping Aperture – **BSA**).

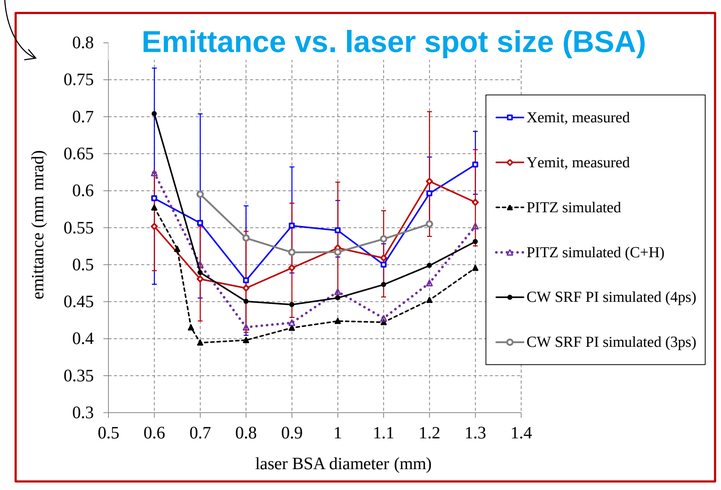
Uniform radially homogeneous, used in CW SRF PI and PITZ simulations	**Measured** CCD camera at Virtual Cathode (VC2@PITZ)	**Core+Halo model** used in PITZ simulations
		

Experimental 100pC Emittance Optimization at PITZ for E_{cath}=40MV/m

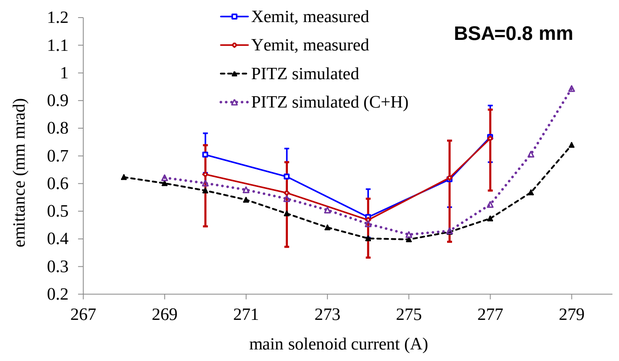
Emittance measurements

Beam transverse normalized RMS emittance was optimized at the first emittance measurement station (EMSY1) located z=5.27 m downstream of the photocathode. The single slit scan technique was applied to measure the horizontal and vertical phase space of the 100 pC electron beam.

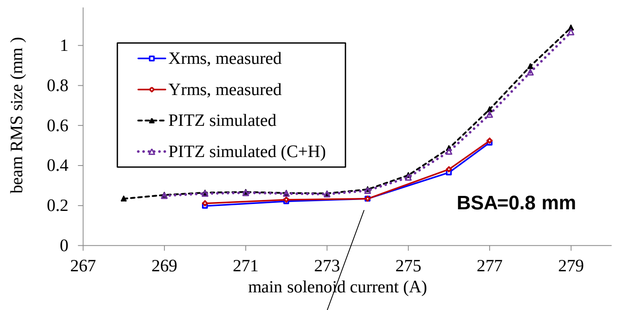
- The laser spot size (**BSA** diameter) was varied from 0.5 mm to 1.3 mm with a step of 0.1 mm
- For each laser spot size (BSA diameter), a main solenoid scan was performed to measure horizontal and vertical emittances.



PITZ Emittance vs. main solenoid current

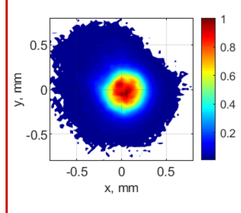


RMS beam size as a function of the main solenoid current

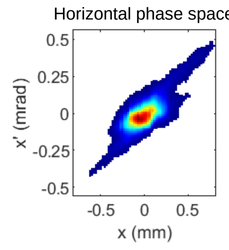


➔**Optimum main solenoid current of 274 A**

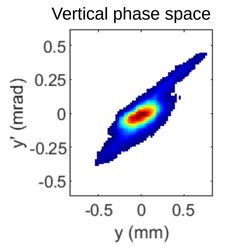
X-Y beam distribution



Horizontal phase space



Vertical phase space



σ_x= 0.220 mm
σ_y= 0.212 mm

$\varepsilon_{x,n}$= $(0.479 \pm 0.006_{stat})$ mm mrad
$\varepsilon_{y,n}$ = $(0.468 \pm 0.005_{stat})$ mm rad

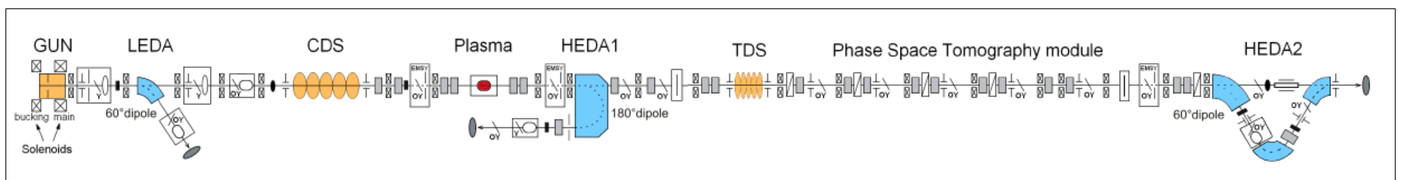
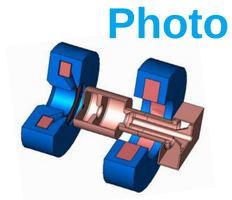
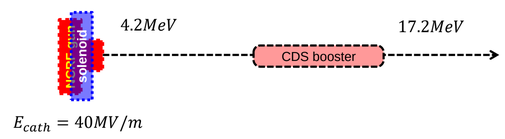
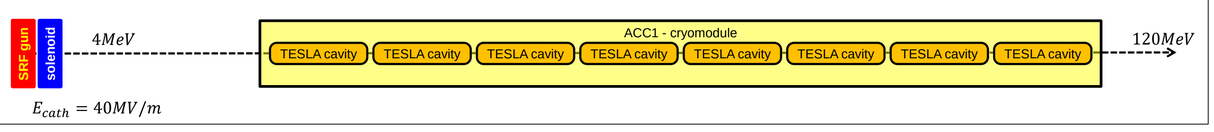


Photo Injector Test facility at DESY in Zeuthen (PITZ)





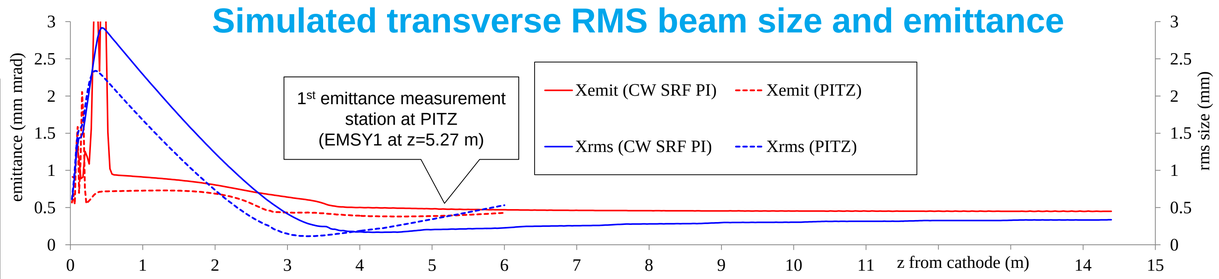
Continuous Wave Superconducting RF Photo Injector (CW SRF PI)



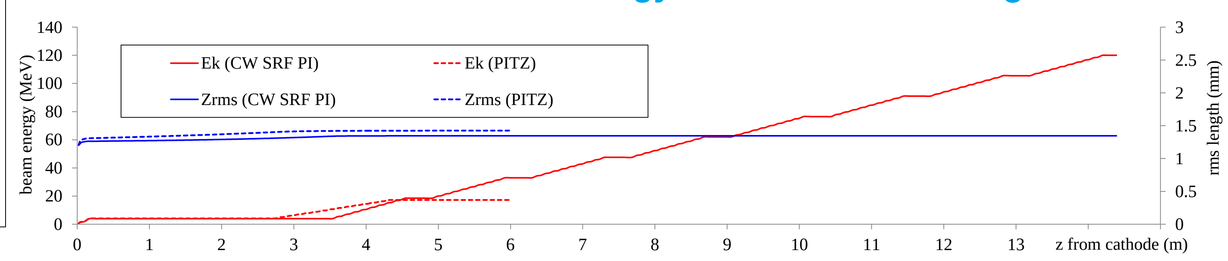
CW SRF Photo Injector optimization:
- Gun:
  - Ecath=40MV/m
  - Phase → tuned
- Photocathode laser:
  - Gaussian 3..4 ps RMS
  - Spot size → tuned
- Gun solenoid:
  - Position (0.4m)
  - Peak field → tuned

PITZ Photo Injector optimization:
- Gun:
  - Ecath=40MV/m
  - Phase =MMMMG
- Photocathode laser:
  - Gaussian 6 ps RMS
  - Spot size → tuned
- Gun solenoid:
  - Position (0.276m)
  - Peak field → tuned

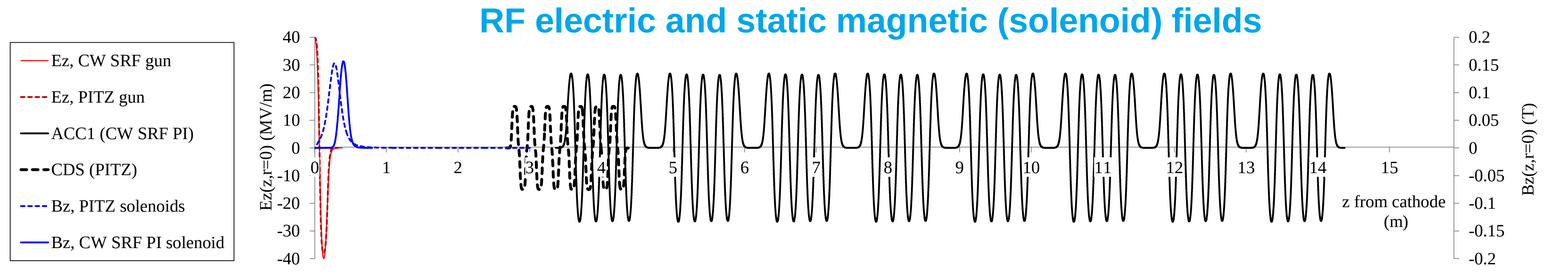
Simulated transverse RMS beam size and emittance

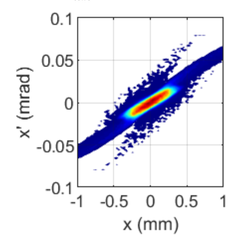
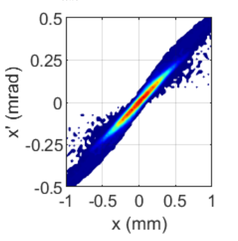
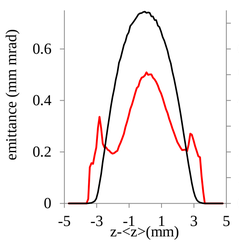
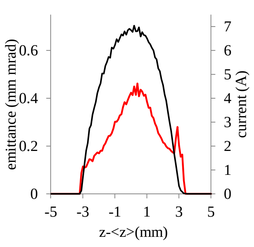
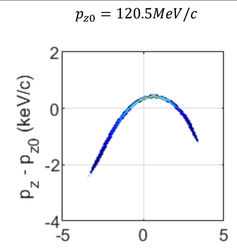
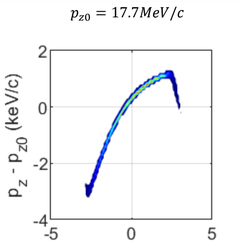


Simulated mean beam energy and RMS bunch length



RF electric and static magnetic (solenoid) fields



	Simulated CW SRF PI beam	Simulated PITZ beam
Transverse phase space	$\varepsilon_{x.n} = 0.45\ mm\ mrad$ 	$\varepsilon_{x.n} = 0.39\ mm\ mrad$ 
Beam current and slice emittance	$\sigma_z = 1.35\ mm$ 	$\sigma_z = 1.43\ mm$ 
Longitudinal phase space	$p_{z0} = 120.5MeV/c$ 	$p_{z0} = 17.7MeV/c$ 

Conclusions

Beam dynamics simulations for a CW SRF photo injector of the European XFEL have been performed assuming a peak RF electric field of 40 MV/m at the photocathode and 100 pC bunch charge generated by Gaussian photocathode laser pulses with 4 ps RMS duration yielding optimum emittance values of ~0.45 mm mrad. Experimental studies for this parameter space have been done at PITZ with Gaussian laser pulses with 2.6 ps RMS duration and yielded measured emittance values of ~0.5 mm mrad which is by ~0.1 mm mrad higher than the minimum expected from the corresponding PITZ simulations. The difference in optimized emittance between PITZ and CW SRF photo injector setups is mainly related to the main solenoid position w.r.t. the gun cavity and to the difference in the photocathode laser pulse duration.

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

PITZ Photo Injector Test Facility Zeuthen