BEAM ASYMMETRY STUDIES WITH QUADRUPOLE FIELD ERRORS IN THE PITZ GUN SECTION .

Q. Zhao[1], M.Krasilnikov, I. Isaev, H. Qian, P. Boonpornprasert, G. Asova[2], Y. Chen, J. Good, H. Huck, D. Kalantaryan, X. Li, O. Lishilin, G. Loisch, D. Melkumyan, A. Oppelt, Y. Renier, T. Rublack, C. Saisa-ard[3] , F. Stephan, DESY, Zeuthen, Germany.

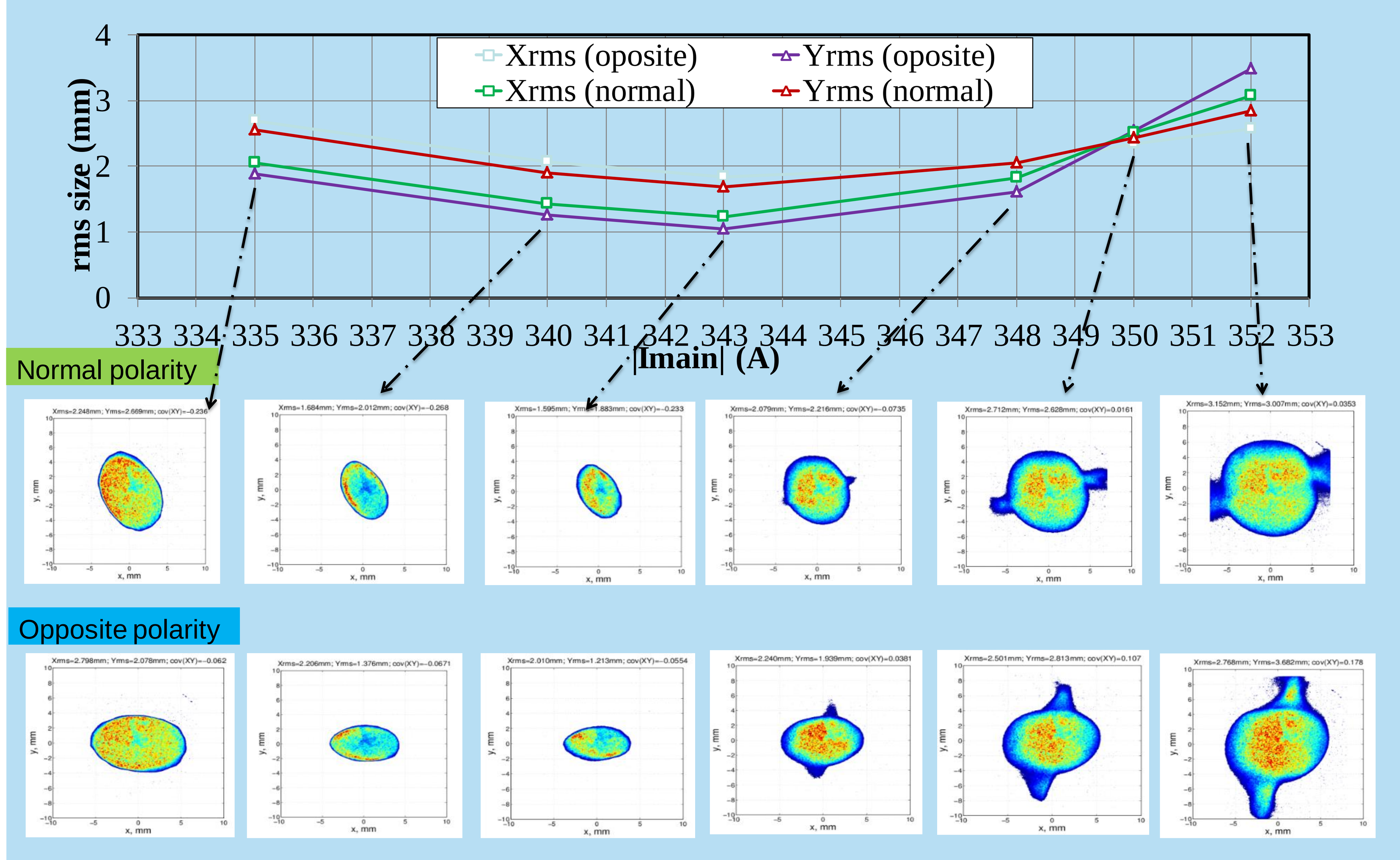
(On leave from [1]IMP/CAS, Lanzhou, China, [2]INRNE, Sofia, Bulgaria, [3]Chiang Mai University, Chiang Mai, Thailand)

Introduction and motivition

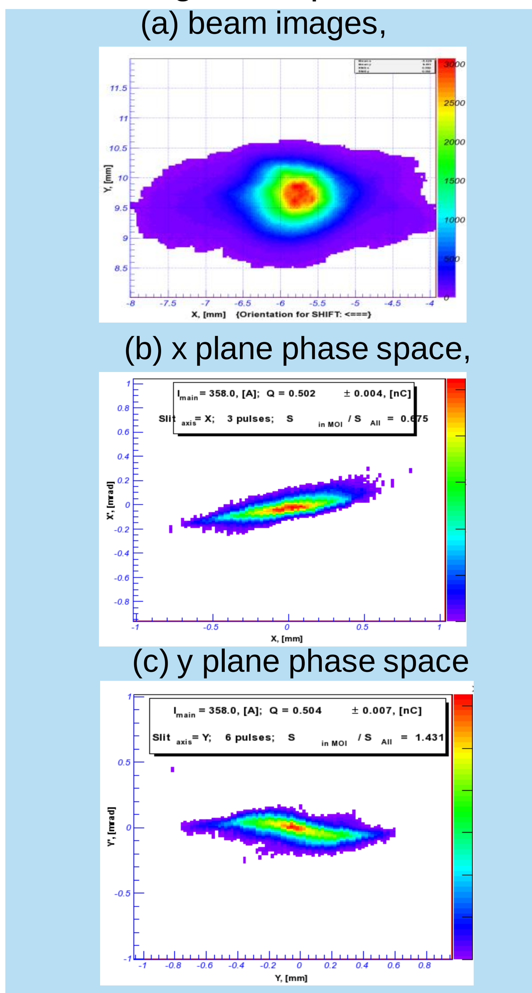
Abstract

The Photo Injector Test Facility at DESY in Zeuthen (PITZ) was built to test and optimize high brightness electron sources for Free Electron Lasers (FELs) like FLASH and European XFEL. Although the beam emittance has been optimized and demonstrated to meet the requirements of FLASH and XFEL, transverse beam asymmetries, such as **wing structures and beam tilts (Figure 1)** were observed during many years of operation with different generations of guns. These cannot be explained by simulations with the rotationally symmetric gun cavities and symmetric solenoid fields. Based on previous coupler kicker, solenoid field imperfection studies and coupling beam dynamics, the beam asymmetries most probably stem from rotated quadrupole field error in the gun section. A thin lens static quadrupole model is applied in the RF gun section simulations to fit the position and intensity of quadrupole field errors by comparing the beam asymmetry directions in experiments and ASTRA simulations. Furthermore, by measuring the laser position movement at the photo cathode and the corresponding beam movement at downstream screens, the integrated quadrupole field strength can also be extracted.

Figure 1: Beam images at High1.Scr1, the position is 5.277m away from cathode, laser RMS size 0.3 mm, 500 pC, 6.0 MeV/c. Measured results from Gun4.6 operation.



Figrue 2: beam emittance measurement and phase space , bunch charge 500 pC.



Quadrupole field error position and rotated angle estimation

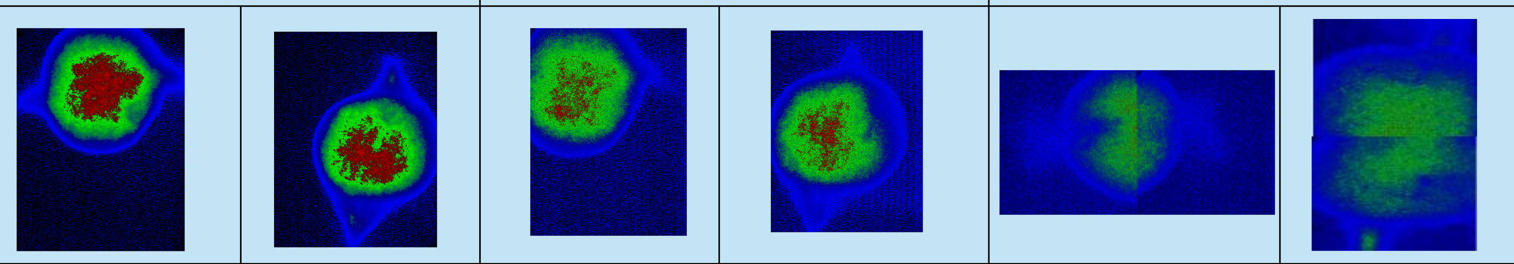
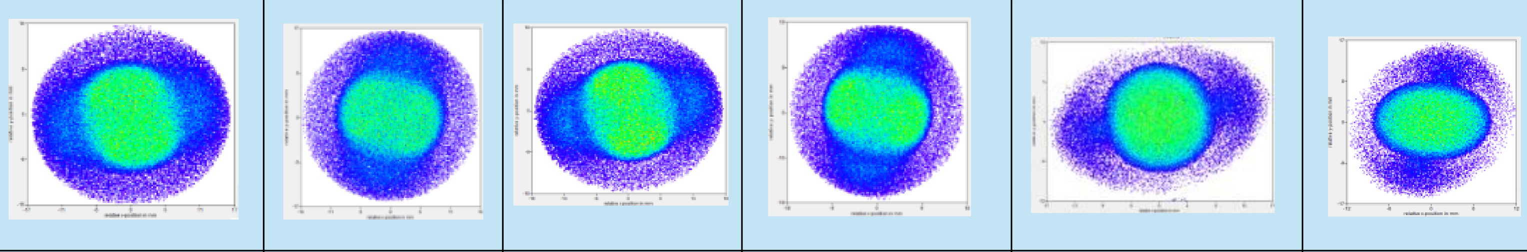
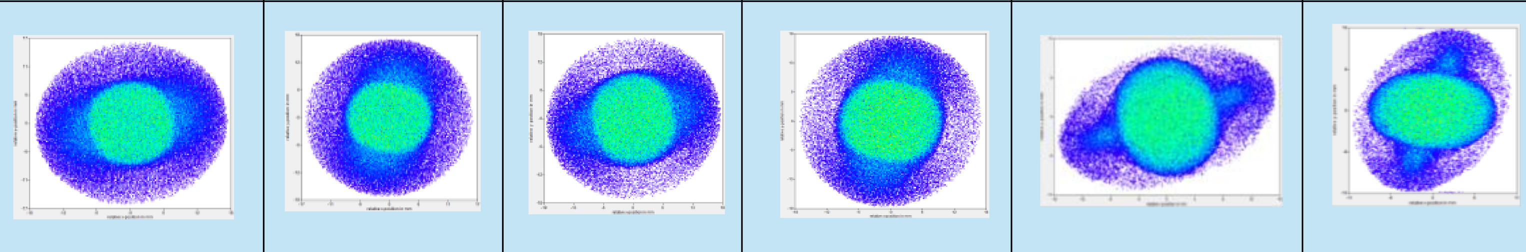
Methods and experiments:

For RF 5 MW in the gun, the beam wings appeared in different directions with two solenoid polarities. With main solenoid current (Imain) Imain = -360 A, the beam wings is about 12 degrees with respect to the anticlockwise direction and for Imain= 360 A the beam wings is about 78 degrees. For 3 kinds of RF power in the gun, the same rotation angle can be found for different Imain but same polarity, shown in figure 3. A rotated quadrupole model is added in simulations with scanning both quadrupole positions along the beam line and rotation angle. The rotation angle scanned from 0 to 360 degrees as a step of 5 degree by which try to fit the beam wings directions to the experiment ones. The quadrupole model parameters are shown in Figure 2, the effective length is 0.01 m.

Table 1: experiment settings for beam wings studies.

Power /MW	Gradient /MV/m	|Imain| /A	Charge /pC	MM /MeV/c
5	54.2	360	502	6.18
3	42.2	290	502	4.85
1.5	31.4	219	334	3.69

Figure 3: the experimental beam images (row 3) and simulation with rotated quadrupole, with skew quadrupole at z = 0.18 m (row 4) and with normal quadrupole at z =0.36 m (row 6), for Gun4.2; row (5) and (7) are the quadrupole strength used in the simulation when the beam wings are appeared.

Solenoid current	-360 A	360 A	-290 A	290 A	-219 A	219 A
Beam momentum From experiment	**5 MW in the gun 6.18 MeV/c**		**3 MW in the gun 4.85MeV/c**		**1.5 MW in the gun 3.69 MeV/c**	
Experiment: Beam at High1.Scr1 at z=5.277 m						
Simulation: High1.Scr1 with skew quad (rotation angle 135 degree) at z =0.18 m						
K_{skew} (m^{-2})	-0.6	-0.6	-1.0	-1.0	-2.0	-2.0
Simulation: High1.Scr1 with normal quad (rotation angle 0 degree) at z =0.36 m						
K_{normal} (m^{-2})	0.2	-0.2	0.3	-0.3	1.0	-1.0

Quadrupole field error strength estimation

Methods and experiments:

Track the beam in solenoid induced coordinate, the coupling due to beam rotation induced by solenoid can be cancelled. In figure 4, (a) laser positions at the cathode, (b) beam positions at the downstream screens in lab coordinate (x, y), (c) beam positions at downstream screens in solenoid induced rotation coordinate (x', y') without any other x-y coupling, (d) beam positions at downstream screens in solenoid induced rotation coordinate (x', y') with other x-y coupling (rotated quadrupole, et al). The beam relative positions in lab coordinate transform to the solenoid induced coordinate, by fitting the simulation results to experiment, shown in figure 5, the rotated quadrupole strength can be estimated.

Figure 5: the laser positions at VC2 (a) and beam positions at Low.scr3 (z = 1.708 m, Imain = -381 A) (b) in lab coordinate from experiment with gun4.2.

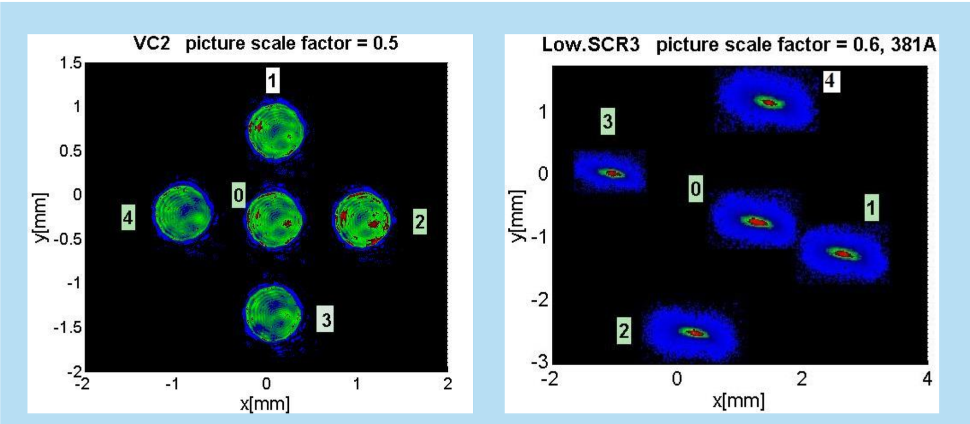


Figure 4: the sketch map of the beam positions in different coordinate.

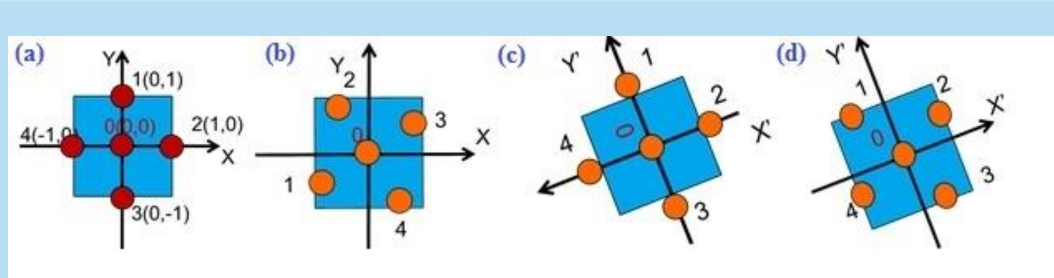


Table 2: experimental and simulated (with quadrupoles) beam relative positions in solenoid induced coordinate.

P	-356A Simulation (x,y)(mm)	-356A Experiment (x,y)((mm)	-381A Simulation (x,y) (mm)	-381A Experiment (x,y)((mm)
10	(-0.11, -1.18)	(0.12, -0.73)	**(-0.20,** -2.21)	**(-0.17,** -1.49)
20	**(-1.08,** -0.11)	**(-0.93,** 0.35)	**(-1.97,** -0.20)	**(-1.97,** 0.57)
30	**(0.11, 1.18)**	**(0.10, 1.12)**	**(0.20, 2.21)**	**(0.21, 2.44)**
40	**(1.08,** 0.11)	**(1.02,** -0.13)	**(1.97, 0.20)**	**(1.91, 0.26)**

✓ The estimated quadrupole strength is: g_{skew} = -0.01 T/m, g_{normal} = 0.04 T/m for Imain = -356 A and g_{skew} = -0.01 T/m, g_{normal} =0.09 T/m for Imain = -381 A, the quadrupole effective length is assumed 1 cm in simulation.

Summary and Conclusions

1) The beam wings and tilt observed from experiments can be reproduced by ASTRA simulation including rotated quadrupoles model.

2) Two positions of the quadrupole-like error fields were found:
- one is skew type at z = 0.18 m, which is most probably from the coupler field asymmetry and it's polarity does not change when change the solenoid polarity.
- another one is normal type at z = 0.36 m, which is most probably from the solenoid field imperfection and it's polarity changes when change the solenoid polarity.

3) From moving the laser positions at the photocathode experiment, combining experimental and simulated results, the skew and normal quadrupoles strength can be estimated on the orders of 10^{-4} T.

4)These results are helpful for the further beam asymmetries compensation and optimization studies.

*Quantang.Zhao@desy.de

HELMHOLTZ | GEMEINSCHAFT

PITZ Photo Injector Test Facility Zeuthen

FEL 2017 SANTA FE, NM