Gun quadrupole tests at the European XFEL

The tests were performed on 19-22.10.2017

The talk is based on preliminary report: pitzr201710igi01

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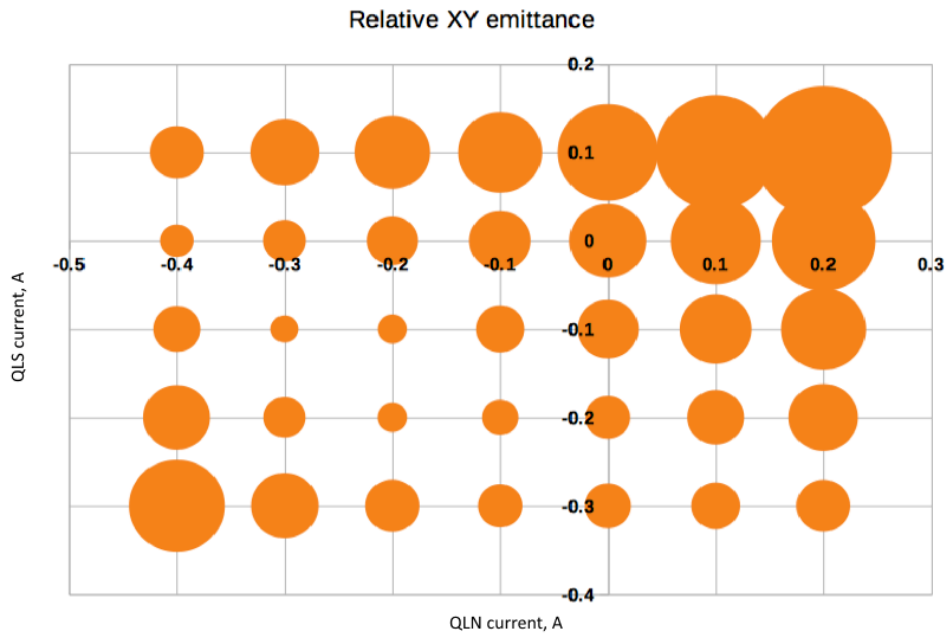
Injector settings for the gun quadrupole test

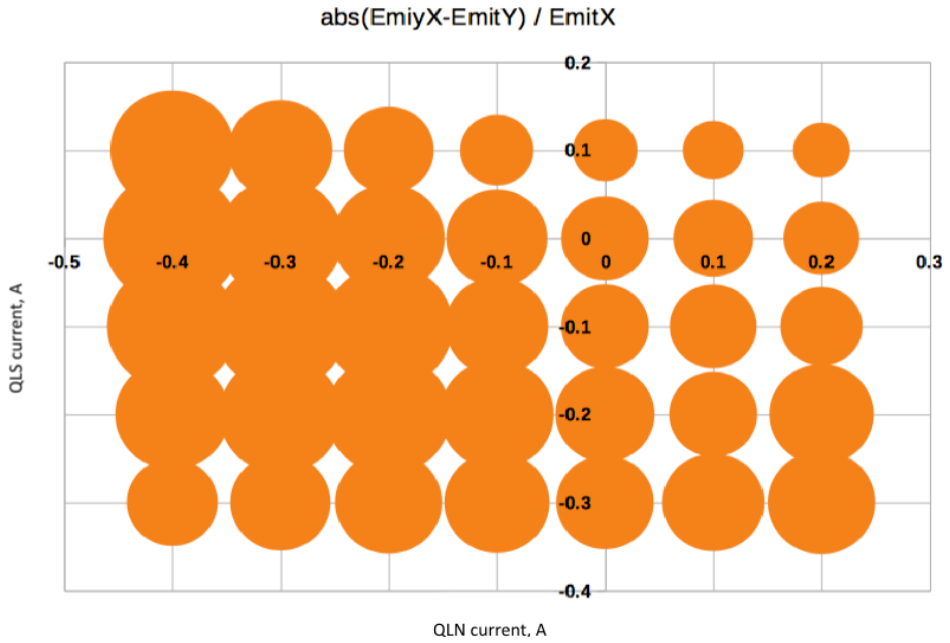
- Gun power: 5.13MW (53MV/m)
- RF pulse length: 70 µs
- Gun RF phase: -43deg (w.r.t. zero-charge phase) it is not MMMG phase
- BSA: 1.2 mm
- Beam momentum after the gun: unknown
- Beam momentum after AH1: 130 MeV/c
- Number of pulses: 1
- Gun main solenoid current 329.5 A
- Gun bucking solenoid current 17.7 A
- Bunch charge: 500 pC
- A1 and AH1 adjusted for MMMG phase

Results of the gun quadrupole adjustments

1st experiment: gun quadrupoles scan

- The measurements utilized **Multi Quad Scan** method (one observation screen, section with quads for matching and section of the quads for measurements). For **each** combination of the gun quads the **starting point for the matching was recovered** to a common settings.
- The utilized beam trajectory is standard for the XFEL operation.

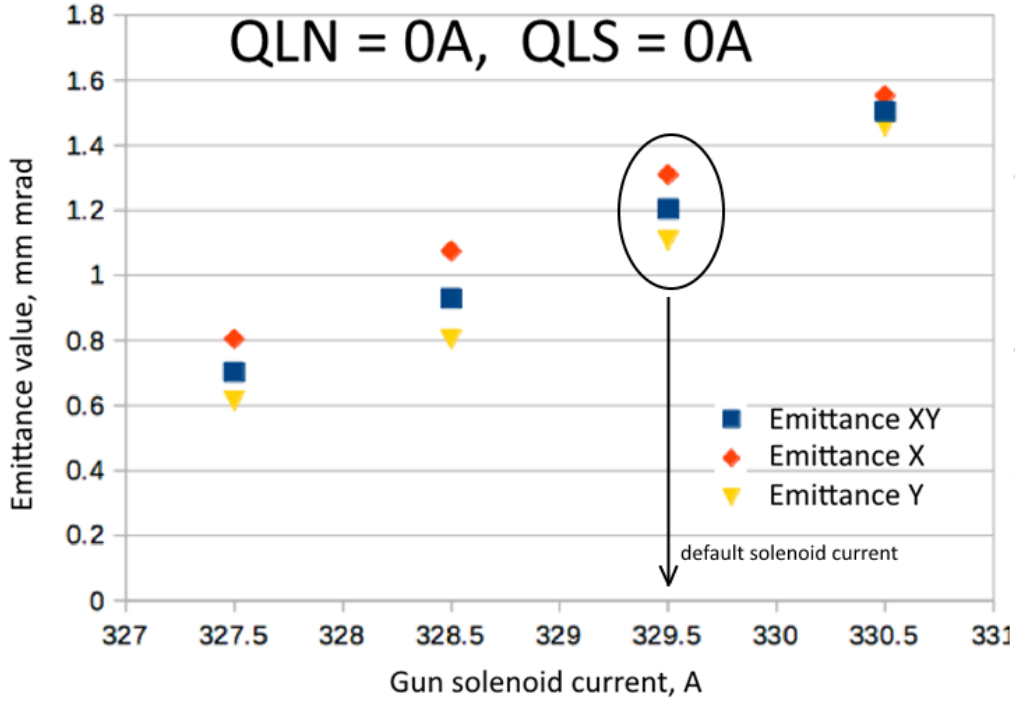


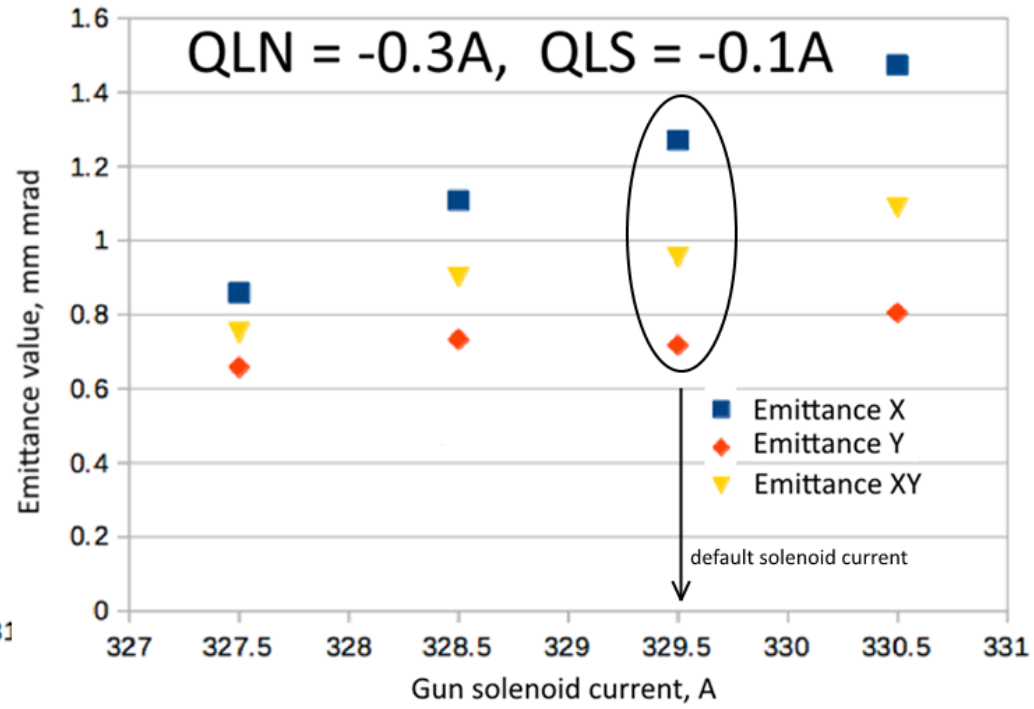


- The results:
  - emittance @ QLN = 0A and QLS = 0A: 1.203 mm mrad
  - emittance @ QLN=-0.3A and QLS=-0.1A: 0.966 mm mrad (minimum) → ~20% reduction

Results of the gun quadrupole adjustments

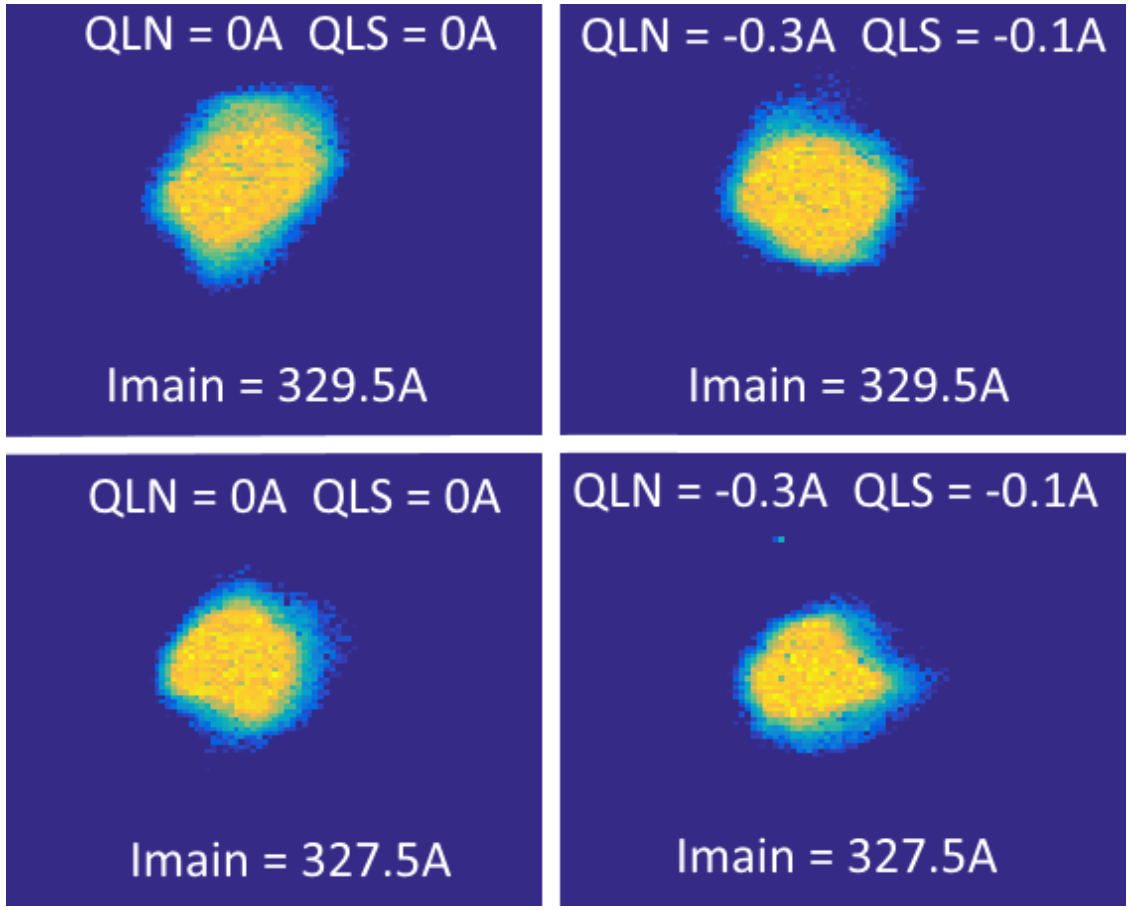
2nd experiment: emittance vs solenoid current





- The experiment shows that **the tuning the gun solenoid current can decrease emittance value at least by ~40%**. But in that case the gun quadrupoles must be readjusted for obtaining the smallest emittance.
- The emittance measurements were not done for the solenoid current **lower that 327A** because at these current **a beam loss in the injector section** was observed (non-optimal beam trajectories and collision with the collimator).

Beam transverse profiles at OTRC59

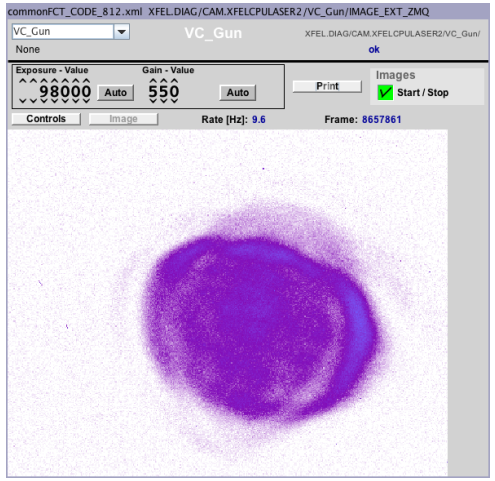


- According to the pictures, one can notice correlation between beam transverse profile roundness and XY transverse emittance values: **as smaller emittance as rounder the beam**.
- **BUT(!)** an important point to be noted: the presented pictures are cutting a lot of low-intensity signal, that is why more analysis is needed.

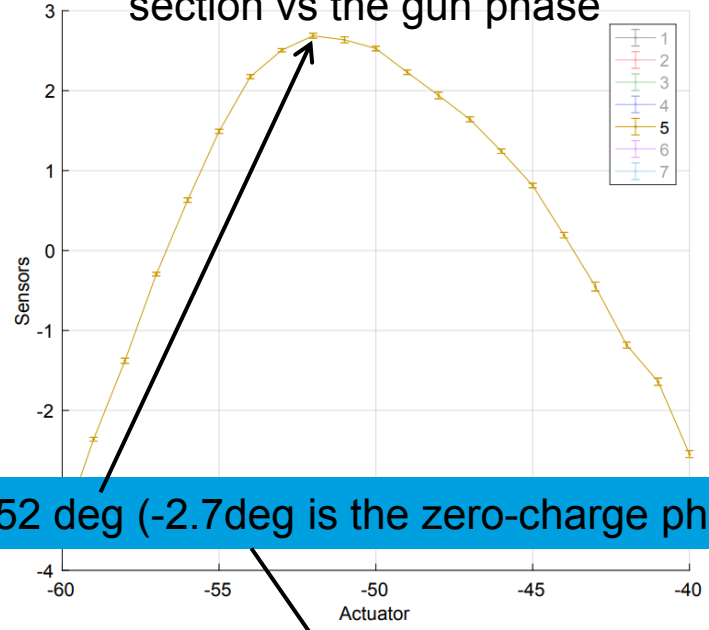
Additional injector adjustment

During the injector adjustments there were done a few more measurements:

Laser profile @ the VC camera

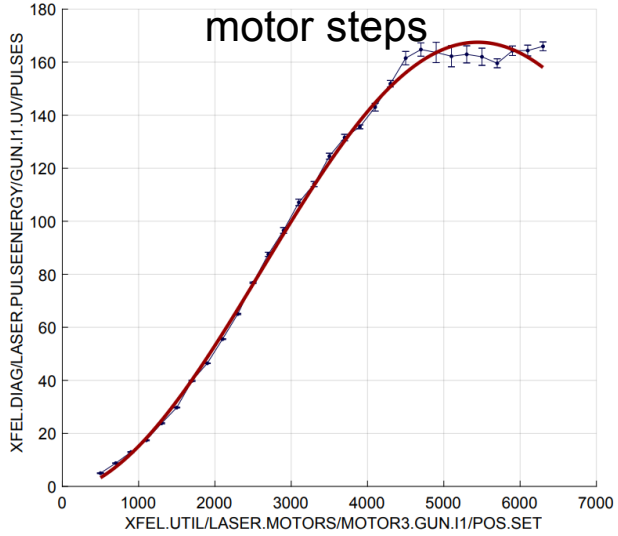


The beam position in the dispersive section vs the gun phase

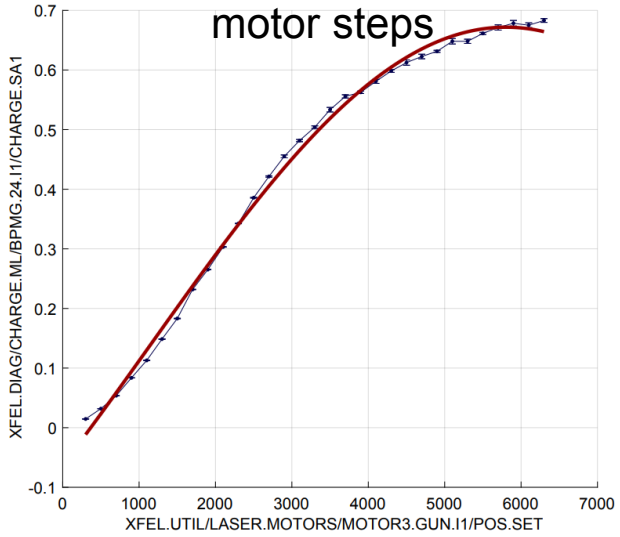


The MMMG is -52 deg (-2.7deg is the zero-charge phase).

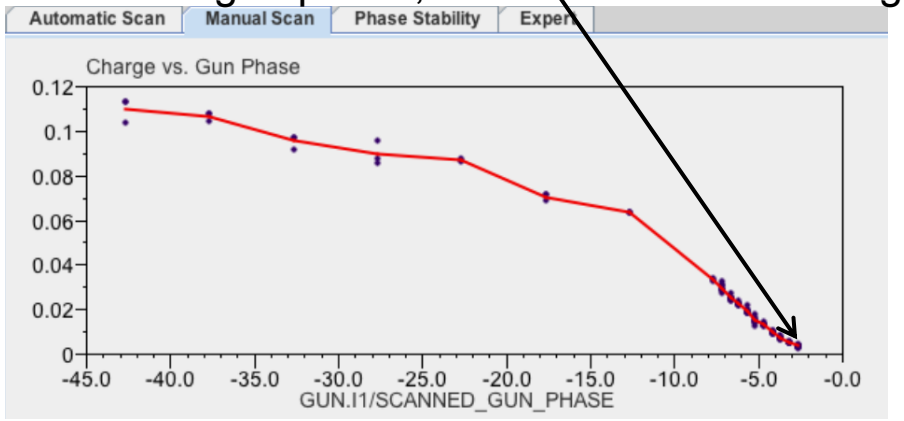
Laser energy vs λ/2 plate motor steps



Beam charge vs λ/2 plate motor steps



X axis is the gun phase, Y axis is the beam charge.



Problems observed during the XFEL operation

1. **Photocathode laser profile**: is not perfect. By the adjusting the gun quads one also compensates the laser transverse profile asymmetry.
2. **LT scan**: the charge on the λ/2 plate motor steps is not Sine-like (on the top of the curve).
3. No intermediate **BSA** sizes were found. There are no BSA size between 1mm and 1.2mm(currently used). But according to PITZ experience, the optimal emittance for XFEL laser pulse length of ~6ps is expected to be at BSA<1.2mm (BSA=1.2mm for 4.8ps for PITZ laser).
4. The **gun phase** setting is not optimum for the emittance, according to the PITZ experience. The currently used phase of -43deg (relative to zero-charge phase) is on 6deg different (shifted towards lower emission field) compared to the MMMG phase.
5. It is not possible to measure absolute electron **beam energy after the gun**.
6. DCM and FC were not adjusted for the **dark current** measurements.
7. The **cameras** for the beam profile observation after the gun were not accessible. The camera 24 was not working; the camera 25 was not accessible due to collimator insertion.
8. No, implementation of the **bucking solenoid** current setting according to the main solenoid settings. The bucking solenoid current always was fixed to the one value of 17.7A.
9. The measured **emittance** values strongly depend on the matching. Even different starting points for the matching make significant difference in the measured emittance values, while mismatch parameters are the same.

Intermediate conclusions

- **The experiments with the gun quads showed that it is possible to decrease the emittance value by 20% just by changing the gun quadrupoles settings.**

- Nevertheless, there were found a few discrepancies between the XFEL injector operational parameters and the parameters for the best emittance (gun phase, main solenoid current).

- A few problems, which were observed during the measurements, are possible to solve with help of PITZ team.