

Weeks 40-41:

last run period with gun-4.6 at PITZ in 2017

Pre-conditions (changed):

- Laser → no OSS these 2 run weeks
 - pulse temporal shaping only with e-beam
 - modulated Gaussian possible (?)

M. Krasilnikov

PITZ RC meeting, 05.10.2017

Week 40/41

- **THz – TR/DR generation (PB)** - 13-15 shifts
- **LLRF tuning (+40MV/m)** - 6.10
- **Emittance -flattop 1nC (MK)** → X
- **Slice emittance (HH, RN)** → ?
- **Beam transport (RN)** → done (3.10M-A)
- **SMAC integration (DdM, Igl)**

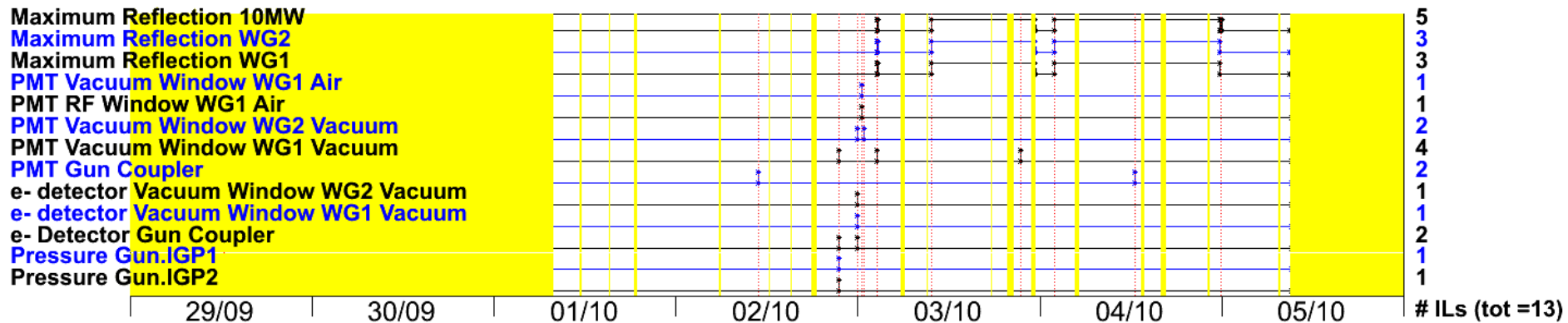
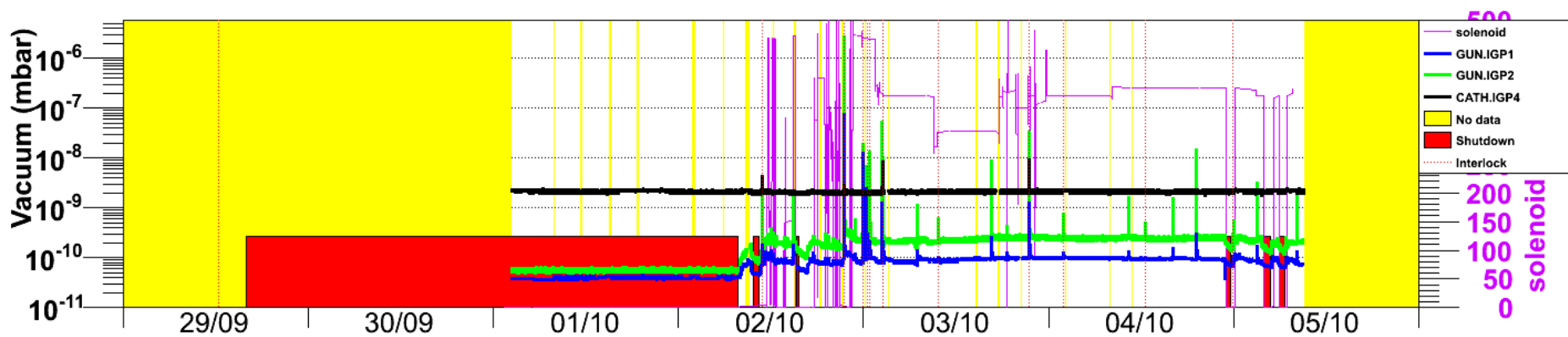
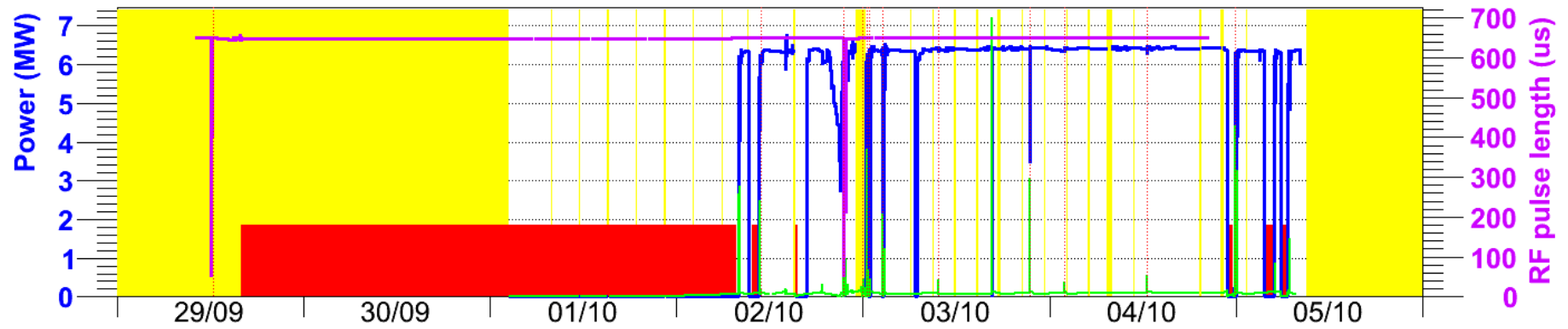
- **Laser flattop/comb tuning with ~~ESS~~ e-beam**
- **Gun/booster stability measurements**
- **Emission studies (YC)**
- **Thermal emittance (??)**
- **BPM (MK)**
- **Asymmetry studies (QZ)**
- **Cathode QE/QE-map**

to do:	Measurements						
Week 40	Mon Oct-02	Tue Oct-03	Wed Oct-04	Thu Oct-05	Fri Oct-06	Sat Oct-07	Sun Oct-08
Morn. 07:00 to 15:30	DarkCurt. II Las. tuning	Gross Yereinyan SGTHz	Gross Loisch	Gross Chen	Gross Chen LLRF+	Gross Yereinyan	Gross Yereinyan
Late 15:00 to 23:30		Isaev Vardanyan Beam transp.	Isaev Yereinyan THz	Isaev Niemczyk	Isaev Niemczyk	Isaev Chen THz	Isaev Chen THz
Night 23:00 to 07:30	Boonpornpras Niemczyk	Boonpornpras Niemczyk	Boonpornpras Vardanyan	Boonpornpras Vardanyan	Boonpornpras Vardanyan THz	Boonpornpras Vardanyan	Boonpornpras Vardanyan

to do:	Measurements						
Week 41	Mon Oct-09	Tue Oct-10	Wed Oct-11	Thu Oct-12	Fri Oct-13	Sat Oct-14	Sun Oct-15
Morn. 07:00 to 15:30	gun/boo stability Krasilnikov	BPM, Beam transp. Krasilnikov	Krasilnikov	Krasilnikov	Krasilnikov	Krasilnikov	Krasilnikov
Late 15:00 to 23:30	Emittance Flattop 1nC Loisch	Loisch	Loisch	Slice emittance Loisch	Good Niemczyk	Good Vardanyan	Good Vardanyan
Night 23:00 to 07:30	Zhao Chen	Zhao Chen	Zhao Chen	Zhao Melkumyan	Zhao Melkumyan	Zhao Niemczyk	Zhao Niemczyk
		emission?			SMAC?		



Week 40 (29.09-05.10.2017), gun run



Week 40 (29.09-05.10.2017)

- 1) finished Monday check list
- 2) Gun Dark Current is quite low: Max_p2p=**72.9uA** @6.4MW @Imain=0A, Max_Ampl=40.5uA @6.4MW @Imain=0A
04.09.2017 p2p=**80uA** @6.4MW @Imain=380A
25.07.2017 p2p~**190uA**
- 3) Measurements on Friday (higher than could be):
 - Gun phase jitter: [0.231deg@2.8MW](#); [0.208deg@6.3MW](#)
 - Gun gradient jitter: [0.068%@2.8MW](#); [0.028%@6.3MW](#)
 - Booster phase jitter: **0.02deg** @3.1MW
 - Booster gradient jitter: **0.024%** @3.1MW
- 4) Beam transport studies for quad scan emittance measurements are done (data taken, to be analyzed)
- 5) First interferogram measurement using a Michaelson interferometer setup were tested successfully by Prach

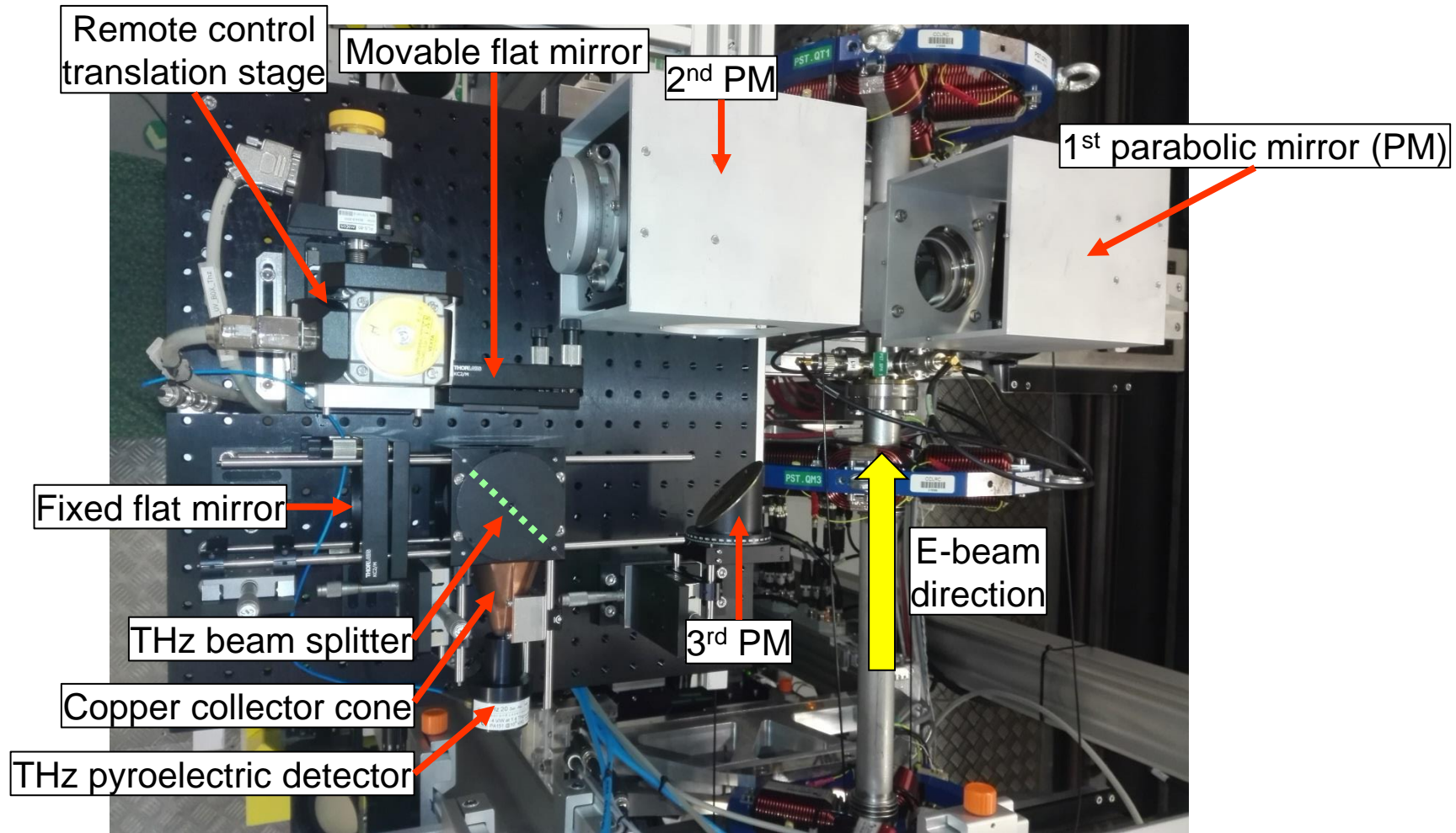
GUN

Power in cavity (MW)	Peak field (MV/m)	FB	PMW	Temp Jitter (°C)	Gradient Jitter (MV/m)	Phase jitter (°)	Grad. jitter %
4.5	50	on	off	0.012	0.037	0.278	0.074%
6.3	60	on	off	0.011	0.023	0.311	0.038%
6.3	60	on	on	0.008	0.017	0.208	0.028%
2.8	40	on	off	0.017	0.058	0.392	0.145%
2.8	40	on	on	0.007	0.027	0.231	0.068%

Booster

Power in cavity (MW)	Peak field (MV/m)	FB	PMW	Temp Jitter (°C)	Gradient Jitter (MV/m)	Phase jitter (°)	Grad. jitter %
3.1?		on	off	0.016	0.003	0.018	0.018%
3.1?		on	off	0.016	0.004	0.02	0.024%

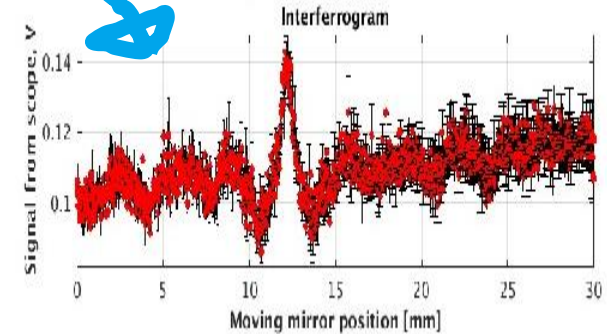
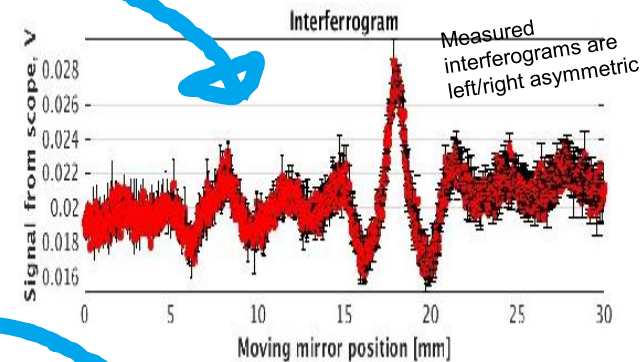
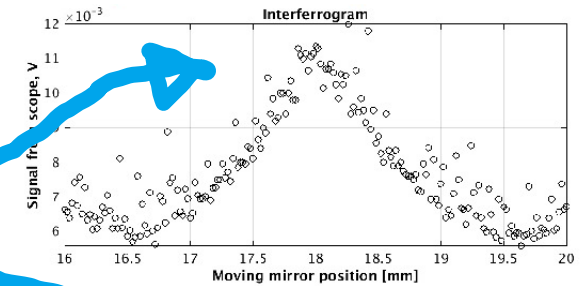




Summary of TR/DR generation experiment so far...

P. Boonpomprasert

Date/Shift	Achievements
29.10	Finish Michelson Interferometer (MIF) setup
02.10_n	First signature of interferogram (IFG) was found
03.10_n	<ul style="list-style-type: none">- First detailed IFG measurement- MATLAB tools using for the measurement are ready- IFG measurements for 500 pC were finished
04.10_m	IFG measurements for 250 pC were finished (wrong scope setting, is repeating on 05.10_m)
04.10_a	IFG measurements for 960 pC were finished
04.10_n	- MIF was realigned (didn't better).
04.10_m	...



Problems:

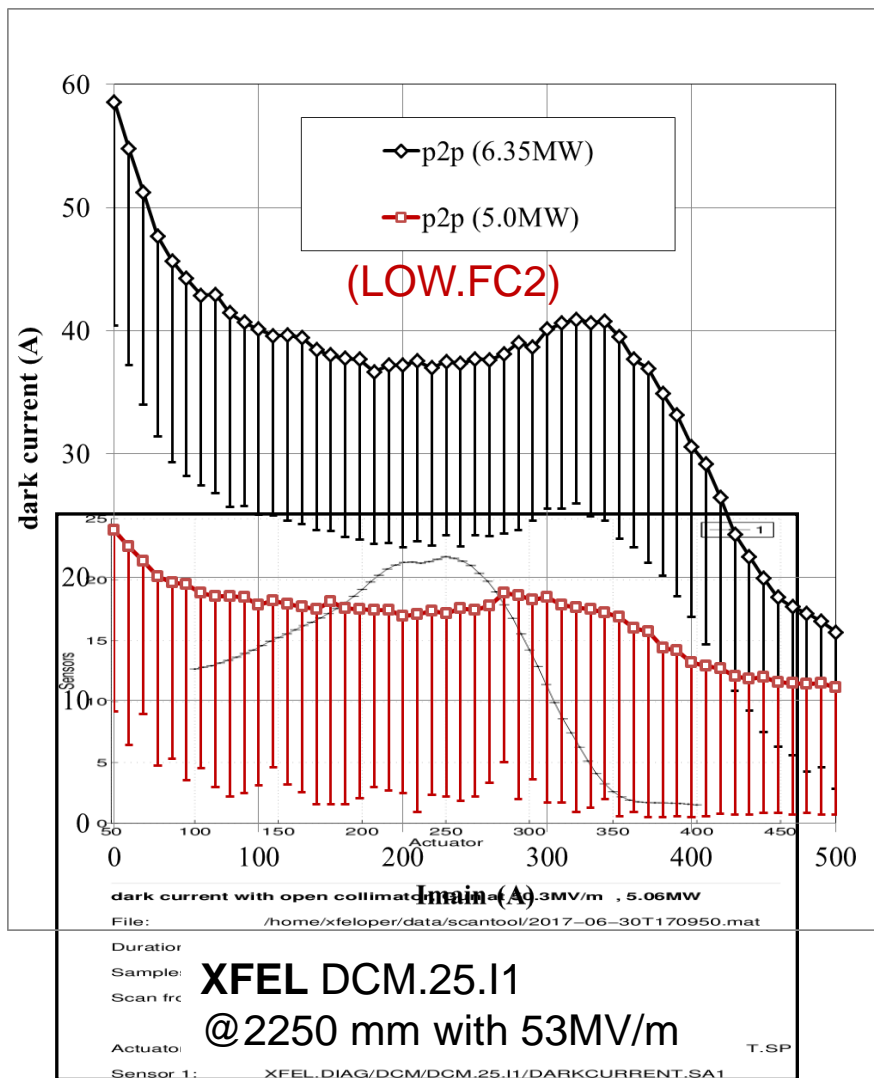
- S/N is quite low, normally about 2-5
- Got radiation warnings when operated with 1 nC

Next steps

- *Comparison* of IFGs from TR and DR
- IFG measurements for *comb beams* (from DLW and pre-modulated PC laser)
- *Total radiation* energy measurements
- *Spatial profiles and polarization* measurements for selective cases



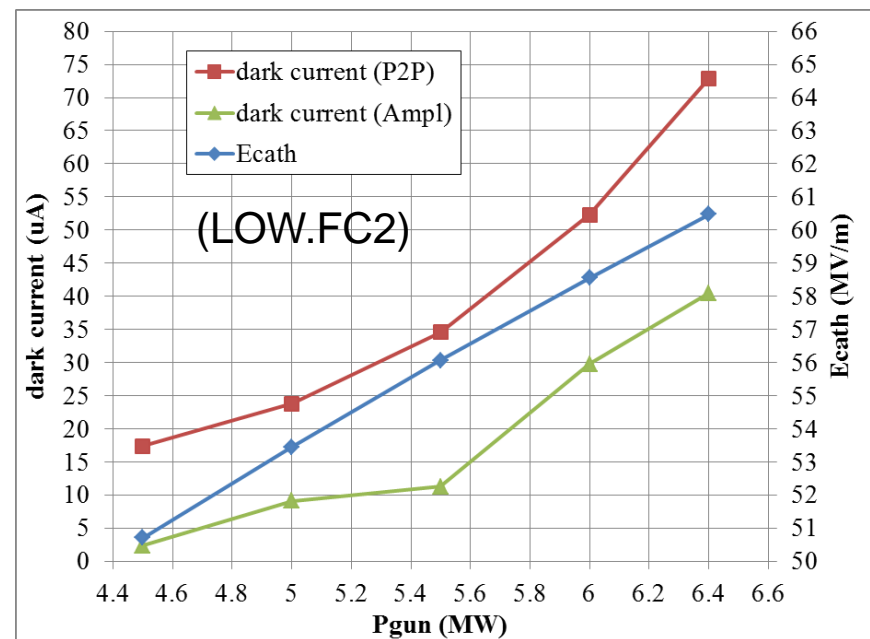
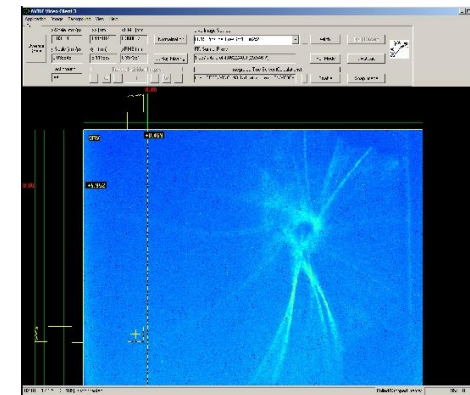
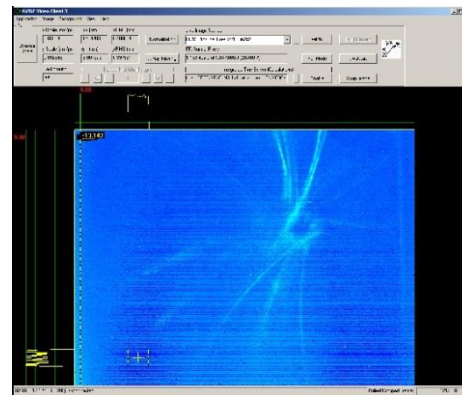
Dark current



Dark current image at LOW.Scr1, 6.3MW in the gun

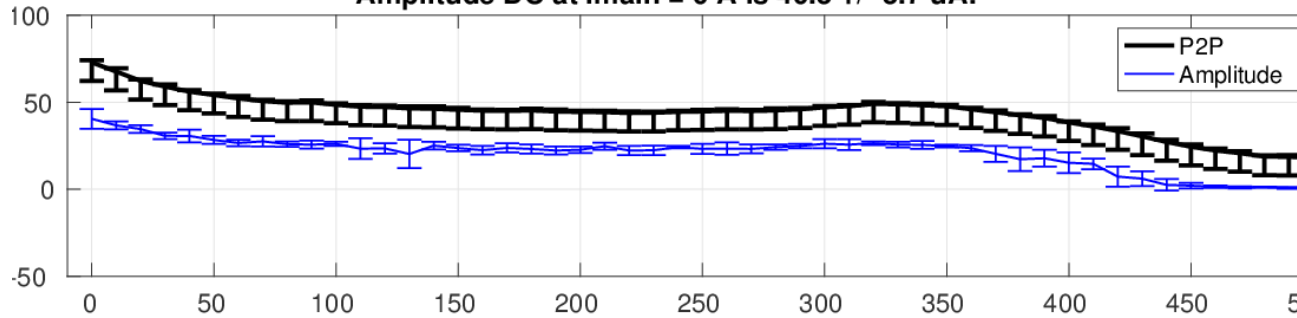
$I_{main} = +420 \text{ A}$

$I_{main} = -420 \text{ A}$

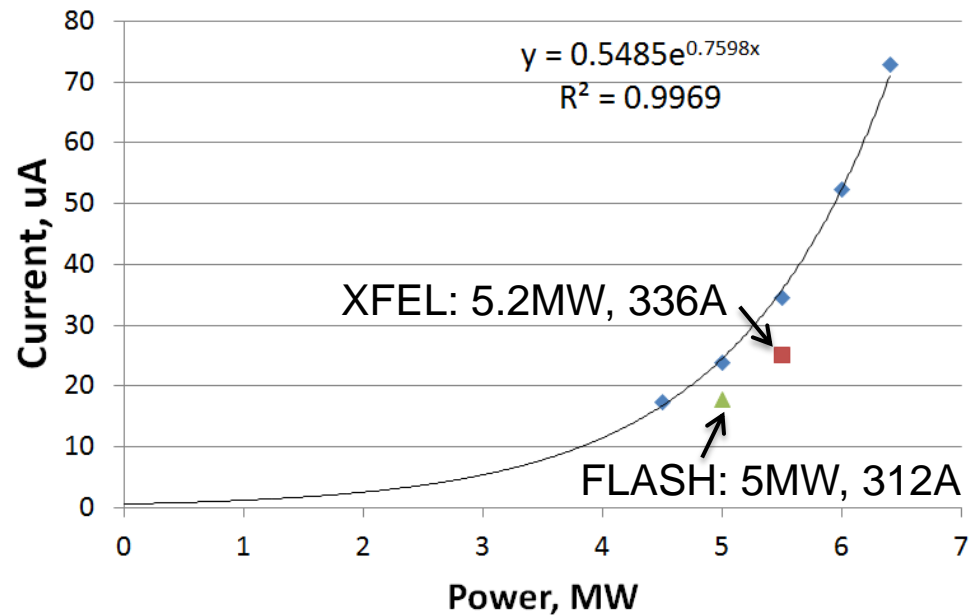
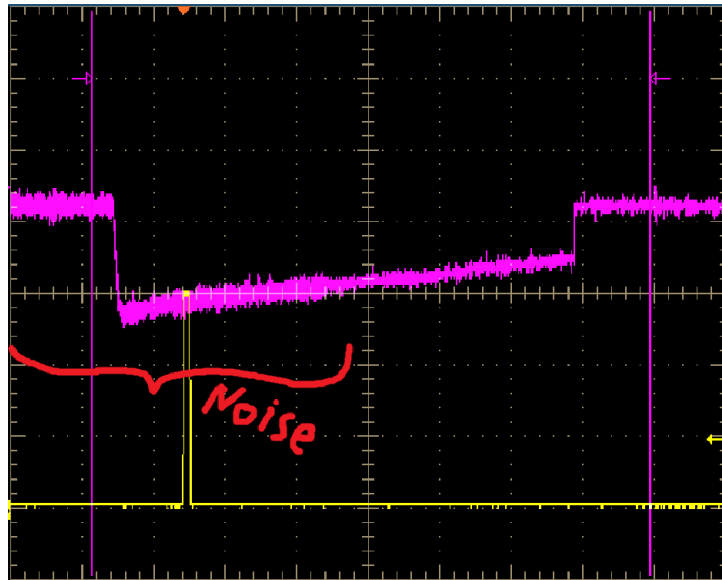


Gun 4.6 dark current measurements

Maximum from P2P = $72.9 \pm 1.2 - 10.6 \mu\text{A}$ at $I_{\text{main}} = 0.0 \text{ A}$.
Maximum from Amplitude = $40.5 \pm 5.7 \mu\text{A}$ at $I_{\text{main}} = 0.0 \text{ A}$.
P2P DC at $I_{\text{main}} = 0 \text{ A}$ is $72.9 \pm 1.2 - 10.6 \mu\text{A}$.
Amplitude DC at $I_{\text{main}} = 0 \text{ A}$ is $40.5 \pm 5.7 \mu\text{A}$.

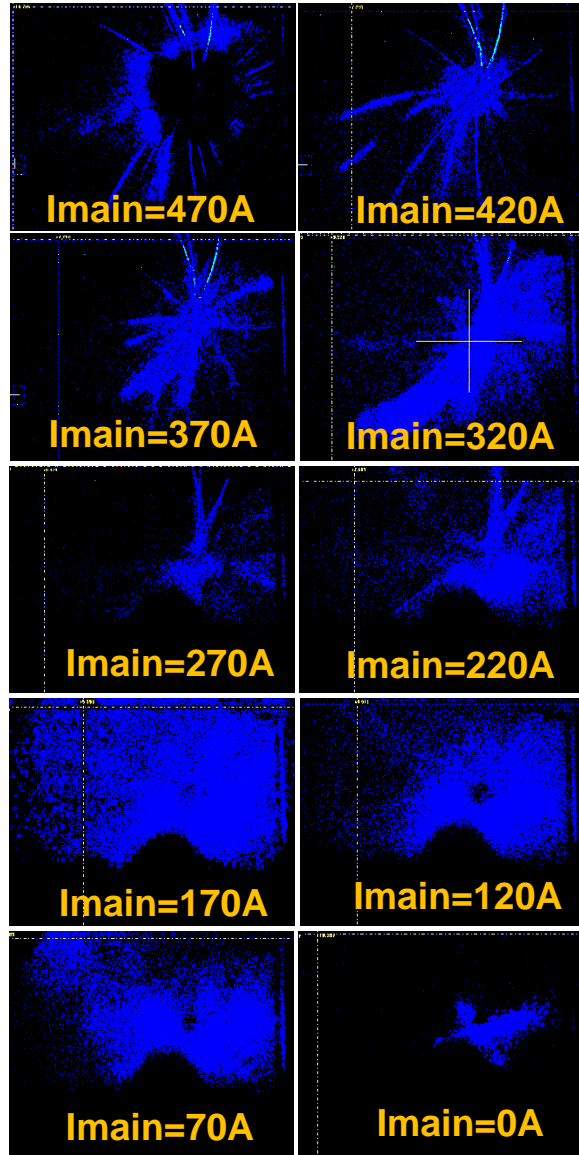


DC vs peak power

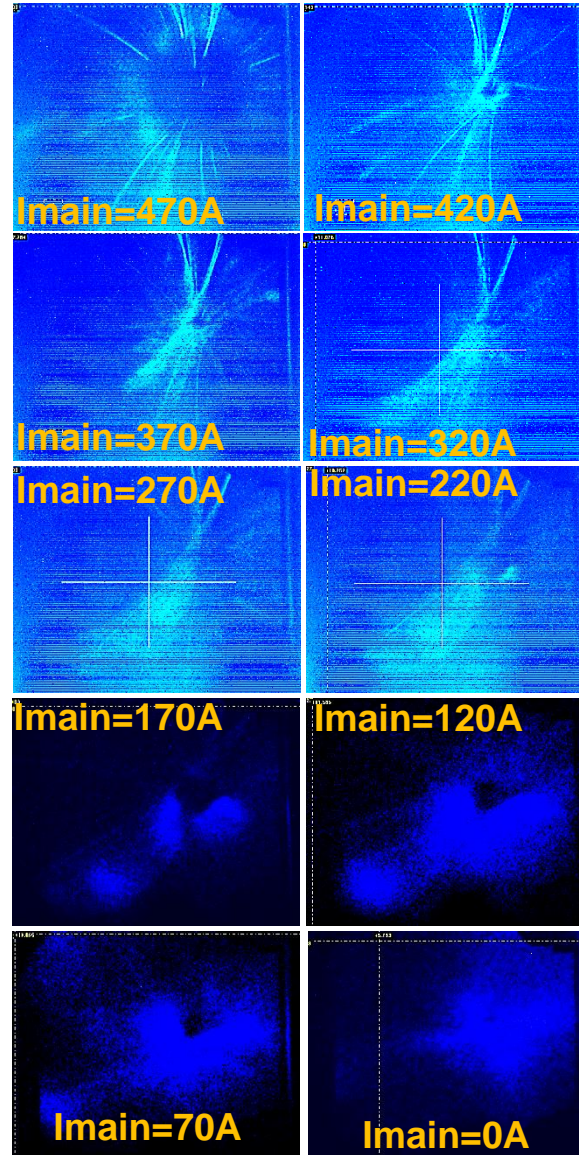


Gun 4.6 dark current measurements: LOW.Scr1, 6.3MW in the gun

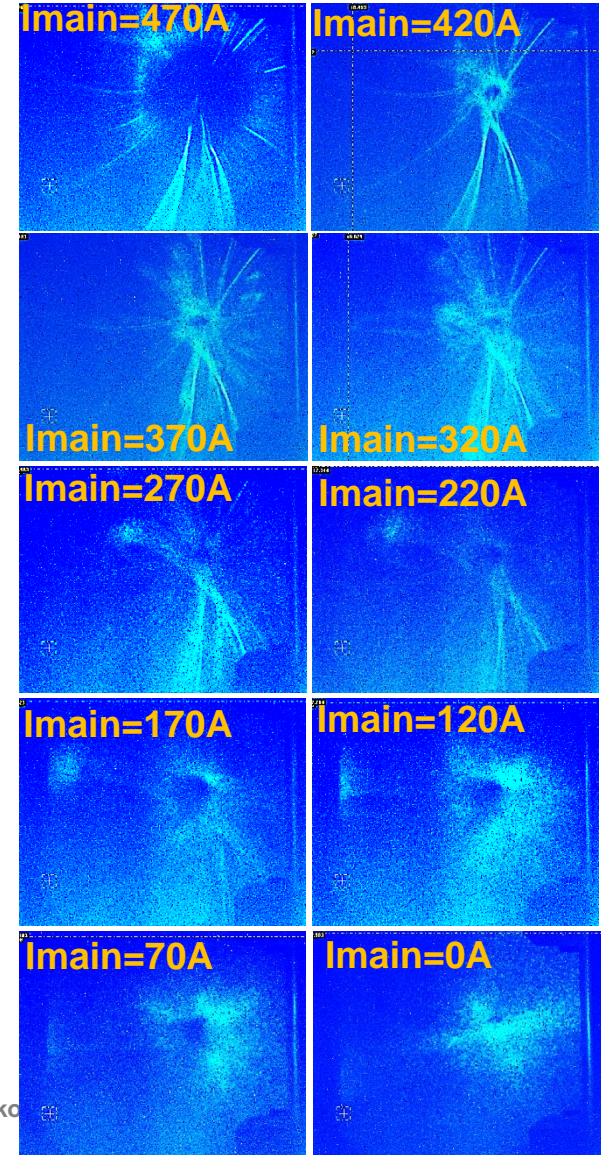
bucking -> compensation,
normal polarity



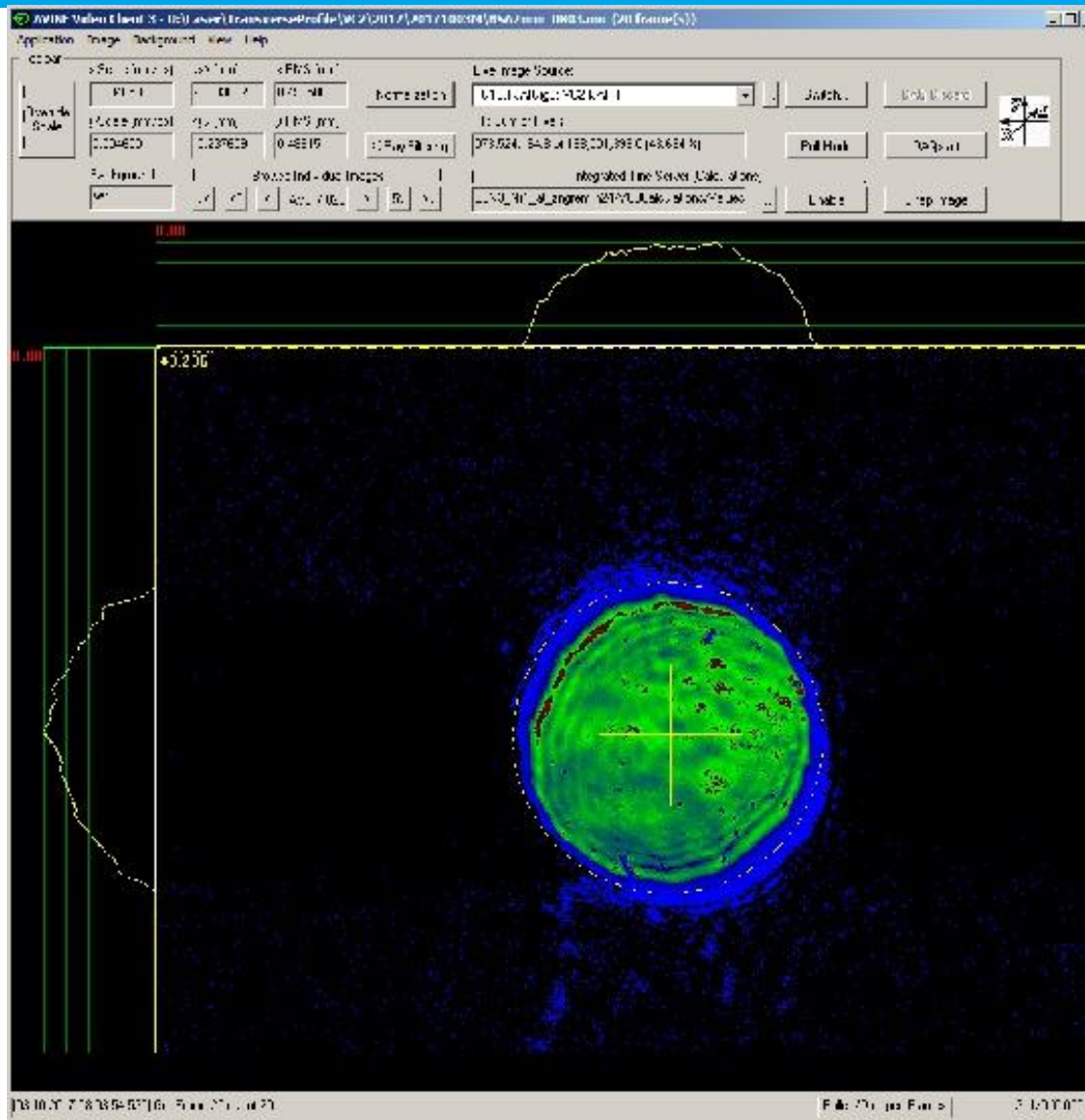
no bukcing, normal polarity



no bukcing, opposite polarity



PC Laser



Week 40 (29.09-05.10.2017), problems

- 1) PST.ST5 does not work -> mechanics must be exchanged
- 2) Low.FC1 show extremely high noise. Cables exchange helped only a bit.
- 3) Low.FC2 show strange additional noise. This does not significantly disturb measurements.
- 4) OSS not working
- 5) Lyot-filter can produce modulated long Gaussian if the adjustments not fully correct.
- 6) HIGH1.Scr1 camera is rotated by 90deg (wrong)



TR/DR generation Experiments: Outline (P. Boonpornprasert)

- > 1st setup: Spectrum profile measurement
 - 1 shift → Station setup and MATLAB script test
 - 2 shift → Short Gaussian laser
 - 1 shift → Comb-like laser
 - 1 shift → DLW (Flat-top-laser)
- > 2nd setup: Total energy measurement
 - 1 shift → Station setup and MATLAB script test
 - 2 shift → Short Gaussian laser
 - 1 shift → Comb-like laser
 - 1 shift → DLW (Flat-top-laser)
- > 3rd setup: Spatial distribution and polarization measurements
 - 1 shift → Station setup and MATLAB script test
 - 2 shift → Measurements



TR/DR generation Experiments: Machine parameters

Parameters	
laser pulse shape	Short Gaussian Flattop Comb-like (5-6 peaks)
laser BSA size	2 mm
Laser NoP	Up to 150 pulses
Gun RF pulse duration	650 us
RF power in the booster	≥ 200 us
RF power in the gun	6.3 MW (HV=9.7kV, AmpSP = 59.5, 1% refl.)
RF power in the booster	3.0 MW (HV=9.3kV, AmpSP = 18, 5% refl.)
Gun RF phase	MMMG
Booster RF phase	MMMG to MMMG-90°

(P. Boonpornprasert)



TR/DR generation Experiments: an example of measurement procedure

Measurement procedure: Spectrum profile measurement (short Gaussian laser used)

A. Preparation

1. Save VC2 image (20 frames). *Only once per BSA*
2. Set Gun phase to about MMMG phase
3. Set Bunch charge to 500 pC.
4. LEDA scans for gun MMMG phase, set gun phase SP to MMMG phase.
5. Tuning LT for bunch charge of 500 pC again if necessary.
6. Set booster phase to about MMMG phase.
7. Set main solenoid current roughly for the best emittance (a bit over-focused at High1.Scr1).
8. HEDA1 scans for booster MMMG phase.
9. Grap HEDA1 profile for booster phase **SETPOINT** of MMMG, MMMG+30, MMMG+60, MMMG+90 (compression phase). *If the beam is too long in HEDA1, just try to measure the central part (average momentum).*
10. Set booster phase to MMMG

B. TR and DR Power measurements

1. Measure the longitudinal profile by TDS (using PST.Scr1).
 2. Screen shot steerers and quads settings
 3. Focus beam to the center of PST.Scr2. *Can use Al-plate gap and Al-plate hole in PST.Scr2 to define the center position.*
 4. Set PST.Scr2 to Al-plate hole
 5. See the beam at PST.Scr3, Try to adjust for maximum beam intensity on PST.Scr3
 - Adjust high steerers
 - Slightly adjust QMs as well if beam focusing change after adjust the steerers
 6. Run Matlab script MichaelsonIFM.m (location: `\measure\THz_MatlabScripts\`)
 7. Repeat 4,5,6 but set PST.Scr2 to Al-plate gap
 8. Repeat 4,5,6 but set PST.Scr2 to Al-plate hole
- C. Repeat B but set booster phase SP to MMMG+30**
D. Repeat B but set booster phase SP to MMMG+60
E. Repeat B but set booster phase SP to MMMG+90
F. Repeat A-E with bunch charge of 1 nC
G. Repeat A-E with bunch charge of 250 pC

(P. Boonpornprasert)

Procedures for other experiments will be released later.



Measurement Program: TDS+slit scan emittance measurement EMSY2->PST.Scr1

Goal: Following proof-of-principle experiments in August, now the slice emittance should be measured at standard conditions, e.g. after fully optimizing BSA & solenoid for the best projected emittance. The additional Q5/Q6-focusing should be varied. Since LYSO@PST.Scr1 is not yet installed, experiments are limited to 500 pC / 1 nC and to manual slit scans (always averaging over 10 events).

If a “proper” flat-top temporal laser profile cannot be achieved, please use long Gaussian instead.

(A) TDS+slit emittance measurement EMSY2->PST.Scr1 (1 nC) , (see also late shift 11.08_a for reference)

To be done directly after standard emittance optimization, including LEDA/HEDA measurement & solenoid scan & statistics (fastscan3/emcalc).

Preferably start with optimized BSA and later repeat with different sizes if time allows.

1. **TDS off**, but use TDS-compliant settings for the whole experiment:

- > 1-2 pulses per train
- > minimum camera exposure time (probably 10 us)

2. Use Q5, Q6 to roughly focus beam vertically at PST.Scr1, keep horizontal rms size of the order of 250 um (just to have similar conditions as in standard slit scan and at the same time reasonable temporal resolution of ~10 slices). **Do not overfocus** (find focus but then reduce both quad currents by a few percent). **If the optimized solenoid alone already overfocuses the beam until PST.Scr1, a lower solenoid current must be chosen** (Q5/Q6=0 would be fine in this case). Vertical beam size should be equal or smaller than 10% of TDS-streaked size.

3. Proj. emittance measurement, between EMSY2 and PST.Scr1 (use 50 um slit for horizontal emittance, no vertical emittance measurement)

- a) Using fastscan3 (choose correct cameras and adjust LDRIFT= **5.153** m in emcalc)
- b) A Matlab tool for this might be available in time, otherwise do a manual slitscan, grab&saving 10 images in VideoClient for each slit position (depending on actual beam size on slit mask, choose ~10 slit positions, but no smaller steps than ~25 um. Make sure to include both low-intensity edges.)

4. **TDS on** (but so that beam is not clipped by EMSY2-X slit or PST.Scr1 apertures)

5. Bunch length measurement using TDS.m

6. Manual slitscan (get EMSY & MOI images, then same procedure as (3.b.))

- > if beamlet intensity too weak, try grabbing more than 10 images and check resulting average with e.g. /MatlabScripts/TDS/IMC_viewer.m)

7. Repeat steps 1-6 for less focusing , e.g. go for +50% xrms size on PST.Scr1, then another +50%, until intensity gets to weak

(B) same for 500 pC

A note on priorities: Please do at least 3 different focusing each for 1 nC and for 500 pC (six measurements in total). Varying the BSA would be nice but has less priority.

(H. Huck, R. Niemczyk)



A) Steerer calibration for HIGH1.St1, HIGH1.StA1, HIGH1.St2 and HIGH1.StA2

Note: The steerer magnets HIGH1.St2 and HIGH1.StA2 only have to be calibrated, if there's enough time to do the second part of part B, otherwise this calibration is not really important.

- 1) Set BSA to 2 mm, set charge to 100 pC
- 2) Set Gun and Booster to nominal, measure LEDA & HEDA1 at MMMG
- 3) Degauss all quads between HIGH1.St1 to High1.Scr5
- 4) Scan HIGH1.St1 from $-2/-1/0/1/2$ A, record beam centroid x & y at HIGH1.Scr5, into excel file
- 5) Scan HIGH1.StA1 from $-2/-1/0/1/2$ A, record beam centroid x & y at HIGH1.Scr5, into excel file
- 6) If there'll be time left for the whole part B): Transport beam to HIGH2.Scr2, with all quads between HIGH1.St2 & HIGH2.Scr2 degaussed
- 7) Scan HIGH1.St2 from $-2/-1/0/1/2$ A, record beam centroid x & y at HIGH2.Scr2, into excel file
- 8) Scan HIGH1.StA2 from $-2/-1/0/1/2$ A, record beam centroid x & y at HIGH2.Scr2, into excel file

If steerer scan range is too big for the measurement screen, scale the range down



Proposed beam transport measurements – B → done

B) Beam transport matrix calibration using quadrupole magnets one by one

Goal: Measure the beam transport through the different quads of PITZ as preparation for emittance measurements which make use of quads. Now every quad should be measured one by one to find sources for errors. In general the beam position on a screen will be measured in dependence of the kick strength of a steerer magnet, with only one quadrupole turned on in between.

- > Set BSA=2.0 mm
- > Adjust charge to $Q = 100$ pC
- > Measure LEDA and HEDA, set phase to MMMG phase
- > Adjust charge to 100 pC
 - Note:** The charge could be further increased to get a good signal on the screens, but could be decreased as well, if the signal is still good
- > Measure the momentum
- > Set $I_{\text{main}} = 307$ A.
- > Set the following magnets to the highest possible quad strength, but not more than $k = 60$, but one by one, using setQuads.m (in docs/measure/Magnets/Quads/setQuads.m, explanation inside the function). Set every quad after the measurement to zero quad strength by degaussing the quad.

If it's not possible to get a reasonable signal on the screen (beam clipped on screen, low signal), change **I_{main}** and the **charge**. If the beam on the screen is still not okay reduce the quad strength and try again. Measure the beam centroid x & y from video client at the following Screen in a .txt file

- a. HIGH1.Q3 HIGH1.Scr3
- b. HIGH1.Q4 HIGH1.Scr3
- c. HIGH1.Q5 HIGH1.Scr3
- d. HIGH1.Q6 HIGH1.Scr3
- e. HIGH1.Q7 HIGH1.Scr4
- f. HIGH1.Q8 HIGH1.Scr5

1. Kick the beam with the steerer magnet **HIGH1.St1** in the range of $-2/-1/0/1/2$ A (at least three different steerer currents, all five if there's enough time)
2. Same with **HIGH1.StA1**

- > Extra (if there's time left): Do the same thing for this quads, but other steerer (see text below). Set the following magnets to a quad strength of $k = 60$, but one by one. Measure the beam centroid x & y from video client at the following Screen in a .txt file

- a. HIGH1.Q9 PST.Scr1
- b. HIGH1.Q10 PST.Scr1
- c. PST.QM1 PST.Scr1
- d. PST.QM2 PST.Scr2
- e. PST.QM3 PST.Scr2
- f. PST.QT1 PST.Scr3
- g. PST.QT2 PST.Scr3
- h. PST.QT3 PST.Scr4
- i. PST.QT4 PST.Scr4
- j. PST.QT5 PST.Scr5
- k. PST.QT6 PST.Scr5
- l. HIGH2.Q1 HIGH2.Scr2

1. Kick the beam with the steerer magnet **HIGH1.St2** in the range of $-2/-1/0/1/2$ A
2. Same with **HIGH1.StA2**

(R. Niemczyk)



Emittance -flattop 1nC → X

- Gun: 60MV/m (6.4-6.5MW), MMMG
- Booster 3MW, MMMG
- Laser temporal flattop ~20ps FWHM
- Laser transverse BSA=1.2mm (→1nC)
- Bunch charge 1nC at MMMG
- Trajectory → to be checked
- Measure projected emittance vs. I_{main} at EMSY1 (see instructions)

(M. Krasilnikov)



Program A (~2 shifts)

> RF

- Gun: 6.5MW, FB on

> Laser

- Priority: FT, ShortG, LongG
- BSA=1.2mm, 0.8mm

> Procedures

1. BSA=1.2mm; Save VC2
2. (If OSS works) Save OSS-measured laser temporal profile
3. LEDA scan, grab at MMMG
4. (If known) Use optimized gun quads settings (from nominal emittance measurements)
5. Gun SP Phase range: **(MMMG-65):5:(MMMG+45) deg; At each gun phase adjust and record solenoid current** -> focus beam at Low.Scr2 using LT=100%
6. Do detailed LT scan **using Low.ICT1** at each gun phase: **(0:5:100) %**
7. Set BSA=0.8mm; Save VC2
8. **Repeat p2 to p6**

+ In case of ShortG and LongG laser profile, grab LEDA spectrum for

1. BSA=2.0mm, Q=100pC, Gun@MMMG
2. BSA=2.0mm, Q=100pC, Gun@MMMG-20
3. BSA=2.8mm, Q=100pC, Gun@MMMG
4. BSA=2.8mm, Q=100pC, Gun@MMMG-20

NB: adjust I_{main} to have sharp image at LEDA

