

Aramis beam through Resonant kicker zero-crossing

M. Paraliev

Charge	200 pC		
Repetition rate	10 Hz		
Switchyard e- E	3.1 GeV		FEL pulse energy
Aramis e- E	4.6 GeV		
FEL wavelength	0.19 nm		
FEL pulse energy	70 uJ (?)		FEL image max intensity (~FEL energy)

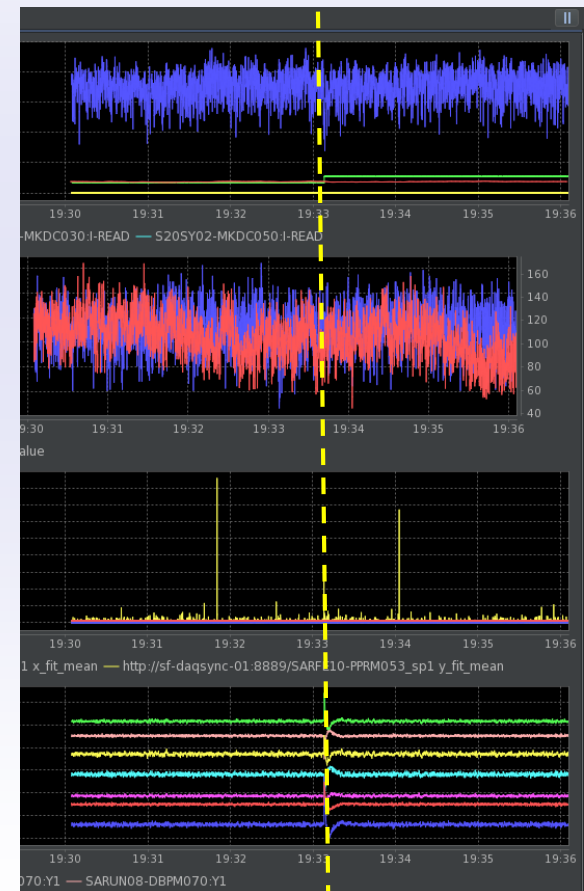
Observed:

- Gas detector (SARFE10-PBIG050-EVR0)
- Screen (SARFE10-PPRM053)*

* Not very useful since max pixel was recorded

RKs
Zero crossing

No RKs
(RKs on delay)

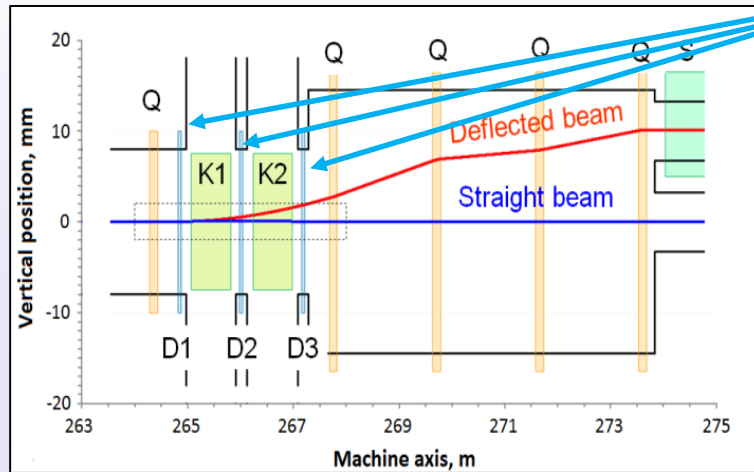


Eingetragene Mannschaft: Rast, Holliger, Holz

Status SwissFEL Mon, 28.Sep.2020: shift 2 @ 14:00

General info		Aramis (bunch 1)		Athos (bunch 2)	
Laser in use:	Bunch 1	Alcor Waveplate angle:	11.175 deg	Jaguar Waveplate angle:	20.198 deg
Mode PV:	UND Aramis / LINAC Athos	Beam frequency bunch 1:	100.00 Hz	Beam frequency bunch 2:	0.00 Hz
Operation msg-date:	Mon 28-Sep-2020 07:14	First ICT bunch 1:	196.399 pC	First ICT bunch 2:	3.905 pC
Operation message:	Tunnel access	First BPM bunch 1:	171.092 pC	First BPM bunch 2:	2.273 pC
Aramis Shift category:	Set-up	Last BPM Aramis:	168.492 pC	Last BPM Athos:	0.331 pC
Aramis Shift status:	Uptime	Electron energy at SARCL02:	4545.1 MeV	Electron energy at SATCL02:	3139.2 MeV
Athos Shift category:	Set-up	Photon energy at SARUN03:	6.618 keV	Photon energy at SATUN21:	0.866 keV
Athos Shift status:	Uptime	Gas detector Aramis:	72.3 μJ	Gas detector Athos:	0.0 μJ

MKDC magnets sensitivity



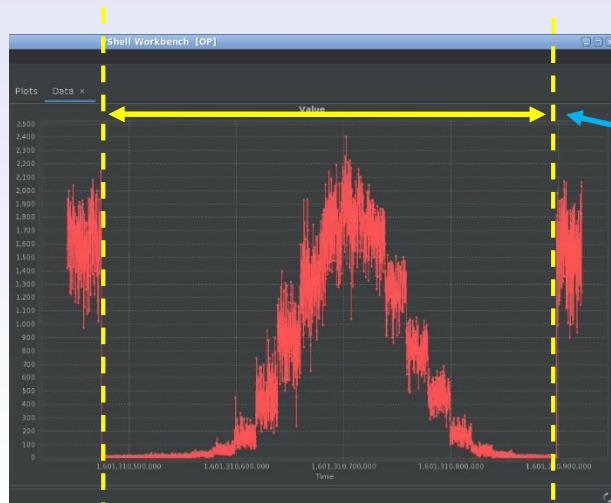
MKDC magnets (compensating dipoles)

Procedure:

- Straight beam in Aramis (no RKs kick)
- Establish lasing (feedbacks on)
- Turn off trajectory feedbacks
- Scan up to $\pm 7 \mu\text{rad}$ static deflection*
- Register FEL pulse amplitude

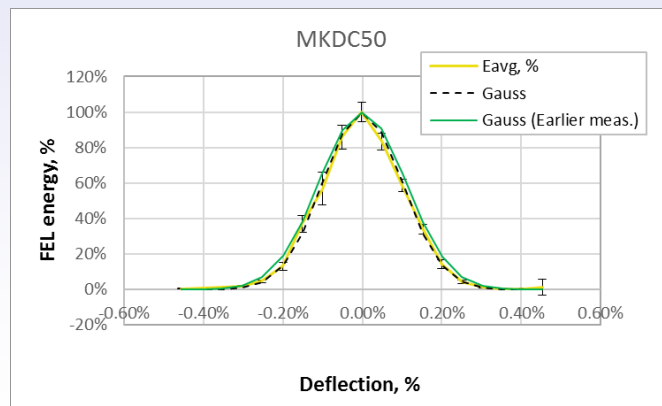
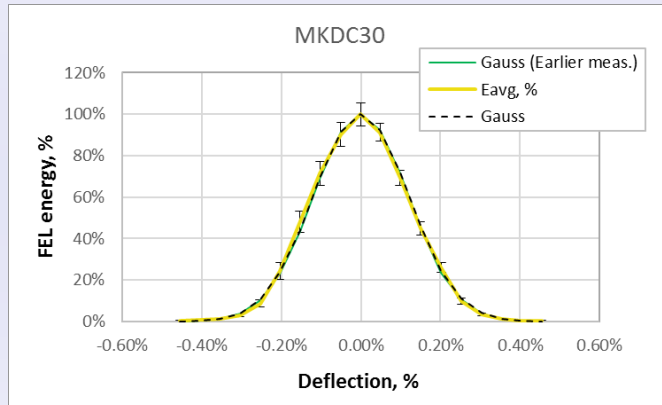
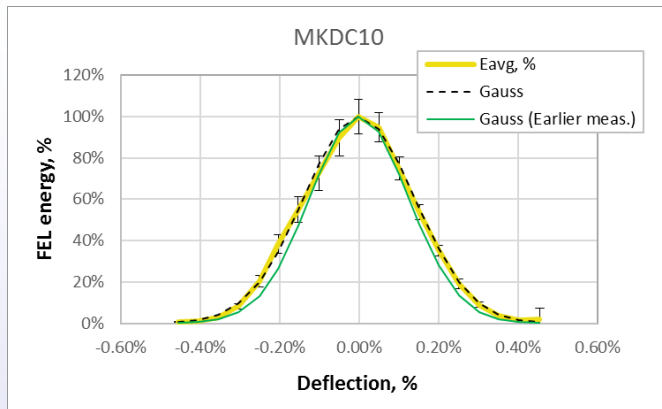
Switchyard layout

*Full deflection is about 1.4 mrad that is reduced to ~ 1 mrad by the quads



$\pm 0.5\%$ of nominal
Switchyard deflection ($\sim \pm 7 \mu\text{rad}$)
(Scan with central compensating
dipole MKDC030)

FEL pulse energy



MKDC magnets sensitivity cont.

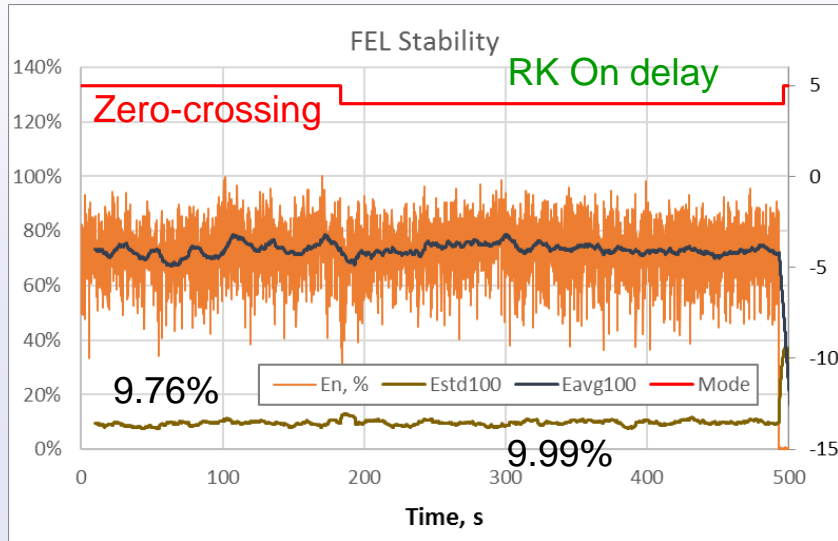
FEL one sigma sensitivity (percentage of full switchyard deflection)

- MKDC10 0.14% (2.0 μ rad)
- MKDC30 0.12% (1.7 μ rad)
- MKDC50 0.10% (1.4 μ rad)

Green graphs represent the results measured earlier

Error bars represent normalized standard deviation at each measured point and at maximum are in the range 12% to 17%

FEL stability at RK zero-crossing (Gas monitor)



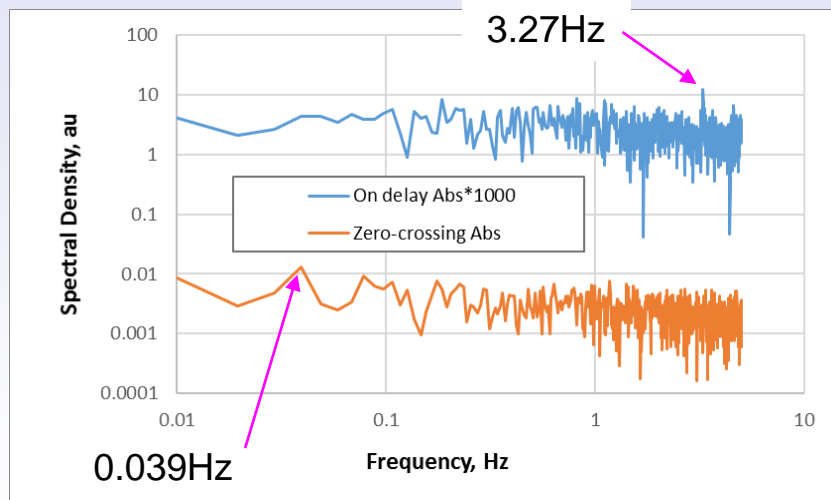
Due to small phase miss-alignment FEL lasing is possible with the trajectory **feedbacks ON**.

Average pulse energy stays roughly the same


Waviness in 100 times averaged pulse energy (25.6 s period, 39 mHz)

Different instability but with similar amplitude

Hard to draw quantitative conclusions about RK stability but it is much smaller than the FEL sensitivity window



How to interpret the results



PAUL SCHERRER INSTITUTE

SwissFEL

Phase stability

Considering multi bunch operation

Phase driven amplitude instability ($\sigma = 5$ mdeg)

In brackets (the upper limit) based on the more conservative instantaneous phase measurement ($\sigma = 24$ mdeg)

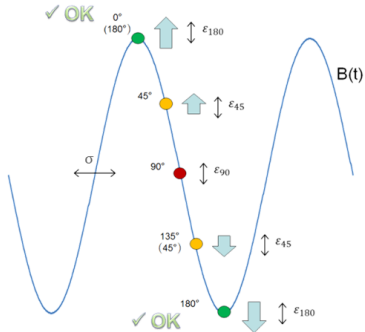
$$\epsilon_{\varphi} = \left| \frac{\cos(\varphi) - \cos(\varphi + \sigma)}{\cos(0)} \right|$$

$\epsilon_{180^\circ}^* = 3.8 \cdot 10^{-9}$ ($8.8 \cdot 10^{-8}$)

$\epsilon_{45^\circ} = 6.2 \cdot 10^{-5}$ ($3.0 \cdot 10^{-4}$)

$\epsilon_{90^\circ} = 8.7 \cdot 10^{-5}$ ($4.2 \cdot 10^{-4}$)

* Half Gaussian distribution



Worst case (highest derivative) phase driven amplitude instability estimation:

180° (on-crest) operation, (two bunches separation)	- negligible - OK
45° operation** (four bunches separation)	- 62 (300) ppm - probably OK
90° operation** (three or five bunches separation)	- 87 (420) ppm - high!

**possible future operation modes

PSI, 06.10.2016

Slide 13/18

Presented by M. Paraliev

Based on electrical phase measurements the estimated zero-crossing jitter was 87 (420) ppm

FEL sensitivity window
sigma MKDC30 – 0.12%

To reproduce the result we need at least 5 times smaller jitter compared to the sensitivity window

Estimated RK induced jitter in order of 200 ppm

Summary

- **Gaussian FEL sensitivity to deflection in switchyard (using MKDC dipoles). In brackets earlier measurement (Oct. 2019 C. Gough)**

MKDC10 – 0.14% (0.13%) rms => 2.0 μ rad rms

MKDC30 – 0.12% (0.12%) rms => 1.7 μ rad rms

MKDC50 – 0.10% (0.11%) rms => 1.4 μ rad rms

- **RKs phase check**

Slight phase mismatch was discovered: MKAC020 2.5 deg and MKAC040 1.6 deg.

This reduces accrual deflection at crest with <1 ppt so it could be neglected.

It is important for zero crossing since the residual deflection due to the phase mismatch leads to complete FEL light loss (25 μ rad)

- **FEL performance through RKs zero crossing**

Due to the phase mismatch the orbit FB has to be ON to get lasing

FEL energy jitter:

- At zero crossing 9.76% rms
- Kickers On delay 9.99% rms

There is a small difference in the fluctuation behavior but it is difficult to draw a quantitative conclusion. The zero-crossing jitter should be at least 5 times smaller than the sensitivity window (~ 0.02%)

In 100 pulses average there is certain waviness (period ~25 s) that is attributed to interaction with orbit correction feedback.