X-FEL Beam Dynamics Meeting
Minutes #2 24.9.03

Topics:

- General
- Discussion on trajectory stabilization systems
- Status of jitter budget calculations
- Next meeting

General

In the future the meeting will be held ½ an hour earlier, i.e. every Wednesdays at 15:30, Room 459, Bldg. 30b.

Trajectory stabilisation systems

Dirk Nölle reports on the meeting with colleagues from PSI and Elettra regarding orbit feedback systems and beam distribution systems (see transparencies).
Results on the following discussion on feedback and beam distribution systems:

Orbit Stability requirements:

- Users: Position and pointing stability, probably most demanding. The requested requirements are presently reviewed.
- SASE: Usually taken to be 10 % of beam sigma, to be reviewed.
- Main Linac: To be taken from existing calculations.
- Bunch compressors, Collimation: To be specified.
- Diagnostic sections: some % of a beam sigma.

Orbit Jitter sources:

- Laser spot motion: Data from TTF
- Magnet vibration: DESY site ground motion spectra, girder amplifications from TTF
- Coupler Kicks: Data from TTF
- Wake fields:
- Switchyard: Fast/DC magnets

A jitter budget throughout the machine is needed. Lots of work has been done, Nick should be able to repeat the analysis done for TESLA LC and BDS for the X-FEL lattice.

Feedback systems:

Pulse structure supposed to be 200 ns bunch-to-bunch, 600 s pulse length (maybe shorter),

10 Hz rep. rate. Bunch selection for users is done at the switchyard. Intratrain feedbacks can thus keep beam properties within specs before the switchyard.
Demanding stability requirements are thus put on the switching devices (10^{-4}).
Error sources with frequencies above approx. 2 Hz behind switchyard have to be kept small.
Feedback locations:
At least one feedback before switchyard. Staged solution with feedbacks at other points in the linac depends on jitter/requirement analysis. At least another feedback at low energy to take out laser jitter, coupler kicks etc. may be necessary. Feedback in front of emittance measurement stations (wires) is obsolete if beam position is measured and taken into account. Latency time will increase with staged feedbacks.

Status Jitter Budget Calculations

Holger Schlarb shows the status of jitter budget calculations (see transparencies). The tight requirements for the bc phases were noted. A review of the bc concept (2 versus 3 stages) is underway and Torsten may report on it next meeting.

Next meeting:

Next meeting October 1st, 15:30.

Tentative program:

- Thoughts on bunch compressor optimization (Torsten)
- Organisation of October 7th meeting with SLS and Elettra (Dirk, Winni)
- Collect orbit tolerance and expected jitter numbers (Winni)

Attachments:

- Transparencies Dirk Nölle
- Transparencies Holger Schlarb

Transverse Feedback Systems and Distribution Systems

Meeting of DESY, SLS and ELETTRA Colleges

D. Nölle, MPY

XFEL Project Group Meeting, Sept.03

Feedback and Distribution Systems

There is Interest of PSI and ELETTRA to take over tasks within the XFEL Project:

- PSI: Orbit Stabilization
- ELETTRA: Beam Distribution Systems

A first Meeting took place during the TESLA Collaboration Meeting.

Technical Requirements

- Definition of Pulse Structure within the Beam -> PM
  - ? 600 µs Beam with *fixed* 200 ns Bunch Spacing
  - ? *Full Bunch Train* all the Time
    - Distribution within the bunch train (arbitrary pattern)
    - Not used bunches send directly to the dump
  - ? *Fixed Energies at the different compression states*
- Definition of the Stabilization Specs
  - Definition of a Jitter Budget -> WP15/16
    - What/Where are the sources to transverse Orbit Jitter
    - What are the expected Amplitudes
  - FEL Performance (undulator entrance) -> WP27
  - User Requirements (undulator end) -> WP25
- Locations for Feed-Back -> WP15/16/25/27
  - BCs, Distribution/Collimation, Undulator (Entrance and End)

Next Step: Meeting on Oct. 7th

Minutes of the Meeting on Sept. 16th available under:
030916_Orbit_Stab_Meeting_DESY.doc

- Discussion of:
  - Formal Aspects of the future Collaboration
  - Technical Aspects
- We need to make up our Mind!
  - -> Agenda + Preparation for this Meeting:
  - Formal Aspects -> PM
  - Technical Aspects -> "Working People"
    - Working Model of the Machine
    - Jitter Budget
    - FEL Requirements
    - User Requirements
    - Technology Aspects
    - First Ideas (Brain Storming by H. Schlarb, D. Noelle,)
      - What Feed-Backs do we need
      - Some Ideas concerning Orbit Feed-Back

Jitter budged for XFEL

Holger Schlarb
DESY
22607 Hamburg

- **Idea:** specify beam parameter jitter at entrance of undulator to avoid SASE simulation (time consuming)
- **Discussion:** Schneidmiller, Yurkov, Saldin, Schlarb
  - simulation with Elegant using reasonable slice of a tracked bunch + errors
  - specification for beam parameter jitter tolerances
- **Problem:** No realistic simulation can be used so far.
- **Progress:** nearly all tools together and tested (except of Genesis simulation)

Status
-jitter tolerances (long. Phase space)-

Table 1. Individual rms sensitivities each cause a +12% peak current change or +0.1% electron energy change at full energy. Most sensitivities listed are approximately linear. These are not tolerances, but individual sensitivities used to form a tolerance budget.

$(\Delta E/E_0) = +0.1\%$ or $\Delta I/I_0 = +12\%$, whichever is tightest

original — adjusted 3.9-GHz

Parameter	Symbol	LCLS	$XFEL_1$	$XFEL_2$	Unit
Gun timing jitter	Δt_0	+1.7	−0.13	−6.0	psec
Initial bunch charge	$\Delta Q/Q_0$	−5.6	−4.1	−1.01	%
mean L0 rf phase	φ_0	+0.71	−0.07	−0.09	deg
mean L1 rf phase	φ_1	+0.19	−0.05	−0.24	deg
mean L*h* rf phase (3.9-GHz & X-band)	φ_h	−1.55	+0.05	+0.19	deg
mean L2 rf phase	φ_2	−0.23	+1.1	−0.49	deg
mean L3 rf phase	φ_3	+0.35	−2.2	−2.2	deg
mean L0 rf voltage	$\Delta V_0/V_0$	+0.27	+0.08	+0.20	%
mean L1 rf voltage	$\Delta V_1/V_1$	+0.27	−0.21	−1.0	%
mean L*h* rf voltage	$\Delta V_h/V_h$	−1.3	−0.3	−1.0	%
mean L2 rf voltage	$\Delta V_2/V_2$	−1.1	+1.6	−1.4	%
mean L3 rf voltage	$\Delta V_3/V_3$	+0.15	+0.11	+0.11	%

Status
-jitter tolerances (long. Phase space)-

Form 'jitter budget' based on uncorrelated jitter: $\sqrt{\sum_{i=1}^{n}\left(\frac{p_{tol}}{p_{sen}}\right)_i^2} < 1$

Table 2. A possible longitudinal jitter tolerance budget for LCLS and TESLA-XFEL.

$|(\Delta E/E_0)| < 0.1\%$ and $|\Delta l/l_0| < 12\%$

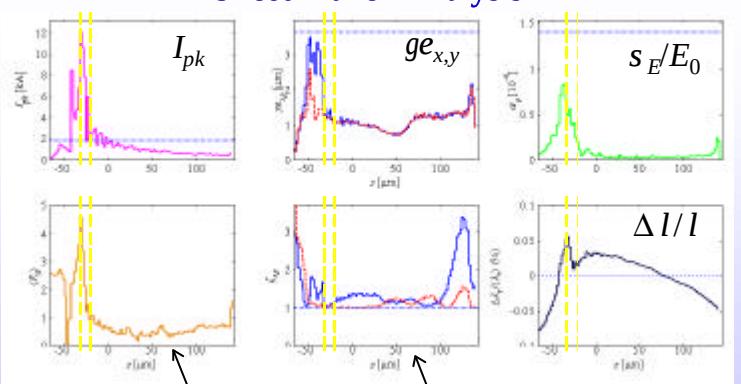
Parameter	Symbol	LCLS	XFEL$_2$	Unit
Gun timing jitter	Δt_0	0.80	1.5	psec
Initial bunch charge	$\Delta Q/Q_0$	2.0	10	%
mean L0 rf phase	φ_0	0.10	0.05	deg
mean L1 rf phase	φ_1	0.10	0.08	deg
mean Lh rf phase 3.9-GHz & X-band	φ_h	0.50	0.07	h-deg
mean L2 rf phase	φ_2	0.07	0.10	deg
mean L3 rf phase	φ_3	0.15	1.0	deg
mean L0 rf voltage	$\Delta V_0/V_0$	0.10	0.08	%
mean L1 rf voltage	$\Delta V_1/V_1$	0.10	0.20	%
mean Lh rf voltage	$\Delta V_h/V_h$	0.25	0.30	%
mean L2 rf voltage	$\Delta V_2/V_2$	0.10	0.20	%
mean L3 rf voltage	$\Delta V_3/V_3$	0.08	0.09	%

Even with new DSP we may cannot guarantee this tolerances!

degrees of X-band or 3.9-GHz

Criteria from Paul Emma

Sliced Bunch Analysis



$$\langle R_0 \rangle = \left[\frac{x^2+(x\alpha_x+x'\beta_x)^2}{\beta_x\varepsilon_x}+\frac{y^2+(y\alpha_y+y'\beta_y)^2}{\beta_y\varepsilon_y}\right]^{1/2}$$

slice 4D centroid osc. amplitude

$$\zeta \equiv \frac{1}{2}\left(\beta_0\gamma - 2\alpha_0\alpha + \gamma_0\beta\right) \geq 1$$

Twiss slice mismatch amplitude

Examples for Beam Parameter to be specified

- Beam centroids (x,x',y,y',t,E)
- Beam second order moments
- Beam emittances

- Slice current
- Slice transverse emittance
- Slice energy spread
- Slice centroid energy
- Slice 4D centroid oscillation amplitude oscillation

$$\langle R_4 \rangle \equiv \left\{ \frac{x^2 + (x\alpha_x + x'\beta_x)^2}{\beta_x \varepsilon_x} + \frac{y^2 + (y\alpha_y + y'\beta_y)^2}{\beta_y \varepsilon_y} \right\}^{1/2}$$

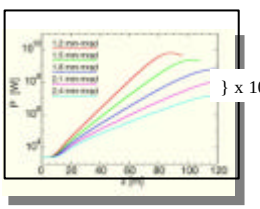
With respect to projected or center slice?

- Twiss slice mismatch amplitude

$$\zeta \equiv \frac{1}{2}\left(\beta_0 \gamma - 2\alpha_0 \alpha + \gamma_0 \beta\right) \geq 1$$

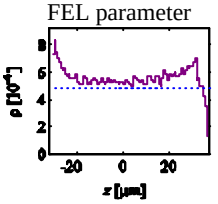
Specification via SASE parameters

- Wavelength (centroid energy)
- Pierce parameter ρ
- Gain length (before saturation)
- FEL power (max. or output)
- Angular divergency
- Angular direction

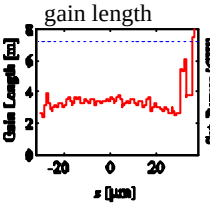


} x 100

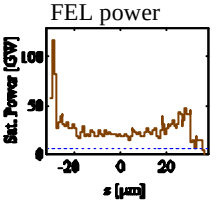
FEL parameter



gain length



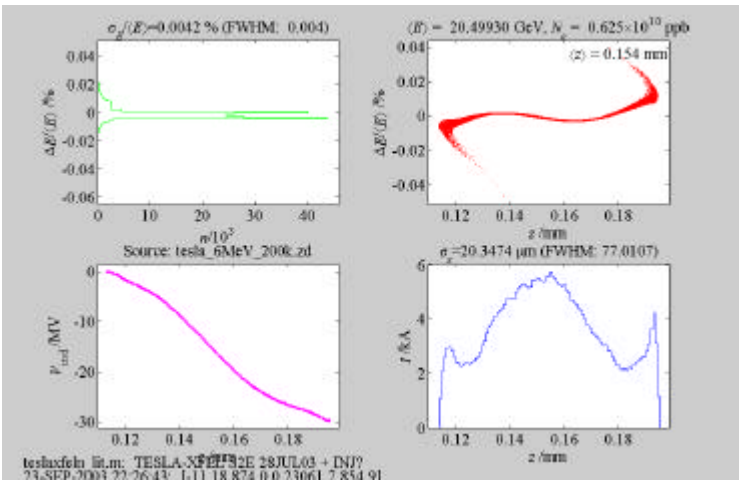
FEL power



'Ming Xie method'

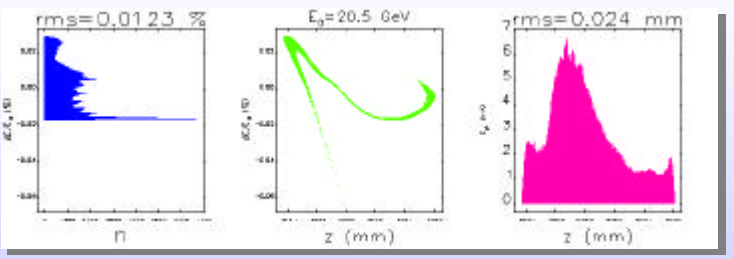
S2E - XFEL

- tracking of long. phase space only (3.9GHz -> 21.4 MV)
- output from Astra -> back tracking to gun -> forward tracking to UND



- from 2d simulation to 6d tracking (Elegant)
- needs adaptation

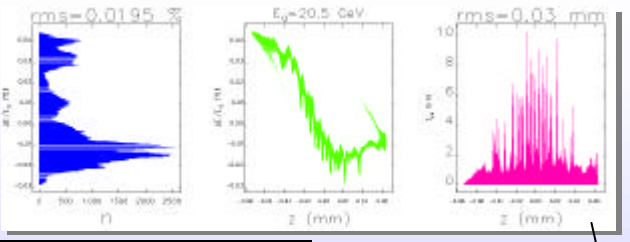
Now test re-optimized setup with full 6D tracking (*Elegant*)

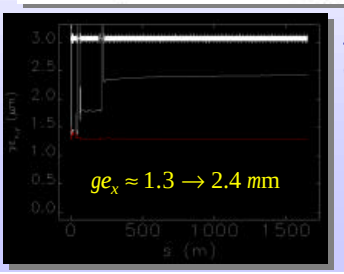


No CSR

• but if CSR is included no reasonable beam distribution is obtained ⇒ most urgent: 100fs smooth lasing beam as input.

Elegant tracking **with CSR** (and increased 3.9-GHz voltage)



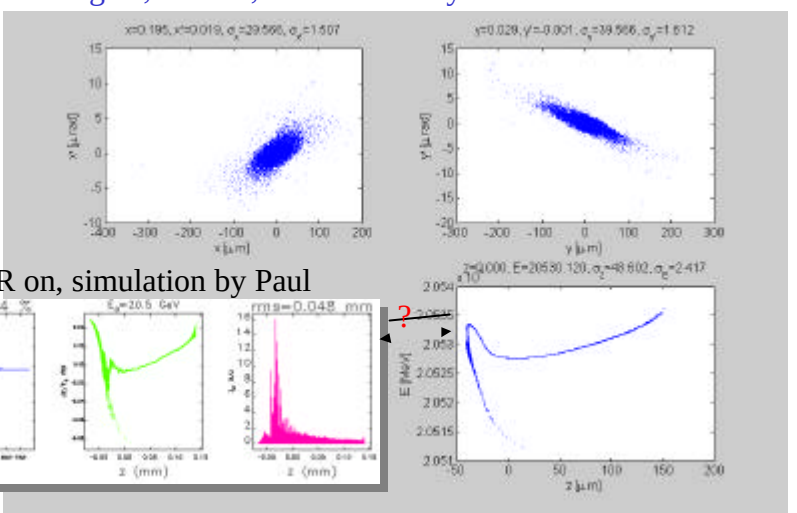


4 keV injector slice energy spread

m-bunching exaggerated by noise, but gain at $l \approx 3$ *m*m may be large (see modulation study below)

And also not an exotic operation mode

• Astra+Elegant, csr off., 3.9 GHz cavity = 17MV/m



CSR on, simulation by Paul

Proposal: We need a review of the bunch compression scheme

- which relaxes the RF phase budged
- compares a two stage with a three stage compression
- check out if an undulator can be used -> E at BC3 higher
- includes the opportunity to measure the beam parameters
- higher harmonic cavities?