Diagnostics overview and FB for the XFEL bunch compressors

Holger Schlarb, Christopher Gerth, Michael Röhrs, …
DESY
22607 Hamburg
• proposed beam line design:

Will be discussed by Ch. Gerth in details
Diagnostics overview BC1

- proposed beam line design:

SRF 1.3 GHz  SRF 3.9 GHz  Bunch compressor  TDS X&Y  Diagnostic section  SRF 1.3 GHz

Standard diagnostics:

TOR  toroid system for transmission measurements (1,3&4 for interlock)
DC  dark current monitors (upstream BC1, downstream BC1)
BPM  beam position monitor ~ 20 (not yet determined ... every quad?)
  purpose: orbit correction, transfer measurements, dispersion correction
OTR  optical transition screen (with wire scanners WS?)

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Special diagnostics:

TDS \(\text{transverse deflecting structure X & Y}\)
EO \(\text{electro–optic longitudinal beam profile monitor}\)
BCM \(\text{bunch compression monitors (CSR at D4 and CDR/CTR)}\)
SR \(\text{synchrotron radiation monitor (energy and energy spread)}\)
BAM \(\text{beam arrival time monitor}\)

B Schmidt

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Diagnostics overview BC1

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Additional devices:

COL  collimators (1st & 2nd to remove dark current, 3rd & 4th for kicked e-)
KIC  fast kicker to off-axis screens (2 x and 2 y)
Align  laser for optics alignment
BLM  beam loss monitors (about 8-10 sufficient)

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• proposed beam line design:

SRF 1.3 GHz

Bunch compressor BC2

TDS X

Diagnostic section

SRF 1.3GHz

Matching sections

Diagnostics elements

Will be discussed by Ch. Gerth in details

TDS  transverse deflecting structure (only X <-dump line in Y)

ORS  optical replica synthesizer

Remaining diagnostics/devices are basically the same as for BC1

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Longitudinal Feedback

• most challenges for BC1

SRF 1.3 GHz  SRF 3.9 GHz  Bunch compressor  SRF 1.3GHz

Problem: 4 regulation parameter $A_1, \varphi_1, A_3, \varphi_3$
+ $\tau$ arrival time of beam into acceleration module ($\varphi = -\omega_{rf}\tau$)

Direct measurement:
- $<\tau>$ beam arrival time $\tau$ (<30fs)
- $<dE/E>$ beam energy (after orbit correction) (<$10^{-5}$)
- $<z^2>$ bunch length (integral pyro signal) (<0.01°)

more difficult
- $|S(\rho)|^2$ spectral content of compressed bunch
- $\rho$ profile (limit resolution!!!)

Ideal operation point: where 2 of 4 parameter have relaxed tolerance (e.g. $A_3, \varphi_3$)

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Ideal operation point: but typically only 1 can be made insensitive

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Next steps at FLASH

- 2007 installation of optical replica synthesizer (< 5fs resolution) in cooperation with Uppsala & Uni. Stockholm

- preparation of longitudinal feedback system (mainly new monitor systems)

- allow for laser based beam manipulation and external seeding option: requires ~ 30-60 fs rms arrival time stability

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Potential upgrades

- normal conducting acceleration cavities for large bandwidth longitudinal FB
  => upstream of BC1 2 * 1 m

- fast kicker for orbit feedback at BC1 or at BC2
  => downstream chicanes 4 * 1 m

- E-SASE operation (laser launched after BC2)
  => ORS can be used (to be confirmed) Laser?

- Beam manipulation in BC1
  => requires addition space!
Laser manipulation BC1

- Most suited in bunch compressor chicane due to large R16 ~ 600mm
- Longitudinal space is mapped to spatial components (Y)
- LCLS insertion of slotted foil to increase emittance for macropulse not possible
- But laser based energy manipulation provides similar option!

- inducing energy spread
- particle migration due to $R_{54}$ ($\sigma_y$ smears out $\sigma_E(z)$)
- in BC2 the energy distribution induced 2.5 larger peak current
- requires 2m space in BC1
Beam manipulation BC1
- simple simulation -

Laser off

Single gap

Two gaps $\Delta x=4\text{mm}$

$2.5 \times \text{I}_\text{peak}$

$\delta z \sim 1\mu\text{m}$

$\Delta z \sim 6.5\mu\text{m}$
Beam manipulation BC1

- spike width and peak current increase tunable via initial energy spread (laser heater)
- allows more complex longitudinal pattern using different masks
- requires more detailed simulation concerning
  - laser launch condition and laser parameters
  - collective effects BC1 & particular at BC2 (micro bunch inst.)
  - FEL simulation to verify possibilities and limitation
- currently not baseline of XFEL design
  but: space should be reserved for future upgrade
- Space requirements (approximately):
  - 1.5 m for undulator
  - 2 m total including screens
  - optical table for laser launching
  - laser beam line injector building to BC1 ?!
- BC2 ?: not so interesting since lower compression (2.5) and much high laser power required

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