Status of the XFEL OTR stations and Emittance Growth due to off-axis screen Wakefields

Christopher Gerth, Dirk Nölle & Igor Zagorodnov
9.06.08
BD meeting, DESY
Diagnostic sections:
- Injector
- Downstream BC1 chicane
- Downstream BC2 chicane

=> Projected and slice emittance measurements and matching
1. Baseline Layout BC Sections: XTL Cross section
1. Baseline Layout BC Sections: Side view

Konstruktionszeichnung Girder: G. Weichert
Meeting on OTR/WS 7.4.2008

- Kickers and off-axis screens available in INJ, BC1, BC2
- Fast WS not required

Advantage:
- Select bunch out of bunch train
- Single bunch resolved (compared to averaged profiles)
- 2D beam shapes

Risks:
- SR from kicker => measurements at FLASH
- COTR => measurements at FLASH
<table>
<thead>
<tr>
<th>Section</th>
<th>OTR/WS old</th>
<th>OTR</th>
<th>OTR-off-axis</th>
<th>WS</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injector[1]</td>
<td>5/5</td>
<td>1+1</td>
<td>4</td>
<td>0</td>
<td>WS taken out/ space reserved Laser Heater OTRs not included</td>
</tr>
<tr>
<td>BC1</td>
<td>9/9</td>
<td>4+1</td>
<td>4</td>
<td>0</td>
<td>WS taken out/ space reserved</td>
</tr>
<tr>
<td>BC2</td>
<td>9/9</td>
<td>4+1</td>
<td>4</td>
<td>0</td>
<td>WS taken out/ space reserved</td>
</tr>
<tr>
<td>Collimator</td>
<td>4/4</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>Screens to detect the beam, wire scanners for precise measurements</td>
</tr>
<tr>
<td>Beam distribution</td>
<td>0/0</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>1 before the switch and 1 in each branch</td>
</tr>
<tr>
<td>Undulator beamlines</td>
<td>0/4</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>1 before the SASE undulator in each line</td>
</tr>
<tr>
<td>Dump</td>
<td>2/2</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>1 for every dump</td>
</tr>
<tr>
<td>Total</td>
<td>29/33</td>
<td>21</td>
<td>12</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>

[1] The gun screens are not included here.
First Conceptual Design

BC1 & BC2: Horizontal streak
=> reflect up or down due to depth of field requirements

Angle of screen: 22.5 deg
To relax depth of field requirements
OTR Screen: XFEL Injector
Front view (1:1) - Intersection B in top view

Field of View: 20 x 25 mm²
Off-axis screen: Δx = 6 mm - d
Resolution: 25 μm
Beam size (rms): 130 μm
Streaked beam: 22 mm
Beam energy: 0.13 GeV
Bunch length: 2.0 mm

beam direction into slide
**OTR Screen: XFEL BC1**

Front view (1:1) - Intersection B in top view

- **Field of View**: 12 x 15 mm²
- **Off-axis screen**: $\Delta y = 6 \text{ mm} - d$
- **Resolution**: 15 μm
- **Beam size (rms)**: 70 μm
- **Streaked beam**: 9 mm
- **Beam energy**: 0.5 GeV
- **Bunch length**: 110 μm

Beam direction into slide
OTR Screen: XFEL BC2
Front view (1:1) - Intersection B in top view

Field of View : 8 x 10 mm²
Off- axis screen: \( \Delta y = 6 \text{ mm} - d \)
Resolution : 10 \( \mu \text{m} \)
Beam size (rms): 40 \( \mu \text{m} \)
Streaked beam : 2.1 mm
Beam energy : 2.0 GeV
Bunch length : 25 \( \mu \text{m} \)
Geometry

OTR Screen: Injector (BC1, BC2)
Front view

Beam pipe
Ø 40.5

Δx

Field of View
8 x 10

Off-axis screen
26 x 9 + d

Asymmetric Field of View!
Simple model (overestimation)

\[ k^0(0,0) = \frac{c Z_0 \left( a \sqrt{-a^2 + b^2} + \left| -2 a^2 + b^2 \right| \text{ArcCot} \left( \frac{a}{\sqrt{-a^2 + b^2}} \right) \right)}{4 a b^2 p^2} \]

G. Stupakov, K. Bane, I. Zagorodnov, Optical Approximation …, PR-STAB, 2007
Improved model

\[ k^1(0,0) = \frac{1}{8 a b^2 h \sqrt{p^2}} \left\{ Z_0 \left( \frac{2 a^2 + b^2}{h} \right) \text{ArcCot} \left( \frac{a}{\sqrt{-a^2 + b^2}} \right) - \right. \]
\[ \left. \frac{a}{a^2 - 2 h^2} \text{ArcCot} \left( \frac{1}{\sqrt{b^2 - h^2}} \right) + \frac{b}{2 a^2 + b^2} h \text{ArcTan} \left( \frac{d}{a} \right) + \right. \]
\[ \left. a \left( - b^2 - 2 h^2 \right) \text{ArcTan} \left( \frac{d}{h} \right) + h \left( \sqrt{-a^2 + b^2} - \sqrt{b^2 - h^2} + d \log \left( \frac{d^2 + h^2}{a^2 + d^2} \right) \right) \right\} \]

\[ b = 20.25 \text{ mm} \]
\[ h = 15 \text{ mm} \]
\[ d = 12.5 \text{ mm} - \text{in Injector} \]
\[ d = 6 \text{ mm} - \text{in BC1} \]
\[ d = 4 \text{ mm} - \text{in BC2} \]
Emittance Growth

\[ S = \frac{eQk_x}{\beta_z^2 E} \]

\[ \varepsilon_x = \sqrt{\varepsilon_{0x}^2 + S^2 \frac{\varepsilon_{0x} \beta}{3}} \approx \varepsilon_{0x} + S^2 \frac{\beta}{6} \]

\[ \frac{\varepsilon_x - \varepsilon_{0x}}{\varepsilon_{0x}} = \sqrt{1 + S^2 \frac{\beta}{3 \varepsilon_{0x}} - 1} \approx S^2 \frac{\beta}{6 \varepsilon_{0x}} \]
Emittance Growth (OTR screen in XFEL Injector)

\[ \frac{\varepsilon_x - \varepsilon_{0x}}{\varepsilon_{0x}} \% \]

Transverse beam size (rms): 130 mm
Energy: 0.13 GeV
\[ \varepsilon_{0x} = 1 \text{ mm}\times\text{mrad} \]
Emittance Growth (OTR screen in XFEL BC1)

\[ \frac{\varepsilon_x - \varepsilon_{0x}}{\varepsilon_{0x}} \% \]

Transverse beam size (rms): 70 mm
Energy: 0.5 GeV
\[ \varepsilon_{0x} = 1 \text{ mm}\times\text{mrad} \]
Transverse beam size (rms): 40 mm
Energy: 2 GeV
\( \varepsilon_{0x} = 1 \text{ mm} \times \text{mrad} \)