Latest projected emittance measurements at FLASH

Accelerator Studies (September 07) – Part I
People involved:
  Katja Honkavaara, Florian Loehl, Eduard Prat
  Pedro Castro, Martin Sachwitz (Wire scanners studies)
FEL Beam Dynamics Meeting, 24th of September of 2007
Overview

When: 1st part of Accelerator studies (06-09-07 and 08-09-07)

Goal (of accelerator and FEL studies):
- Check functionality of filters in the undulator WS (done)
- Study emittance transport (done)
- Study impact of orbit through the modules on emittance (started)
- Comparison between OTR and WS in the seed section (not done)

Conditions: on crest at all accelerator modules, 1nC, 700MeV

Emittance measurements done at DBC2 (with OTR), seed (with OTR) and undulator

Difficulties:
- none BPM calibrated after the shutdown (special problems with BPMs in ACC456 area)
- Machine very sensitive to dark current loses → not possible to measure systematically in the undulator
WS measurements in the undulator

3 wires are available in the undulator: 50 μm T, 10 μm T and 10 μm C

Before the shutdown

# photons $\propto d^2 \cdot A^2$  \quad \rightarrow \quad # photons_{50\mu mT} = 25 \cdot # photons_{10\mu mT} = \sim 4000 \cdot # photons_{10\mu mC}$

Tungsten $\rightarrow$ Non-linear behavior of PM $\rightarrow$ ↑ beam sizes $\rightarrow$ ↑ calculated emittances

During the shutdown

Placement of filters with attenuation factor of 32 in front of each PM

After the shutdown (08-09-2007)

Check functionality of the filters
- Measure different wires with filters
- Remove filters and repeat measurement
- Place again filters and repeat measurement

Measurements done at WS5UND4
(by P. Castro, M. Sachwitz and E. Prat)
WS measurements at 5UND4 – 08.09.07
Horizontal plane

1) With filters

2) Without filters

3) With filters again
WS measurements at 5UND4 – 08.09.07
Vertical plane

1) With filters
2) Without filters
3) With filters again

FEL Beam Dynamics Meeting - 24/09/07
Eduard Prat, DESY
Summary table for the 6th of September
(in brackets values corresponding to 90% of the beam)

<table>
<thead>
<tr>
<th>Where &amp; when</th>
<th>Comments</th>
<th>$\varepsilon_x$ [mm mrad]</th>
<th>$\varepsilon_y$ [mm mrad]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injector 8.10h</td>
<td>Matched</td>
<td>$3.6 \pm 0.2$</td>
<td>$2.9 \pm 0.1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>($2.1 \pm 0.1$)</td>
<td>($1.5 \pm 0.1$)</td>
</tr>
<tr>
<td>Seed 10.14h</td>
<td>Not matched</td>
<td>$3.2 \pm 0.2$</td>
<td>$5.8 \pm 0.2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>($1.9 \pm 0.1$)</td>
<td>($4.0 \pm 0.1$)</td>
</tr>
<tr>
<td>Seed 11.39h</td>
<td>Matched – Orbit corrected at ACC23 &amp; ACC456 respect to previous measurement</td>
<td>$3.3 \pm 0.2$</td>
<td>$3.8 \pm 0.2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>($2.1 \pm 0.1$)</td>
<td>($2.1 \pm 0.1$)</td>
</tr>
<tr>
<td>Seed 12.33h</td>
<td>Matched – Same conditions as previous measurement</td>
<td>$2.2 \pm 0.1$</td>
<td>$3.2 \pm 0.2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>($1.2 \pm 0.1$)</td>
<td>($1.9 \pm 0.1$)</td>
</tr>
<tr>
<td>Seed 12.45h</td>
<td>Matched – Same conditions as previous measurement</td>
<td>$2.6 \pm 0.2$</td>
<td>$3.4 \pm 0.1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>($1.4 \pm 0.1$)</td>
<td>($1.9 \pm 0.1$)</td>
</tr>
<tr>
<td>Seed 13.53h</td>
<td>Matched – Same conditions as previous measurement</td>
<td>$3.0 \pm 0.2$</td>
<td>$3.4 \pm 0.1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>($2.0 \pm 0.2$)</td>
<td>($2.0 \pm 0.1$)</td>
</tr>
</tbody>
</table>

**SEED section**
- Similar emittances as in the injector
- Orbit correction in the modules reduced vertical emittance by ~40%
- Bad reproducibility of emittance, beam size unstable (maybe due to unstable LLRF)

**Undulator**
- Not possible to measure due to huge dark current loses
### Summary table for the 8\textsuperscript{th} of September
(in brackets values corresponding to 90\% of the beam)

<table>
<thead>
<tr>
<th>Where &amp; when</th>
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<tr>
<td>Injector 17.21h</td>
<td>Matched</td>
<td>3.7 ± 0.1</td>
<td>3.6 ± 0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.2 ± 0.1)</td>
<td>(2.1 ± 0.1)</td>
</tr>
<tr>
<td>Seed 18.42h</td>
<td>Matched</td>
<td>3.5 ± 0.1</td>
<td>5.1 ± 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.1 ± 0.1)</td>
<td>(3.1 ± 0.1)</td>
</tr>
<tr>
<td>Seed 19.35h</td>
<td>Matched – Orbit corrected at ACC23 respect to previous measurement</td>
<td>2.9 ± 0.1</td>
<td>3.9 ± 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.8 ± 0.04)</td>
<td>(2.3 ± 0.1)</td>
</tr>
<tr>
<td>Seed 19.44h</td>
<td>Matched – Same conditions as previous measurement</td>
<td>2.9 ± 0.1</td>
<td>3.8 ± 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.8 ± 0.1)</td>
<td>(2.3 ± 0.1)</td>
</tr>
<tr>
<td>Undulator 15.45h</td>
<td>Not matched – 10 µm C wire</td>
<td>4.2 ± 0.3</td>
<td>2.0 ± 1.3</td>
</tr>
<tr>
<td>Undulator 16.03h</td>
<td>Not matched – 10 µm C wire</td>
<td>4.1 ± 0.2</td>
<td>2.2 ± 0.5</td>
</tr>
<tr>
<td>Undulator 16.28h</td>
<td>Not matched – 10 µm C wire</td>
<td>4.5 ± 0.3</td>
<td>2.8 ± 0.1</td>
</tr>
<tr>
<td>Undulator 16.42h</td>
<td>Not matched – 10 µm C wire</td>
<td>4.3 ± 0.3</td>
<td>2.8 ± 0.2</td>
</tr>
</tbody>
</table>

#### SEED section
- Similar emittances as in the injector
- Orbit correction in the modules reduced emittance by ~20%

#### Undulator
- Similar emittances as in the injector
- Good reproducibility of emittance and mismatch parameters in the horizontal plane but not in the vertical one

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Impact of orbit bumps on emittance

20-12-06: A -6mm vertical bump at BPM9ACC2 caused an emittance increase from 2.6 to 6.2 mm mrad

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</tr>
</thead>
<tbody>
<tr>
<td>Seed 10.45h</td>
<td>No bump</td>
<td>4.4 ± 0.1</td>
<td>2.6 ± 0.1</td>
</tr>
<tr>
<td>Seed 17.08h</td>
<td>-6mm y bump</td>
<td>4.1 ± 0.1</td>
<td>6.2 ± 0.2</td>
</tr>
<tr>
<td>Seed 18.27h</td>
<td>No bump</td>
<td>3.8 ± 0.1</td>
<td>2.6 ± 0.1</td>
</tr>
</tbody>
</table>

Simulations predict much weaker effect

Goal of these studies:
Make a more general study of the impact of orbit through the modules:
- for both planes
- with different amplitudes
- for different modules

8th of September → Different bumps for both planes at BPM9ACC2
Horizontal correctors: $H11DBC2$, $H10ACC2$, $H10ACC3$ and $H2UBC3$.
Vertical correctors: $V11DBC2$, $V10ACC2$, $V10ACC3$, $V2UBC3$, $V1DBC3$, $V3DBC3$

Coupled orbit not corrected
After each bump, emittance was measured at the SEED section.
Vertical bumps

- Negative bump affects more the vertical emittance
- Positive bump affects more the horizontal emittance
- A 5mm bump increases the emittance by ~ 40%
Horizontal bumps

- Effect to both planes qualitatively similar but bigger impact in the vertical emittance
SUMMARY

• Attenuation filters of the WS stations in the undulator work as expected
• 1st emittance measurements after the shutdown show similar emittances along the machine:
  • 100% emittances: between 3 and 4 mmmrad
  • 90% emittances: around 2 mmmrad (design value)
• Started studies on the impact of orbit through modules on emittance.

NEXT STEPS

• Next measurements:
  • 26th of September – Accelerator Studies – 2 shifts
  • 14th of October – FEL studies – 1.5 shifts
• Comparison between OTR and WS in the SEED section
• Continue the study of the impact of orbit bumps through the accelerator modules on the emittance