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Overview of FLASH 2
Hamburg, 2016-03-22

Charge: 0.5 nC
Overview

1. FLASH 2 Overview
   1. Layout parameters

2. Operation FLASH2.
   1. Lasing at wavelengths between 4 and 60 nm.
   2. Parallel operation FLASH1 and FLASH2 established.
# Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>FLASH1</th>
<th>FLASH2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beam parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam Energy</td>
<td>0.5 – 1.25 (1.6) GeV</td>
<td>0.5 – 1.25 (1.6) GeV</td>
</tr>
<tr>
<td>Normalized emittance (proj.)</td>
<td>1.4 – 3 mm mrad</td>
<td>1.4 – 3 mm mrad</td>
</tr>
<tr>
<td>Energy spread</td>
<td>0.2 MeV</td>
<td>0.5 MeV</td>
</tr>
<tr>
<td>Peak Current</td>
<td>2.5 kA</td>
<td>2.5 kA</td>
</tr>
<tr>
<td>Bunches per second*</td>
<td>&lt;8000</td>
<td>&lt;8000</td>
</tr>
<tr>
<td>Bunch Charge</td>
<td>0.07 – 1 nC</td>
<td>0.02 – 1 nC</td>
</tr>
<tr>
<td><strong>Undulator parameters</strong></td>
<td>Fixed gap</td>
<td>Variable gap</td>
</tr>
<tr>
<td>Period</td>
<td>27.3 mm</td>
<td>31.4 mm</td>
</tr>
<tr>
<td>Segments length</td>
<td>4.5 m</td>
<td>2.5 m</td>
</tr>
<tr>
<td>Number of segments</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Focusing Structure</td>
<td>F0D0</td>
<td>F0D0</td>
</tr>
</tbody>
</table>

*Shared between FLASH1 and FLASH2*
• Separation FLASH and FLASH2 behind last accelerator module
• Tunability of FLASH2 by undulator gap change
• Extend user capacity with SASE and seeding
Separation FLASH1 and 2: the septum.

Small apertures to get FLASH1 and FLASH2 beam through.

Size of normal vacuum pipe
Kicks of Quadrupoles Q19ACC7, Q1TCOL and Q2TCOL are needed to get beam into FLASH2
Different Quad settings → different kick = angle or offset.
With a FLASH1 vertical beam offset, FLASH2 will normally have the same offset with respect to Septum.

*Courtesy M. Scholz*
Undulators Control (status November 2015).

Set undulator gaps based on beam energy and desired wavelength. All undulators characterized individually.

Allows tapering (in different groups) and global phase change.
 Undulator focusing.

> Undulators focus the beam vertically
  
  ▪ Focusing usually much smaller than quad focusing.
  ▪ Energy dependence of quad and undulator focusing different.
  
> At low energy, this effect becomes comparable to quad focusing

  ▪ Quadrupole currents need to be adjusted.
  ▪ Optics depend on energy and on undulator gap (as compared to FLASH1, where the gap is fixed).
  
> Server should take care of the optics inside the undulator, depending on gap of each individual undulator.

The effect could be seen during the beamtime at 0.4 GeV (38 nm at FLASH1).
**Optics at 0.4 GeV.**

- **Hor.**
- **Vert.**

**Beam size $\sigma^2 \sim \beta$**

- Undulator open
  - $4<\beta_y<12$ m
- Last 6 undulator closed
  - $1<\beta_y<120$ m
- All 12 undulators closed
  - $0<\beta_y<3000$ m
LLRF Steps

Max. step: 10MV, 5°
Gun only without pulse width feedback
SASE tuning

Slow online Intensity Monitor
LLRF learning FF
Main timing of FLASH.

Settings for FLASH1 and 2 chosen independently.

1 Hz operation at FLASH2 possible.

Start time for FLASH2 flexible: all diagnostics on electron and photon side, kicker and LLRF steps adjusted automatically.

Long pulse trains are also possible at FLASH2.
Long bunch trains at FLASH 2.
Orbit feedback.
Orbit feedback.
Orbit feedback.
Orbit feedback.
Orbit feedback.
Orbit feedback.
Photon Diagnostics.

Gas monitor detector slow-signal in operation.
Online spectrometer being commissioned.
Mirrors in operation.
Photon screen(s) in operation.
Grating spectrometer (was) in operation.

Details on Photon Diagnostics in two weeks by M. Kuhlmann!
Commissioning/Setup.

Most setup FLASH2 (including lasing) done by FLASH operators.

Only dedicated studies/tests done by experts.

Programs of FLASH1 and FLASH2 now always in parallel (mostly during user runs FLASH1).
FLASH1: 13.57 nm for users
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FLASH2: large variation in intensity from 350 to 1 µJ
Tunability.

FLASH1: 13.57 nm for users
FLASH2: Wavelength scan from 40 to 10 nm

FLASH1: 13.57 nm for users
FLASH2: Wavelength scan from 40 to 10 nm
Fast Tunability.

FLASH1: 13.57 nm for users
FLASH2: Wavelength scan from 40 to 10 nm

26 wavelength in 55 minutes

-> change wavelength in a 1nm step took in average 2 minutes
Wavelengths reached.

Complete wavelength ranges have been covered:
- Sometimes without GMD
- Sometimes with pulse energy below 50 µJ

Open symbols for 2.5 kA
Filled symbols for 1.5 kA

**Complete wavelength ranges have been covered:**
- Sometimes without GMD
- Sometimes with pulse energy below 50 µJ
Wavelength reached at FLASH 2

This includes measurements of experts as well as from the shift crew
Tunability: study by expert(s).

For same shift we have:
- Pointing
- Divergence
- Spectra with OPIS and grating spectrometer
Tunability: setup by operators.

Comparison taper/no taper

At short wavelength, optimization is needed.
Tapering of undulators.

Untapered case:
- 220 uJ after 12 modules
- 100 uJ after 9 modules (saturation point)

Linear tapering: 440 uJ
Quadratic tapering: 440 uJ

Increase of output pulse energy over saturation is x4
Increase of output pulse energy at full undulator length is x2

*Courtesy M. Yurkov & E. Schneidmiller*
Outlook

Continued commissioning
- Further education of operators.
- Commissioning of photon diagnostics (see M. Kuhlmanns talk).
- Commissioning of CRISP5 (right now there is no bunch length measurements at FLASH2).
- Steps in the gun
- Wider ranges of charge differences between FLASH1 and FLASH2.
- Further optimize and automatize undulator server.
- Energy server, orbit feedback, ...
- Beam Based Alignment, Optics studies
- Influence of varying conditions FLASH1 (bunch number) on pyro signal of FLASH2
- Lasing at short wavelength

User operation
- First users starting from April

Thanks
- To all the operators
- Special thanks to B. Faatz, he did most of the work presented here