sFLASH

First results from the seeding experiment at FLASH

FLASH Seminar
Hamburg
05/10/2010

On behalf of the sFLASH team
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Hamburg University

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• DFG GrK 1355, FSP 301
• Joachim Herz Stiftung
Outline

• Introduction / Motivation
• sFLASH components
  – Seeding source
  – Injection beam line and diagnostics
  – sFLASH Undulators
  – FEL extraction beam line and diagnostics
• First Lasing Results (SASE) (August Shifts)
• Seeding Status (Shifts last week)
• Conclusion
• Outlook
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Introduction

- Demonstration of direct seeding with high harmonics (HHG) at wavelength below 40nm
- Temporal stability for pump-probe experiments in order of fs
- Improve the longitudinal coherence of the FEL in comparison to SASE radiation
- Simultaneous operation of FLASH and sFLASH


Comparison of a SASE pulse (red) and a seeded pulse (blue) in time domain
sFLASH Installation

FEL extraction

Undulator section

ORS* section

Seed injection

HHG source

* Optical Replica Synthesizer
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HHG laser system

- 81 MHz Ti:Sa oscillator, 0.5 mW output power
- CPA – reg. amplifier with 4x multi pass booster section

- Compressor is placed close to the HHG target chamber to avoid pulse distortions due to self focusing effects
HHG laser system

- Pulse energy: typ. 35 mJ (50 mJ max)
- Rep. rate: 10 Hz
- Energy stability: 4 % rms
- Bandwidth: 35 nm
- Pulse length: 33 fs (FWHM)
- $M^2 \leq 2.5$

HYDRA USP-25 near field, amplified
HHG Source
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Injection beam line

Coating change

13 nm  30 nm
Injection beam line

Coating change

e-beam
Focusing the XUV radiation

- To match the beam size of the XUV and the electron beam, the seed source need to be imaged to the undulator.
- sFLASH uses spherical mirrors with a multi layer coating for 38nm or 13nm. For each wavelength three focal length can be used (f: 6.25m; 7m; 8.5m)
Transverse overlap diagnostics

- OTR-screen
- YAG-screen
- Filter, Optics, EMCCD-cam.
- BPM
- Wirescanner
Longitudinal overlap diagnostics

- using synchrotron radiation from a short (N=5) electromagnetic undulator together with 800nm laser pulses on a streak camera to find the temporal overlap

![Diagram of experimental setup]

- Modulator tuned to 1.3µm
- Off axis screen: 40mm*20 mm @ (45 deg) position: 4.5 mm above beam axis
- Streak camera
- 650 nm bandpass and 750 shortpass filter
- Parasitic operation

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sFLASH Undulators

U32s (PRN2)
31.4 mm period length
Gap_min = 9 mm \( \rightarrow \) K_max = \( \sim \) 3
Number of poles = 120

U33 (upgraded PII undulator)
33 mm period length
Gap_min = 9.8 mm \( \rightarrow \) K_max = \( \sim \) 3
Number of poles = 240
Vacuum Chamber

Achieved:
Better than ±100 μm flatness (8.6 mm width) spending 8 hr.person for 4 m long undulator.

Courtesy: T. Wohlenberg
sFLASH Undulator
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FEL extraction and diagnostics

YAG screens and apertures
Mirror chambers
Intensity monitor
Spectrometer
To experiment

Poster: F. Curbis TUPB21
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straightening the orbit

- using the laser as the orbit reference
- setting the electron beam on the straight laser line
- applying the slow orbit feedback
Transverse overlap

- detectors for HHG beam

![Diagram showing overlapping beams and detectors](image)

E.g. after the first sFLASH undulator module

HHG-beam on YAG

![Image of HHG-beam on YAG](image)

e-beam OTR

![Image of e-beam OTR](image)

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Longitudinal overlap („coarse“)

laser and electron beam are separated in time by ~2 ps

laser and electron beam are overlapped within ~1 ps
Close all undulator modules
The slow feedback keeps the orbit constant
On 8. August first electron beam through the undulator

First beam through the tuned undulator
?? Seeding ??

And what about seeding?
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Wednesday 29.09.2010:

- Systematic setup of long. phase space using LOLA
  - Goal: “LASER-able” bunch length >250 fs
- Tune SASE@FLASH undulator to high values >100µJ
- Setup longitudinal overlap (ORS modulator to 1.3µm ...)
- Adjust the orbit in sFLASH using “laser alignment”
  - Apply slow orbit feedback
- Close sFLASH undulators (frequency overlap)
- Tune sFLASH SASE
- Recheck and adjust transverse overlap with HHG beam
- Timing scans
Wednesday 29.09.2010: Some SASE at 18:41
After orbit checks in sFLASH and tuning in FLASH

Without RF-Tuning!
After a technical problem with the vacuum system all sFLASH valves in the diagnostic branch closed and could not be opened again! Happened at 0:22h in the night. ;-(

Waiting for the expert ...

Start to investigate simultaneous operation of FLASH when sFLASH undulator where closed.
  - Full transmission could easily being achieved.
  - SASE of a few μJ was produced
    - Unfortunately VMEDIAG6 was offline (SMATCH and some undulator BPM´s were not available)
Wednesday 29.09.2010: Arrival time feedback

- Holger set up a slow arrival time feedback acting on ACC1 gradient measuring BAM 3DBC2
- Beam arrival time stabilized to ~300 fs over the shift
Wednesday 29.09.2010: Timing Scans

sFLASH timing scan, 200 shots per time step, step size 25fs

MCP signal [a.u.]

timing scan range [ps]

sFLASH timing scan, 200 shots per time step, step size 25fs

MCP signal [a.u.]

timing scan range [ps]
Thursday 30.09.2010:

- Studies on temporal overlap setup
  - No time dependence of 6ORS screen position could be observed
- Studies on focusing of the seed laser
  - Using a „knife edge“ method to determine the focus position
- Phase shifter optimization
  - Factor of 5 increase of the SASE power
- Fine tuning of transverse seed beam position
- Fine tuning of undulator gaps
Thursday 30.09.2010: „knife edge“ method

- Using screen 10ORS to block the seed beam partly
- Observe HHG beam on 1SFUND1 and 1SFUND2

Case 1
Thursday 30.09.2010: „knife edge“ method

- Using screen 10ORS to block the seed beam partly
- Observe HHG beam on 1SFUND1 and 1SFUND2

Case 2
Thursday 30.09.2010: „knife edge“ method

- Using screen 10ORS to block the seed beam partly
- Observe HHG beam on 1SFUND1 and 1SFUND2

Result
Thursday 30.09.2010: Timing Scans

sFLASH timing scan, 100 shots per time step, step size 50fs

MCP signal [a.u.]

timing scan range [ps]
Thursday 30.09.2010: Timing Scans

sFLASH timing scan, 100 shots per time step, step size 50fs

Loop Scan; average 5 shots; step size 50fs

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Friday 01.10.2010:

- Use ORS setup to do a laser-electron interaction at 800nm wavelength to proof temporal overlap works
- Setup sFLASH and to seed with this timing reference
Friday 01.10.2010: ORS time scan

Streak Camera measurement

ORS Signal

5.5 ps!
Friday 01.10.2010: ORS time scan

ORS timing scan, 100 shots per time step, step size 25fs

sFLASH timing scan, 100 shots per time step, step size 25fs
Seed Source / Transverse Overlap

21st harmonic beam size for f = 6.25m

- Blue diamonds: 21st harm. hori.
- Red squares: 21st harm. vert.
- Black solid line: Sim hori
- Black dashed line: Sim vert

Focal mirror position

1/e² beam radius [mm]

Z-position [m]

1st undulator

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### ZEMAX beam transport

**ZEMAX Input deck**

<table>
<thead>
<tr>
<th></th>
<th>$w_0$ (M²=1)</th>
<th>$w_0$ (source)</th>
<th>$zw$ (w.r.t. source)</th>
<th>$z_R$</th>
<th>$\theta$</th>
<th>M²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>0.0600 mm</td>
<td>0.240 mm</td>
<td>890 mm</td>
<td>0.297 m</td>
<td>0.806</td>
<td>16</td>
</tr>
<tr>
<td>Vertical</td>
<td>0.0725 mm</td>
<td>0.290 mm</td>
<td>1560 mm</td>
<td>0.434</td>
<td>0.667</td>
<td>16</td>
</tr>
</tbody>
</table>

**Simulation for focal length: f = 7 m**

<table>
<thead>
<tr>
<th>M² = 16</th>
<th>Source (waist)</th>
<th>7HHGBL</th>
<th>1SFUND1</th>
<th>1SFUND2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>0.240 mm</td>
<td>6.369 mm</td>
<td>1.767 mm</td>
<td>0.369 mm</td>
</tr>
<tr>
<td>Focus parameter</td>
<td>w₀ = 0.240 mm; $\theta$ = 0.806 mrad; $z_R$ = 0.297 m</td>
<td></td>
<td>w₀ = 0, 357 mm; $\theta$ = 0.542 mrad; $z_R$ = 0.658 m; focus pos.: 2.55 m</td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>0.290 mm</td>
<td>4.828 mm</td>
<td>1.931 mm</td>
<td>0.861 mm</td>
</tr>
<tr>
<td>Focus parameter</td>
<td>w₀ = 0.290 mm; $\theta$ = 0.667 mrad; $z_R$ = 0.4345 m</td>
<td></td>
<td>w₀ = 0.501 mm; $\theta$ = 0.386 mrad; $z_R$ = 1.297 m; focus pos.: 4.19 m</td>
<td></td>
</tr>
</tbody>
</table>

**Measurements**

<table>
<thead>
<tr>
<th></th>
<th>Source</th>
<th>7HHGBL</th>
<th>1SFUND1</th>
<th>1SFUND2</th>
</tr>
</thead>
<tbody>
<tr>
<td>horizontal</td>
<td>0.240 mm</td>
<td></td>
<td>1.678</td>
<td>0.790</td>
</tr>
<tr>
<td>vertical</td>
<td>0.290 mm</td>
<td></td>
<td>3.276</td>
<td>1.708</td>
</tr>
</tbody>
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• Laser-electron overlap could be achieved using ORS setup
• Streak Camera measurement has a systematical offset of ~5ps
• Matching of the seed beam with the electron beam insufficient (bad emittance of the seed beam)
• By now, no significant seed signal could be observed reproducible
Outlook

• To Do´s for the next beam time:
  – Improve the beam quality of the seed beam
  – Measure seed energy
  – Statistic analysis of the FEL spectra
  – ...

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