Results from the test of sFLASH photon diagnostics using the FLASH FEL beam

FLASH beamtime KW 29-30 (23-24 July '09)

Francesca Curbis, Tim Laarmann
Outlook

• Why seeding?
• sFLASH within FLASH-upgrade`09
• Layout of sFLASH
• Photon diagnostics beamline
• Intensity monitor:
  - simulations and measurements
• Summary and plans
Motivation: why **direct** seeding?

- Longitudinal coherence
- Better intensity stability
- Temporal pulse shape control
- High precision synchronization for pump-probe experiments
- Additional experimental station
FLASH upgrade “for” sFLASH

3rd harmonic accelerating module

sFLASH
40m redesigned electron beamline

3.9 GHz RF cavity: 200fs electron bunches, few kA peak current

Beamline modifications to the section between the collimator and SASE undulators
**sFLASH layout**

**HHG-Laser system**
- 35 mJ, 800 nm, 10 Hz, 35 fs (fwhm)
- 5-10 mJ HHG generation on gas target outside the tunnel
- multilayer mirrors at 13 and 30 nm

**4 variable gap undulators:**
- 3 PETRA III ($\lambda_u=31.4$ mm, 2 m long)
- 1 PETRA II ($\lambda_u=33$ mm, 4 m long)
- min gap ~ 9 mm
- phase shifters, additional steerers
- intra-undulator diagnostics

**HHG-Laser system**
- 35 mJ, 800 nm, 10 Hz, 35 fs (fwhm)
- 5-10 mJ HHG generation on gas target outside the tunnel
- multilayer mirrors at 13 and 30 nm

**Experimental hutch (28 h)**
- 10 m
- 70 cm
- 28 g
Photon beamline

~186 m
Diagnostic branch

Inside the tunnel

- Apertures
- YAG screen
- Deflecting mirror chamber

Photon diagnostic blocks
- Camera
- Alignment laser
- Switching mirror chamber

Intensity monitor
- Spectrometer

Diagnostic branch to the experiment

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Grazing Incidence Spectrometer

**Purpose:** matching undulator-HHG wavelength

Single-shot capability
Resolution: $\lambda/\Delta\lambda = 1000$
Range: 1 - 35 nm

![Graph showing He II at 30.38 nm](image)

Test next week with plasma source
Intensity monitor

**Purpose: to measure the gain curve of the seeded FEL**

- detection of radiation scattered from a gold mesh with MCP
- cross calibration with gas monitor detector
- dynamic range \(~10^4\) per MCP (voltage)
Final design

3 MCPs for wider dynamic range:

- 2 MCPs with hole on axis
- 1 MCP at 90°

Mesh at 45°

MCP 1

- efficiency = 4.7%

MCP 2

- efficiency = 2.6%

MCP 3

- efficiency = 0.04%

Gold mesh

Source: $10^8$ rays

500 μm FWHM

30 nm (41.3 eV)

ZEMAX simulation
Simulations at 30 nm

**mesh**: spacing = 0.25 mm, wire diameter = 0.06 mm, open area = 65%

**Efficiency**
- MCP1 = $4.7 \times 10^6 \rightarrow 4.7\%$
- MCP2 = $2.6 \times 10^6 \rightarrow 2.6\%$
- MCP3 = $4.2 \times 10^4 \rightarrow 0.04\%$

**Different Configuration**
- MCP1 = $1.5 \times 10^6 \rightarrow 1.5\%$
- MCP2 = $1.1 \times 10^6 \rightarrow 1.1\%$
- MCP3 = $1.6 \times 10^4 \rightarrow 0.16\%$
Simulations at 30 nm

**Mesh 1** (0.25 mm, Ø 0.06 mm, 65%)
- MCP1 = $4.7 \times 10^6 \rightarrow \sim 4.7\%$
- MCP2 = $2.6 \times 10^6 \rightarrow \sim 2.6\%$
- MCP3 = $4.2 \times 10^4 \rightarrow \sim 0.04\%$

**Mesh 2** (0.011 mm, Ø 0.004 mm, 44%)
- MCP1 = $6.3 \times 10^6 \rightarrow \sim 6.3\%$
- MCP2 = $3.6 \times 10^6 \rightarrow \sim 3.6\%$
- MCP3 = $6.7 \times 10^4 \rightarrow \sim 0.07\%$

**SAME CONFIGURATION, DIFFERENT MESH**

Two different meshes are mounted on a translation stage allowing to select the most suitable one depending on the photon flux.
### Mesh comparison at 13 nm

**Starting with $10^8$ rays**

**mesh 1**
- |↔| 0.25mm
- Ø 0.06mm
- Open area 65%

<table>
<thead>
<tr>
<th>MCP 1</th>
<th>MCP 2</th>
<th>MCP 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="MCP 1" /></td>
<td><img src="image2" alt="MCP 2" /></td>
<td><img src="image3" alt="MCP 3" /></td>
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<tr>
<td>Efficiency: 4.5%</td>
<td>Efficiency: 2.4%</td>
<td>Efficiency: 0.02%</td>
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</table>

<table>
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<tr>
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<tr>
<td>65%</td>
<td>4.5%</td>
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<tr>
<td></td>
<td>2.4%</td>
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<tr>
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<td>0.02%</td>
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**mesh 2**
- |↔| 0.011mm
- Ø 0.004mm
- Open area 44%

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<th>MCP 1</th>
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<td><img src="image4" alt="MCP 1" /></td>
<td><img src="image5" alt="MCP 2" /></td>
<td><img src="image6" alt="MCP 3" /></td>
</tr>
<tr>
<td>Efficiency: 5.9%</td>
<td>Efficiency: 3.2%</td>
<td>Efficiency: 0.03%</td>
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Calibration measurements

Measurements at BL1@FLASH  
~ 500 μm spot size

λ = 13.7 nm

We simulated the amplification curve of sFLASH attenuating the SASE beam from the μJ range down to the pJ range by means of a combination of the gas attenuator and aluminum filters (thickness 200 and 137 nm).

We measure the spontaneous emission from the undulators detuning SASE. This is similar to the starting point of the commissioning phase.

experimental setup

FLASH beam → GMD - T → gas attenuator → GMD - B → Al filter → Al filter → intensity monitor ← BL1
The short MCP signal (~1ns) is amplified, then stretched before entering the ADC. We measured the MCP output signal for different high-voltage settings.

*signal from the ADC as recorded by DAQ*
we recorded the shot-to-shot energy of the pulses measured by the gas monitor detector

Precision of absolute energy calibration ~20%
Cross-calibration

For one voltage setting

![Graph showing shot-to-shot energy vs. ADC value with different MCP signals: MCP1, MCP2, MCP3.](image)
Total dynamic range

<table>
<thead>
<tr>
<th>Gas attenuation</th>
<th>filter1</th>
<th>filter2</th>
<th>Voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>-</td>
<td>-</td>
<td>930 1130 670</td>
</tr>
<tr>
<td>90%</td>
<td>-</td>
<td>200nm</td>
<td>1350 1500 1050</td>
</tr>
<tr>
<td>99%</td>
<td>200nm</td>
<td>130nm</td>
<td>1650 1710 1350</td>
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</tbody>
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ADC signal [V]

Energy [µJ] from GMD

Voltage (V):
- mcp1
- mcp2
- mcp3

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amplification factors estimated looking at regions where for different voltage settings we measured the same pulse energy
Conclusions

sFLASH:

- fully coherent beam with small SASE background
- high peak power operation ~ 1-2 GW
- variable bunch duration 20 - 40 fs (FWHM)
- temporal pulse shape control
- wavelength: 30 nm - 13 nm
- parasitic mode (hence parallel experiments)
- pump-probe experiments with fs synchronization

Photon diagnostics:

- shot-to-shot spectral measurements
- absolute calibration for measuring the gain curve (photon flux)
Acknowledgements

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