Designing the FLASH II Photon Diagnostic Beamline and Components.

D. Meissner, M. Hesse, U. F. Jastrow, H. Mahn, F. Marutzky, E. Plönjes,
H. Schulte-Schrepping (DESY, Hamburg, Germany) for the FLASH II Community

Abstract

From 2013 to 2016 the free electron laser FLASH at DESY in Hamburg, Germany was upgraded with a second undulator line, photon diagnostic line, beam distribution and experimental hall connected to the same linear accelerator. This poster shows the layout of the photon diagnostic section and an overview of the civil engineering challenges. The mechanical design of selected components, e.g. vacuum components, diagnostic equipment and safety related components is presented.

Introduction

The x-Ray Free Electron Laser FLASH at DESY has been running as a user facility for XUV and soft x-ray photon experiments since 2005. In 2010 the upgrade project FLASH II was started to increase the number of user end stations by adding a second undulator line to the FLASH accelerator and operating both beamlines simultaneously and independently regarding wavelength. [1, 2]

Two largely identical photon diagnostic sections had to be developed to provide beam parameters to accelerator operation and user experiments. The first section is located inside the accelerator tunnel starting at 10m from the source where the beam is very small and intense, the second section is in the experimental hall and is fully accessible to users. Both provide data on beam intensity, position and wavelength. The complete layout is described in [2].

Since most of the components use various gases at different pressures main focus in designing the vacuum system was on differential pumping, especially the gas attenuator located between tunnel and hall where the beam crosses the PETRA III accelerator tunnel. Additional mechanical component development focused on absorbers and mirror chambers for beam steering and radiation protection.

Flash II Project Overview

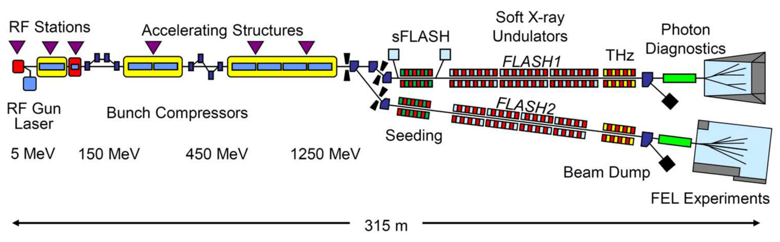

Figure 1: Schematic overview of the FLASH I and FLASH II accelerators

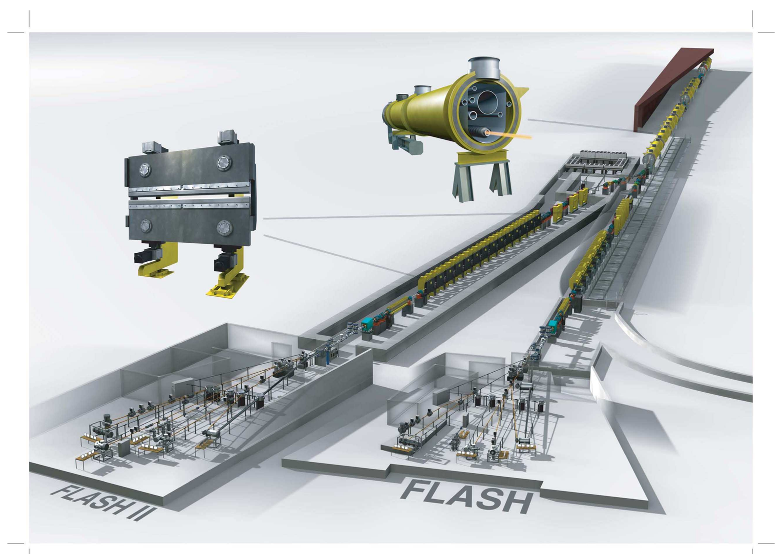

Figure 2: Schematic overview of the FLASH I and FLASH II accelerators buildings

Photon Diagnostic Section - Layout

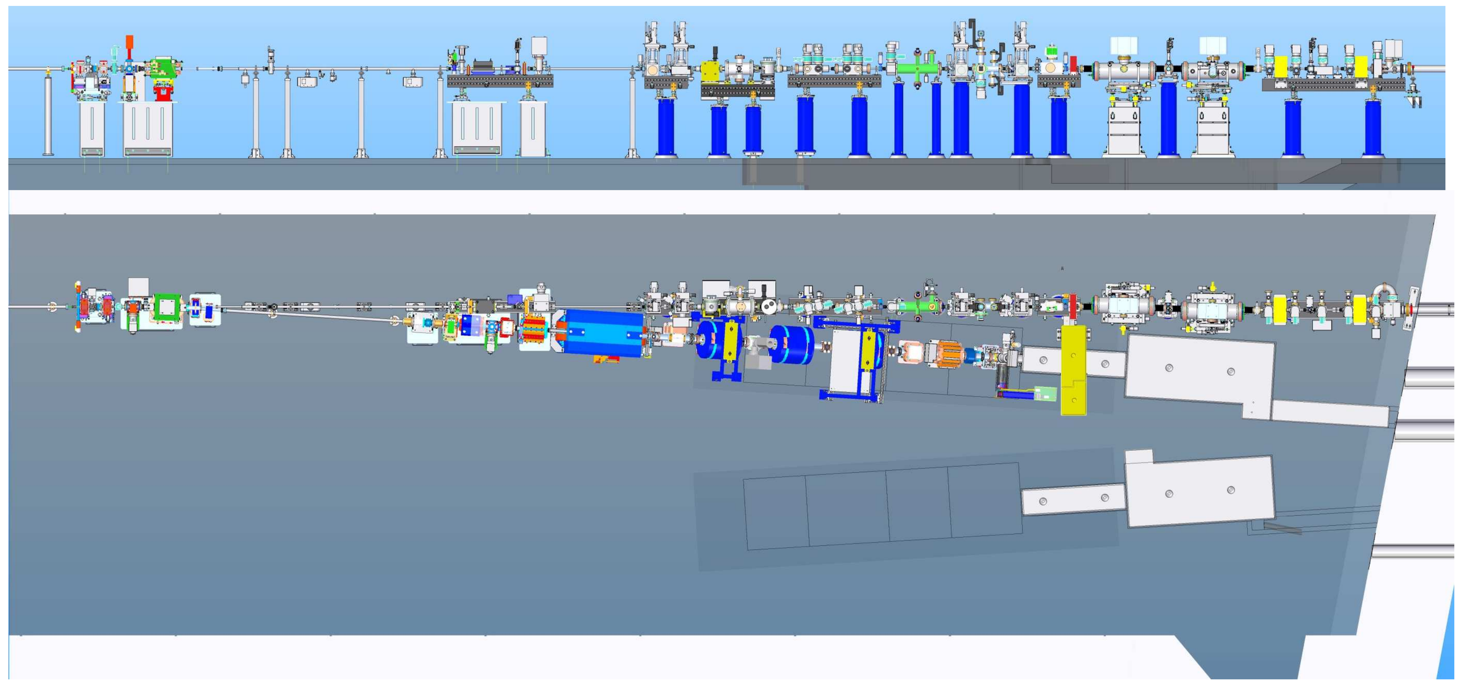

Figure 3: Layout of FLASH II tunnel photon diagnostic section. Upper image shows side view without dump beamline. Lower image shows top view with tunnel walls, dump beamline and additional radiation protection.

Components used in photon diagnostic tunnel section [2]:

- Valve protection absober
- Vacuum valve to machine vacuum
- Beamline safety magnet
- Alignment laser
- Pumping chamber (Turbomolecular and ion getter pump)
- Aperture and diagnostic unit / differential pumping
- Vertical BPM, intensity monitor, horizontal BPM
- Differential pumping
- OPIS – ToF photo-ionization spectrometer
- Diagnostic unit / differential pumping
- MCP Beam intensity detector
- Aperture unit / differential pumping
- Beam absorber and radiation collimator
- Mirror Chambers (with flourescent screen in between)
- Five-Stage differential pumping and gas supply for attenuator
- Additional in second photon diagnostic (FLASH II Hall):
  - Fast shutter, changeable filters, space reserved for pulse length measurement

Gas Attenuator and Differential Pumping

The straight section of 12m between the FLASH II Tunnel and the experimental hall is used as a beam intensity attenuator. For the purpose of reducing beam transmission for selected wavelengths this section can be flooded with gas up to a pressure of 0.5 mbar. Gases available are Xe, N2, Kr and Ar. [2]

The differential pumping system to separate the gases from the UHV environment is shown in fig. 4-5 and the resulting pressure gradient is displayed in table 1.

The pumping stages consist of pumping chambers and connected flow restricting tubes of various optimized apertures and lengths. They are precision manufactured and welded to the chambers and aligned by their manufacturing tolerances to the support structure (granite girder with alignment grooves on adjustable three-point kinematic mount) or, in case of the first stage 1m cantilevered tube, adjustable by a wire tension system. Figure 4 also shows the 12m attenuator tube and its supports.

Table 1: Pressure at all pumping stages from attenuator to following UHV chamber [3]

Stage	Diameter / mm	Length / cm	Pump Type / mbar l s^-1	Pressure mbar
Attenuator	100	1300	300, TP, cooled	5E-01
1.	16	100	300, TP	9E-03
2.	16	29	300, TP	8E-05
3.	16	28	300, TP	7E-07
4.	16	28	300, TP	7E-09
5.	16	29	300, TP	6E-11
6. (UHV)	25	7	55, Ion-GP	3E-11

Attenuator Differential Pumping – Details

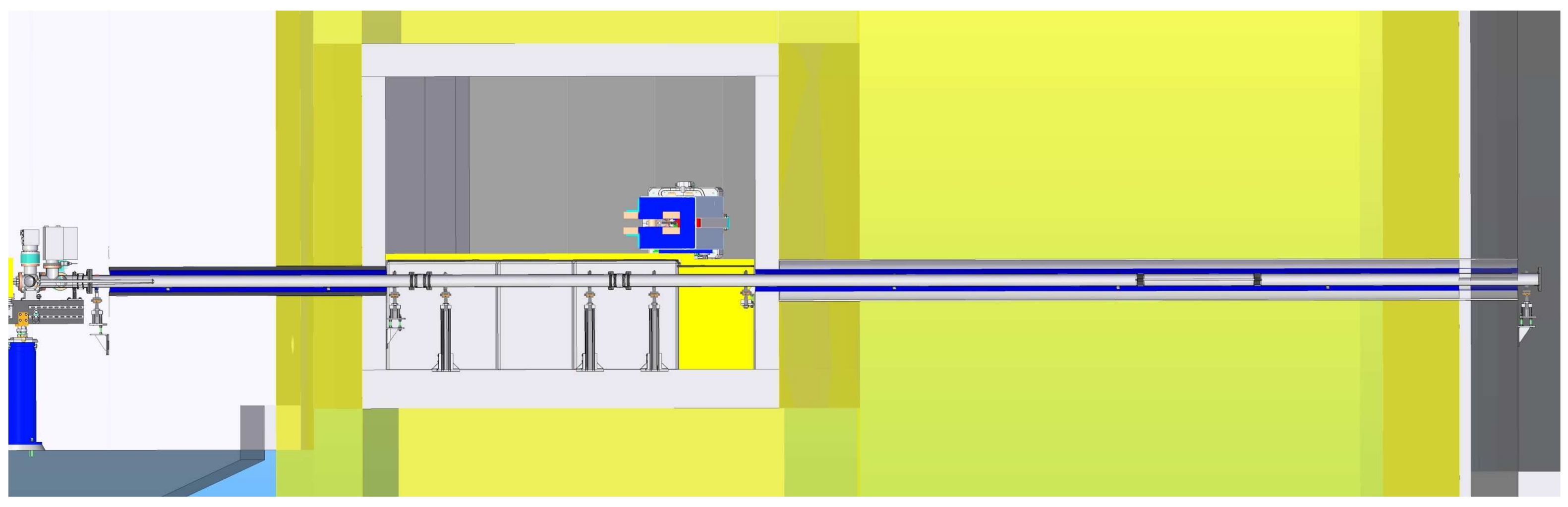

Figure 4: Cross section of the first section from FLASH II to PETRA III, crossing of PETRA III and connecting flange in the FLASH II hall.

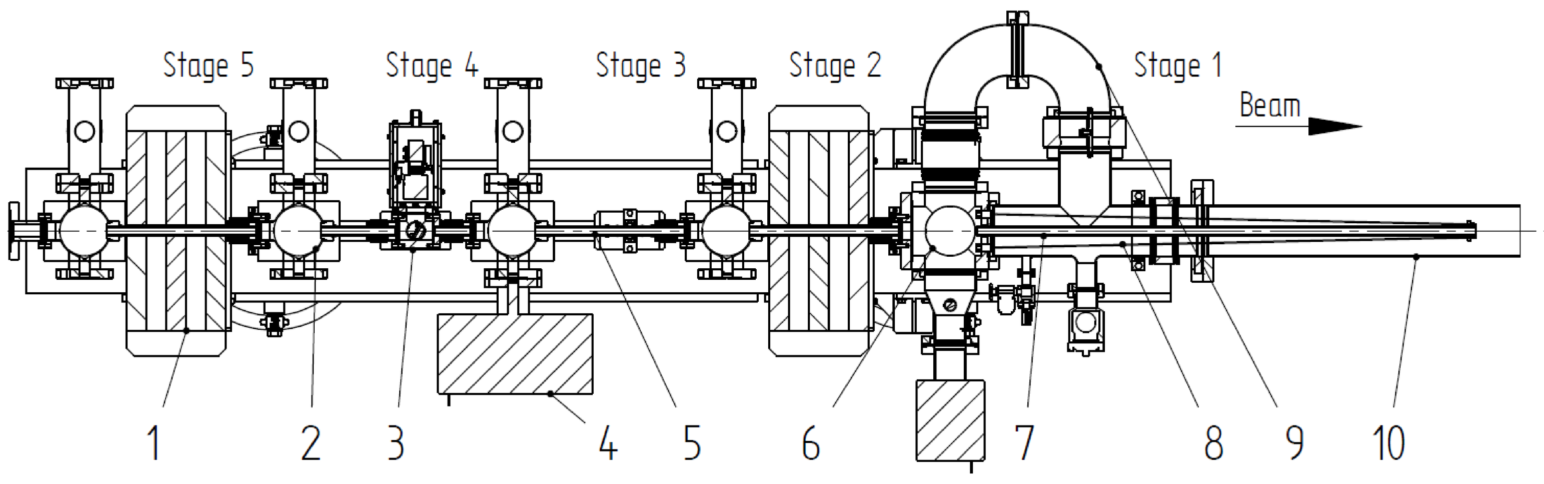

Figure 5: Attenuator Differential Pumping, vertical section. 1: Radiation Collimator, 2: Pumping Chamber, 3: Beam Position Monitor, 4: Ion Getter Pump, 5: Flow Constriction Tube, 6: Stage 1 Pumping Chamber and Support for Cantilever Tube (7), 8: Cantilever Tube Support and Adjusting Wires, 9: Bypass, 10: Attenuator Tube. Turbomolecular pumps not shown.

Aperture and Beam Diagnostic Unit

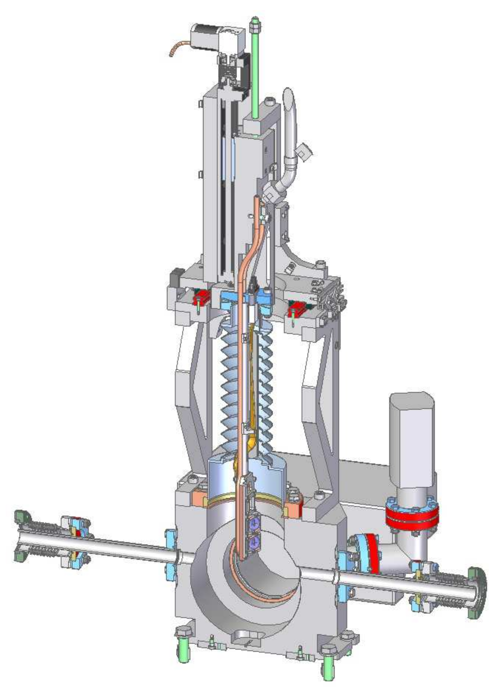

Figure 6: Cross section of aperture and diagnostic unit. Diagnostic paddle in fully retracted position

The re-engineered aperture and beam diagnostic unit fixes long-known mechanical problems with the previous design. To save space it also doubles as differential pumping station. It features a 3-axis motor driven linear stage setup to adjust components and retract them out of the beam with a reproducibility of 0.1mm.

For mechanical stability the main chamber is milled from a stainless steel block. The support structure for the linear stages is precision manufactured from aluminum plates and provides a very rigid base for the paddle.

Aperture- / Diagnostic Paddle Setups

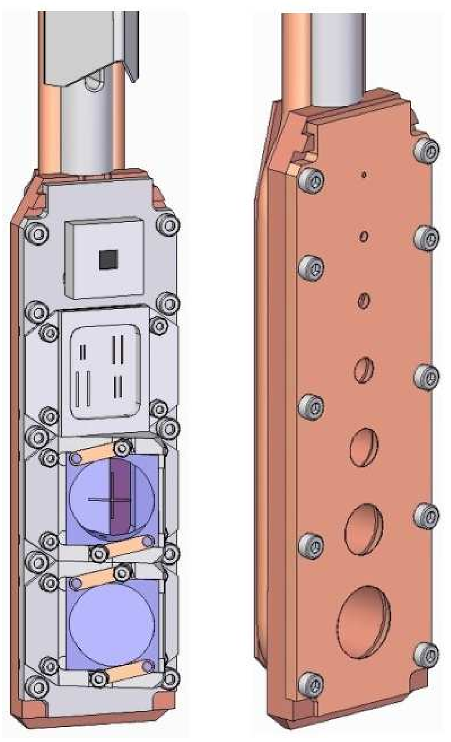

Figure 7: Diagnostic paddle (left) and aperture paddle (right). Aluminum support rod and copper cooling pipes visible on top.

Two compilations can be mounted alternatively to the water cooled heat sink paddle. The diagnostic unit is outfitted with a diode, double slit unit, flourescent screen and diffusing screen. The aperture paddle has seven apertures from 1mm to 14mm in a copper plate.

Beam Absorber – Mechanics

Both photon diagnostic sections feature retractable copper absorbers which were initially placed at 10m and 45m along the beamline to allow for machine operation while the photon beamlines are not in use. The thermal load from bunch trains of 3500 bunches with a repetition rate of 10Hz is 3988 Wmm^-2. The mechanical design is a water cooled copper plate at 6° that can be retracted upwards by pneumatic pistons. The absorber consists of an electrical discharge machined housing with 40mm aperture in the open position. For security reasons and to absorb scattered radiation the back plate of the absorber housing is also made of copper and can be cooled externally. Figure 8 shows the mechanical concept with a cut open housing. [2,5]

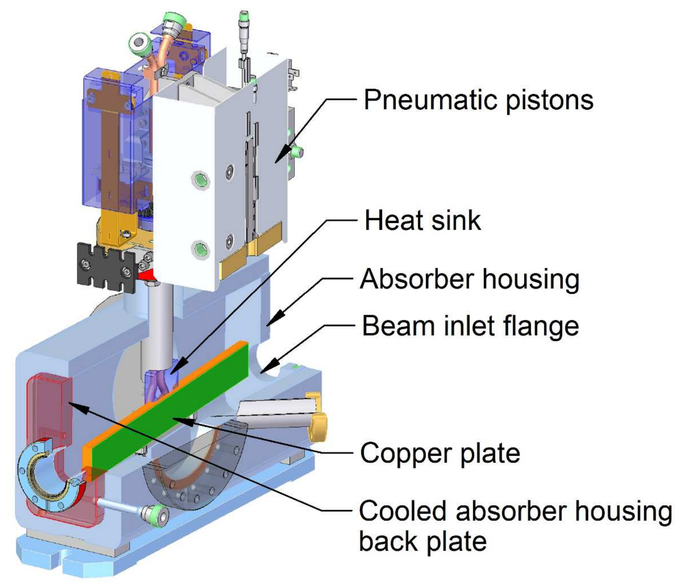

Figure 8: Mechanical concept. Absorber housing cut open.

Beam Absorber – FE Analysis

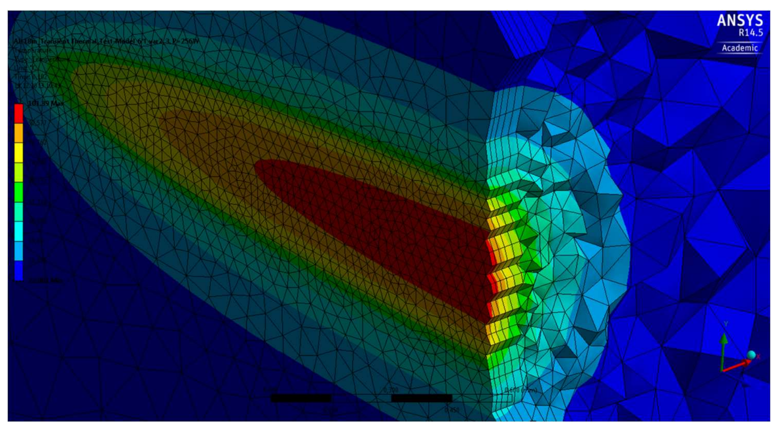

Figure 9: Final FEA result, peak temperature of 102°C in red in the middle.

FEA calculations at the given values showed peak temperatures in the copper plate of 1041°C and so variations of geometry and cooling options were considered but none showed significant improvement. Because of the peak temperature the beamline layout, as well as machine operating conditions, had to be changed. The first absorber was moved to 18m from the source and bunches were limited to 800 per bunch train. This reduced the mean beam power from 1120W to 256W and the resulting temperature dropped to 102°C (see fig. 9). [5]

Conclusion and Outlook

Manufacturing and installation of all components described went as planned and without problems. The tunnel beamline was commissioned for UHV in August 2013 and received first beam in January 2014. The attenuator and experimental hall saw first light in 2014 and commissioning of the machine started. First user experiments took place in April 2016 on beamline FL24. It is planned to extend FLASH further by adding the FLASH III undulator beamline which will have an identical diagnostic setup in the same tunnel and hall.

References

[1] Faatz, B. *et al*, “Simultaneous operation of two soft x-ray free electron lasers driven by one linear accelerator”, New Journal of Physics, Volume 18, June 2016
[2] Plönjes, E. *et al*, “FLASH2 Beamline And Photon Diagnostic Concepts”, in Proc FEL2013, New York, NY, USA, Aug. 2013, paper WEPSO50, pp. 614-617
[3] Jastrow, U. F., “Differential Pumping Stage for Flash2 – Part 7”, Presentation at Flash2 Beamlines and Photon Diagnostic Meeting, unpublished
[4] Mahn, H., “Diagnose- / Apertur-Druckstufe für FLASH II”, Poster at KITE - DESY Engineering and Innovation Day 2014, unpublished
[5] Marutzky, F., “Absorber für FLASH II”, Poster at KITE – DESY Engineering and Innovation Day 2014, unpublished