FLASH II: A PROJECT UPDATE

V. Ayvazyan, N. Baboi, V. Balandin, W. Decking, S. Duesterer, H.-J. Eckoldt, B.Faatz*, M. Felber, J. Feldhaus, N. Golubeva, K. Honkavaara, M. Koerfer, T. Laarmann, A. Leuschner, L. Lilje, T. Limberg, D. Noelle, F. Obier, A. Petrov, E. Ploenjes, K. Rehlich, H. Schlarb, B. Schmidt, M. Schmitz, S. Schreiber, H. Schulte-Schrepping, J. Spengler, M. Staack, K. Tiedtke, M. Tischer, R. Treusch, M. Vogt, H.C. Weddig,
Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany
J. Bahrdt, R. Follath, K. Holldack, A. Meseck, R. Mitzner,
Helmholz Zentrum Berlin (HZB), Berlin, Germany
M. Drescher, A. Hage, V. Miltchev, R. Riedel, J. Rönsch-Schulenburg, J. Rossbach, M. Schulz, A. Willner, University Hamburg, Germany
F. Tavella, Helmholtz-Institute Jena, Jena, Germany
M. Gensch, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany
B. Liu, J. Chen, H. Deng, Shanghai Institute of Applied Physics (SINAP), Shanghai, China

Abstract

FLASH has been a user facility since 2005, delivering radiation in the wavelength range between 4.1 and 45 nm using the SASE principle. So far the user requests for beam time by far exceeds the time available. In order to increase user beam time and improve the radiation properties delivered to users, a mayor extension of the user facility called FLASH II has been proposed by DESY in collaboration with the HZB, which is a seeded FEL over the parameter range of FLASH.

After several years of design, the project now enters its construction phase, which will last approximately 2 years. In the mean time, tests are performed in order to prepare for a multi-undulator operation of the facility. In addition, complete start-to-end simulations will complete the simulations which have been performed so far.

INTRODUCTION

FLASH, the free-electron laser at DESY in Germany has been in operation as a user facility since summer 2005 [1]. Initially, the minimum achievable wavelength was approximately 13 nm at an electron beam energy of 700 MeV. Since the upgrade in 2010, the energy beam energy is 1.25 GeV, thus decreasing the wavelength [2]. The wavelength produced has ranged from 4.1 to 60 nm with pulse trains of up to 800 microbunches at 1 MHz. For users, wavelengths from 4.6 to 45 nm with pulse trains from 40 kHz to 1 MHz, from single to 500 bunches with 100 ms (10 Hz) intervals have been produced.

FLASH II is a second undulator beamline built in a separate tunnel. It will make full use of the existing accelerator of FLASH. Part of the bunch trains are kicked from the main beamline into the new undulator beamline with an angle of 12 degrees. An important feature of FLASH II will be the production of seeded FEL radiation. All undulators will have a variable gap to obtain a reasonable flexibility in the choice and tuning of the wavelength. A separate experimental Hall is planned for an additional set of experimental stations making use of the new undulator line.

In this paper, we will discuss the layout of the FLASH II facility, the expected beam parameters and its performance. We also show results of first tests for simultaneous operation of FLASH1 and FLASH2.

EXTENSION OF THE FACILITY

Over the past years, the FLASH facility has been steadily improved and the wavelength range extended. The number of requests for user time has been growing in time as well, as shown in [3]. One of the advantages of FLASH II is that it makes to large extent use of the existing facility and infrastructure. A description of the FLASH facility can be found in Ref. [2]. Behind the last accelerating module, the beam is switched between the present fixed-gap undulator line of FLASH (now referred to as FLASH1) and the new variable gap undulator FLASH2 (see Figure 1). The modification needed to the present facility is minor. In addition, the new undulator line is located in a new tunnel. This ensures that enough space is available for future upgrades and extensions, and that construction can take place with minimum interference to FLASH user operation. Only when the connection of the tunnels and of the vacuum systems is made, a shutdown is needed.

In the new tunnel, the beamline consists of a matching and diagnostics section, a seeding section which is reserved for the Modulators 1 and 2 as well as radiator 1 of a cascaded HGHG scheme and a large undulator section which is used as last amplification stage for HGHG or for direct seeding with HHG. The length is sufficient to allow for saturation from noise in SASE mode. Behind this undulator section, space is reserved for an afterburner and more (photon) diagnostics.

Space for a total of at least five experimental stations is foreseen, not including the possibility of experiments in a row or experiments at larger angles for the longer wave-

* bart.faatz@desy.de

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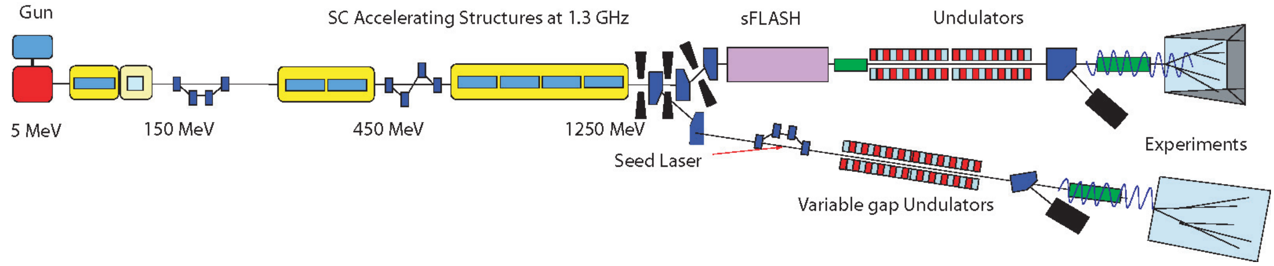

Figure 1: Schematic layout of the FLASH facility. The electron gun is on the left, the experimental hall on the right. Behind the last accelerating module, the beam is switched between FLASH1, which is the present undulator line, and FLASH2, which is the upgrade. Behind the extraction point, space is reserved for an additional laser system for seeding.

lengths.

FLASH II PARAMETERS AND CHARACTERISTICS

Table 1: Expected Parameters for FLASH II

Electron Beam	Value
Energy Range	0.5 – 1.2 GeV
Peak Current	2.5 kA
Bunch Charge	0.1 - 1 nC
Normalized Emittance	1.4 mm mrad
Energy Spread	0.5 MeV
Average β-function	6 m
Rep. rate	10 Hz
Bunch separation	1-25 µs
Undulator	**Value**
Period	31.4 mm
K	0.5 - 2
Segment length	2.5 m
Number of segments	12
Photon Beam SASE	**Value**
Wavelength range (fundamental)	4 - 60 nm
Average single pulse energy	1 - 500 µJ
Pulse duration (FWHM)	10 - 200 fs
Peak power (from av.)	1 - 5 GW
Spectral width (FWHM)	≈ 0.5 - 2 %
Peak Brilliance	10^{28} - 10^{31} B
Photon Beam HHG	**Value**
Wavelength range (fundamental)	10 - 40 nm
Average single pulse energy	1 - 50 µJ
Pulse duration (FWHM)	10 - 50 fs
Peak power (from av.)	1 - 5 GW
Spectral width (FWHM)	≈ Fourier Limited %
Peak Brilliance	10^{30} - 10^{31} B

In Table 1, the parameters expected for FLASH II are shown. They are similar to those for FLASH with the exception of the energy spread, which is increased due to synchrotron radiation and the large angle of 12 dg, needed to separate the two undulator lines.

HHG seeding is only foreseen for wavelengths between 10 and 40 nm. It uses a laser which is being developed in

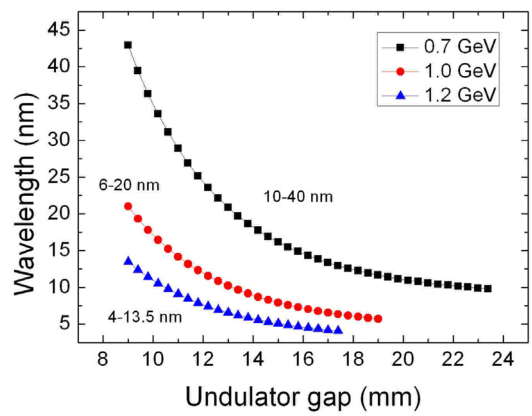

Figure 2: Wavelength range which can be reached for three different energies that are mostly used at FLASH.

parallel to FLASH II [4]. For longer wavelengths, although not excluded, we expect problems transporting the seed to the entrance of the undulator. To ensure that the radiation source for the users is at a fixed position, the upstream undulator gaps are opened, which means that the seed laser has to reach further into the vacuum pipe at longer wavelength. This means that at longer wavelengths, the SASE scheme has to be used, which results in a time jitter for longer wavelengths. Further decrease in wavelength is possible by employing a classical HGHG scheme, where we go to a higher harmonic before saturation, thus avoiding a large energy spread which decreases the saturation power.

Seeding at wavelengths shorter than 10 nm is still being studied. A promising candidate here is cascaded HGHG [5], but more recently also studies for an EEHG option have been performed (see Ref. [6]). A final decision on what option is best is postponed and all effort at the moment is dedicated to a baseline design.

An important issue is the way in which FLASH1 and FLASH2 will share the electron beam. Because FLASH1 has a fixed-gap undulator, the wavelength needed here fixes the energy. Within a certain wavelength range, the FLASH2 undulator gap is changed to deliver the wave-

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length required by users of this undulator line, as shown in Fig. 2. A slow switching mode is foreseen in which both users get bunches at a repetition rate of 5 Hz, while the machine is running at 10 Hz. Because of the superconducting accelerator technology used at FLASH, an alternative is to switch between the two undulator lines within an RF-pulse, thus delivering part of a bunch train to FLASH1 and the second part to FLASH2. First tests for this option are discussed below.

SIMULTANEOUS OPERATION OF FLASH1 AND FLASH2.

Even though FLASH2 is not yet constructed, several tests can already be performed. Users of FLASH1 and 2 will need different repetition rates and a different number of bunches, but most likely also different charges (which results in different bunch lengths). With FLASH1 having a fixed gap, an additional wish is that one can make minor changes to the wavelength (which means changes to RF settings) without adjusting settings for FLASH2. These tests have been started and show first promising results.

The most important test, however, is to prove that the kicker is fast enough, stable enough and has the pulse-flatness needed for FLASH2 lasing. With this aim, we have used a kicker at nominal settings needed to kick the beam to FLASH2 and corrected the orbit back to the original one to get lasing at the original level with the same stability and flatness over the pulse train. Results are shown in Fig. 3.

The top shows the normal distribution of the SASE intensity fluctuations without kicker. The next two (middle and bottom) pictures show the SASE intensity and fluctuation with the kicker switched on. Correctors have been used to get the orbit back to the original one in the undulator to get the same SASE level as before. As can be seen, the kicker did not influence the stability. Also the flatness over a pulse train has not changed. Similar tests have been performed at shorter and longer wavelengths, showing similar results.

Next tests are planned to be performed before the commissioning of FLASH II starts. They include switching injector laser systems, having them run at different repetition rates and charges while keeping lasing at optimal level. Also final tests with the kicker are planned in the near future.

SUMMARY AND OUTLOOK

The FLASH II project starts it construction phase before the end of 2011. Most of the beamline design in the tunnel has been fixed. Starting point is SASE, similar to FLASH1, but noiw with variable gap undulators. The design includes HHG seeding, for which the laser development and source development and characterization are on schedule. Furthermore, space is reserved for a future upgrade which could include a cascaded HGHG seeding in order to obtain seeding for the complete wavelength range of FLASH2. First

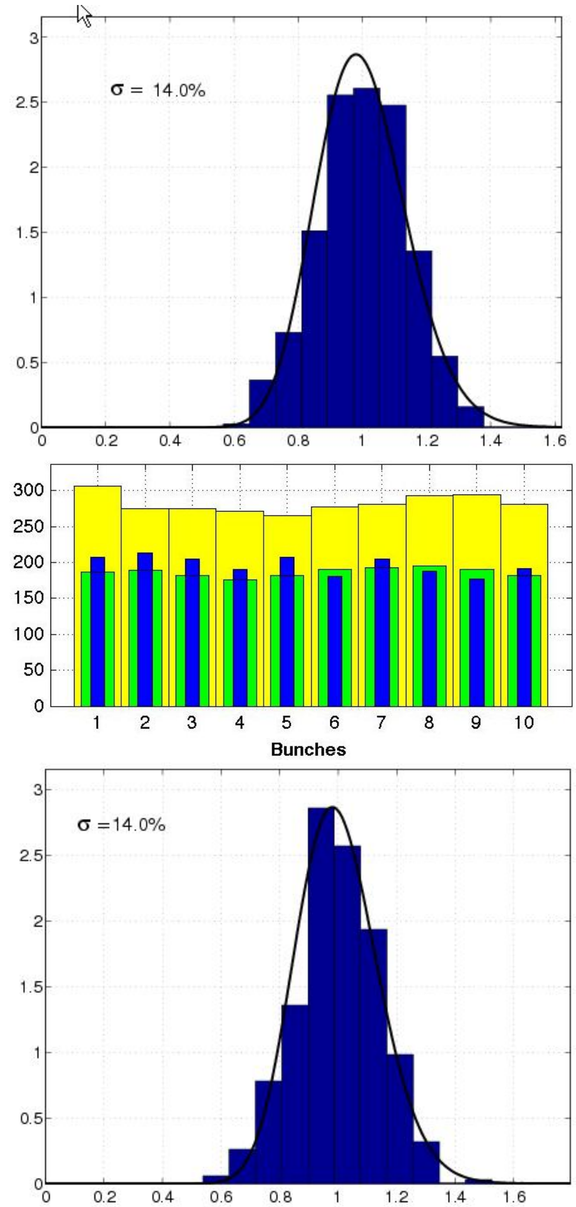

Figure 3: Result of fast kicker test, showing virtually no change in SASE characteristics over the pulse train with kickers switched on or off. Shown is the intensity distribution without kicker (top), lasing and distribution with kicker on (middle and bottom) correcting the orbit with a steerer in front of the undulator. The middle plot shows lasing over a pulse train of 10 bunches at 100 kHz. Indicated the maximum (yellow), average(green) and actual (blue) pulse energy of around 200 μJ. All measurements are performed at a wavelength of around 13 nm.

tests have been performed to show simultaneous operation FLASH1 snd FLASH2.

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