FLASH II: A SEEDED FUTURE AT FLASH

B.Faatz*, N. Baboi, V. Ayvazyan, V. Balandin, W. Decking, S. Duesterer, H.-J. Eckoldt, J. Feldhaus, N. Golubeva, 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, F. Tavella, K. Tiedtke, M. Tischer, R. Treusch, A. Willner, Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany
J. Bahrdt, R. Follath, M. Gensch, K. Holldack, A. Meseck, R. Mitzner, Helmholz Zentrum Berlin (HZB), Berlin, Germany
M. Drescher, V. Miltchev, J. Rönsch-Schulenburg, J. Rossbach, University Hamburg, Germany

Abstract

FLASH has been a user facility since 2005, delivering radiation in the wavelength range between 7 and 47 nm using the SASE principle. After the present upgrade, the wavelength range will be extended to wavelengths below 5 nm and with the 3rd harmonic accelerating module in place to linearize the longitudinal phase space, the stability and reproducibility of the machine will be improved. 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. As logical continuation, the HHG development program started with sFLASH will result in direct seeding. Because in the foreseeable future there will probably not be HHG seed lasers available at high repetition rates down to wavelengths of 4 nm, a cascaded HGHG scheme is proposed to produce short wavelengths.

After a first design report, the project now enters its preparation phase until the decision for funding will be taken. During this time, the FLASH beam parameters after the present upgrade 2009/2010 will be characterized and the present design will be re-evaluated and adjusted. In addition, complete start-to-end simulations will complete the simulations which have been performed so far, including a complete design of the extraction area.

INTRODUCTION

FLASH, the free-electron laser at DESY, 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 2007, the energy has been increased to 1 GeV, thus decreasing the wavelength [2]. The wavelength produced has ranged from 6.5 to 60 nm with pulse trains of up to 800 microbunches at 1 MHz with a 5 Hz repetition rate. For users, wavelengths from 6.8 to 47 nm with pulse trains from 50 kHz to 1 MHz, from single bunch to 140 pulses with 200 ms (5 Hz) intervals have been produced. With the recent upgrade which started in 2009, FLASH runs at 10 Hz and will deliver wavelengths below 5 nm [3].

In addition to this SASE radiation delivered to users, a second undulator is built to test HHG seeding [4]. For this purpose, a special experimental setup for a pilot experiment in a separate container has been setup. This proof-of-principle is a first step towards a completely seeded FEL at FLASH, called FLASH II.

FLASH II is a second undulator beamline built in a separate tunnel. It will make full use of the existing accelerator of FLASH. Parts of the bunch trains are separated from the main beamline into the new undulator beamline with a shallow angle. The main feature of FLASH II will be the production of seeded FEL radiation and in a later stage, polarization. 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.

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 Fig. 1. The possibilities to extend user time by using fast switching mirrors and stacking experiments behind each other has already been done or are foreseen in the coming user run. However, Fig. 1 shows that this will not be enough in the future. Beside the improved quality of the radiation which is expected from the seeding scheme foreseen at FLASH II, the extension of beam time is therefore a second important argument for extending the facility with an additional undulator line.

One of the advantages of FLASH II is that it makes to large extend use of the existing facility and infrastructure. A description of the FLASH facility can be found in Ref. [5]. Behind the last accelerating module, the beam is switched between the present fixed-gap undulator line of FLASH (now referred to as FLASH I) and the new vari-

* bart.faatz@desy.de

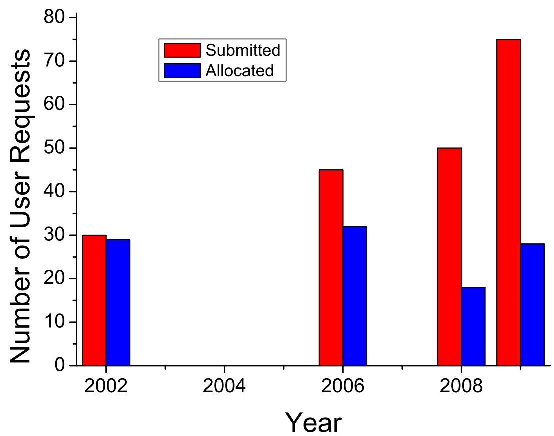

Figure 1: Beam time requested and allocated to users since the start of FLASH as user facility. The total amount of beam time available is constant but the number of requests has almost tripled. Note that the smaller number of experiments receiving beamtime in 2008 were added to the second user run which was extended by approximately 5 months.

able gap undulator FLASH II (see Figure 2). 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 I 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 HGHG undulators and a large undulator section which is used as last amplification stage for HGHG or as HHG undulator. 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 diagnostics. Behind the dump magnet, some 20 m of space is available for photon diagnostics, similar to what has been in use so far for FLASH [7], but extended with an on-line spectrometer [8] and a detector for polarization.

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 wavelengths (indicated in green at the top of the new experimental hall in Fig. 2).

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 m
Number of segments	12
Photon Beam	**Value**
Wavelength range (fundamental)	4 - 80 nm
Average single pulse energy	1 - 1000 μJ
Pulse duration (FWHM)	10 - 200 fs
Peak power (from av.)	1 - 5 GW
Spectral width (FWHM)	$\approx$ 0.1 - 1 %
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 I with the exception of the energy spread, which is increased due to

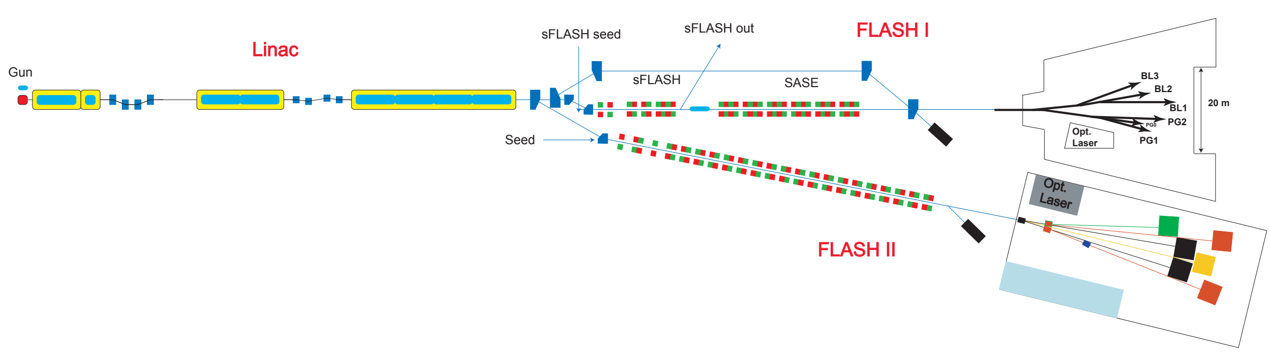

Figure 2: Schematic layout of the FLASH facility. The electron gun is on the left, the experimental hall on the right. Behind the last accelerating module, the beam is switched between FLASH I, which is the present undulator line, and FLASH II, which is the upgrade. Behind the extraction point, space is reserved for an additional laser system for seeding.

synchrotron radiation and the large separation angle of 12 dg.

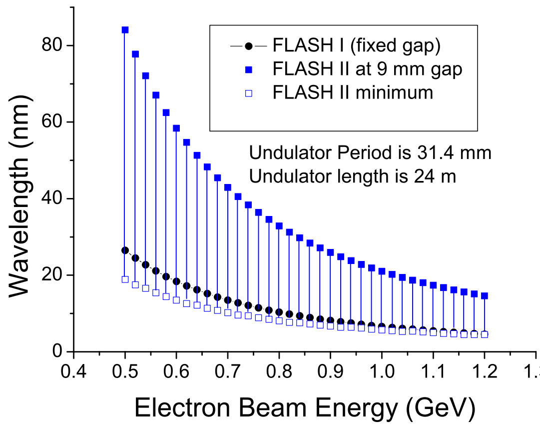

Figure 3: Tunability range of FLASH II for a given energy determined by FLASH I users.

A cascaded HGHG is foreseen over the entire wavelength range. The seed laser is a Ti:Sa laser at a repetition rate of 100 kHz, which is under development at DESY [6]. This seed enters at the beginning of the vacuum pipe, as indicated in Fig. 2. Foreseen are two frequency multiplication stages with a fresh-bunch chicane between the first radiator and second modulator. In both stages, up to the fifth harmonic is foreseen, resulting in a minimum wavelength of 8 nm. In order to reach a shorter wavelength, the use of the seventh harmonic is possible, although only at reduced power due to the limited modulation depth compared to the energy spread.

HHG seeding is only foreseen for wavelengths shorter than 40 nm. It uses the same laser as is used for the HGHG scheme. 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 HGHG scheme has to be used, or SASE, which results in a time jitter for longer wavelengths. At the smaller wavelength end, the seed power expected is still enough down to 10 nm. 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. For this reason, the HHG seed enters upstream of the first HGHG radiator (not shown in Fig. 2, which allows for a single frequency multiplication step.

An important issue is the way in which FLASH I and FLASH II will share the electron beam. Because FLASH I has a fixed-gap undulator, the wavelength needed here fixes the energy. Within a certain wavelength range, the FLASH II undulator gap is changed to deliver the wavelength required by users of this undulator line, as shown in Fig. 3. 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 FLASH I and the second part to FLASH II.

SUMMARY AND OUTLOOK

The FLASH II project is at the moment in its preparation phase, which is finished in the next few months. After this phase, the project will enter its technical design phase. Main effort will be the extraction area which is needed to maintain the good beam quality in the presence of coherent synchrotron radiation. First simulations show that even with an extraction angle larger than 10 degrees, the (projected) emittance growth can be kept below 50%. In addition to ongoing simulation work, part of the study time at FLASH during the next two years will be dedicated to get operational experience with long pulse trains, needed to operate FLASH I and FLASH II simultaneously.

REFERENCES

[1] V. Ayvazyan *et al.*, Eur. Phys. J. D **37** (2006) 297-303.

[2] W. Ackermann *et al.*, Nature Photonics **1** (2007) 336.

[3] K. Honkavaara *et al.*, "FLASH Upgrade", these proceedings

[4] Status of sFLASH, the seeding Experiment at FLASH, Hossein Delsim-Hashemi et.al., Presented at this conference

[5] FEL USER FACILITY FLASH, S. Schreiber et.al, Presented at this conference.

[6] High Repetition Rate seeding of a Free-Electron Laser at DESY Hamburg, A. Willner et.al, Presented at this conference.

[7] K. Tiedtke *et al.*, New J. Phys. **11** (2009) 023029.

[8] The new online Photoionization Spectrometer at FLASH, P. Juranic, S. Bonfigt, M. Ilchen, K. Tiedtke, J. Viefhaus, L. Jahn, S. Klumpp, M. Martins, Presented at this conference