SIMULTANEOUS OPERATION OF A MULTI BEAMLINE FEL FACILITY

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Abstract

The FLASH II project will add an undulator beamline and a new experimental Hall to the existing FLASH Facility. In addition to improving the radiation properties of the FEL by using seeding, one of the main goals is to double the beamtime of the facility for users. At the moment, we deliver photon pulses in 10 Hz bursts with up to 800 bunches within each RF pulse. In order not to limit parameter ranges, we will have to give those same tuning possibilities within an RF pulse for each of the users independently.

For this purpose, several tests have been performed to determine the limits of the difference in beam parameters which can be delivered. We will show to what extend we can switch fast between two beamlines, how we can change photon pulse length by allowing different charges, have different energy in the two beamlines simultaneously to allow for wavelength scans for the fixed-gap undulator presently built in FLASH, while not interfering with user operation of the new beamline.

INTRODUCTION

FLASH [1–4], the free-electron laser (FEL) user facility at DESY, delivers high brilliance XUV and soft x-ray FEL radiation for photon experiments since summer 2005. In order to provide more beam time for experiments and to improve the properties of the delivered FEL radiation, an extension of the FLASH facility - FLASH II Project [6] - was proposed in 2008 by DESY in collaboration with Helmholtz Zentrum Berlin (HZB). The project has been approved in 2010 and the civil construction started in 2011. The first beam of the extended facility is foreseen in late summer 2013.

Because the user time is overbooked by approximately a factor of four, one of the main goals is to extend the capacity of FLASH. Important in this respect is that a doubling of the capacity should not be at the expense of flexibility. This means that we need to be able to deliver all parameters requested by users independently to both beamlines.

LAYOUT

The present FLASH facility consists of an injector with a laser driven RF-gun to produce high quality electron bunches, a superconducting linac with TESLA type accelerator modules to accelerate the electron beam up to 1.25 GeV, and an undulator section with fixed gap undulators to produce SASE (Self Amplified Spontaneous Emission) FEL radiation in the wavelength range from 4.1 nm - 45 nm. More details of FLASH and its parameters are, for example, in [2, 3].

The aim of the FLASH II project is to extend FLASH with a second undulator beamline to allow a more flexible operation and more beam time for photon experiments with improved photon beam properties. The FLASH linac drives the both undulator lines: the present fixed gap undulator (referred here as FLASH1) and the new variable gap undulator (referred here as FLASH2). The separation between the two is downstream of the last accelerating module. Figure 1 shows the layout of the extended FLASH facility. Details of the FLASH II project and its parameters are discussed in Ref. [5]. More details on the extraction can be found in [7].

In order to actually achieve a doubling of beamtime for users, a number of conditions have to be fullfilled. The minimum requirement is that both users get the 10 Hz rep. rate that present FLASH users have. In order to achieve this, a faster kicker-septum system is needed to disxctribute the beam beatween the two undulators. Because both users need to have the long bunch trains, the kicker needs to have, in addition to stability, also a flatness over the bunch trains of 800 μs to achieve equal lasing for all bunches.

The fast switching (and the independent wavelength tunability) does not give us the flexibility needed to organize experiemnts independently. Users will request different bunch patterns, different photon pulse lengths and for FLASH II the possibility to seed with HHG. In order to meet with this lagre variety of conditions, FLASH I and FLASH II will use two different injector laser systems which are shifted in time by a few tens to a few 100 μs, depending on required bunch number and rep. rates for each of the users. This way we can independently set charge and rep.rate for both users. In addition, we need to be able to change compression settings, e.g. RF-parameters, depoending on bunch charge.

In the next section, we will first show results on the stratus of the fast kicker system. Then, we will show the progress on the RF-system to allow for changes in RF phase and gradient within an RF-pulse. This is compared to the parameters which have been experimentally determined as sufficient to obtain lasing over a large range of charges. Finally, we will look at the steps still needed for a full test.

FAST SWITCHING

Figure 2 shows the switching scheme as it is foreseen for FLASH. Each RF pulse with a flat-top of 800 μs has to be distributed between FLASH1 and FLASH2 users. The

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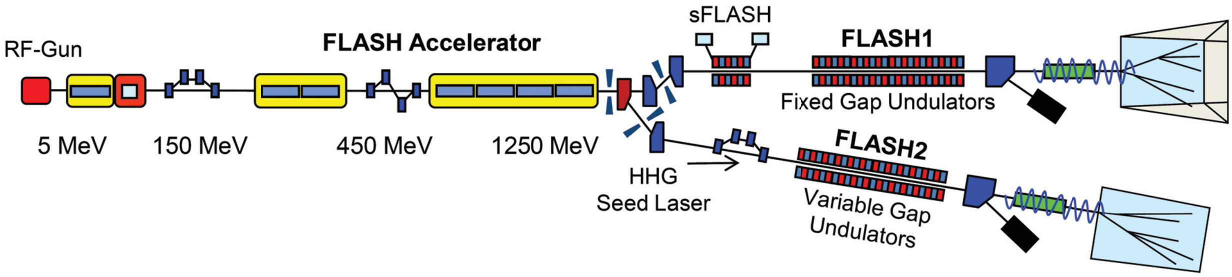

Figure 1: Layout of the extended FLASH facility with two undulator lines FLASH1 and FLASH2 (not to scale). The total length of the facility is about 315 m.

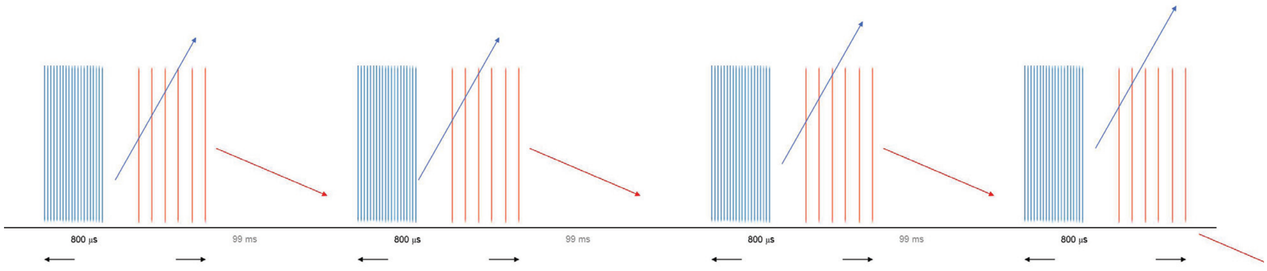

Figure 2: Switching between FLASH1 and FLASH2, allowing for variable charge, rep. rates and bunch numbers.

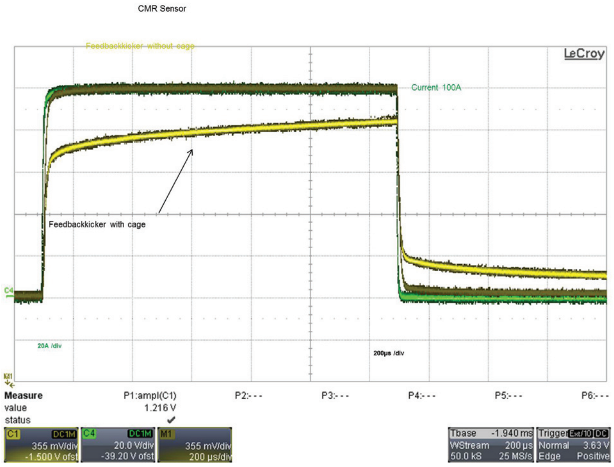

Figure 3: Flatness of the fast flattop kicker with(yellow) and without (black line) casing.

switching time has to be below 50 μs in order to avoid that two many of the bunches are not available for users. A similar system is foreseen for the European XFEL (see Ref. [9]). Fig. 3 shows two results of kicker tests.

In order to test the stability of the kicker with the existing FLASH facility, first SASE was established. Then, the kicker was switched on and DC correctors were used to correct the orbit back to its original to obtain lassing again. The intensity fluctuation with kicker were compared to those with the original orbit without the kicker.

For both configurations, the stability was good enough not to increase the fluctuartion in intensity beyond what is expected from the natural SASE fluctuations. However, the yellow curve shows a droop over the pulse, which results in a large variation of SASE over the pulse train. In addition, the long trailing edge showed effect on the bunch train for several ms. The problem was caused by the metal cage in which the kicker was built. In a temporary cage, the same tests, represented with the green line, showed no effect on the SASE level. Only moving the beam to within 10 μs of the trailing or leading edge resulted in a measurable decrease of the SASE level.

A test with the final kicker design is planned for late 2012.

VARIATION IN PHOTON PULSE PROPERTIES

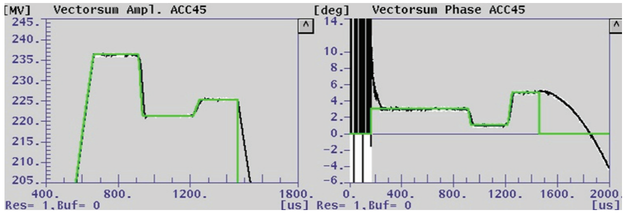

Figure 4: Energy and phase variations possible to allow for charge dependent compression and wavelength fine-tuning. A future extension with an additional beamline is already foreseen, as can be seen by the three different levels.

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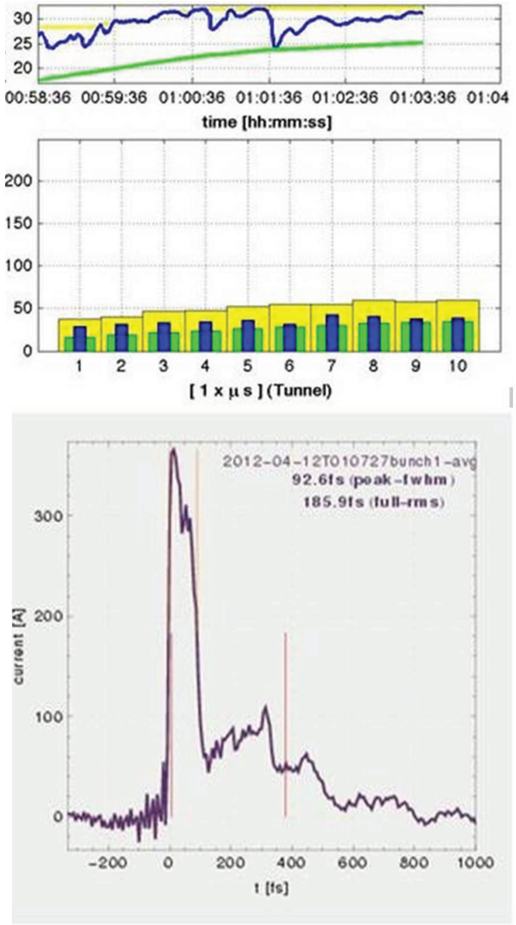

Figure 5: Bunch Profile measured with a THz spectometer and the corresponding SASE level for 0.07 nC bunch charge.

Table 1: RF Changes within an RF Pulse Checked for Various RF Stations

RF Station	Phase (Deg.)	Ampl. (MV)	Transition time (μ s)
Gun	+5	-0.1	50
ACC1	+/-2	+/-3	30
ACC39	+/-9	-3	60
ACC23	+/-3	-15	100
ACC45	+/-5	+/-15	100
ACC67	–	–	–

Being able to deliver 10 Hz to both users is a minimum requirement in order not to reduce the number of photon pulses. However, without a certain amount of flexibility to adjust beam parameters, it is impossible to plan beamtime for two users simultaneously. For example, if FLASH1 users require short pulses, the only way to supply this is by reducing the bunch charge. Without the possibility to have different beam parameters for FLASH2, this would exclude long bunches and therefore for example seeding. Since different charges require different compression, especially in the first compression stage, one must be able to independently set phase and amplitude in a limited range for FLASH1 and FLASH2, e.g. within the RF-pulse. Fig. 4 shows in this case for the RF station used for accelerators 4 and 5 that both amplitude and phase we are able to make steps. The steps that are needed to charge dependent compression are shown in Table 1.

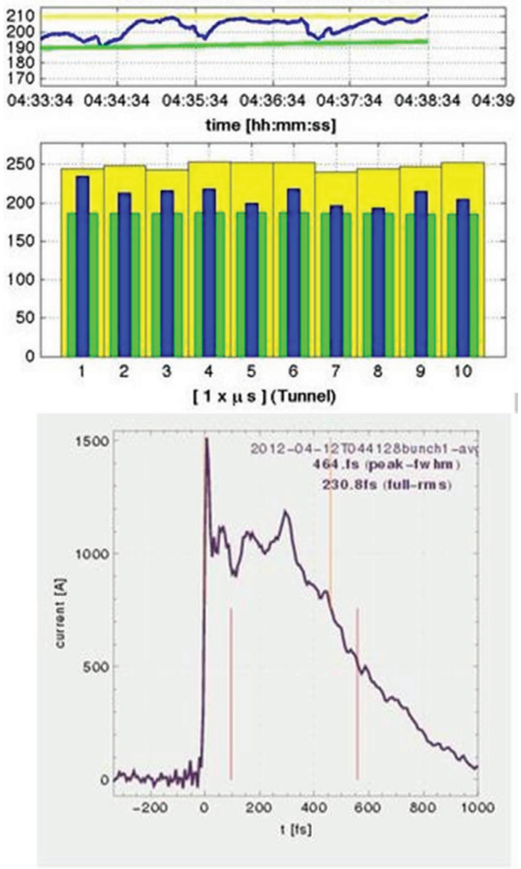

Figure 6: Bunch Profile measured with a THz spectometer and the corresponding SASE level for 0.6 nC bunch charge.

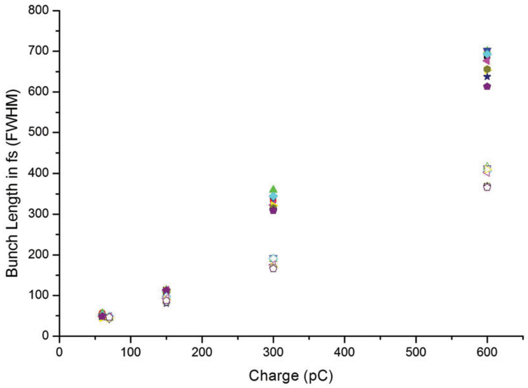

Figure 7: Bunch length measured for different charges.

Since at the moment, we cannot get bunch trains at dif-

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Table 2: SASE dependence on charge. scans have been performed by going from high charge to low charge, only touching RF parameters which can be switched within an RF-pulse, and the injection angle and offset into the undulator. At low charge, the machine has been optimized and the same scan has been performed again from low to high charge. The final point at 1. GeV and 0.6 nC was not optimized because of a lack of time

Charge (nC)	SASE (μJ) at 0.7 GeV	SASE (μJ) at 1.1 GeV
0.6	210	165/110
0.3	170	80/100
0.15	110	75
0.07	30/55	35

ferent gradient and phase lasing in the present machine with only one lser system, tests have been performed to determine how close one can get to the edges of these steps on both sides. Results in Table 1 show that only steps in gradient exceeding 10 MerV would increase the switching time significantly. This, however, is only needed to perform wavelength changes in FLASH1 while keeping FLASH2 running. Further studies to improve this show significant improvement.

Table 2 shows what SASE has been achieved for different charges. The bunch length measured with a THz spectrometer showed a variation between a factor of 5 to 10 for a factor 10 in charge. The SASE over the bunch train is shown in Fig. 5 for low charge and in Fig. 6 for high charge. Further tests are planned to confirm and reproduce these results at different wavelengths and beam energies. In addition, further study is needed to determine the cause for the slight slope in lasing intensity which is clearly visible at low charge. the However, it seems that a large variation in charge can be transported and can radiatewithout touchingg any parameter except RF parameters, which can be switched fast, and the injection angle and offset of the electron beam into the undulator. This would also mean that we can have a seeded FEL at FLASH2, which requires longer bunches, and have short, low charge bunches for FLASH1 at teh same time.

STATUS AND OUTLOOK

First tests have shown that both fast switching and different parameters to FLASH1 and FLASH2 simultaneously are possible. This enables the possibility to deliver to both users long pulse trains with different bunch parameters, such as rep. rate and bunch charge and compression. Especially when FLASH1 users require short photon pulses while FLASH2 wants with seeded bunches, this is a must.

So far, we could not show this simultaneously, because we need at least a second laser system to provide different parameters at the same time within an RF pulse. A second laser system is foreseen to become operational this year at which point switching both lasers to the gun with an adjustable delay has to be tested. With two lasers available we can test the possibility of different charges and different compression simultaqneously.

Tests to allow a larger scanning range of the wavelength for the fixed gap undulators of FLASH1, while keeping FLASH2 operation untouched, are continued. They show promissing results that we can have up to 50 MeV variation in FLASH1. The limit is given by the rise and fall-time of the RF in superconducting structures and the losses in the collimator. The latter is caused by the fact that we cannot change the optics without influncing also FLASH2 and the shared optics also contains the transverse collimnation system, which is partly shared by FLASH1 and FLASH2.

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