FIRST LASING AT FLASH2

S. Schreiber*, B. Faatz, DESY, Hamburg, Germany†

Abstract

FLASH, the free-electron laser user facility at DESY (Hamburg, Germany), has been upgraded with a second undulator beamline FLASH2. The installation of the FLASH2 electron beamline, including twelve variable gap undulators, was finalized early 2014, and beam commissioning of the new beamline started in March 2014. We announce first lasing at FLASH2 achieved at a wavelength of 40 nm on August 20, 2014.

INTRODUCTION

FLASH [1–5], the free-electron laser (FEL) user facility at DESY (Hamburg), delivers high brilliance XUV and soft X-ray FEL radiation for photon experiments. FLASH is a user facility since 2005.

FLASH is a linear accelerator with a photoinjector followed by a superconducting linac. The maximum electron beam energy is 1.25 GeV, allowing lasing down to 4.1 nm with its fixed gap undulators. This undulator beamline (FLASH1) is in operation since 2004. More details on the FLASH facility and its present status can be found in these proceedings [5].

As FLASH, all high gain FEL's in the soft and hard X-ray range are driven by a linear accelerator. Therefore, beam can only be delivered to one experiment at a given time. FLASH has five experimental beamlines, so that usually two or sometimes three experiments can be set-up in parallel. But, they usually receive beam by a day to day basis, not at the same time.

Fortunately, the superconducting accelerating technology of FLASH allows to accelerate several thousand electron bunches per second. The bunches come in bursts with a repetition rate of 10 Hz. The maximal burst length is 0.8 ms, the smallest distance between single bunches is 1 µs allowing a maximum number of 800 bunches per burst.

Since years, beam time for users is overbooked by a factor of about four. Therefore, a second undulator beamline FLASH2 has been constructed in 2011-14. The burst of electron bunches is now shared between two undulator beamlines, such that two experiments receive beam simultaneously with 10 Hz each. Sharing is possible for pairs of experiments requiring together at maximum the full burst duration of 0.8 ms, minus a transition time of 30 µs for the kicker-septum system to divide the pulse train burst.

An additional important and unique feature is, that beam parameters and bunch pattern can vary for the two undulator beamlines, so that two experiments with different wavelengths, pulse durations, and pulse pattern are possible at the same time. The flexibility is realized with three main features. Firstly, variable gap undulators allow to adjust the wavelength for FLASH2 experiments, while the beam energy is determined by the wavelength required for FLASH1. Secondly, two different laser systems operated in parallel at the photoinjector allow different charges, different pulse pattern, and to create a variable gap between the sub-bursts for FLASH1 and FLASH2. Thirdly, the low-level RF control of the accelerating structures are able to adjust phases and amplitudes – to a certain extend – independently for both beamlines, thus making different compression schemes possible.

For details on FLASH2 photon beam parameters the reader is referred to [6].

COMMISSIONING AND FIRST LASING

Mounting the FLASH2 electron beamline, including 12 undulator modules (Fig. 1), was finished in January 2014. The official permission of FLASH2 beam operation was given in early February, and the beam commissioning started in March.

Figure 1: FLASH2 undulator beamline with twelve variable gap undulators.

Due to FLASH1 user operation, dedicated beam time for FLASH2 had been restricted to a few days only until simultaneously operation was established end of May. Starting with June, the FLASH2 beam commissioning has taken place, whenever possible, parallel to FLASH1 user operation. This increased significantly the time available for FLASH2 commissioning with beam.

The first electron beam was transported into the FLASH2 extraction beamline on March 4, 2014, and beam transport up to the dump was achieved on May 23, 2014. In order to avoid radiation damage on the permanent undulator magnets, the first beam operation has been carried out with open undulator gaps.

* siegfried.schreiber@desy.de
† for the FLASH team

ISBN 978-3-95450-133-5

After a thorough preparation of the electron beam up to the FLASH2 dump, the undulator gaps of the last four undulators have been closed for the first time in August 20, 2014 resulting immediately in a first signal of SASE radiation. The signal was optimized by adjusting the phase shifters between the modules together with a slight orbit correction.

Figure 2 shows the first SASE photon beam seen on a Ce:YAG screen in the photon beamline, about 18 m distant from the end of the undulators. The estimated photon wavelength was 40 nm, determined by the undulator gap of 9.5 mm and the beam energy of 680 MeV. The spot size in Fig. 2 is about 3 mm FWHM yielding in an opening angle of 80 µrad. This is expected for SASE radiation; spontaneous radiation would have a spot size of 60 mm. Also the fluctuation of the pulse energy is in agreement with the typical SASE fluctuations for high-gain, but not saturated lasing.

A few days later, the photon spectrum could be measured with two different undulator gap settings giving photon wavelengths of 42 nm and 23.5 nm.

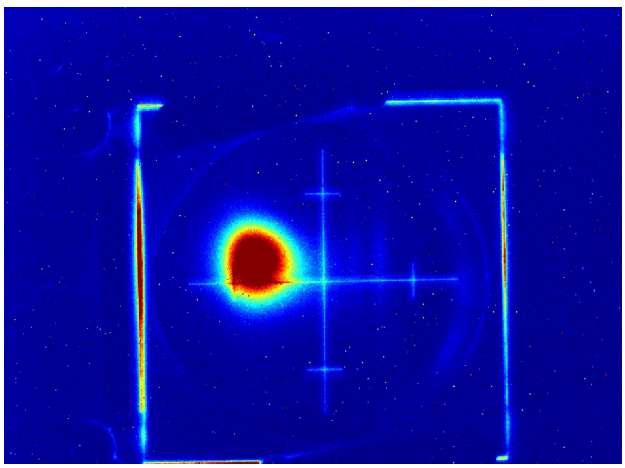

Figure 2: Photon beam on the Ce:YAG screen of the FLASH2 beamline. The distance of the cross marker to the center is 5 mm. The distance undulators – screen is about 18 m.

Of uttermost importance for the two beamline scheme is, that first lasing of FLASH2 has been achieved while FLASH1 was running SASE with 250 bunches in the burst at a wavelength of 13.5 nm prepared for a user experiment.

This is the first time that a soft X-ray FEL facility has operated successfully two undulator beamlines driven by the same accelerator simultaneously.

SUMMARY AND OUTLOOK

The FLASH2 beam commissioning started in March 2014 and the first lasing was achieved on August 20, 2014. The FLASH2 commissioning continues mainly in parallel to the FLASH1 user operation. The first FLASH2 pilot photon experiments are expected in 2015, and regular user operation in 2016.

With FLASH2 in operation, the user capacity of FLASH will be significantly increased. The variable gap undulators ease photon wavelength changes in FLASH2, and, together with two injector lasers and the flexible LLRF system, allow parallel operation of FLASH1 and FLASH2 with to a certain extent independent parameters.

ACKNOWLEDGMENT

We like to thank all colleagues participating in the construction and commissioning of FLASH2. Your devoted involvement has been indispensable and highly appreciated.

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ISBN 978-3-95450-133-5