ELECTRON BEAM DIAGNOSTICS FOR FLASH II

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Abstract

Up to now, the FLASH linac serves one SASE undulator. The radiation produced can be guided to one of 5 beamlines. In order to increase the availability of the machine, a second undulator section, called FLASH II, will be built in the next 2 years to generate SASE light. A HHG laser will alternatively serve to produce seeded radiation in the undulators. The electron beam diagnostics in FLASH II has to enable the precise control of the beam position, size, timing, as well as the overlap of the electron beam with the HHG laser. Losses have to be kept under control, and the beam has to terminate safely in the beam dump. In comparison to FLASH, which was designed to run with rather high charge, the dynamic range of the diagnostics has to be between 0.1 to 1 nC, similar to the European XFEL. This paper gives an overview of the diagnostics for FLASH II.

INTRODUCTION

FLASH is a free-electron laser, based on the self-amplified spontaneous emission principle (SASE-FEL) [1]. The user facility delivers short laser-like pulses with wavelength from 47 nm down to 4.5 nm to one of five beamlines. The linac is also used as a test facility.

FLASH II is an extension to FLASH, planned to be built in the next 2 years [2]. A seeded scheme, now under test at FLASH, is planned to be used, due to the cleaner spectrum of the generated radiation [3]. SASE radiation will also be produced. The increased availability of beam time and the improved quality of the seeded radiation are the main motivation for FLASH II.

Overview of FLASH II

Fig. 1 shows the layout of FLASH, including FLASH II [2]. After acceleration the electron beam is sent either to the present fixed-gap undulators, referred to here as FLASH I, or to a new undulator section, FLASH II. A new experimental hall is included in the upgrade. In order to be able to adjust the photon wavelength without influence on FLASH I, variable-gap undulators are required. A HHG (High Harmonic Generation) laser will be used to produce seeded radiation. The electron beam will be then sent to a second dump. The main parameters of the electron beam are shown in Table 1.

Table 1: Main electron beam parameters of FLASH II

Energy	0.5 – 1.2 GeV
Bunch charge	0.1 – 1 nC
Repetition rate	10 Hz
Bunch frequency	0.04 – 1 MHz
Peak current	2.5 kA
Normalized emittance	1.4 mm·mrad
Energy spread	0.5 MeV
Photon wavelength (SASE)	4-80 nm
Photon wavelength (HHG)	10-40 nm

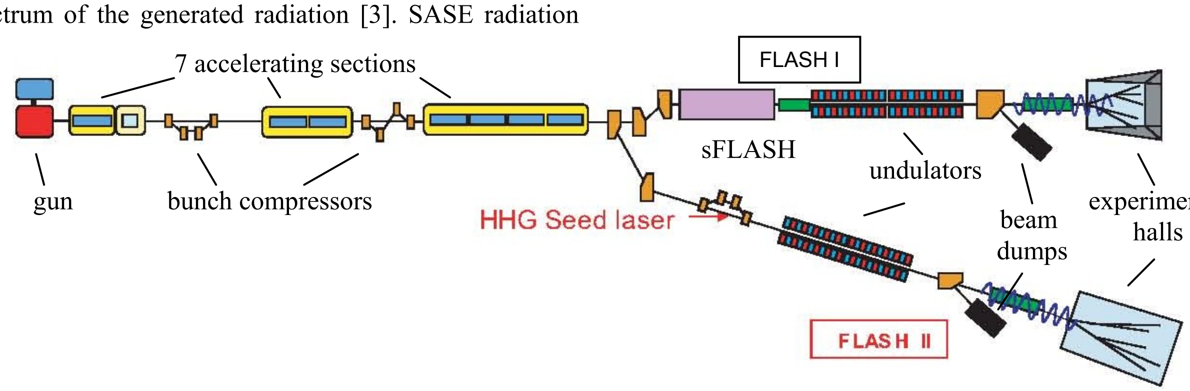

Figure 1: FLASH layout (courtesy B. Faatz).

ELECTRON BEAM DIAGNOSTICS OVERVIEW

Beam parameters like charge, transverse, position, size, phase have to be controlled for a high photon beam quality. With few exceptions, components developed for the European X-ray Free Electron Laser (E-XFEL) will be used [4]. This regards the mechanical parts as well as the electronics.

Thus the electronics system for FLASH II will be based on the µTCA standard [5], using commercial as well as custom developed boards. The timing system will also be upgraded. With a staged approach, the E-XFEL timing will replace the existing timing.

For the mechanics, a special type of CF50 flange will be used, reducing the impedance of the machine by shielding the flange gaps.

Different to the E-XFEL is the diagnostics for the dump line. The maximum average beam current per pulse is 4.5 mA, similar to the E-XFEL. Therefore a safe beam

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dumping is essential. However, due to the different energy, the requirements for the dump lines are different. In FLASH II, the same diagnostics will be used in the dump line as in FLASH I [6]. Several beam loss detectors will be installed: glass fibers, ionization chambers and beam halo monitors. In addition, a special beam position monitor (BPM) shows the beam offset just after the dump vacuum window.

The various beam monitors are describes in the following.

BEAM POSITION MONITORS

Cavity BPMs

Cavity BPMs will be installed between individual undulator segments [7]. Each monitor consists of a monopole and a dipole resonator. Both resonators have a frequency of 3.3 GHz. The loaded Q is of about 70, low enough to prevent coupling of the signal from bunch to bunch even at the maximum bunch repetition frequency of 4.5 MHz. In FLASH, 3 prototype cavity BPMs were installed (Fig. 2). Tests have shown that 1 µm rms resolution can be achieved. The electronics for the cavity BPM will be the PSI type developed for the E-XFEL [8].

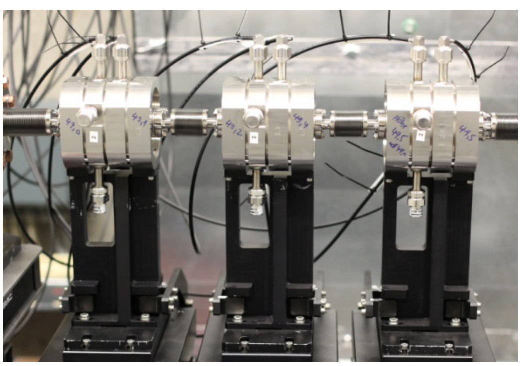

Figure 2: Three prototype cavity BPMs installed on a test section in FLASH.

Button BPMs

Due to several beam pipe diameters, several types of button BPMs are required. From the design they will be as close to the E-XFEL ones as possible [9]. Where possible, the same feedthroughs will be used.

Electronics with special emphasis on low charge operation is under development for the button BPMs [10].

Magnetic-coupled BPM

Like in FLASH I, a BPM will be installed just behind the dump vacuum window, in order to avoid the risk of vacuum leak in case of pickup damage by the high power beam. This area is filled with dry Nitrogen N_2. Instead of using typical buttons, magnetic loops have been designed to couple to the magnetic field of the beam only and to suppress signals from ions (see Fig. 3) [11]. This BPM can be read out with the button BPM electronics.

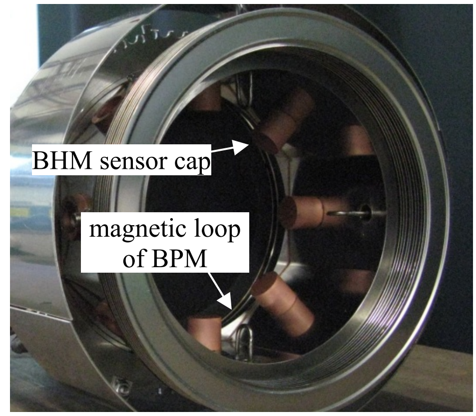

Figure 3: View from the dump of the magnetic-coupled BPM and the BHM sensors, as installed in FLASH I.

CHARGE MONITORS (TOROIDS)

FLASH II will require 4 current transformers, so called toroids. Due to recent developments [12], the entire system of toroids will be upgraded with modified transformer housings and new µTCA-based electronics. It will provide better charge resolution than the ones in FLASH I. Furthermore, the beam transmission interlock system [13], called TPS, will be renewed. Additional features are required due to the branching into two beamlines and the use of single bunches kicked out before the dump for special diagnostics.

SCREEN/WIRE SCANNER STATIONS

Combined screen/wire scanner stations will be used for beam size measurements. The setup is shown in Fig. 4.

Since the installation of the 3rd harmonic cavities, FLASH is suffering from coherent optical transition radiation (COTR) effects on the screen stations, similarly to LCLS and the E-XFEL. Therefore, it is planned to use luminescent screens instead of OTR targets in the FLASH II beamline. Intensive studies on screen material and observation geometries are currently going on [14]. It turns out, that an observation geometry under 45° with respect to the beam has many advantages. The screen angles with respect to the beam provide observation angles different from the reflection angles, so that a spatial suppression of COTR seems possible. The "Scheimpflug Scheme" to extend the depth of field for the imaging seems to be inevitable for this scheme.

Fast, triggered wire scanners will be installed in the same vacuum vessel of the screens [15]. The wire-scanners are based on linear motors and will be able to run with a speed of 1 m/s. They are suited to provide a beam profile within a single bunch train of FLASH. The trigger jitter was measured on a prototype to be less than 10 µm or 10 µs. For detection, the usual scheme of a scintillator/photomultiplier detector will be used. Due to the time synchronized readout of all bunch related data, provided by the DOOCS control system [16] also other detectors like BLMs or high energy gamma detectors can be used. This allows also using charge or orbit information from the same bunches to correct the profile data.

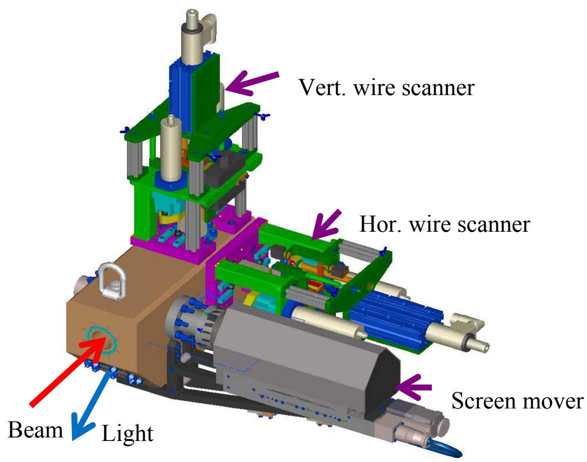

Figure 4: Drawing of a combined screen and wire-scanner system (courtesy A. Delfs).

Different screen/WS stations will be used between some undulator units, like the ones used in the sFLASH section in FLASH I [17].

LOSS MONITOR SYSTEMS

Beam Loss Monitors (BLM)

The beam loss monitors to be used at FLASH will be the same as the ones used at the E-XFEL [18]. The design is based on the experience with the FLASH system. About 40 monitors based on scintillators read out by photomultipliers will be distributed along the beamline. In the last 2 m of the dump beamline, four glass fibers will be installed instead of scintillators [6]. The BLMs are connected to the machine protection system that is able to stop beam operation within a few µs, this delay being mainly determined by cable length. The electronics follows the same strategy as the FLASH system, but it will be a mainly digital system based on the µTCA standard. Only fast single bunch alarms are detected by an analog comparator, in order to avoid additional latency due to the ADC.

Ionization Chambers

Four air-filled Heliax HF cables will be installed along the last 2 m of the beamline, in parallel to the glass fibers [6]. These ionizations chambers have a large dynamic range, from 10^{-4} to 10^{4} µA.

Beam Halo Monitor (BHM)

The beam halo monitor is made of four diamond and four sapphire sensors [19]. They will be installed after the dump vacuum window, next to the magnetic-coupled BPM (see Fig. 3).

OTHER DIAGNOSTICS

Several other diagnostics monitors are considered for installation in FLASH II: beam arrival monitor to measure the beam phase [20]; bunch compression monitor to check the length [21]; dark current monitor to measure the dark current transported from the gun [22]; so-called Cherenkov fibers to monitor beam losses along the undulators [23].

OUTLOOK

The installation of the components in the FLASH II tunnel will start in summer 2012. The commissioning is planned to start in 2013, parallel to the commissioning of the E-XFEL injector. The electronics of most diagnostics components is intended to be exchanged at a later time with the XFEL-type. The goal is a high compatibility of the E-XFEL and FLASH electronics.

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