ELECTRON BEAM DIAGNOSTIC SYSTEM FOR THE JAPANESE XFEL, SACLA

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Abstract

We present the design and performance of the beam diagnostic instruments for the Japanese x-ray free electron laser (XFEL) facility, SACLA. XFEL radiation is generated by self-amplified spontaneous emission (SASE) process in SACLA, which requires a highly brilliant electron beam with a normalized emittance of less than 1 mm mrad and a peak current of more than 3 kA. To achieve this high peak current, 1 A beam with 1 ns duration from a thermionic electron gun is compressed down to 30 fs by means of a multi-stage bunch compression system. Therefore, the beam diagnostic system for SACLA was designed for the measurements of the emittance and bunch length at each compression stage. We developed a high-resolution transverse profile monitor and a temporal bunch structure measurement system with a C-band rf deflecting cavity etc. In addition, the precise overlapping between an electron beam and radiated x-rays in an undulator section is necessary to ensure XFEL interaction. Therefore, we employed a C-band sub-μm resolution rf cavity BPM to fulfill the demanded accuracy of 4 μm. All the performances of our developed beam monitors reached the demanded resolutions. By using these beam diagnostic instruments, the first x-ray lasing at a wavelength of 0.12 nm was achieved and SACLA has been stably operated for user experiments since March, 2012 in the wavelength region from 0.08 nm to 0.25 nm.

INTRODUCTION

The x-ray free electron laser (XFEL) facility, SACLA (SPring-8 Angstrom Compact Free Electron LAser) [1], was successfully commissioned and the first x-ray lasing was observed in June, 2011 at an x-ray wavelength of 0.12 nm. SACLA has been stably operated for various user experiments since March, 2012 in the wavelength region from 0.08 nm to 0.25 nm. In SACLA, XFEL radiation is generated by a self-amplified spontaneous emission (SASE) process. The SASE process in the x-ray region requires a high peak current of more than 3 kA and a small normalized emittance of less than 1 mm mrad [2].

To achieve these requirements, we designed and constructed a low-emittance injector, an 8 GeV C-band accelerator and a short-period in-vacuum undulator beamline, as shown in Fig. 1. An electron beam is generated by a thermionic electron gun with a CeB_6 cathode. The normalized emittance of the electron beam is 0.6 mm mrad, the initial current is 1 A and its pulse width is 1 ns (FWHM) formed from 3 μs (FWHM) by a high-voltage chopper. The beam is accelerated to 8 GeV by the following series of rf accelerator cavities: 238 MHz pre-buncher, 476 MHz booster, L-band (1428 MHz), S-band (2856 MHz) and C-band (5712 MHz) accelerators. In the meantime, the bunch length is shortened from 1 ns to 30 fs by using a velocity bunching process through the sub-harmonic acceleration cavities and a bunch compression process by means of three magnetic chicanes. The peak current is finally boosted up to 3 kA without substantial emittance growth. The electron beam is then fed into in-vacuum undulators with a period of 18 mm and the maximum K-value of 2.2, and XFEL light is finally generated.

In order to maintain the high gain SASE process at an x-ray wavelength, we need to monitor a beam position, a transverse beam profile, beam arrival timing and a temporal bunch structure at each acceleration stage. The resolution of the beam-position monitor in the undulator section is required to be less than 1 μm so as to maintain the overlap between the electron beam and radiated x-rays within 4 μm precision [3]. The transverse beam profile should be measured with a spatial resolution of less than 10 μm in order to measure a normalized emittance less than 1 mm mrad. The required resolution of the temporal bunch structure measurement is 10 fs at a position after the full compression, since the bunch length becomes 30 fs. In addition, since the initial bunch length is 1 ns, temporal profile monitors with a wide time scale from 1 ns to 10 fs are demanded. Therefore, we developed

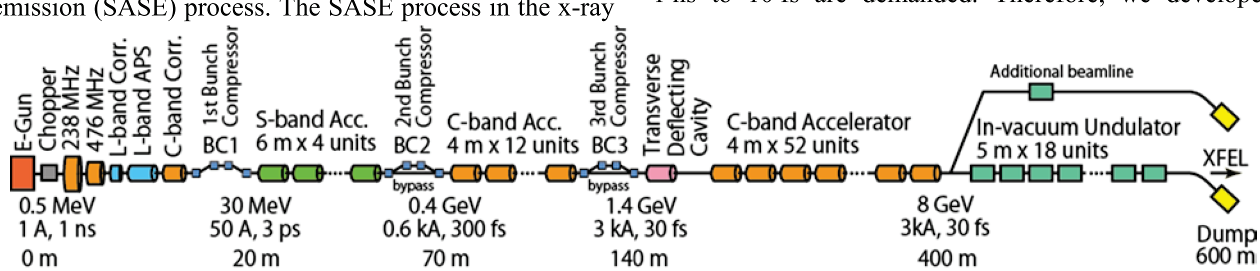

Figure 1: Schematic layout of SACLA.

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