BUNCH LENGTH MEASUREMENTS AT SCSS TEST ACCELERATOR TOWARD XFEL/SPRING-8

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Abstract

The SCSS test accelerator, which was constructed to check feasibility of XFEL/SPring-8, is operated for user experiments using stable EUV (Extreme Ultra-violet) SASE. This accelerator provides a high quality electron beam with parameters, such as a bunch length of 300 fs and a peak current of 700 A, for power saturation of the EUV SASE. Evaluating the parameters is very important to ensure the stable generation of the SASE. The bunch length measurement systems to evaluate the parameters have been developed. The systems use the rf zero phase crossing method, the EO sampling method with temporal decoding and an 800 nm laser, and the method observing OTR (near infrared region) by a streak camera (fesca-200), which is mature technology. All the measured bunch lengths were about 300 fs (FWHM), which is consistent with the individual methods. The most important result is that the streak camera with optimum tuning directly measured the temporal structure with femto-second resolution, and the reliability of these systems were mutually checked.

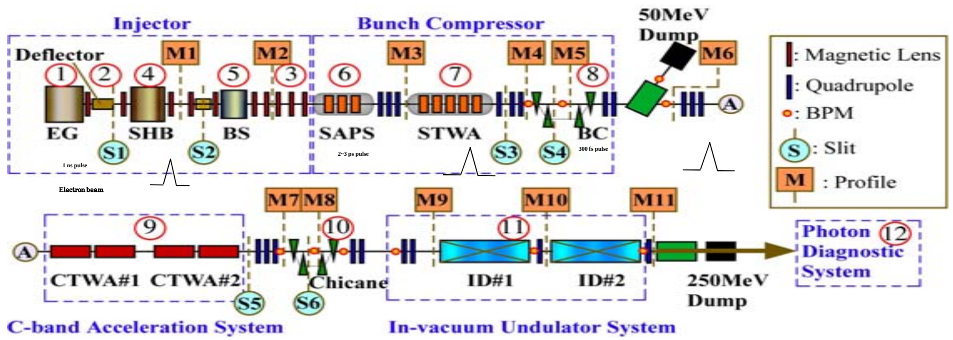

Figure 1 : Schematic layout of the SCSS test accelerator. 1 EG: electron gun, 4 SHB: sub-harmonic buncher, 5 BS: booster cavity, 6 SAPS: S-band APS cavity, 7 STWA: S-band travelling wave accelerator, 9 CTWA: C-band travelling wave accelerator. 11 ID: insertion device (undulator).

INTRODUCTION

Keeping constantly the peak currents of the electron bunches of a free electron laser at SPring-8 (XFEL/SPring-8) and the SCSS test accelerator to check feasibility of the XFEL/Spring-8 which are to generate coherent and extremely intense x-rays and extreme ultra-violet (EUV) light, respectively, is one of the most important points to ensure stable generation of their lasers. In the present technology, the charge amount of the bunch can be only and reliably measured by a current transformer with reasonable accuracy of 1~5 %. Therefore, a measurement of a bunch shape, which determines the peak current, is very important. Furthermore, we introduced the SCSS concept for the XFEL and the SCSS test accelerator. The SCSS concept employs a velocity bunching process using multi sub-harmonic bunchers (SHB) for an injector and a magnetic bunching process using a chicane bunch compressor (BC) comprising four bending magnets after the injector. For the SCSS test accelerator, a single BC is used, and for the XFEL, three stage BCs are employed after the injector. For this reason, the individual bunch compression processes have different bunch lengths, such as the bunch width of the velocity bunching is from 1 ns to 10 ps (1~20 A in peak current), the bunch length after the 1st BC is 2~3 ps (~70 A), the bunch length after the 2nd BC is around 150 fs (~600 A), and the bunch width after the 3rd BC is about 30 fs (~3 kA). Since the stability of the laser is extremely dependent on their bunch lengths, evaluating and properly adjusting the bunch lengths at each process are very important to ensure the stable laser. To establish measurement reliability and adapt measurements with the different bunch lengths, the different kinds of the bunch length measurement methods are employed for the XFEL and the SCSS test accelerator, even through the methods almost cover the same temporal resolution and range. Because, the temporal accuracy of the individual bunch length methods in the case of measurement with a resolution under 1ps, such as a streak camera for observing optical transition radiation (OTR) and an rf zero-crossing, still has some ambiguity caused by measurement errors. For example, the errors are sensitivity dependent on an wavelength, where the streak camera is used [5], and the aberration of an electron beam optical system, where the rf zero-crossing is employed. Therefore, we think that the reliability on the temporal resolution of the bunch length measurements in a femto-second region is not established in the present time.

The six kinds of bunch length measurement systems to guarantee reliability of the beam monitor system of the XFEL have been developed or are under development. In this presentation, we report the already developed bunch length measurement systems using a streak camera method, an rf zero-phase crossing method, and an EO sampling method selected from the bunch length monitors for the XFEL, which are described next. These methods cover a temporal measurement range of several hundred femto-seconds. This time range can adapt observing the electron bunch of the 1st BC and the 2nd BC.

To check the reliability of the developed methods and evade the ambiguity of the measurement accuracy, the electron bunch length of the SCSS test accelerator was measured by the developed systems, and the data taken by the systems were compared. The test accelerator uses multi- SHBs of 238 MHz and 476 MHz for the velocity bunching and a BC for magnetic bunching. A schematic layout of the test accelerator is illustrated in Fig. 1. The electron bunch length of the accelerator is compressed from 1 ns to a spiky lasing part of 300 fs with the 750 A peak current by the bunching process, while the final whole compressed bunch length is about 1ps including the spiky lasing part. These bunch compression processes were numerically simulated, and their performance was experimentally confirmed by measurements. In this presentation, we firstly show a brief overview of the beam diagnostic system of the XFEL/SPring-8, and then the experimental set-ups of the developed bunch length measurement systems to monitor the bunch characteristic of the test accelerator, as previously mentioned, are presented and their experimental results are also reported.

Table 1: Number of the beam monitors for the XFEL and the SCSS test accelerator.

Kinds of Monitor	Number of Monitors (XFEL/SPring-8)	Number of Monitors (SCSS test accelerator)
RF cavity BPM	56	10
Screen Monitor	43	11
Current Transformer	30	12
Transverse rf Deflector	1	0
Streak Camera using OTR	3	1
EO Sampling	1	1
Waveguide Spectrometer	4 ~ 5	2 ~ 3
CSR Pyro-detector	3	1

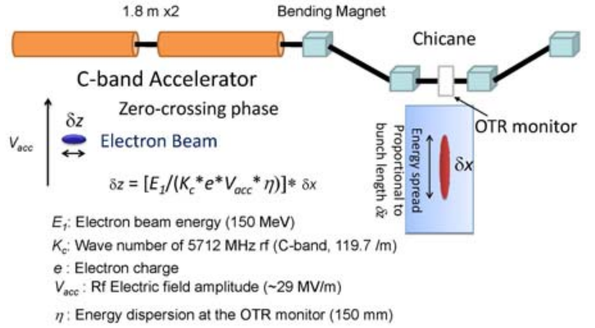

Figure 3. Measurement instrumentation configuration of the rf zero-crossing method.

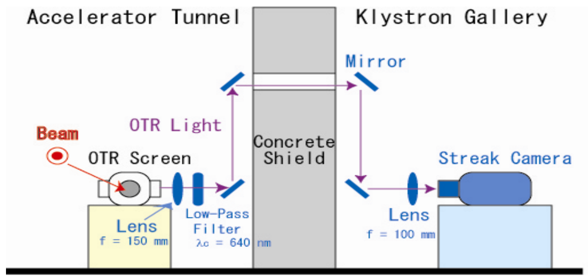

Figure 2. Experimental set-up of an electron bunch length measurement using OTR light and the streak camera (FESCA-200, Hamamatsu Photonics).

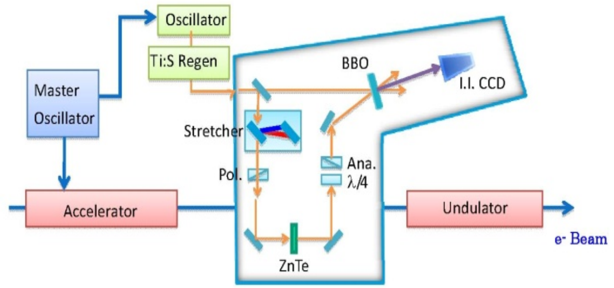

Figure 4. Experimental set-up for E/O sampling using a Zinc Telluride, ZnTe, crystal. This schematic shqws the temporal decoding method.

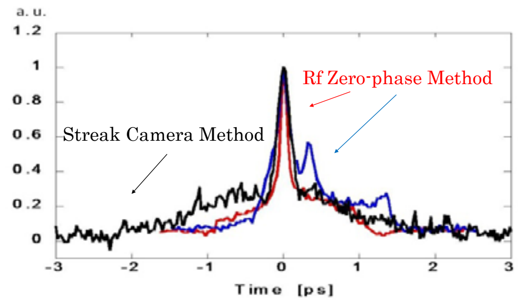

Figure. 5. Bunch length data taken by the streak camera and the SCM, and the rf zero-phase crossing method. The red is at a bunching phase. The blue is at a debunching phase.

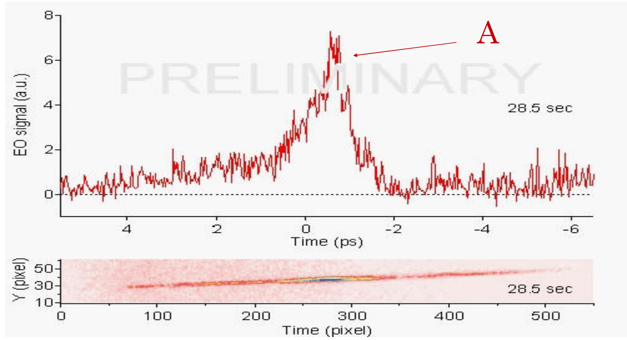

Figure. 6. Experimental result by the E/O sampling with the temporal decoding. The "A" could be the spiky lasing part.

SUMMARY

The bunch length of the SCSS test accelerator was measured by three methods, which were a streak camera method, an rf zero-phase crossing method, and an EO sampling method. The results of bunch length experiments using these methods were consistent, with which the measured bunch lengths were about 300 fs. This consistency mutually proved reliability of the measurement accuracy of the methods. Furthermore, the most important result is that the streak camera being mature technology with optimum tuning directly measured the temporal structure of an electron beam bunch with femto-second resolution. I believe that our taken data being around 300 fs (FWHM) bunch lengths by the systems are the first experimental results in the world, because of comparing these data. The authors thank the members of the XFEL/SPring-8 project for their help.