ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-MOPO040

COHERENT SYNCHROTRON RADIATION MONITOR FOR MICROBUNCHING INSTABILITY IN XFEL

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Abstract

The microbunching instability is an important issue in an X-ray Free Electron Laser (XFEL) [1-4]. In Pohang Accelerator Laboratory X-ray Free Electron Laser (PAL-XFEL), the CCD camera installed in the accelerator tunnel at Coherent Radiation Monitor. The CCD camera measured the Coherent Synchrotron Radiation which made from the electron bunch compressor. This facility is called the Coherent Synchrotron Radiation (CSR) monitor. The CSR monitor measured the CSR and used for the microbunching instability measurement tool.

INTRODUCTION

The X-ray Free Electron Laser of the Pohang Accelerator Laboratory (PAL-XFEL) can produce a 0.1 nm wavelength XFEL [5]. The electron beam of the 150 pC charge is generated in the photo-cathode RF gun with an ultraviolet (UV) laser pulse. The generated electron bunch is accelerated by the 4 accelerating columns, and the electron bunch accelerated to 10 GeV energy. Moreover, four magnetic bunch compressor installed next to the accelerating column 1, 2, and 3 and soft x-ray part. Each electron bunch compressor has the coherent radiation monitor (CRM). The coherent radiation generated by the dipole magnet of the bunch compressor. They are synchrotron radiation and edge radiation. Also, another coherent radiation produced by a mirror with a hole in the middle which is called the diffraction radiation [6,7]. The PAL-XFEL structure is shown in Fig. 1. In the CRM, the pyro-electric detector is installed to detect the THz range coherent radiation. Using the pyro-electric detector, we can measure the THz range of coherent radiation, and it related with the electron bunch length. However, the measurement result of the pyro-electric detector in the very short electron bunch length range shows the saturation result. So, we need shorter electron bunch length range measurement tool. For this purpose, we installed the CCD camera in the CRM. In the CRM, we installed the moving stage then we can choose the CCD camera and pyro-electric detector. The CRM structure is shown in Fig. 2.

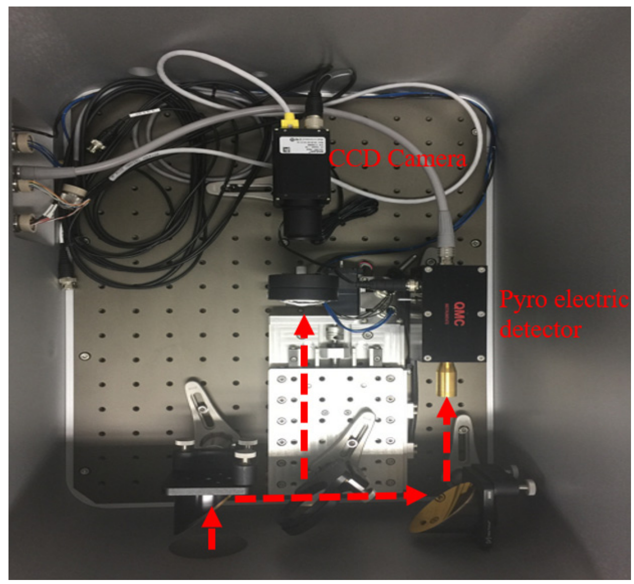

Figure 2: CRM structure.

The CCD camera is called the coherent synchrotron radiation (CSR) monitor, and it is detected the visible range radiation. The detecting radiation image is shown in Fig. 3. The visible range radiation made from the shorter longitudinal structure than the longitudinal structure of the THz radiation range. So, we can conclude that the visible radiation is related to small longitudinal structure such as the microbunching state.

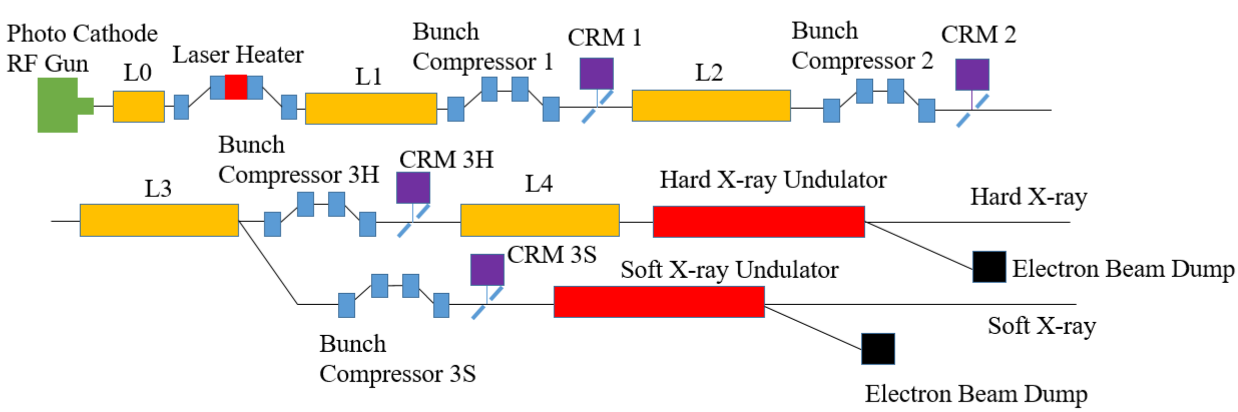

Figure 1: Schematic structure of PAL X-FEL.

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In Fig. 3, we can see the partial circle. The partial ring shows the diffraction radiation from the mirror with a hole in the middle. To explain the physical property of the CSR monitor's detecting result, we compare the detecting result of the pyro-electric detector and the CSR monitor. We use the laser heater to show the relation of the coherent radiation result and a laser heater condition. And, we concluded that the CSR monitor is a measurement tool for the microbunching instability. These results are shown in the next chapter.

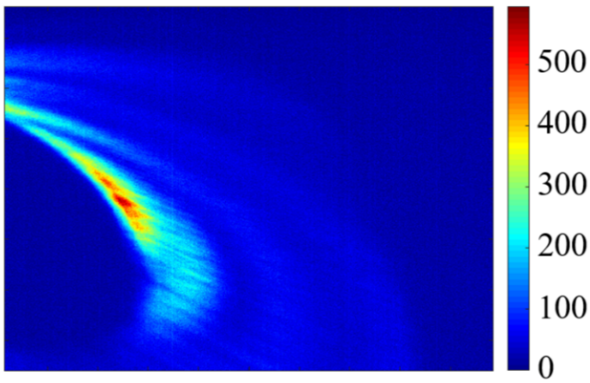

Figure 3: Detecting image in the CCD camera.

EXPERIMENT RESULT

In our experiment, we use the electron bunch compressor 1, 2 and we do not use the bunch compressor 3, and we use the CRM 3H. The RF phases fixed in the L0, L1, L3, L4 and the bunch compressor 1 is fixed. We control the L2 RF phase and the bunch compressor 2 and laser heater.

In the PAL-XFEL, the laser heater is installed to reduce the microbunching instability [8]. If the CSR monitor is the detecting tool of the microbunching instability, the CSR monitor and pyro-electric detector showed the different measurement result. We measure the radiation intensity of the CSR monitor and pyro-electric detector with the different laser heater condition. These results are shown in Figs. 4 and 5.

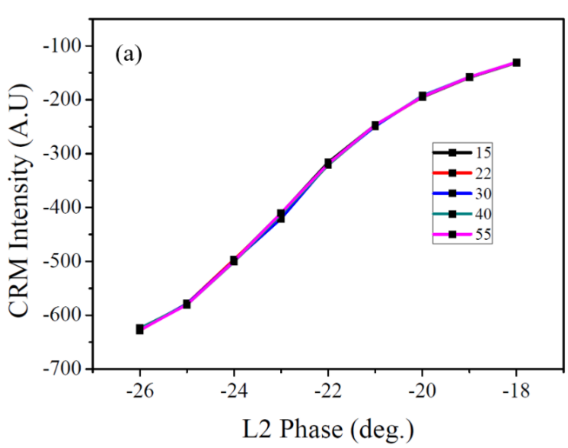

Figure 4: Pyro-electric detector intensity in different half wave plate angle.

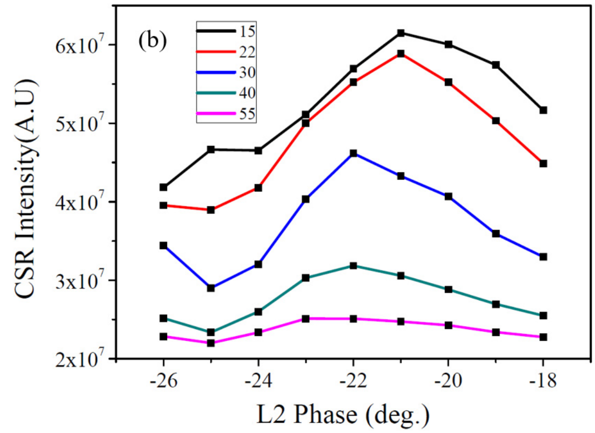

Figure 5: CSR monitor intensity in different half wave plate angle.

Figures 4 and 5 show the radiation intensity of the pyro-electric detector and CSR monitor. The CRM means the radiation intensity of the pyro-electric detector. The CSR implies the radiation intensity of the CCD camera. The radiation intensities measured in the different laser heater condition that is called the half wave plate angle. The IR laser energy of the laser heater is controlled by the half wave plate angle. The number 15, 22, 30, 40, 55 of Figs. 4 and 5 mean the different half wave plate angle. In Figs. 4 and 5, the different half wave plate angle does not relate with the radiation intensity but in Fig. 5, the radiation intensity is changed by the changes of half wave plate angle value. It means the measurement results of the pyro-electric detector do not relate with the laser heater. Because the pyro-electric detector detects the THz range radiation, and it did not associate with the microbunching instability. However, the CCD camera detects the visible radiation, so the measurement result of the CCD camera is related to the microbunching instability. The L2 RF phase related to the electron bunch length and the laser heater condition associated with the microbunching instability. Using this result, we can conclude the pyro-electric detector is the measurement tool of the electron bunch length, and the CCD camera is the measurement tool of the microbunching instability.

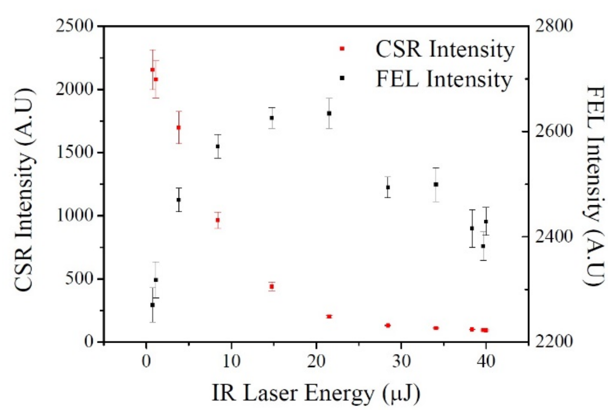

Figure 6: CSR intensity and FEL intensity as a function of IR laser heater energy.

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We compare the CSR intensity which is detected by the CCD camera and the FEL intensity in different laser heater condition [9]. The result is shown in Fig. 6.

In Fig. 6, the CSR intensity decreases as the IR laser energy increases. It means the microbunching instability is reduced by the IR laser energy increasing. The CSR intensity decreased until the IR laser energy is 20 μJ and over the 20 μJ, the CSR intensity has nearly zero intensity. The FEL intensity increased to the 20 μJ, and over the 20 μJ, the FEL intensity decreased. It means the decreasing microbunching instability has a good effect on the FEL intensity but over the 20 μJ, IR laser Energy the effect of the laser heater is worse than under 20 μJ IR laser energy.

Using this result, we can control the IR laser Energy of the laser heater. So we can find the optimization of IR laser energy value.

CONCLUSION

In the PAL-XFEL, the CCD camera is installed to measure the visible radiation which is related to the microbunching instability. The CCD camera is called the coherent synchrotron radiation (CSR) monitor, and it installed in the coherent radiation monitor (CRM) which is the next part of the electron bunch compressor. Using the detection data of the pyro-electric detector and the CSR monitor, we can conclude the CSR monitor is the detecting tool of the microbunching instability, and we show the CSR monitor can use the laser heater optimization. In the future, we can conduct the particular experiment of the microbunching with the CSR monitor in the BC2, BC3 H, and BC 3 S.

ACKNOWLEDGEMENTS

This research has been supported by the Ministry of Science and ICT of Korea and partly by Basic Science Research Program [Grant No. 2017R1A2B4007274] through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT of Korea.

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