DEVELOPMENT OF BEAM POSITION FEEDBACK CONTROL SYSTEM IN KU-FEL

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Abstract

The feedback system has been developed in KU-FEL linac to stabilize the FEL power fluctuation. The system consists of six 4-button type BPMs and the signal processing system. As the first step, the beam displacement information at the RF-gun section was used for the feedback control to stabilize the electron energy and the vertical beam position at the RF-gun section. As the result the FEL power fluctuation was largely improved from 40% to 20%, factor 2.

INTRODUCTION

Stabilization of an electron beam parameter, such as charge, position, energy, energy spread and so on, are crucial for a stable operation in mid-infrared Free Electron Laser (FEL) facility in Kyoto University (KU-FEL). At first the KU-FEL has introduced the beam charge feedback system in 2007 for the 4.5 cell thermionic RF-gun. The beam charge feedback system stabilized the output charge of the RF-gun [1]. Then the first lasing in KU-FEL was observed in 2008 [2] and FEL beam has been delivered to users. However the output power of the FEL has not been stable one, because the other electron beam parameters are still fluctuated due to fluctuation of the room and the cooling water temperatures, the timing jitter of the RF pulses between the RF-gun and the S-band accelerator tube, and so on. The electron beam position could reflect these fluctuations. Therefore, to monitor the electron beam movement non-destructively, we have installed a Beam Position Monitor (BPM) system consisted of six 4-button electrode type BPMs, double balanced mixers (DBMs), clipping modules and CAMAC-ADCs. By using the BPM information we start to develop an electron beam feedback system from RF-gun section.

In this paper we will describe the BPM system installed in KU-FEL, the feedback system in the RF-gun section, and the improvement of the FEL power stability.

BPM SYSTEM

The 4-button electrode type BPM (Fig.1) has been installed in the KU-FEL driver linac. The location of 6 BPMs are 2 BPMs for in the RF-gun section (Low Energy Section), 2 BPM for the S-band accelerator tube section (High Energy Section), and 2 BPM for the Undulator Section. Figure 2 illustrates the overview of the KU-FEL driver linac and location of each BPM.

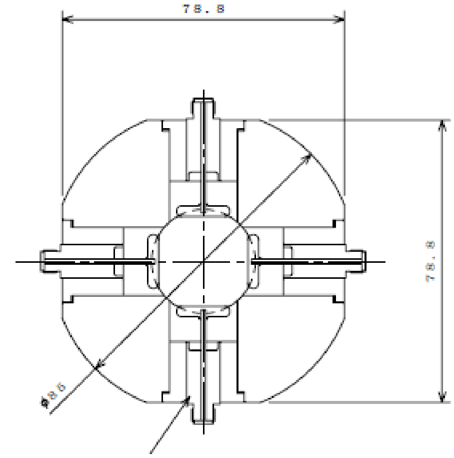

Figure 1: Cross sectional drawing of 4-button type BPM.

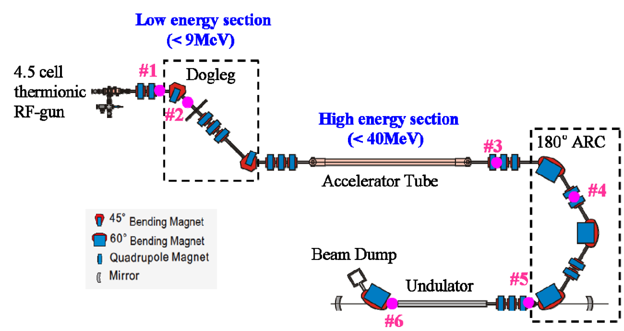

Figure 2: Layout of the KU-FEL driver linac. #1-#6 indicate the each position of BPM.

Table 1: BPM Position and Related Beam Parameter

BPM #	Location	Beam Parameter
# 1	Exit of RF-gun	Position, RF-Phase
# 2	Dispersive section	Energy
# 3	Exit of Acc. tube	Position, RF-Phase
# 4	Dispersive section	Energy
# 5	Entrance of Undulator	Position
# 6	Exit of Undulator	Position

As is shown in Table 1, #2 and #4 BPMs will be used for the energy feedback which could be controlled by RF powers fed into the RF-gun and the accelerator tube separately. On the other hand signals from #1 and #3

BPMs are used for RF-phase detection as well as the beam position measurement, because KU-FEL linac employs the modulated RF power method to cure the serious backstreaming electron in the 4.5-cell thermionic gun [3]. Therefore the signal from pick-up electrodes of #1 and #3 BPMs are divided by RF-dividers and sent to the phase detectors. The signal processing of the BPM system consists of DBMs, which work as heterodyne type frequency down-converters, clipping modules (N026, Hoshin Electronics Co.Ltd.), CAMAC charge sensitive ADCs. The position information is calculated and put into PV which is accessible in the KU-FEL control system which is PC-LabView based system using EPICS-CA [2]. Therefore a feedback system have been developed in LabView software, because our first target of the system is stabilization of a long term (> minutes) drift of beam position as well as FEL output power.

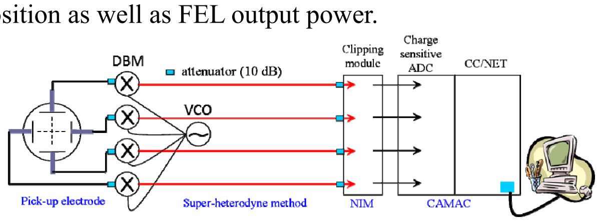

Figure 3: Signal processing diagram of BPM system.

FEEDBACK CONTROL

Before applying the feedback system, the time trend of the FEL output power (Fig.4) and the beam position at BPM #2 (Fig.5) were measured with the electron beam energy of 8.4 MeV at the exit of the RF-gun and 25 MeV at the undulator. The electron beam charge was 3.15 μC stabilized by beam charge feedback system with the macro-pulse length of 6.8 μs. The FEL wavelength was 10.9 μm. In this paper the electron beam and the FEL parameter were fixed during the measurement. The BPM data was taken in 1 Hz which corresponds to the linac operation frequency.

As shown in Fig. 4, the output power of FEL shows a shot-by-shot fluctuation and gradual up and down by time. The deduced standard deviation of the FEL power was 40%.The vertical movement of the electron beam position (dY in Fig.4) at BPM #2 shows gradual increment as well as sudden jumps that may come from a charge-up of a ceramic duct of a current transformer. On the other hand corresponding displacement of the horizontal beam position (dX in Fig.4) shows sinusoidal movement. Since the BPM #2 is located at dispersive section, dX reflects the electron beam energy fluctuation which may come from the room and/or water temperature. The standard deviation of dX was 111 μm and dY of 44 μm.

We applied a feedback control to the klystron high voltage (HV), which was fed in the RF-gun, by using a reference value of the horizontal displacement (dX) at BPM #2. The time trend of the FEL output power is shown in Fig. 6. As shown in Fig. 6, the stability of the FEL power was largely improved and the standard deviation was 27%. The corresponding displacement of the beam position (dX and dY) at BPM #2 are also displayed in Fig. 7. The sinusoidal movement in dX was disappeared by the feedback control. On the other hand, dY in Fig.7 still shows large jumps. The standard deviation of dX was 56 μm and dY of 48 μm.

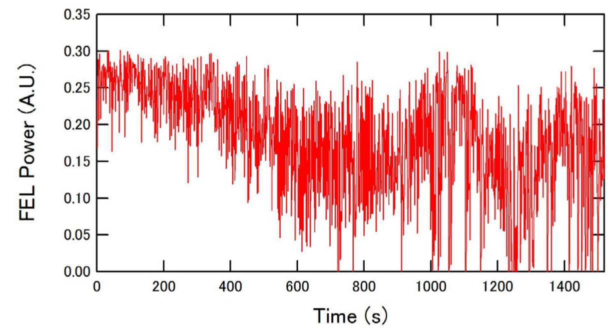

Figure 4: Time trend of the FEL output power without feedback control.

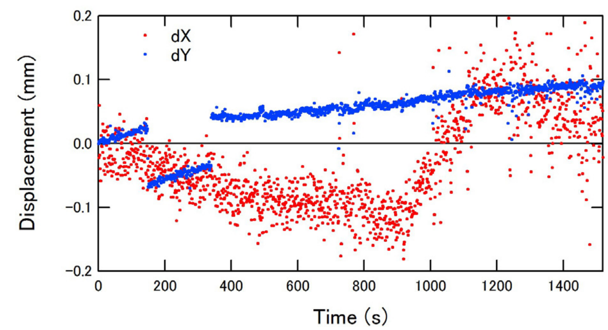

Figure 5: Time trend of the beam displacements at BPM #2.

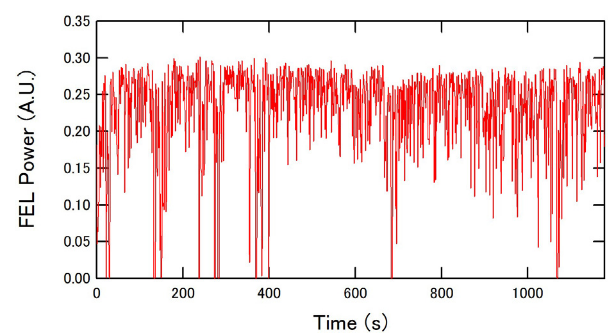

Figure 6: Time trend of the FEL output power with the BPM #2 (dX) feedback control.

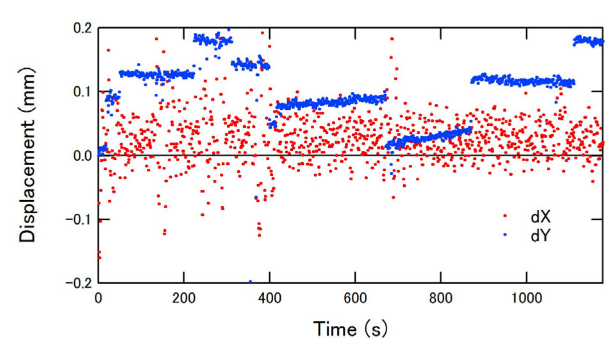

Figure 7: Time trend of the beam displacements at BPM #2 with the dX feedback control.

Next, we applied a feedback control to a vertical steering magnet in the Gun section with the reference value of the vertical displacement (dY) at BPM #2. However the stability of the FEL power was not improved and the standard deviation was 47%. The corresponding displacement of the beam position (dX and dY) at BPM #2 are also measured and the time trend of dY showed almost constant position by the feedback control. The standard deviation of dX was 97 μm and dY of 25 μm. Consequently, the FEL power fluctuation is mainly affected by fluctuation of the electron beam energy and the feedback control with dX value can largely reduce the FEL power fluctuation.

Finally, we applied a feedback control to the HV with the reference value of dX and to the vertical steering magnet in the Gun section with the reference value of the dY. The time trend of the FEL output power is shown in Fig. 8. As shown in Fig. 8, the stability of the FEL power was improved and the standard deviation was 20%. The corresponding displacement of the beam position (dX and dY) at BPM #2 are also displayed in Fig. 9. The dX and dY are at the centre positions by the feedback control. The standard deviation of dX was 36 μm and dY of 16 μm. Consequently, the FEL power fluctuation was largely reduced as factor 2 by using the feedback system.

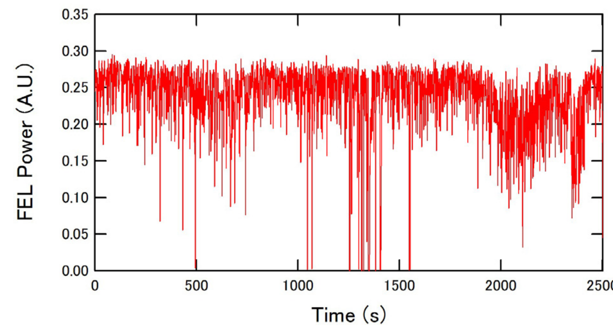

Figure 8: Time trend of the FEL output power with the BPM #2 (dY) feedback control.

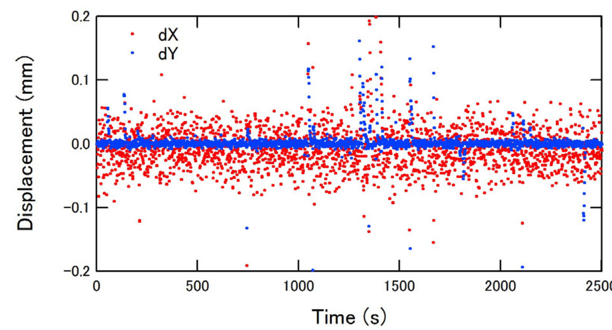

Figure 9: Time trend of the beam displacements at BPM #2 with the dY feedback control.

CONCLUSION

The feedback system has been developed in KU-FEL driver linac to stabilize the long term fluctuation in the FEL output. Four-button type BPMs were installed and the signal processing system has been set up. The beam displacement information at the RF-gun section was used for the feedback control to stabilize the electron energy and the vertical beam position at the RF-gun section. As the result the beam position displacement in horizontal and in vertical was improved from 111 μm to 36 μm and from 44 μm to 16 μm, respectively. Consequently, the FEL power fluctuation was largely reduced from its' original value of 40% to 20%.

However, since we applied the feedback control just in the RF-gun section at this moment, the FEL output power still has large fluctuation. We will implement feedback system in the high energy section, where energy and position feedback will be required, as well as the undulator section. In parallel, we have started to investigate the relation between the beam position movement with the room and water temperature, the timing jitter of the RF power in the accelerator tube, and so on.

ACKNOWLEDGMENT

The author thanks KEK-ATF staff for their great help to implementation of the BPM system. This work is partially supported by an "Energy Science in the Age of Global Warming" of Global Center of Excellence (G-COE) program (J-051) and The Collaboration Program of the Laboratory for Complex Energy Processes, Institute of Advanced Energy, Kyoto University.

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