CONTROL AND SUPPORT SYSTEM FOR LEBRA FEL OPERATION*

K.Nakao†, K.Hayakawa, Y.Hayakawa, K.Nogami, T.Tanaka, LEBRA, Funabashi, Japan
M.Inagaki, T.Sakai, I.Sato, Nihon University, Tokyo, Japan

Abstract

The near infrared Free Electron Laser (FEL) has been provided for scientific studies in various fields since 2003 at the Laboratory for Electron Beam Research and Application (LEBRA) in Nihon University. The operation time of the LEBRA 125MeV Linac reached approximately 2000 hr/year in 2007. About half of the machine time was scheduled for the experiments using FEL. So far only 3 staffs have been dedicated to the operation of the Linac and the FEL beam line. Therefore, the control and support system has been required to realize stable oscillation of FEL during a long operation time and to reduce the work load of the operators. The architecture and the main capabilities of the control and support system for LEBRA FEL are described in this report. The system consists of the electron beam energy feedback program and the FEL resonator mirror control program. The beam energy feedback program has successfully operated to suppress the pulse-to-pulse fluctuation of the beam energy to less than 0.1%.

INTRODUCTION

The electron linac at LEBRA consists of the 100kV DC electron gun, the prebuncher, the buncher, and three 4m long travelling wave accelerator tube. The specification of linac are listed in Table 1. Figure 1 shows schematic layout of the linac, the beam lines for FEL and PXR, and the RF system.

The FEL beam line and the optical resonator system have been installed to provide the near-infrared FEL for various studies[1]. To generate a monochromatic and spatially coherent X-ray beam, the PXR (Parametric X-ray Radiation) beam line has been installed next to the FEL beam line.

The 13 Beam Position Monitors (BPM) have installed in the accelerator, the 90 degree bending section, the FEL beam line, and PXR beam line[2]. The undulator consists of a planer Halbach-type permanent magnets. The specification of the FEL system are listed in Table 2. The architecture and the main capabilities of the control and support system for LEBRA FEL are described in this report.

Table 1: Main Parameter of the LEBRA 125MeV Linac

Accelerating rf frequency	2856	MHz
Klystron peak output RF power	30	MW
Number of klystron	2	
Electron Eergy	30 - 125	MeV
Macro pulse beam current	200	mA
Macro pulse duration	20	μsec
Maximum repetition rate	12.5	Hz

Table 2: Main Parameter of the LEBRA Undulator

Resonator length	6.718	m
Undulator period	48	mm
Undulator length	2.4	m
Number of period	50	
Maximum K value (rms)	1.35	

HOW THE OPERATORS OPERATE THE LINAC

Work of the linac operator of LEBRA is the following; to start the accelerator, to oscillate FEL, to keep FEL oscillation, and to stop the linac. When starting of an accelerator, an operator starts a cooling system, prepares RF system, and transport an electron beam to the FEL beam line. Next, in order to oscillate FEL, the operator adjusts angle and distance of resonator mirror, and adjusts orbit and energy of the electron beam. When the user starts experiment, the operator, until experiment ends, keeps FEL oscillation. After a user experiment finishes, the operator stops an electron beam and stop the linac.

The operators keep FEL oscillation until the user experiment finish. It take this process most longer time than other three processes. For FEL lasing, it is difficult for the operators to adjust angle and distance of the resonator mirrors, and to adjust energy and orbit of the electron beam. Therefore to reduce work load for the operator, the support system for these two process required.

CONTROL AND SUPPORT SYSTEM FOR FEL OPEBRATION

FEL Resonator Mirror Control System

Figure 2 shows the block diagram of FEL resonator mirror control system. The angle and distance of two resonator mirrors are controlled by the stepping motors, and are tuning distance between the resonator mirrors finely by the piezo actuator.

The drivers of the stepping motors which are controlling the resonator mirrors are connected to Mirror Control Server. The Mirror Control Server is a server program, and the operator console of the resonator mirrors is a client program of Mirror Control Server. The protocol between clients and server is CORBA/IIOP. CORBA

* *"Academic Frontier" Project for Private Universities: matching fund subsidy from MEXT Japan, 2005-2007.
† nakao@lebra.nihon-u.ac.jp

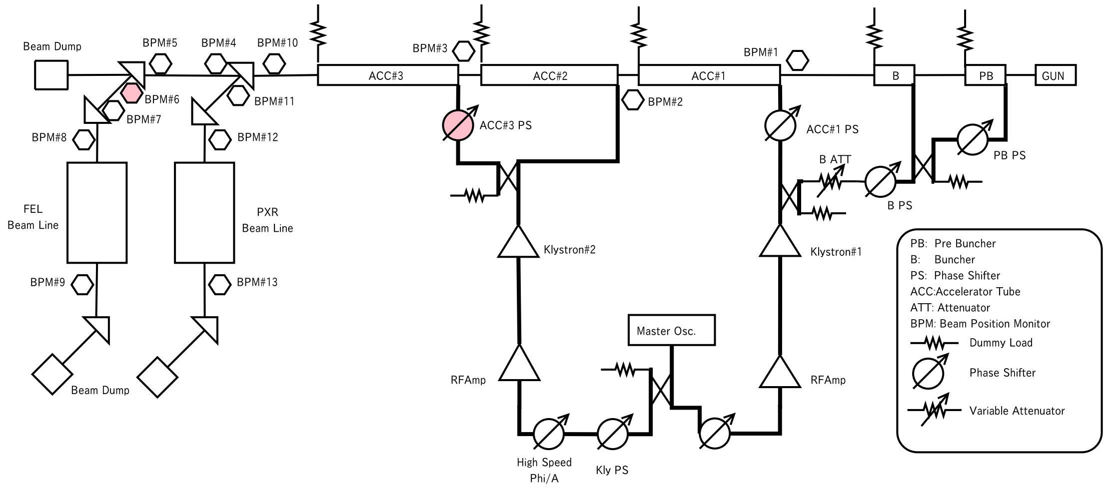

Figure 1: Schematic layout of the LEBRA 125MeV linac, the beam lines, and the RF System

(Common Object Request Broker Architecture) is a standard defined by OMG (Object Management Group) to enable software components running on multiple computers to work together.

The operator console of FEL resonator mirror control system was implemented as client program of Mirror Control Server.

Figure 4 shows the operator console window of Mirror Control System. When the Save button (Save is written in Japanese in Figure 3) on the right side of the console window is pushed, the current position of resonator mirrors and time are saved. Loading the saved position enables to reproduce resonator mirror position. If the mirror position in FEL lasing is saved, it is easy to find suitable position of the resonator mirrors. By Using this system, the operators are able to oscillate FEL easily.

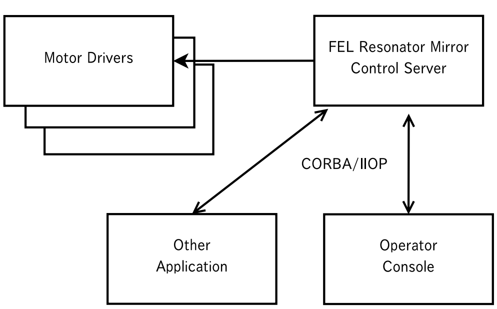

Figure 2: Schematic diagram of FEL Resonator Mirror Control System

Beam Energy Feedback System

The beam energy feedback system consists of the BPM#6, the BPM server, the beam energy feedback program and the RF control program. Figure 4 shows schematic layout of this system. The BPM#6 has been installed at downstream of first 45 degree bending magnet in

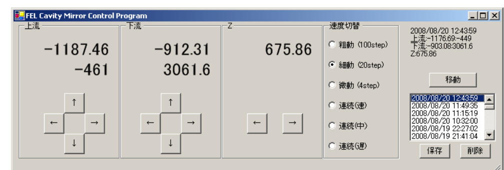

Figure 3: Operator Console of the Mirror Control System

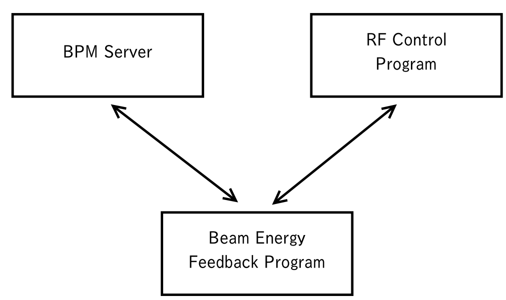

Figure 4: Schematic layout of the beam energy feedback system

the 90 degree bending section. Beam energy fluctuation is calculatable from beam position change at this point. The beam positions measured by BPM are distributed by the BPM server through Local Area Network (LAN).

The operators are able to control the phase shifters and the attenuators by RF control program. RF control program has a server socket and can control RF phase from an external program remotely. The beam energy feedback program is a PID control program which it uses a beam position by BPM#6 as a monitor and uses the phase converter by which it is called “ACC#3 PS” to it as an actuator. When the operators push the ”Energy Lock” button on the window of RF control program, a UDP packet is sent to the feedback program and begins energy feedback.

At first, this program acquires a beam position at BPM#6 from the BPM server, and records this value as a desired value. Second, this program acquires the beam position from BPM#6, and it calculates change of beam energy using difference from desired position. Third, the moving average of change of beam energy is calculated and the phase shifter is controlled to suppress beam energy fluctuation. Moreover, it returns to the second process and beam energy is kept. This loop is processed until it receives an end command from the RF control program.

Figure 5 shows the variation of the beam energy. The red line in figure 5 is fluctuation of the beam energy when the feedback program was stopped, and the green line is variation of the beam energy when feedback was turned on. Figure 6 shows the histogram of the beam energy variation when the feedback program operates. And Figure 8 shows the histogram of the beam energy variation when the feedback program was stopped. Fig. 7 shows that change of beam energy is controlled to 0.1% or less in the time of feedback program operation.

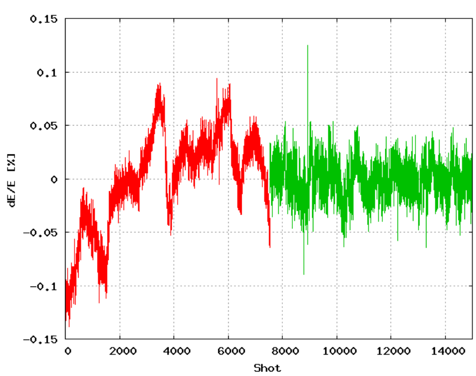

Figure 5: Variation of beam energy

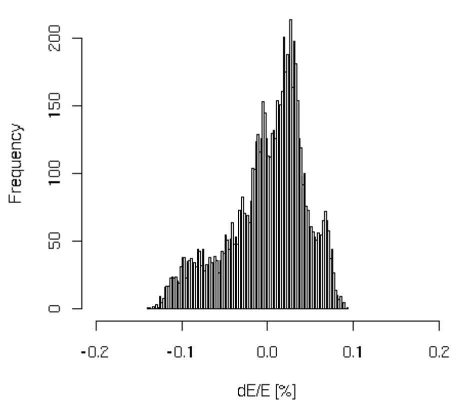

Figure 6: Variation of beam energy in the feedback program stopping

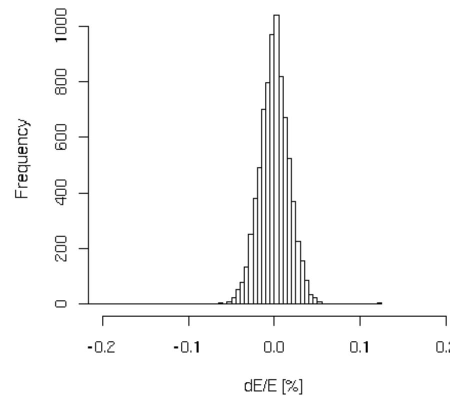

Figure 7: Variation of beam energy in the feedback program running

CONCLUSION

The FEL operation support system was developed to reduce operator's work load. This system consist of the resonator mirror control system and the beam energy feedback system. The resonator mirror control program has a capability of reproducing of position of the mirrors. When the operators use this function, they are able to generate FEL easily.

The beam energy feedback program is a PID control program. The beam energy feedback program has operated to suppress the pulse-to-pulse beam energy fluctuation to less than 0.1%.

REFERENCES

[1] K.Hayakawa, et al, "The LEBRA 125MeV electron linac for FEL and PXR generation", LINAC'04, Luebec, August 2004, MOP25, p. 90, http://www.JACoW.org.

[2] K.Ishiwata, et al, "Development of Strip-Line Type Beam Position Monitor", LINAC'02, Gyeongju, August 2002, MO460, p. 178, http://www.JACoW.org.