MAIN CONTROL SYSTEM OF THE LINEAR ACCELERATOR FOR THE HUST THz-FEL*

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Abstract

A free-electron laser terahertz source (THz-FEL) with a table-top scale is constructed in Huazhong University of Science & Technology. The whole facility is under joint-debugging currently, and main measured parameters have already matched with design targets. This paper describes the main control system of the Linac-based injector, especially auto-matching and auto-commissioning modules. The former occurs at the beginning of daily operation, which contains one key pre-heating and searching the best electric parameters and RF parameters automatically based on last operation status. The later applies in beam commissioning for both Linac and transport line combining with beam diagnostic system, which could save operation time and improve commissioning efficiency. Moreover, real-time monitoring and controlling for water-cooling and vacuum states are inserted in the main control system to protect the accelerator.

INTRODUCTION

In order to promote the progress of miniaturization and application of THz technique, a free-electron laser terahertz radiation source (THz-FEL) with a table-top scale is constructed in Huazhong University of Science & Technology. The main parameters of the LINAC are given by Table 1 respectively [1].

Table 1: Main Specifications

Parameter	Unit	Value
Energy	MeV	4-15
Energy spread	%	0.2-0.5
RF frequency	MHz	2856
Width	us	1-5(Macro pulse)
	ps	1-10(Micro pulse)
Nor. emittance	mm mrad	<15

The facility is mainly composed of a novel EC-ITC RF gun, constant gradient travelling wave structure with a collinear absorbing load and an input coupler which makes the electric field symmetry, and its focusing coil, beam diagnostics system, microwave power system, vacuum system, control system and so on [1]. Through the corporation of EC-ITC RF gun with two independent cavities and focusing system consists of short magnetic and solenoids [2], the Linac-based injector provides high quality electron bunches for the whole facility.

To ensure reliability and high efficiency of beam commissioning, user-friendly control system with close-loop feedback and on-line monitoring must be established for daily debugging of THz-FEL source. Based on distributed control scheme, the main control system consists of beam diagnostic system, EC-ITC gun control system and parameter monitor system. The subsystems are programmed for user-oriented high-level operational applications in the development environment of Labview. Meanwhile, the subsystems employs the EPICS (experimental physics and industrial control system) toolkit for the low-level mechanism, which makes communications between subsystems more convenient. The subsystems receive coordinated control commands, in order to perform two major functions: equipment monitoring and debugging parameter optimizing. On the other side, they are implemented by divided into two working modules: auto-matching and auto-commissioning modules. Auto-matching module performs the function of pre-heating and searching the best electric parameters and RF parameters automatically based on last operation status. Auto-commissioning module is designed to save operation time and improve commissioning efficiency, based on the fixed commissioning procedure.

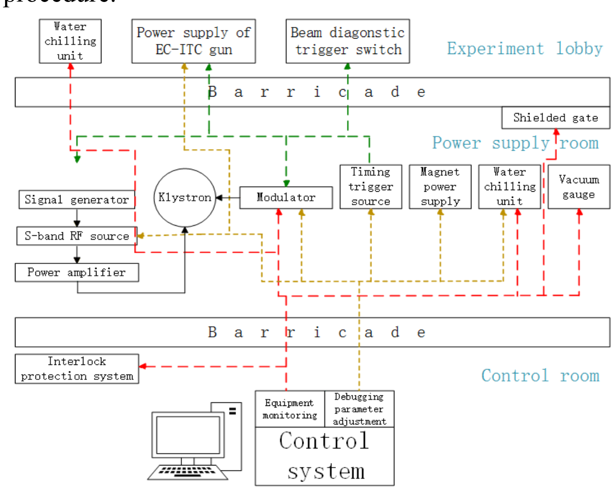

Figure 1: Overall control sketch of the HUST THz-FEL Linac.

SUBSYSTEMS

Beam Diagnostic System

Electron beam measurement mainly involves emittance, energy spread, beam spot size and intensity. To detect these beam parameters and make the full use of the facility that already exists [3], beam diagnostic system contains one Flag with a fluorescent, two Torrids, an energy analysis system, two fluorescent targets, and three CCD cameras [4].

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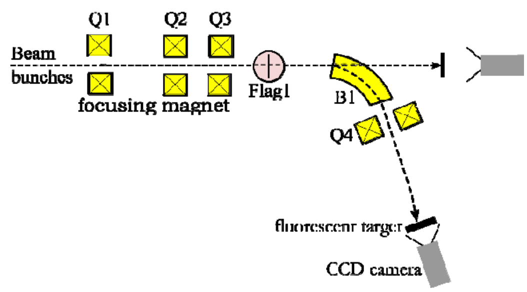

Figure 2: Layout of devices used in the beam diagnostic system.

Therefore, beam diagnostic system mainly adjusts the parameters of the following physical devices to get the best beam quality:

1. Microwave signal generator.
2. Modulator and klystron.
3. Timing trigger source.
4. Magnet power supplier.
5. CCD camera.
6. Stepper motors.

For the sake of abundant tests and experiment environment, beam diagnostic system adjusts the beam spot shape to get best working condition via following simplified ways:

1. To adjust power fed-in phase of the second standing-wave cavity of EC-ITC RF gun and the linear accelerator.
2. To adjust electric current of four focusing power supply and analysis magnet power supply.
3. To set effluent temperature of water cooling chiller and frequency of S-band RF source.

EC-ITC Gun Control System

Since the EC-ITC gun plays an important role in transferring DC beam to short bunches then determines beam properties of the LINAC, its control system is fundamental. Considering the operation of EC-ITC gun is independent from other facilities, its control system is programmed individually to enhance performance of the whole system. Through the control of power supply switch, the set of filament current and negative high voltage and monitoring of operating state of the cavity, electric bunches of high performance can be mastered precisely.

Parameter Monitor System

Vacuum gauge and water cooling unit are necessary physical devices of accelerator. The vacuum of the whole system must be kept under a stable level and the effluent temperature of water cooling chiller ought to be constant. As a result, these parameters are collected in real-time and displayed on parameter monitor system. If any of them exceeds the threshold level, the system will send a warning to the operator in charge and start the interlock protection devices for protection.

Epics

For the sake of advanced controlling and data communications, these subsystems must be integrated. EPICS is a net-based communication protocol, spreading variables on servers and accessing them by clients. CA Lab is a high performance interface between Labview and EPICS. Any VI can use calabGet.vi to read and calabPut.vi to write variables. If control computers are within the same local area network, subsystems can swap data throughout the use of CA Lab. As a result, there is no need of great changes of the main control system.

WORKING MODULES

Auto-Matching Module

In order to improve commissioning efficiency and save human resources, two working modules are designed to simplify daily debugging mission, realized by programming logic diagram of parallel operation.

Previous pre-heating procedure is tedious and fixed, including initiation of water chilling unit, removal of residual magnetism of the magnets and activation of modulator and EC-ITC gun. To get rid of such basic work, Auto-matching module is designed to implement pre-heating process automatically and evaluate the repeatability of the whole machine. The specific description of pre-heating process is displayed as figure 3. Once the pre-heating process is done, subsystems will load the best electric parameters and RF parameters based on last operation status, which is recorded in database on the last operation status. If the results are beyond acceptable level, beam diagnostic system will send a warning.

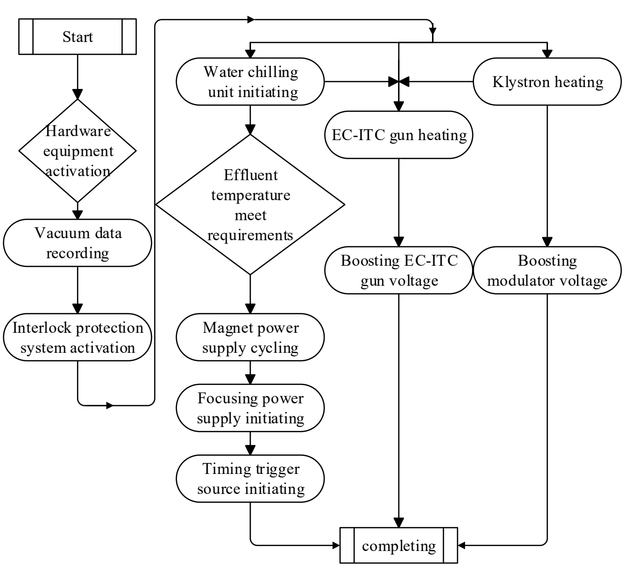

Figure 3: Flow diagram of the pre-heating process.

Auto-Commissioning Module

As stated above, process of beam commissioning is relatively fixed. Therefore, it can be programmed by bottom algorithm to enhance commissioning efficiency as figure 4. At the same time, auto-measurement of electric beam parameters is added into this module, including emittance, beam energy and energy spread. For example, once the set of current values of selected focusing magnet

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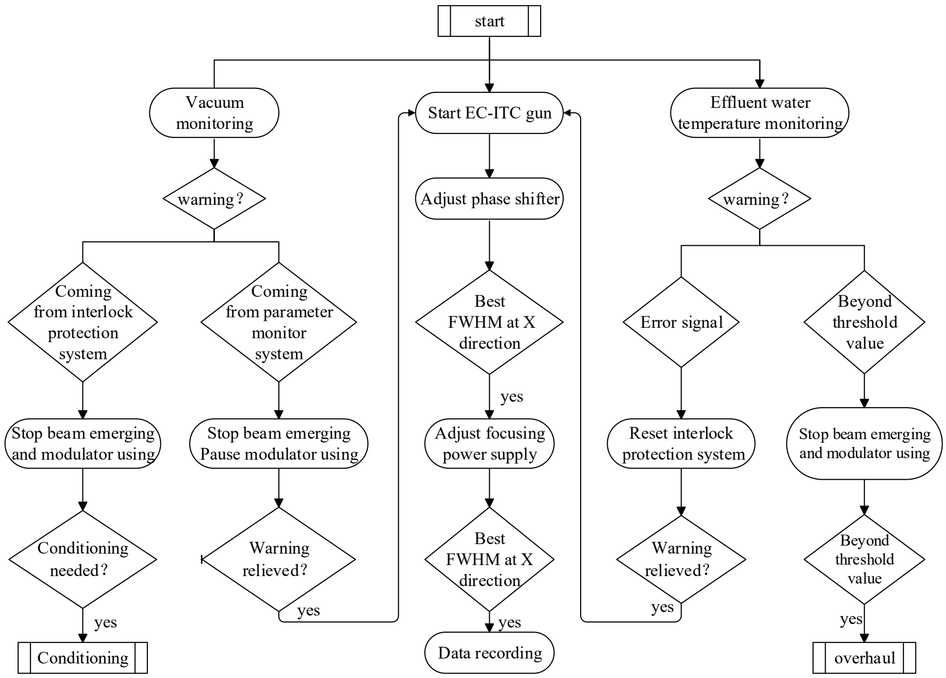

Figure 4: Flow diagram of the auto-commissioning process.

is completed, this module will calculate the emittance and plot trends of the FWHM at horizontal direction automatically.

Since the EC-ITC gun is a narrow-band radio frequency resonant structure, its resonance frequency is sensitive to structural distortion, which is induced by operating temperature. The affection can be concluded as follows:

$$\frac{\partial f}{\partial T} = -48kHz / °C \qquad (1)$$

Under the procedure of beam commissioning, FWHM at horizontal direction intuitively reflects the quality of beam spot. Therefore, the auto adjustment of effluent temperature of water cooling chiller is added. As a result, self-driven changes of effluent temperature within the set scope, can maintain FWHM at horizontal direction at an optimum level.

CONCLUSION

After long-time operation of debugging, the control system proves to be reliable and meets the requirements of electric beam monitoring and parameter measurement, leading to credible examination of pre-supposed physic targets. However, there are some extra adjustments to be taken into urgent implementation, such as establishing an instant access of historic database and enhancing the universality of the system. Moreover, further experiments ought to be taken, so that more precise auto-commissioning module can be established.

REFERENCES

[1] Y. J. Pei *et al.*, "Design of 14 MeV Linac for THz source based FEL", in *Proc. 4th Int. Particle Accelerator Conf. (IPAC'13),* Shanghai, China, June 2013, paper WEPWA023, pp. 2181-2183.

[2] Tong-Ning Hu *et al.*, "Physical design of FEL injector based on the performance-enhanced EC-ITC RF gun", *Chinese physics C*, vol. 38.1, p. 018101, 2014.

[3] T. N. Hu *et al.*, "Beam diagnostic of the LINAC for the compact high-performance THz-FEL", in *Proc. 6th Int. Particle Accelerator Conf. (IPAC'15),* Richmond, VA, USA, May 2015, paper MOPTY023, pp. 987-989.

[4] Y. J. Pei *et al.*, "R & D on a compact EC-ITC RF gun for FEL", in *Proc. 1st Int. Particle Accelerator Conf. (IPAC'10),* Kyoto, Japan, May 2010, paper TUPEC013, pp. 1737-1739.