COMMISSIONING OF THE COMPACT 14MEV LINAC FOR AN FEL-BASED THZ SOURCE

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Abstract

This paper will describe the commissioning of a compact LINAC of 14MeV which is used for FEL to produce THz radiation through 30µm to 300µm. Main design parameters are given in this paper. The compact LINAC of 14MeV was composed of novel EC-ITC-RF gun, constant gradient travelling wave accelerator with a collinear absorbing load, focusing system, RF power system, beam diagnostic system, vacuum system, control system and so on. The LINAC was installed on November of 2014. Now the LINAC has been operating and commissioning for THz radiation test. So far, the facility is running well and the main beam parameters tested are coincident with design parameters of the LINAC.

GENERAL DESCRIPTION OF THE FACILITY

The facility is designed for producing a THz radiation with wavelength of 30um~300um. In order to satisfy the strict requirements of high performance of electron beam for THz-FEL and obtain a more compact layout for the facility, HUST (Huazhong University of Science and Technology) and NSRL (National Synchrotron radiation Laboratory)/USTC (University of Science and Technology of China) are cooperating to do R &D work. The facility is main composed of a novel EC-ITC RF gun, transverse focusing system, constant gradient travelling wave LINAC with an input coupler offset and a collinear absorbing load to improve the electric field to be symmetry. Besides, other inevitable sub-systems are established either, such as beam diagnostics system, microwave power system, vacuum system, control system and so on. The layout of the facility is shown as Figure 1 [1,2,3] .

Table 1: Measuring Parameters of the LINAC

parameter	unit	value
energy	MeV	13.58
Current	A	0.665 (macro pulse) 29~47 (micro pulse)
Width of beam	us ps	1~2 (macro pulse) 5~8 (micro pulse)
Repeat frequency	pps	2-10
Charge per pulse	pC	~230
Energy spread	%	0.332
Nor. emittance	mm mrad	24.1
Input power	MW	24

The building for the machine was finished in July 2014 and all parts of the LINAC were tested. In August of 2014, we started to install the machine and got the first beam from the LINAC, which energy was of 13.4MeV, macro pulse current was of 1.1A. After that, we started to commission the LINAC, improve diagnostic system and test its parameters in detail. The parameters of the LINAC we've measured are listed in Table 1.

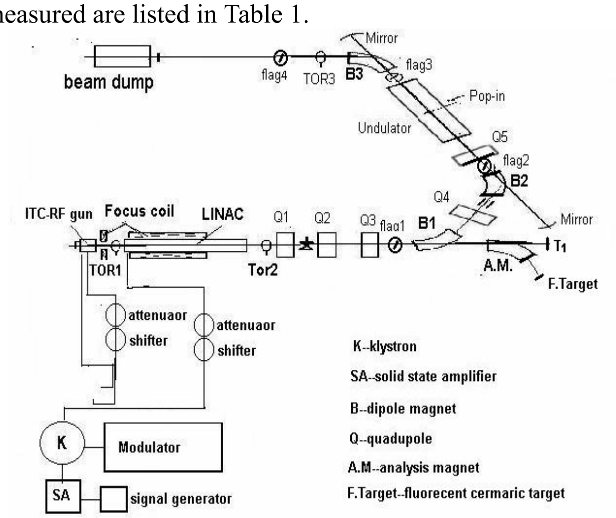

Figure 1: Layout of the facility.

BEAM PARAMETER MEASUREMENT

Energy and Energy Spread Measurement

We employ an analysis magnet, Flag1 and a fluorescent target (F. Target) located at the end of the vacuum chamber (see Figure 1) to measure the energy and the energy spread. The transmission matrix of the energy analysis system can be expressed by Eq. (1),

$$\begin{pmatrix} x_1 \\ x_1' \\ (\frac{\Delta p}{p})_1 \end{pmatrix} = \begin{pmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{pmatrix} \begin{pmatrix} x_0 \\ x_0' \\ (\frac{\Delta p}{p})_0 \end{pmatrix} \quad (1)$$

In the system, m_{12} is designed to 0, and m_{11} should be designed close to 0. Then, by observe the beam spot on Flag1 and F. Target, beam radii at these two positions can be obtained, so that the energy is easy to be obtained by means of magnet calibration and the energy spread can be calculated by Eq. (2),

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$$\frac{\Delta p}{p} = \sqrt{\sigma_1^2 - (m_{11} \cdot \sigma_0)^2} \,/\, m_{13} \tag{2}$$

Emittance Measurement of the Electron Beam

In order to measuring the beam emittance in site, we adopt a quadrupole scanning technique [4]. Since the beam matrix at Target T_1 can be written as Σ_1, and the beam matrix at the entrance of the Quadrupole chosen to be scanned is Σ_0. So the two beam matrixes can be connected by the transmission matrix of the Quadrupole M, $\Sigma_1 = M\Sigma_0 M'$, If we change the exciting current of the Quadrupole three times, three different beam spot sizes $\sigma_{11}^{(1)}, \sigma_{11}^{(2)}, \sigma_{11}^{(3)}$ will be obtained on Target T_1 by CCD3, then we can obtain the following equation set,

$$\begin{pmatrix} \sigma_{11}^{(1)} \\ \sigma_{11}^{(2)} \\ \sigma_{11}^{(3)} \end{pmatrix} = \begin{pmatrix} m_{11}^2(1) & 2m_{11}(1)m_{12}(1) & m_{12}^2(1) \\ m_{11}^2(2) & 2m_{11}(2)m_{12}(2) & m_{12}^2(2) \\ m_{11}^2(3) & 2m_{11}(3)m_{12}(3) & m_{12}^2(3) \end{pmatrix} \begin{pmatrix} \sigma_{11}^0 \\ \sigma_{12}^0 \\ \sigma_{22}^0 \end{pmatrix} \tag{3}$$

By solving above equation set, the normalized emittance can be determined as the following,

$$\varepsilon_x = \beta\gamma\sqrt{\sigma_{11}^0 \sigma_{22}^0 - \sigma_{12}^{0\,2}} \tag{4}$$

Where, β and γ are the relative velocity and the relativity factor, respectively.

Beam Bunch Length Measurement

In order to measure the beam length, we adopt a method which is by means of a relation of electron energy and its phase in the LINAC. When beam locates at the "0" phase, the energy will be maximum and the energy spread will change less. If the beam located at the "φ" phase which is different from the "0", their energy and energy spread will change. And the changes depend on beam length and phase, so measuring these energy, energy spread and their phase, we can get micro-pulse width.

COMMISSIONING OF THE FACILITY

Before commissioning the LINAC, the vacuum system of the facility must be ready with the vacuum be of 2×10^{-6} Pa. We tested the RF power system which including a klystron of E37308 and its Modulator, microwave exciting system, microwave power measuring equipment, and so on. All of these were satisfied design requirements, then conditioning of the waveguide system, RF gun and LINAC, and activating of the DC electron gun were started.

First Beam Performance of the LINAC

In Nov. 2014, we start to commission the LINAC. After setting all parameters to be design values for the LINAC, the electron beam past through the whole LINAC, and beam parameters got was: beam energy of 13.0, macro pulse beam current of 0.744A, beam waveform (green line) is shown as Figure 2.

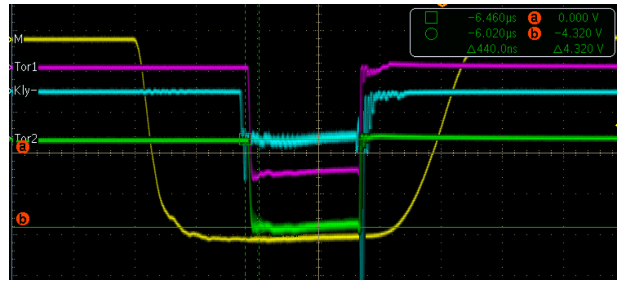

Figure. 2: Waveform: high voltage of Modulator(yellow); RF power(blue); beam current of EC-ITC RF gun(Violet); beam current of LINAC(green).

Improving the Facility

When we tried to run the machine that it was difficult to get stable beam parameters. Because some equipments did not run well, such as modulator, microwave exciting system, DC power supplies, timing system, CCD system and so on. It took us about one year to improve the stability of high voltage of the modulator so that its pulse top ripple was reduced down to 0.3% (including the fall time in the pulse top). DC power supplies were improved also, and employed a shielding box to protect the camera of the CCD from the strong radiation, so that the CCD system can run longer time enough.

When we measured the emittance using a quadrupole scanning way that the centre position of the beam spot in T_1 will move, that means the beam past through the quadupole was not at its magnetic centre. So we must re-align the quadrupoles. The quadrupoles (Q_1, Q_2, Q_3) were aligned using BBA. After that, the position of the beam spot was stable at T_1, when change exciting current for quadrupole.

Results Measured of Beam Parameters

As mentioned above, we employ a magnet analysis system to measure the beam energy and its energy spread. We adjust all parameters carefully, such as feed power into the first cavity, the second cavity, and the phase between them, feed power and its phase into LINAC, focusing magnetic field and so on, so that the spot in the energy spectrum target (F. Target) to be minimum. The photos of the spot in Flag 1 and F. Target are showed in Figure 3.

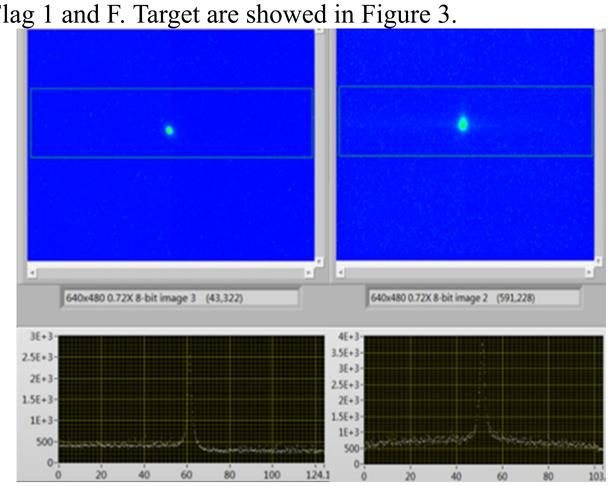

Figure 3: Beam spot on Flag1 and F. Target.

The normal emittance measurement is using a quadrupole scanning way, which is by means of changing the exciting current in a quadrupole to get different beam spot sizes in T_1, then these data will give a fit curve shown as Figure 4.

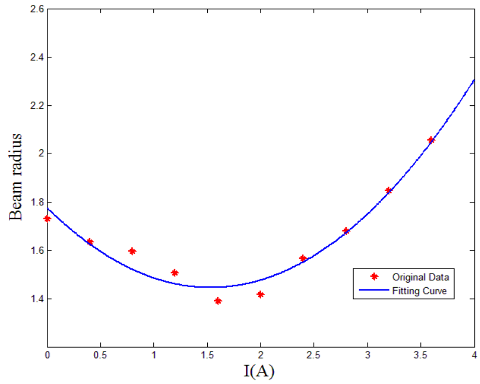

Figure 4: Fitting curve for measuring emittance.

Beam bunch length measurement is by employing a phase way which is based on the relation between beam energy and phase in the LINAC (Figure 5) as mentioned above.

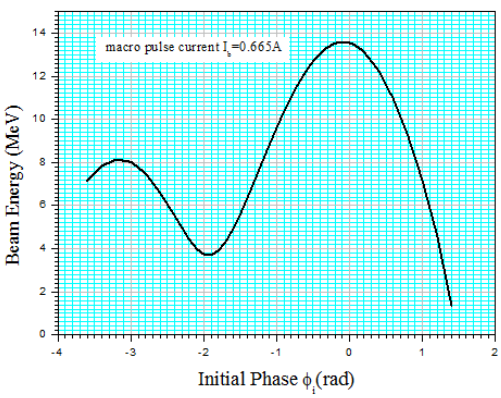

Figure 5: Beam energy vs. initial phase

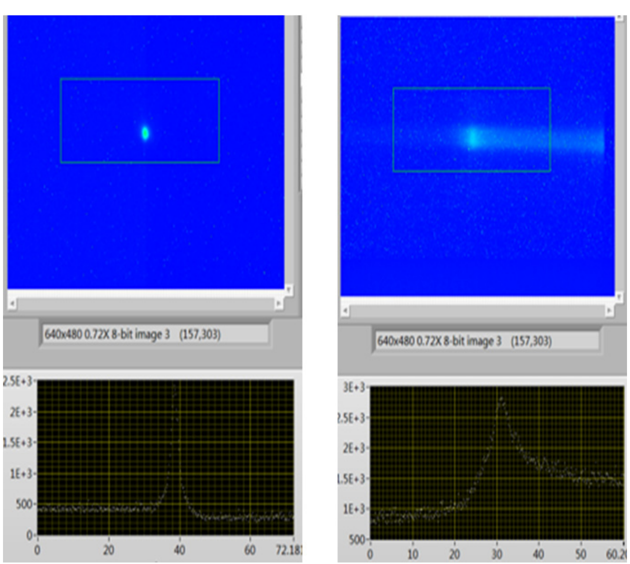

Figure 6: Beam spots on the F. Target in different phases.

According to the spot sizes given in Figure 6, we can calculate the beam length by means of the relation between energy and phase as Figure 5 showed will be 8ps.

As for macro pulse beam current is easy to using a fast current transformer (Toriod) to measure it. In our case, it is 665mA, and beam width is 1us~2us

In a word, so far the running parameters measured is showed as in table 1. The RF power fed into first cavity, second cavity are 0.59MW, 2.9MW respectively, and the phase different between them is 76.77°. The RF power fed into the LINAC is 11.47MW.

FUTURE PLAN

The LINAC is designed for producing a THz radiation (as a THz source), so the beam performance will be important, now the typical beam parameters of the LINAC can satisfy the main requirements. We will commissioning the LINAC so that the beam pass through an undulator and let the beam will be located right position in the whole optic resonance and undulator path. On the other hand, the running parameters of the LINAC will be improved that the macro pulse width of the beam must increase to 4us, repeating frequency of the macro pulse of the beam must reach 50pps and so on.

Recently, some equipments for measuring THz radiation characteristics, such as THz radiation spectrum, radiation power (pulse and average etc.) have been installed near the end of the facility. We hope that preliminary parameters of the THz radiation will be got at the end of this year.

Next year, we plan to complete the project of THz source and to open the facility to users.

CONCLUSIONS

The results measured show that the LINAC which is composed of a novel EC-ITC RF gun and constant gradient travelling wave structure, will run well for the THz source. But maybe, it will meet a trouble to increase the repeating frequency. On other hand, when the LINAC run at low energy level, the beam parameters will be not so good enough. we plan to do some R & D to overcome these problems.

REFERENCES

[1] Y.J. Pei, et al., "R & D on a compact EC-ITC RF gun for FEL", Proceedings of IPAC'10, Kyoto, Japan. 1737-1739 (2010).

[2] T.N. Hu, Q.S. Chen, Y.J. Pei, et al., "Physical design of FEL injector based on performance enhanced EC-ITC RF gun", Chinese Physics C, 38, 018101 (2014).

[3] Y.J. Pei, et al., "Design of 14MeV Linac for THz source based FEL", Proceedings of IPAC2013, Shanghai, China. 2181-2183 (2013).

[4] T.N. Hu, et al., "Beam diagnostic of the Linac for the compact high-performance THz-FEL", Proceedings of the IPAC2015, VA, USA, 987-989 (2015).

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