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COMMISSIONING OF A COMPACT THz SOURCE BASED ON FEL*

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Abstract

The layout of the THz source based on FEL was described in this paper. The THz source was based on a FEL which was composed of a compact 8-14MeV LINAC, undulator, optical resonance, THz wave measurement system and so on. The facility was designed in 2013 and the typical running parameter got in 2017 were as the following: energy is of 12.7MeV, energy spread is of 0.3%, macro-pulse is of 4 µs, pulse length of micro-pulse is of 6ps, emittance is of 24 mm.mrad. After that the machine was commissioning for production THz radiation. In November 2018, the THz wave was test and got THz wave signal, the spectrum was also got. This year, we plan to measure the output power of the THz source.

COMMISSIONING OF THE FACILITY

The THz source is a compact FEL facility operating wavelength on THz range. The facility is main composed of an electron LINAC, an undulator and an optical resonance cavities etc. The layout of the facility is shown as Fig. 1 [1]. The main running parameters of the LINAC are shown in Table 1.

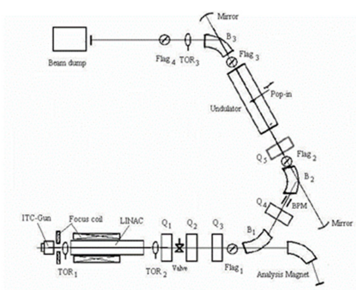

Figure 1: Layout of facility.

Table 1: Main Running Parameters of the LINAC

Parameter	Unit	Value
Energy	MeV	9.7-13.5
Beam Current	A	0.5-0.74(macro) 30~40 (micro)
Width of Beam Pulse	µs ps	1~4.2 (macro) 1~10 (micro)
Repeat Frequency	pps	2-10
Charge per Pulse	pC	>200
Energy Spread	%	0.26-0.4
Nor. Emittance	µm	<27
RF Frequency	MHz	2856
Input Power	MW	20

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Linac

The electron LINAC consists of a novel EC-ITC RF gun, constant gradient travelling wave structure accelerating tube, focusing coil, beam diagnostics system, microwave power system, vacuum system, and control system and so on.

EC-ITC RF gun is employ an ITC RF cavities which input power and phase can to be adjusted [2] independently, and a thermal cathode diode gun of 15 kV which is located out the first RF cavity, its anode voltage can be adjust also. The diode gun can provide high electron beam current of 4 A. The EC-ITC RF gun is very compact which size is of 18 cm and the gun is running well now.

In order to reduce LINAC size, a constant gradient, travelling wave, mode and collinear load structure have be employed [3], which made the linac's output coupler to be removed so that the LINAC's radial size and the focusing coil size is reduced. The input coupler of the LINAC is an off-axial structure so that the electric field in the coupler will be symmetry near axial of the LINAC. Figure 2 showed the electric field distribution in the input coupler. According to simulation, we choose off-axial distance is of 1.35 mm.

In order to restrain the emmitance growing and focusing the beam, one short magnetic lens and one set solenoid coil have be adopted, their magnetic field distribution were showed as Fig. 3 [4].

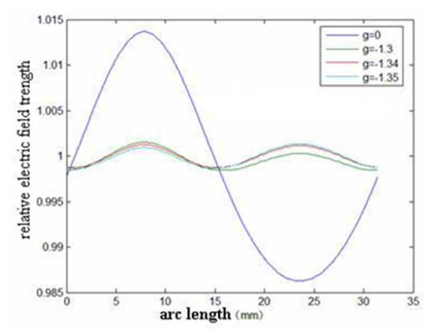

Figure 2: Field distribution in coupler.

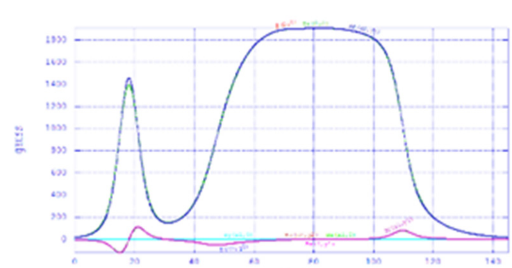

Figure 3: Magnetic distribution.

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Beam Transport Line

The beam parameters from the LINAC must match with undulator and to be achromatic, so two bend magnets and five quadrupoles are adopted in the transport line. Their parameters are chosen as shown in Table 2, and bending angle of bend magnet is of 60°.

Table 2: Main Parameters of Quadrupoles

Quadrupoles	K [T/m]
Q1	2.492
Q2	-2.165
Q3	3.590
Q4	3.229
Q5	1.608

Undulator

The linear polarization undulator with K=1.0-1.25 has been designed and manufactured by Kyma s.r.l., by using a pure permanent magnet scheme as shown in Fig. 4. The undulator's main parameter is listed in Table 3.

Figure 4: Photo of the pure pemanented undulator.

Table 3: Main Parameters of the Undulator [5]

Parameter	Unit	Value
Undulator Period	mm	32
Period Number N		30
K		1.0-1.25
Gap	mm	16-28
rms peak error	%	≤0.5
rms period error	%	≤0.2
rms phase error		≤3°
First Integral (normal/skew)	T*m	≤1.0x10^{-5}
Second Integral (normal/skew)	T*m	≤1.0x10^{-5}

Optical Resonant Cavities

The THz source based on FEL is an oscillator with wavelength 50-100 μm, so an optical resonator was employed, which is composed of two reflection mirror, and their layout is shown in Fig. 5, its main parameters is listed in Table 4.

Table 4: Main Parameters of the Optical Resonance System

Parameter	Unit	Value
Ditance between two mirror	m	2.992
DOC of resonator mirror	m	1.548
Diameter of output coupled hole	mm	1
Reflection coefficient of mirror		≥0.98

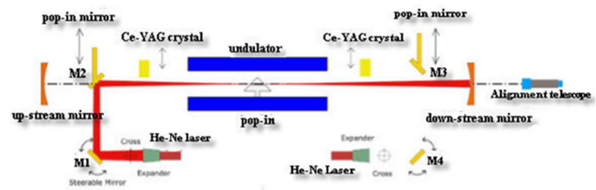

Figure 5: Layout of optical resonant cavity system.

COMMISSIONING OF THE FACILITY

Installing and Test

In 2014, the machine was installed, in the end of this year the machine was got first electron beam from the LINAC. After that, beam parameters of the LINAC were measured and all of the parameters measured shown that the LINAC were running well. In 2016 the undulator and optical resonant cavities system were installed. In June of 2016, testing the undulator and optical resonant cavities system, which parameters measured have been reached design requirements, and pass through the acceptance check of experts from universities and institutes in China. Fig. 6 showed the photo of the THz source facility.

Figure 6: Photo of the THz source based on FEL.

THz Radiation and Test

In 2017, the facility has been running for measuring the THz radiation, the layout of the measuring system is shown

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in Fig. 7. The main test equipment were Golay cell detector, DTGS-PE detector and Bolometer detector. While the test work was going on, we found that the window is opacification for the THz wave, there were so much noise around the test equipment, and electron beam position was changed etc. After changing THz window, making some shielding and doing BBA alignment, the test was going.

Test Results

Main test results were shown in Fig. 8-11. Fig. 8 showed the waveform test by using Golay cell detector located out near the port 3(see Fig. 7). Fig. 9 showed the waveform tested by using Bolometer detector located out port of the Michelson interferometer (see Fig. 7). Fig. 10 and Fig. 11 were the spectrum of THz radiation, respectively corresponding to beam energy of 10.85 MeV and 12.711 MeV, which the signal were from the Bolometer detector.

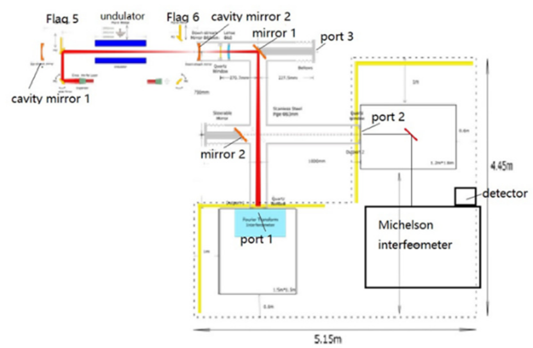

Figure 7: The layout of measuring system for testing the THz radiation.

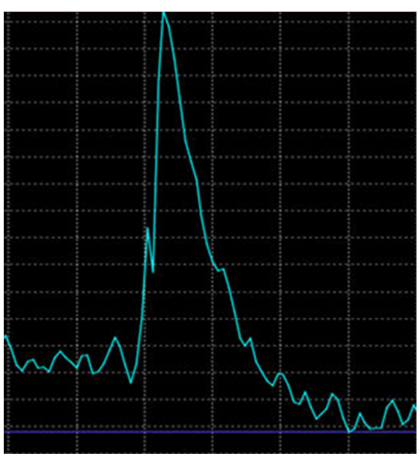

Figure 8: Output waveform from Golay.

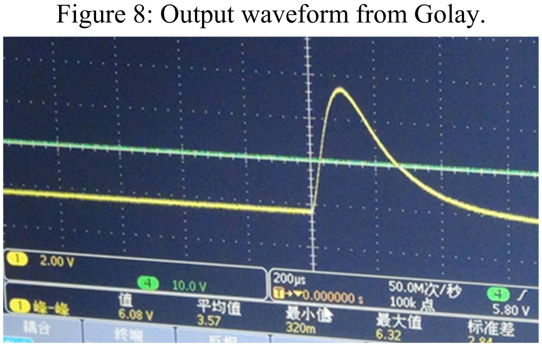

Figure 9: Output waveform from the Bolometer.

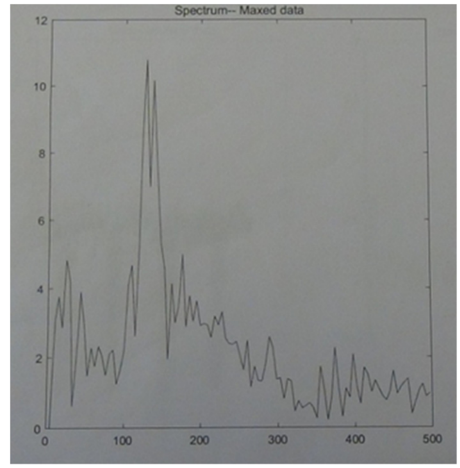

Figure 10: Spectrum at energy of 10.851 MeV.

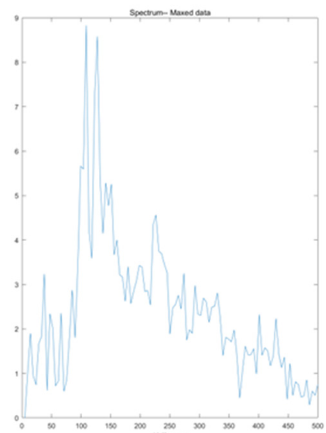

Figure 11: Spectrum at energy of 12.732 MeV.

CONCLUSION

Some results measured as mentioned above were a preliminary study, but it have showed that the machine was running well. We plan doing some improvements so that the machine can prove THz radiation for users.

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