THE TERAHERTZ FEL FACILITY PROJECT AT CAEP

X. Yang, M. Li, Z. Xu, Institute of Applied Electronics, CAEP, China
X. Shu,Y. Dou, Institute of Applied Physics and Computation Mathematics, China
X. Lu, Peking University, China
W. Huang, Tsinghua University, China

Abstract

To meet the requirement of material and biomedicine study, a Terahertz FEL user facility project was proposed by China Academy of Engineering Physics(CAEP). At present the project has been approved and the facility will be constructed within 5years. The facility will operate in the quasi CW mode and the average power is about 10W . The wavelength of the light can be adjusted between 100μm/3THz to 300μm/1THz according to the user needed by changing the electron energy and the magnetic field of the wiggler. The facility mainly consists of the electron source, the main accelerating structure, the hybrid wiggler, the optical oscillator cavity, the THz-ray transmission system and the detector. In order to achieve the high brightness beam, the photocathode DC gun will be used as the electron source. The electron will obtain the energy by passing through a superconducting accelerator, the electron energy after the accelerator is about 8MeV, which is suitable to obtain the terahertz light. The facility will be a useful tool to the science.

INTRODUCTION

FEL-THz is one important kind of THz source which has the merits of high power, wide tunable spectral region[1,2,3]. The goal of the THz radiation frequency spans 1THz to 3THz which is absence of source and other kind of THz sources are not good at at the same time. The use of superconductive rf-linac cavities enables quasi-cw operation with the associated higher average THz radiation power level of ten Watt. The facility will operate at up to 8 MeV and with up to 5 mA average current at a 54.16 MHz pulse repetition rate. The length of the resonator is 2.769m, and the THz ray will output through the downstream mirror with an outcoupling hole in the center. A waveguide will be installed to fit the optical resonator mode into the wiggler gap. The cross section of the waveguide is rectangular with 30mmx14mm. The waveguide spans from the upstream mirror to the downstream mirror. The sketch map is showed in Fig. 1. The people from the Institute of Applied Physics and Computation Mathematics, Peking University, Tsinghua University and Institute of Applied Electronics will take part in the project.

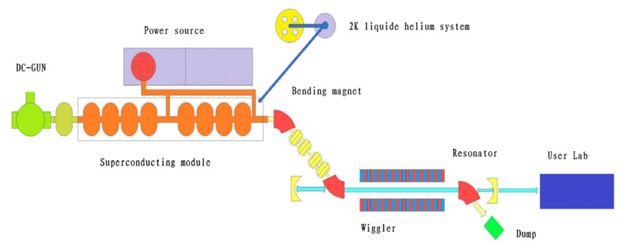

Figure 1: Layout of the FEL-THz facility.

THE SIMULATION OF THE OSCILLATOR

The normal parameters of the facility are listed in Table 1 which is used as the input parameters for the simulation.

Table 1: Parameters used for the Simulations

ELECTRON BEAM	
Energy	7.5MeV
Peak current	10A
Micro bunch	10ps
Normalized Emittance	10πmm mrad
Energy Spread (FWHM)	0.75%
Repetition rate	54.17MHz
WIGGLER	
Amplitude	3300Gs
Period	38mm
Length	42 periods/1.6 m
Optical	
Wavelength	160.3μm
Cavity length	2.769m
Mirror curvature	1.85m
wave-guide Cross-section	30mm×14mm

The simulation of oscillator cavity was done by a three dimension code[4], it includes the gain according the current, the energy spread and the emittance, the light power rising progress in the cavity, the optical loss, the coupling efficiency, the detuning, the sensitivity to vibration and misalignment etc. The simulation results are shown in Figs. 2~3. The calculated THz radiation power according different frequency is listed in Table 2.

Copyright © 2012 by the respective authors

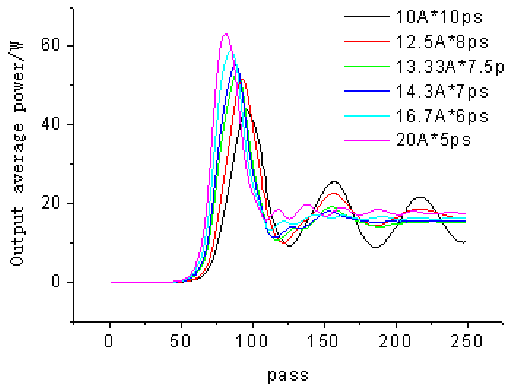

Figure 2: Output average power as a function of electron current.

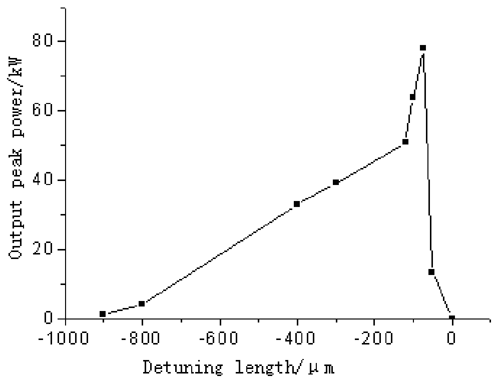

Figure 3: Output peak power as a function of detuning length.

Table 2: Calculated Power with Different Frequency

Frequency/THz	wiggler/T	Electron energy/MeV	Output power/W
1	0.49	6	10.6
1.2	0.475	6.5	10.4
1.4	0.414	6.5	29.9
1.6	0.468	7.5	24.5
1.8	0.42	7.5	20.6
2	0.378	7.5	54.5
2.2	0.35	7.6	43.2
2.4	0.315	7.6	73.5
2.6	0.283	7.6	101.4
2.8	0.25	7.6	67.0
3	0.22	7.6	74.1

ELECTRON LINAC

The electron linac mainly includes the electron source, the bunch compressor, the accelerating module, the beam transport system and the beam diagnostic system. In order to obtain the high brightness electron beam, we are planning to develop a NEA-GaAs photocathode DC-gun as the electron source. The design value of the DC voltage is about 320kV and the electric field is about 4MV/m. It delivers pulses with a bunch charge up to 100 pC at 54.16 MHz repetition rate and about 20ps length. The transverse emittance in this case is about 5πmm mrad. At present, a DC-GUN test facility has built in our institute as shown in Fig. 4. The cathode-driving laser system includes the mode-locked oscillator(from Time-Bandwidth), diode-pumped amplifier and second harmonic generator.The average power of the laser is 5W. The laser has the macro-pulse operating mode which is used for the beam commissioning. The frequency of the macro-pulse is up to 20Hz, and the length is 20μs. In order to obtain high electron current, pulse compression down to 5~10 ps will be done by a RF bunch compressor operating at 1.3 GHz.

Figure 4: DC-GUN test facility.

A superconducting rf linac module operating at 1.3 GHz is used as the main accelerator. The accelerator comprises two 4cell cavities and will operate at 10MV/m, and the electron energy is up to 8MeV. The cavities are kept at 2K using superfluid helium delivered by a commercial helium liquefier and the cavity frequency can be regulated on-line. The liquid helium consumption is calculated and it is about 50W when the accelerating field is 12MV/m. The superconducting module is shown in Fig. 5.

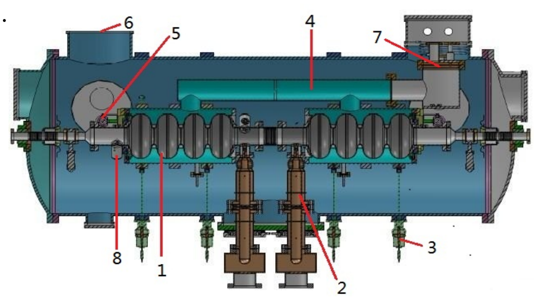

Figure 5: The superconducting module.1 – 4cell cavity , 2 – microwave coupler , 3 – knighthead, 4 – 2K shield, 5 – tuning system, 6 – inlet port of liquid nitrogen, 7 – inlet port of liquid helium, 8 – HOM coupler.

To operate the FEL requires high quality electron beams with small transverse and longitudinal emittance. The beam dynamics is calculated using the PARMELA code. The transit efficiency of the beam is almost 100% which is needed for the high average power electron beam. The beam envelope through transport system is shown in Fig. 6.

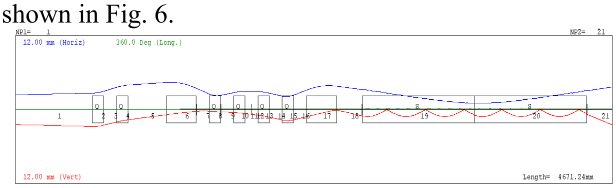

Figure 6: Electron beam envelope in the transport system.

ISBN 978-3-95450-123-6

Copyright © 2012 by the respective authors

The beam properties that the diagnostic system should provide mainly include the beam position, the electron energy, the energy spread, the emittance, the bunch charge, the bunch length and the longitudinal shape .The schematic diagnostics system is given in Fig. 7.

The primary purpose of BPM will be for alignment and steering of the beam centroid. The stripline BPM will be used. The bunch charge will be measured by using the integrating current transformer (ICT). Beam profiles will be measured using YAG and optical transition radiation (OTR) screens. For low energy (at the exit of the DC-GUN), the emittance will be measured using multi slit. The beam emittance at the exit of the accelerating module will be measured using the quadrupoles and the OTR. Bunch length will be measured by streak camera.

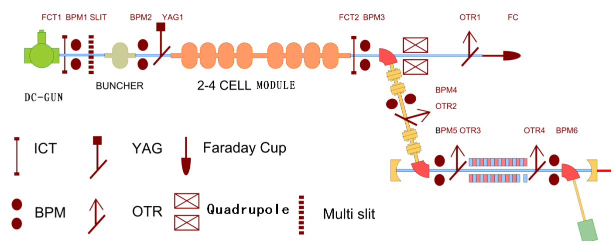

Figure 7: Schematic of beam diagnostics.

THE WIGGLER

The wiggler is one of the most important components for FEL and it is the region where the relative electron and the radiation field will interact. Its performance, such as the peak field, good field aperture etc will determine the FEL gain. A hybrid type wiggler which is composed of 42 magnetic periods, each 38 mm long will be used in the THz facility. The hybrid structure consists of NdFeB magnets and soft-iron poles. The wiggler parameter K can be adjusted from 0.71 to 1.74 which corresponds to gaps of 30 to 18 mm. The calculated relations of wavelength ranges and the K are shown in Fig. 8. The simulation trajectory of the electron is shown in Fig. 9. The main parameters are listed in Table 3. The resonator mirrors are made of gold coated copper with a 1.6mm (in diameter) hole in the center.

Table 3: Parameters of the Wiggler

Amplitude/T	0.2~0.49
Period/mm	38
Wiggler parameter K	0.71~1.74
Gap/mm	18~30
Length	42 periods/1.6 m
Amplitude ripple	<1%
Good region/mm	12
Offset of the electron trajectory/mm	0.1
Magnet material	NdFeB
Soft material	FeCoV

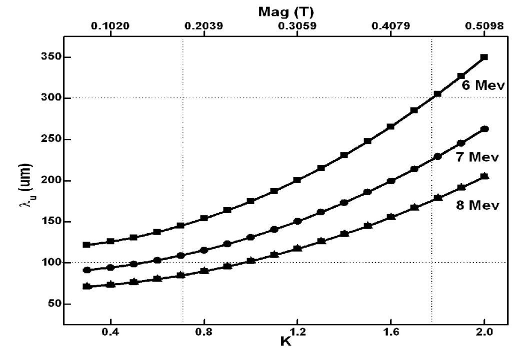

Figure 8: Wavelength ranges as a function of wiggler parameter K for the indicated values of the electron kinetic energy.

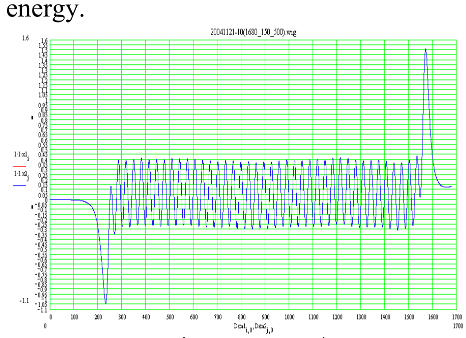

Figure 9: The simulation trajectory of the electron.

SUMMARY AND OUTLOOK

In this paper we have introduced the oscillator FEL-THz user project developing at CAEP. A DC-GUN will be used as the electron source and a superconducting accelerator will be used as the main accelerating section. The simulation of the oscillator and calculation of beam dynamics is finished. The simulation shows that the facility can provide about 10W THz ray which is useful for the scientific researching. We have built a DC-GUN test facility which can work at 230kV and the initial quantum efficiency is about 4% at present. Great efforts should pay out at the cathode study to improve the life time and the stability.

REFERENCES

[1] G.R. Neil et al. Phys. Rev. Lett. 84 (2000), p. 662.
[2] N.A. Vinokurov etc, STATUS OF THE NOVOSIBIRSK HIGH POWER TERAHERTZ FEL, Proceedings of the 2006 FEL Conference, p.492-495, Germany.
[3] P. Michel, etc, THE ROSSENDORF IR-FEL ELBE, Proceedings of the 2006 FEL Conference, p.488-491, Germany.
[4] Shu X J, Simulation and design of the CAEP far-infrared FEL, NIM 2002, A483:205-208.

Copyright © 2012 by the respective authors

ISBN 978-3-95450-123-6