Present Status of CAEP THz FEL Facility

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***Abstract*—A high power THz free electron laser (FEL) facility is under construction at China Academy of Engineering Physics (CAEP) since October, 2011. The radiation frequency of the FEL facility will be tuned in range of 1~3 THz and the average output power will be about 10 W. Much effort has been done for the THz FEL facility. The system mainly consists of a GAAS photoemission DC gun, superconductor accelerator, the hybrid wiggler, optical cavity. In this paper, the design considerations and present status are given.**

I. INTRODUCTION

One of the most exciting areas at present to explore scientific and engineering phenomena lies in the terahertz (THz) spectral region, so the generation and utilization of THz radiation have very important scientific value [1]. At present there are some methods for generating THz radiation [2-4], among which free-electron laser (FEL) is such one that uses a relativistic electron beam traveling through an undulator magnet to produce coherent electromagnetic radiation [4]. The tunability, high power and flexible picoseconds-pulse time structure of THz radiation make the THz FEL a very attractive THz source of coherent radiation [3, 5]. At China Academy of Engineering Physics (CAEP), a THz FEL facility is now building with a radiation frequency range of 1~3 THz[6-8]. The facility operates in the quasi CW mode and the average output power is about 10 W. Layout of the high average power CAEP THz-FEL facility is shown in Fig.1. In this facility, in order to achieve high quality beam, a NEA GaAS photocathode DC-gun[9] is used, which will offer the electron beam with about 100pC/bunch (the average current of 5mA). The electron will obtain energy by passing through a superconducting accelerator, and the electron energy after the accelerator is about 6-8MeV. The facility will be as a user facility and will be available for users in 2016.

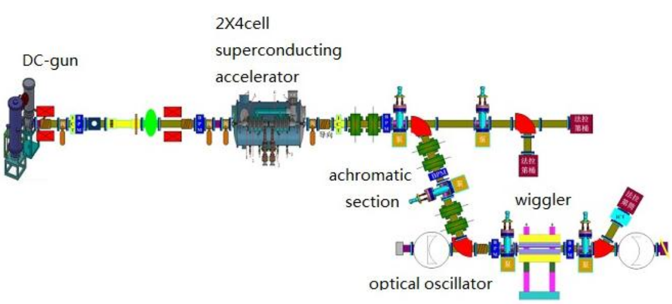

Fig. 1. Layout of the high average power CAEP THz-FEL facility.

II. DESIGN AND SIMULATION

An important goal of the CAEP THz FEL is to achieve the radiation wavelength tunable in the range of 1~3 THz by tuning the electron beam energy and wiggler field strength. In the frequency range of 1~3 THz, The wiggler field strength and electron beam energy have been selected. The main parameters of CAEP THz FEL are listed in Table 1.

Table 1 Main parameters of CAEP THz FEL

Electron beam		**Wiggler**	
Energy /MeV	6~8	Period /cm	3.8
Peak current /A	12.5	Peak field strength /kG	2.5~5.0
Micro bunch /ps	8	Number of periods	42
Emittance / π mm mrad	10	Cavity length /m	2.769
Energy spread /%	0.75		
Repetition rate/MHz	54.17		

The gain and power of resonator are calculated corresponding to different frequency. Using our 3D-OSIFEL code, the parameters of wiggler and electron beam are optimized corresponding to different frequencies. To increase the output power and resonator quality, the scheme of elliptical hole-coupling optical resonator [10] is proposed and will be used in the facility. In the simulation, the mirror reflection rate is 98.5%; the cross section of waveguide is 30 mm×14 mm; the electron beam current is 12.5 A and its pulse length is 8 ps. The repetition rate of the micro bunch is 54.17 MHz, so the cavity length is designed to be 276.9 cm long. The electron beam energy of the CAEP THz FEL is tunable in the range of 6~ 8 MeV and the largest value of the wiggler peak field can be tuned to about 0.5 T.

III. PHOTOCATHODE INJECTORS

The RF photocathode injectors are the key component for high-power, high-duty-factor FEL at CAEP THz facility, as the

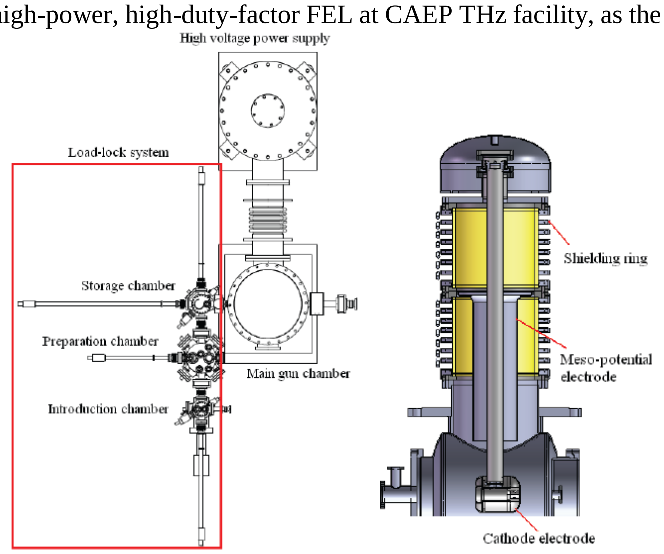

Fig. 2. Layout of load-lock DC gun.

High-current, low-emittance and low-energy- spread electron beams lead to high gain, efficient and robust lasing, and reduce unwanted stray particles that can impact or even preclude high-duty operation. The RF photocathode injectors mainly consist of photocathode preparation system, DC high-voltage electron gun, photocathode drive laser and buncher and measuring & transporting device. Scheme of load-lock DC gun[9] is shown in Fig. 2. To date, a new NEA GaAS photocathode DC-gun has been finished and is debugging. Great efforts are made for achieving vacuum of 1E-10 Pa and working stably in the current continuance of 5mA longer.

IV. SUPERCONDUCTING ACCELERATOR

The superconducting accelerator has been finished by Peking University. It consists of two 4-cell superconducting accelerating cavity. The Fig. 3 shows the structure of the superconducting module. The cavity operates at a frequency of 1.3GHz and a temperature of 2K. The energy after accelerator will be adjusted between 6MeV and 8MeV. The accelerator has been finished and will be sent to Chengdu THz lab center this year.

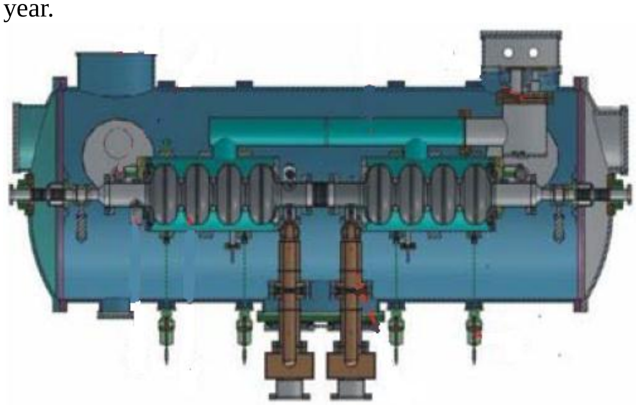

Fig. 3. The structure of the superconducting module.

V. WIGGLER

The hybrid wiggler has been finished. The structure of wiggler is shown in Fig. 4. The dimension of permanent magnet block [11] is 8cm×1.3cm×6cm; the period length and period number of the wiggler are respectively 3.8 cm and 42. And the dimension of pole is 5cm×0.6cm×4.8cm. The gap of the wiggler is variable.

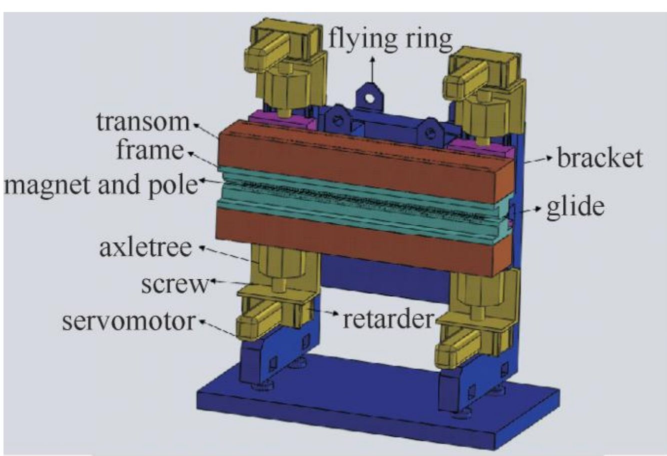

Fig. 4. The structure of wiggler.

The clearance adjustment ranges from 18mm to 32 mm, and the adjustment precision and taper are 0.01mm and 0.015mm respectively. The length of good field area is 21mm to 30mm and the range of peak magnetic field strength is 1.8kG to 5.3kG.

VI. CONCLUSIONS

The design considerations and present status of CAEP THz FEL facility has been introduced. To date, the superconducting accelerator and hybrid wiggler have been finished. We are working on improving the quality of photocathode DC-gun achieving vacuum of 1E-10 Pa. The whole system will be installed and tested at the THz center lab in Chengdu in this year.

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REFERENCES

[1]. Tonouchi M., “Cutting-edge terahertz technology”. Nature Photo. 1, 97, 2007.

[2]. Scalari G., Walther C., Faist J. et al., “Electrically switchable, two-color quantum cascade laser emitting at 1.39 and 2.3 THz”. Appl. Phys. Lett. 88, 141102, 2006.

[3]. Bratman V.,et al.“Review of subterahertz and terahertz gyrodevices at IAP RAS and FIR FU”, IEEE Trans.on Plas. Sci.37(1),36-43,2009.

[4].Williams G. P., “Far-IR/THz radiation from the Jefferson Laboratory, energy recovered linac”, free electron laser. Rev. Sci. Instr. 73, 1461, 2002.

[5]. Tecimer M.,et al. “Dynamically tunable mirrors for THz free electron laser applications”. Phys. Rev. S T Accel. Beams, 13(030703),1-10,2010.

[6]. Xingfan Yang, Ming Li, Xu Zhou, Xiaojian Shu, Yuhuan Dou et al. “The terahertz FEL facility project at CAEP” , Proceeding of FEL 2012, Japan, Aug 26-31, 2012.

[7]. Yuhuan Dou,Xiaojian Shu, Derong Deng, et al. “Design and simulations of CAEP high power THz free-electron laser”, High Power Laser and Particle Beams. 25(3) 662-666. 2013.

[8]. Zhou Xu, Xingfan Yang, Ming Li et al. “Design of a high average power terahertz-FEL facility” J. Tera. Sci. Elc. Infor. Tec. 11(1) 2013.

[9]. Hanbin Wang, Kai Li, et al. “A GAAS photoemission DC gun for CAEP high-average-power THz FEL” Proceeding of FEL 2014, Basel Switzerland, Aug. 2014.

[10]. Yuhuan Dou, Xiaojian Shu, “Elliptical hole-coupling optical resonator in THz FEL”, High Power Laser and Particle Beams. 25(6) 1455-1459. 2013.

[11]. Longgang Yan, Derong Deng, Yuhuan Dou, et al. “Physics design of undulator in high average power free electron laser terahertz source”, High Power Laser and Particle Beams. 25(s0) 153-157. 2013.