R&D ON A MAIN ACCELERATING SECTION OF A COMPACT THZ-FEL

X. M. Shen, W. Bai#, M. Li, X. F. Yang, H. B. Wang
Institute of Applied Electronics, CAEP, Mianyang 621900, China.

Abstract

In order to develop a terahertz (THz) radiation source and to make scientific researches on application of THz technology, a study on terahertz source is performed at CAEP. The radiation source is based on technology of free electron laser (FEL). The energy booster section of the injector uses a 9 Cell standing wave accelerator as the main accelerator for the FEL. The accelerator works at a frequency of S band, excited by a microwave power of about 3.5 MW. At the end of the accelerator, the beam energy is 6.5 MeV ~ 7 MeV, and the current about 300 mA. This paper presents the theoretical design results, as well as the working condition of the main accelerator.

INTRODUCTION

Terahertz wave is the electromagnetic wave which frequency ranges form 0.1 THz to 10 THz(wavelength within range 3 mm ~ 30 cm). Terahertz technique is an important scientific problem in the region of international electronics and information. It is the conjunction between macroscopic electronics and microscopic wavelength study. It has vast application prospects in the fields of electronics, information science, bionomy, national defense scientific, space aeronautics and etc. Free - electron laser (FEL) is the electromagnetic wave radiation source with the best performance characteristics. It can give laser with high pulse power or high average power. Its operating wavelength can cover entire terahertz wave band. Furthermore its output wavelength is continue adjustable through the adjusting of the electron beam's energy. At present, a free electron laser with power of 20 W is successfully built up by JLab in US. Its peak power reached 2.7 kW, and frequency range from 0.1 THz ～5 THz. Its maximum output power can be greater than 100 watt through improvement [1,2]. As to an other free electron laser set constructed by Novosibirsk in Russia , its average power reach 200 watt , and its maximum peak was 0.6 MW[3]. In China, the first set of FEL terahertz radiation source is developed in 2005. The device is a tunable coherent terahertz (THz) light source[4].

In the general situation, the size of free - electron laser device is quite large, and manufacturing cost is costly. Therefore, this situation restrict the application of free - electron laser. For these reasons, technical study on a compact FEL terahertz source is performed at China Academy of Engineering Physics. The Free - electron laser device use a multi-cavity thermionic - cathode rf gun with low back bombardment as electron beam source. And then boost the electron beam produced by rf gun to the energy of 6 MeV ～7 MeV by main accelerator. When the electron beam with high quality and high-energy outgoing from main accelerator gets through the wiggler, it subjects to the action of the magnetic field and then produces coherent radiation.

DESIGN OF ACCELERATING TUBE

The cavity shape and electric field distribution of main accelerator is obtained by optimum design. As is shown in Figure 1. The beam aperture of the accelerating cavity is about 10 mm. And its quality factor (Q value) reach 16000 in theory, shunting impedance about 110 MΩ/ m. The accelerating tube of the main accelerator consist of 9 accelerating cavities and 8 coupling cavities, with a total length of less than 50 cm. as is shown in Figure 2.

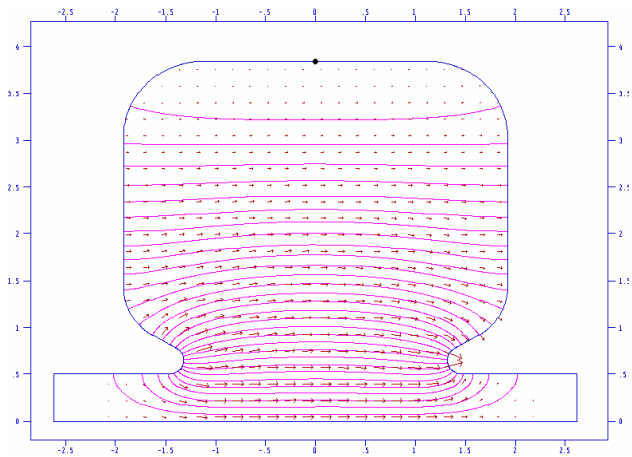

Figure 1: Cavity shape and field distribution of main accelerator.

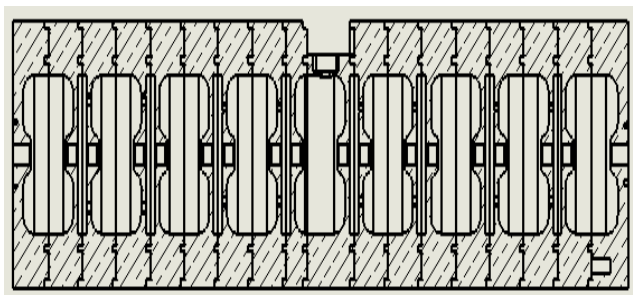

Figure 2: Cutaway view of the accelerating tube.

RESULT OF NUMERICAL SIMULATION

Figure 3 shows the theoretical model of Beam dynamic simulation. As is shown by the picture, The high quality electron beam produced by rf gun goes through a solenoid coil at first, and next transmits a quite long distance. And then the beam enter in main accelerator and get boosted.

#bweimail@163.com

The input microwave power of the main accelerator is about 3.5 MW.

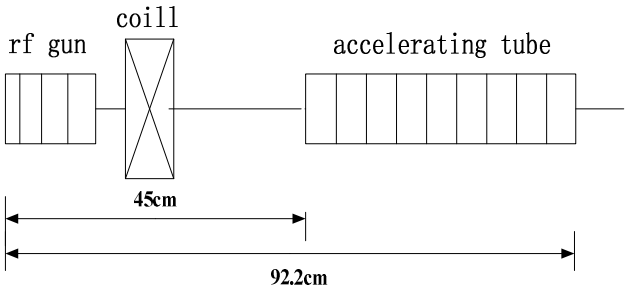

Figure 3: Simulation model of beam dynamics.

We perform numerical simulation of beam dynamics of the accelerator by PARMELA software. Simulation result shows that, the root-mean-square (rms) energy of the beam is about 1.8 MeV at the entrance of the Main accelerator, and its total pulse current is over 500 mA. In condition of beam's energy spread would be less than 1% (rms), the beam' intensity is about 300 mA, normalized emittance about 7.1 π mm·mrad, and bunch length about 8.6 ps (rms). The detailed parameters at the entrance of the main accelerator obtained by beam dynamic simulation is given by Table 1.

Table 1: Beam Parameters at the Entrance of Main Accelerator (z=45)

current	Xrms	Yrms	emittance	bunch length
A	mm	mm	π mm·mrad	ps
0.564	0.855	0.804	7.089	8.519

The detailed parameters at the exit of the main accelerator obtained by beam dynamic simulation is given by Table 2. It can be seen from the two Table that, The main accelerator can boost the electron beam came from rf gun to the average energy over 6 MeV, furthermore, the loss of beam intensity is less, and less the emittance growth too. In condition of beam's energy spread would be less than 1 % (rms), at the entrance of the main accelerator, the beam' intensity is over 300 mA , and bunch length less than 10 ps (rms).

Table 2: Beam Parameters at the Exit of Main Accelerator(Z=92.2)

current	Xrms	Yrms	emittance	bunch length
A	mm	mm	πmm·mrad	ps
0.515	1.126	1.124	8.304	9.032

Figure 4 is the energy density distribution and energy vs. phase distribution at the exit of main accelerator. It can be seen from the picture that, At the exit of the main accelerator, Particle's phase distribution is centralized between 0° ~ 15°, bunch length is about 9 ps, Particle's energy distribution is centralized between 6.5 MeV ~ 6.6 MeV, and energy spread is no more than 1 %.

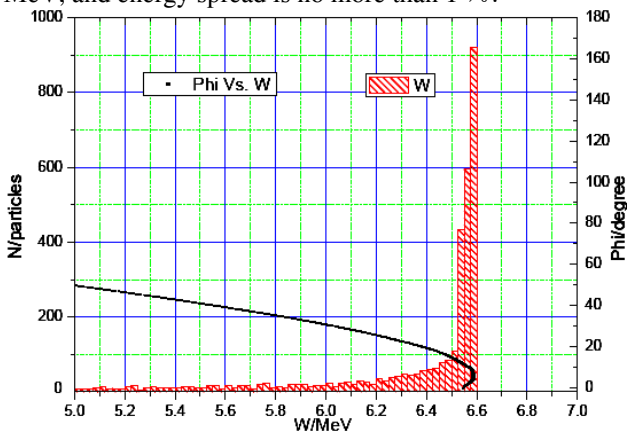

Figure 4: Energy density distribution and energy vs. phase distribution at the exit of main accelerator.

ACCELERATING TUBE DEVELOPMENT

After physical design and theoretic study on the accelerating tube is completed, we perform such work of accelerating tube as processing, cooling test, assembly, and weld. At present, these work have already carried out, and prospective effect have been acquired. Figure 5 is the photo of the accelerating tube after welding. Figure 6 is the result of the on-axis electric field distribution measured in the accelerating tube.

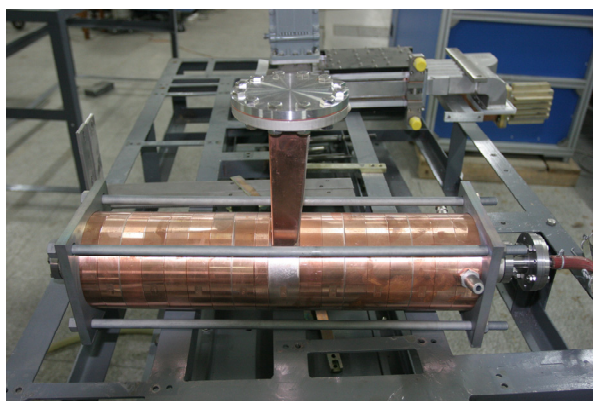

Figure 5: Photo of main accelerating tube after welding.

ISBN 978-3-95450-122-9

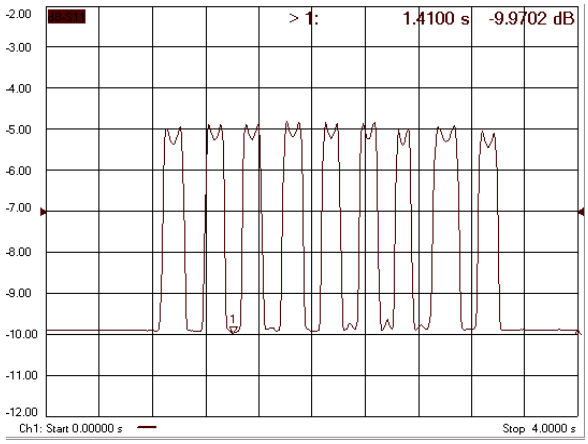

Figure 6: The measured result of field distribution of the accelerating tube.

CONCLUSION

In order to development high power THz radiation source, technical study on a compact FEL THz source is performed at China Academy of Engineering Physics. A main accelerator to boost electron beam with high quality is developed. The accelerator is able to boost the electron beam produced by thermionic - cathode rf gun to the energy of 6MeV ～7MeV directly. And electron beam of high quality can be attained. The main accelerator has been already developed successfully. And it has being used for high power test now.

REFERENCES

[1] Ncil, George R.,Carr, G.L., et al. Detectors and Associated Equipment.p. 537~540 (2003).
[2] Ncil, George R., Williams, G. P. Infrared Physics and Technology. p.389~391 (2004).
[3] E. A. Antokhin, R. R. Akberdin, V. S. Arbuzov, et al. Probl. At. Sci. Technol. (2004).
[4] M. H. Wang, Q. ZH. Xue, P. K. Liu, Journal of Electronics & Information Technology. p.1766-1771 (2008).