THE PARAMETER STUDY OF TERAHERTZ FREE-ELECTRON LASER OSCILLATOR BASED ON ELECTROSTATIC ACCELERATOR*

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Abstract

Free-Electron Laser Oscillator based on Electrostatic Accelerator (EA-FELO) is one of the best methods to realize the powerful terahertz source, which can not only produce high power, but also obtain coherent and tunable wavelength. In this paper, we investigate the effects of the main parameters in this scheme, including the initial electron-beam energy spread, emittance and beam current. Besides, the influence of the radius of the mirrors and the position of the undulator on FEL performance is also studied. The numerical results from 1D FEL Oscillator simulation code FELO are presented, and show that this compact device could achieve the terahertz light with the peak output power is about 5.3kW.

INTRODUCTION

Since the terahertz sources provide wide applications in medical science, material science and industry, a compact, wavelength tunable and high-power THz source attracted much attention in many laboratories [1]. It is noteworthy that EA-FELO could achieve high average power generation, high energy conversion efficiency and high spectral purity, because of its CW operation. Such devices have been developed and operated successfully, such as University of California Santa Barbara FEL (UCSB- FEL) employed a 6MeV Pelletron accelerator and obtained 2.5 mm to 30 μm FEL [2], Israel FEL based on a 6 MeV EN tandem acceleration can produce average power of 1kW in the range of 70-130 GHz [3]. Recently, we also have made some primary research and analysis on it [4-5].

On the basis of the research on FEL Oscillator's basic principle, a conceptual design and parameters study of a compact EA-FEL is proposed in this paper. The numerical modeling has been carried out by using 1D FEL stimulation code FELO [6].

BRIEF REVIEW OF THE EA-FEL OSCILLATOR SCHEME

In this scheme, electrostatic accelerator generates continuous beams of very high quality electrons and small energy spread. The resonator is of a symmetric near-concentric design and a collector collects the decelerated electrons. The schematic of this EA-FEL Oscillator is provided in Figure 1.

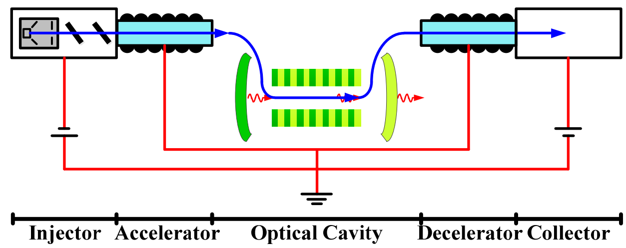

Figure 1: Conceptual design of the EA-FEL Oscillator.

Reference to the electron beam parameters of normal electrostatic accelerator and the present technology, we use a 3MeV beam to limit the size of EA tank and apply other electron parameter as in UCSB-FEL. According to the equation of maximum gain of FEL Oscillator, the small signal gain is proportional to the number of periods and on-axis field strength, so we must strike a balance between achieving larger output power and satisfying device miniaturization. The main design parameters for the simulations are listed in Table 1.

Table 1: The Main Parameters for EA-FEL Oscillator

Electron Beam	
Beam energy	3 MeV
Current	2 A
Energy spread	0.01%
Emittance	10 π mm-mrad
Undulator	
K	0.3
Period length	2 cm
Number of periods	50
Optical Cavity	
Radius of curvature of mirrors	1.08 m
Radiation wavelength	303 μm
Distance from upstream mirror to undulator centre	1m
Optical cavity length	2m

* Work supported by the Major State Basic Research Development Programme of China under Grant No. 2011CB808301 and the National Nature Science Foundation of China under Grant No. 10975137
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PARAMETER STUDY OF THE EA-FEL OSCILLATOR SCHEME

The goals of the EA-FEL Oscillator optimization are maximum net gain and peak output power. Firstly, the influence of electron beam on gain and output power is studied as shown in Figure 2. It is found that when the energy spread is less than 0.02%, the peak output power is considerable, about 5300W. Refer to the energy spreads of electron beam in UCSB FEL, this parameter of beam could be set to 0.01%. As shown in Figure 3, with the increase of beam current, the FEL could grow considerably and the saturation time is reduced. The output powers at different emittance are also simulated and the results indicate the emittance of beam has little influence on the FEL performance.

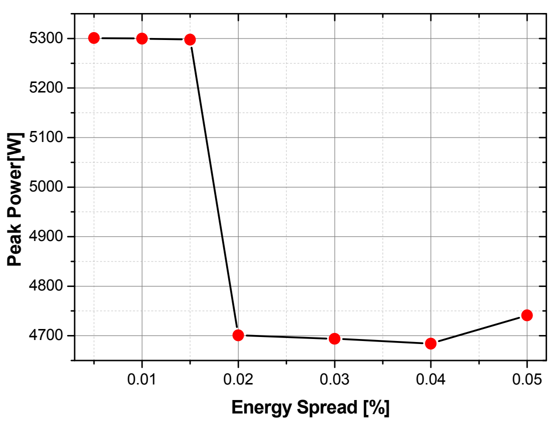

Figure 2: The peak output power vs. energy spread.

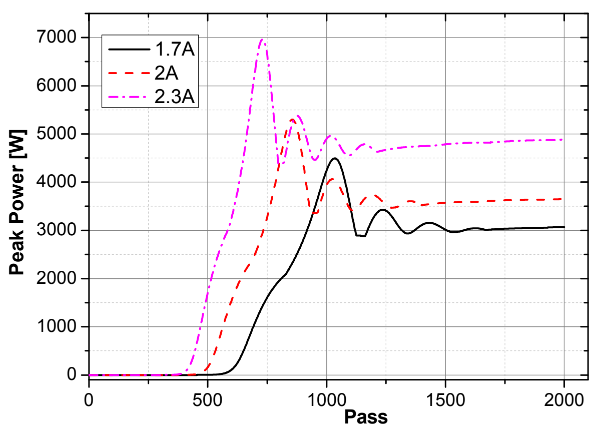

Figure 3: The peak output power vs. pass.

Then the effects of the radius of curvature of mirrors and the position of undulator in optical cavity to the FEL output power are simulated. Figure 4 illustrates the effects of varying the radius of curvature of mirrors on the net gain and output power. Though the maximum peak output power could be obtained if the radius of curvature of mirrors is 1.2m, FEL will take longer to achieve saturation for the Rayleigh length affects the filling factor of the net gain. When the radius ranges from 1.08m to 1.2m, the cavity stability parameter is less than 0.95 and the average output has litter changes. Therefore, the mirrors with the radius of curvature of 1.08m are used in this scheme.

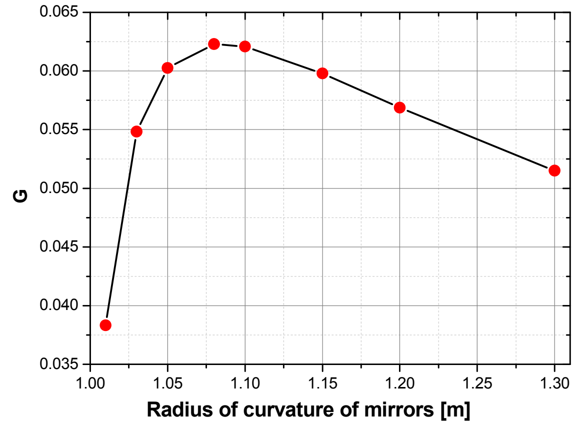

Figure 4(a): The net gain as a function of the radius of curvature of mirrors.

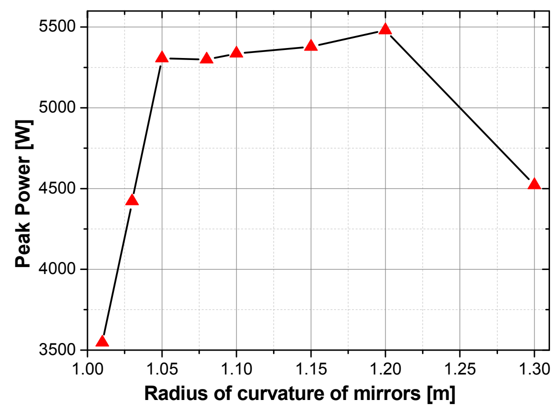

Figure 4(b): The peak output power as a function of the radius of curvature of mirrors.

Figure 5 shows the dependence of the net gain and peak output power on the position of undulator in resonator. The distance between undulator and the upstream mirror with the out-coupling hole could be adjusted freely. As this distance increases, the net gain and peak output would grow. The best option is to set undulator in the center of resonator.

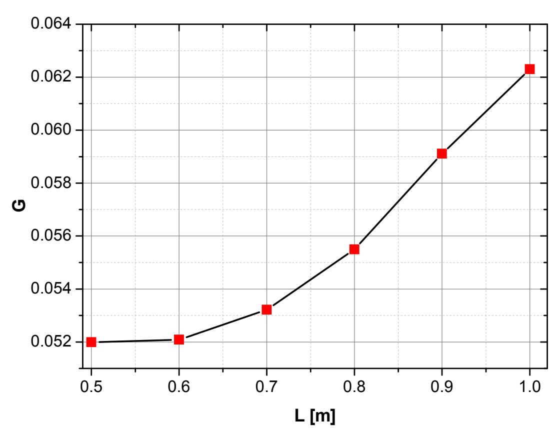

Figure 5(a): The net gain vs. the position of undulator; L stands for the distance from upstream mirror to the undulator centre.

ISBN 978-3-95450-123-6

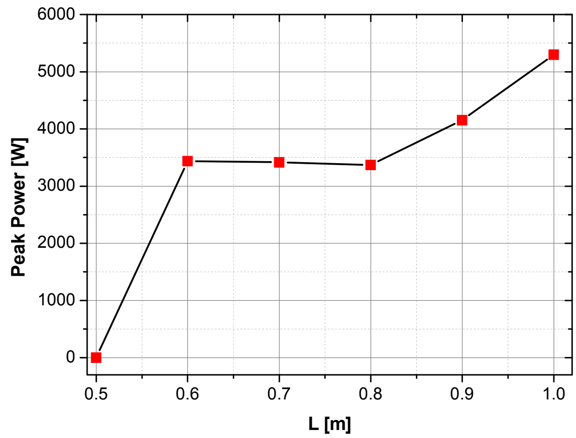

Figure 5(b): The peak output power vs. the position of undulator; L stands for the distance from upstream mirror to the undulator centre.

From the analysis above, the main parameters of this scheme could be determined. In Figure 6, the simulated evolution of the net gain and peak output power up to the saturation are present. It could be found that after about 850 passes, the peak output power gets the highest value, about 5.3 kW.

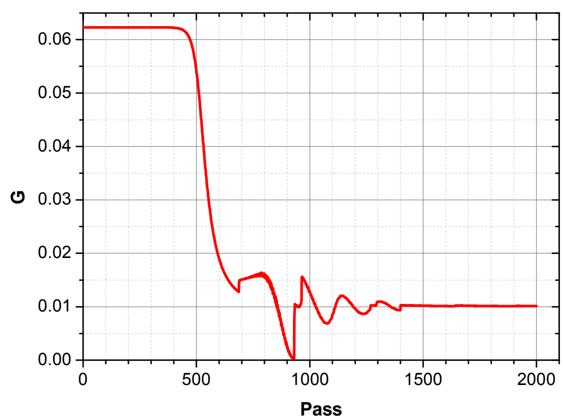

Figure 6(a): The net gain vs. pass.

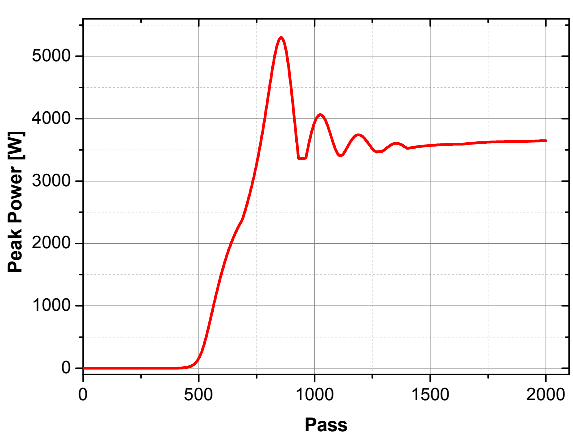

Figure 6(b): The peak output power vs. pass.

CONCLUSION

The parameters of terahertz sources based on EA-FEL Oscillator are studied. Firstly, the effect of electron-beam energy spread, current and emittance to the peak output power is discussed. We find the electrostatic accelerator offers a very high quality electron beam, which has low emittance (10mm-mrad), small energy spread (0.01%) and large current (2A). And this is very favorable to this scheme. Then we also investigate the influence of parameters of resonator on FEL performance, such as the radius of curvature of mirrors and the position of undulator in optical cavity. The results of numerical simulation and optimization show the EA-FEL Oscillator could provide CW terahertz light with the peak output power of 5.3kW.

ACKNOWLEDGMENT

Authors would like to express sincere thanks to Faya Wang and Juhao Wu of SLAC for valuable suggestions and useful discussions.

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ISBN 978-3-95450-123-6