NUMERICAL SIMULATION OF CAEP COMPACT FEL THz SOURCE

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Abstract

Free Election Laser Terahertz source is a good choice for THz source, whose wavelength is tunable [1]. Using 1D FEL stimulation code FELO [2], we simulate the output characteristics of China Academy of Engineering Physics (CAEP) THz FEL, which is a waveguide FEL oscillator. The beam quality's influence on the operation of FEL, such as energy dispersion, emittance and beam current have been studied to designate a set of beam parameters. Besides, the output performance of FEL at different output coupling ratio is analyzed. The cavity detuning is discussed too. Meanwhile the influence of the position of the undulator in the cavity on the FEL performance is also studied.

INTRODUCTION

THz radiation is the common name of the radiations whose frequencies range from 0.1 THz to 10 THz, covering the bandwidth from far infrared to millimeter-wave. THz radiation has many characteristics different from common Electromagnetic waves, thence THz has broad application prospects.

A compact FEL THz source has been constructed in China Academy of Engineering Physics (CAEP). 1D FEL simulation code FELO is used to simulate the influence of current, emittance and energy spread of electron beam on the output characteristics. There is a plane waveguide to confine the optical wave [4]. To simulate the FEL with a waveguide, filling factor is used as an approximate method [5]. The spontaneous emission has been detected, and the results are going to be reported in other papers.

NUMERICAL STUDIES AND SIMULATIONS

FEL Parameters

The chosen parameters in simulation are shown in Table 1 and Table 2.

Table 1: Undulator and Optical Cavity Parameters

Undulator and Optical Cavity	
K	1.49
Period length	3.2 cm
Number of periods	44
Radius of curvature of mirrors	1.768 m
Radiation wavelength	121 μm
Optical cavity length	2.536 m

Table 2: Electron Beam Parameters

Electron Beam	
Beam energy	8 MeV
Peak current	3.7 A
Bunch length	20 ps
Energy spread	1%
Emittance	20 π mm*mrad

Numerical Simulations

The simulation is carried out in the code FELO. Peak power and gain of the FEL radiation are shown as followed.

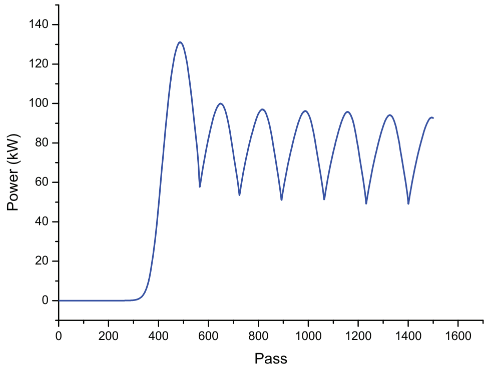

Figure 1: Peak power versus pass of CAEP FEL THz.

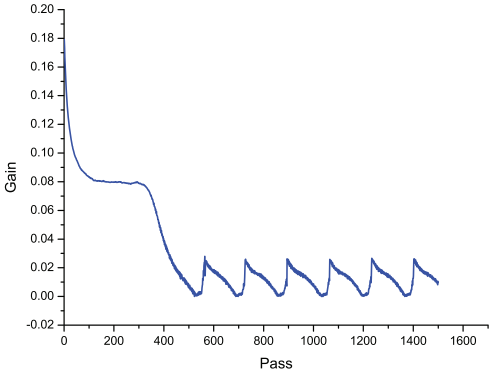

Figure 2: Gain versus pass of CAEP FEL THz.

Seen from the simulation result, the initial small signal gain is about 15%, and saturated peak output power is 70

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ISBN 978-3-95450-117-5

kW. By calculating our technical indicators, duration of macro pulse is 4 μm, and the time of radiation passing through the optical cavity needs 16.9 ns, therefore, one macro pulse includes 237 micro pulses. The average output power is approximately 4 kW, meeting the design requirement of 1 kW output power.

Detuning Curve

The influence of cavity detuning length on output power was studied, and the detuning curve was plotted as in Figure 3.

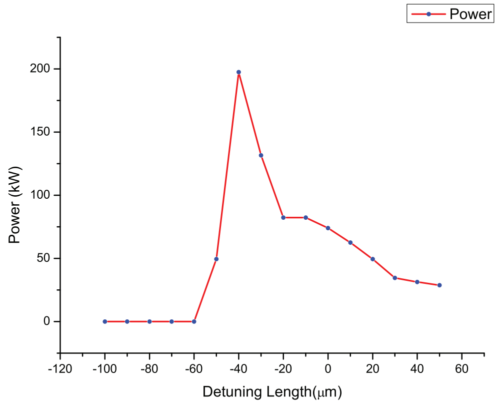

Figure 3: Cavity detuning length of CAEP FEL THz.

Comparing the slip length and electron bunch length, which is the so called S factor, $S=N_w\lambda_s/l_b<1$, so the slippage is not serious, and the cavity detuning length would be short. Figure 3 shows that the maximum peak output power will be obtained while the cavity detuning length is -40 μm, and it is about 200 kW.

Current

Output powers at different beam current are shown in Figure 4.

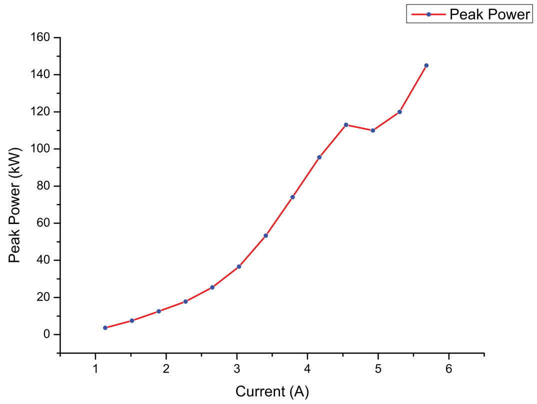

Figure 4: Output power versus beam current of CAEP FEL THz.

According to the Madey theory, the small signal gain of FELs is proportional to beam current, thus FEL output power would grow while the charge of bunch increasing.

It is shown that the THz FEL can work when current achieve 4.5 A, with a high peak output power. For the Lawson-Penner Limit [3], the gain could not grow with the charge stintless, a maximum power will be reached.

Emittance

The influence of beam emittance on FEL was simulated also, and a figure was plotted as Figure 5.

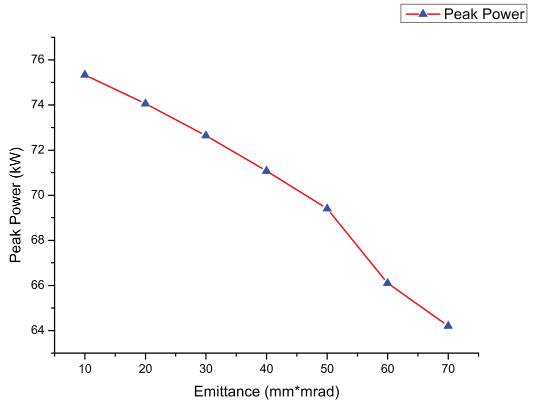

Figure 5: Peak power versus emittance.

In Figure 5, the output power decreased while beam emittance varied from 10π to 70π (mm*mrad). While emittance increased to 70π, power reduced 14% than which at the emittance of 10π. It can be seen that emittance affect very little on the output power. Emittance no more than 30π would be suitable. In fact, the emittance at the entrance of undulator of CAEP FEL-THz is less than 15π.

Energy Spread

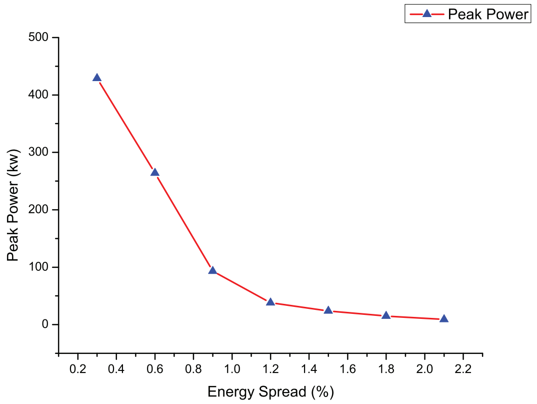

Figure 6: Peak power versus energy spread.

Energy spread is one of the most important parameters in FEL design, which determines whether FELs can work. In the simulation, energy spread varied from 0.3% to 2.1%, which is shown in Figure 6.

Growth of energy spread will significantly affect the quality of light. If energy spread is less than 1%, output power will be enough, but there will be a sharp decline of power when energy spread is bigger than 2%, and the FEL could not work anymore. The design specification of energy spread is about 5% in CAEP FEL THz.

Position

Different positions of undulator in the optical cavity will result in different output characteristics. A simulation is made to find a most suitable place of the undulator, and that is shown in Figure 7.

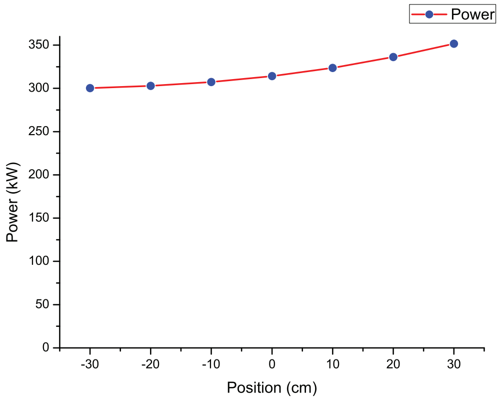

Figure 7: Influence of the position of undulator in optical cavity on the output power.

Figure 7 shows that the output power will slightly increase when undulator is placed at the downstream of the optical cavity centre, but that's only a small increment. Actual position of undulator would be determined by the considering of beam diagnosis.

CONCLUSIONS

By simulation, the main beam parameters of CAEP FEL THz were designated. As for the chosen parameters, CAEP FEL can work well and attain the design specifications.

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