# Design of a high-efficiency C-band backward wave oscillator *

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**Abstract** For practicability of the high power microwave source, a C-band backward wave oscillator (BWO) which has high conversion efficiency is designed. When the axial guiding magnetic field is 0.83 T, the electron energy and the beam current of the diode are respectively 80 keV and 2.1 kA, a microwave output power of 100 MW at 7.4 GHz microwave frequency with 65% conversion efficiency is achieved in simulation.

**Key words** high conversion efficiency, C-band, BWO, miniaturization

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## 1 Introduction

Nowadays investigation of the high power microwave (HPM) relies on the traditional pulsed power technology whose output voltage and peak output power reach the level of MV and 10 GW respectively, and whose weight reaches the level of 10 t [1–4]. For practicability of the HPM source, the pulsed power equipment must be minimized, and the conversion efficiency of the HPM device must be enhanced.

A C-band backward wave oscillator (BWO), whose output power is 100 MW and whose conversion efficiency is 65%, is presented in this article.

## 2 Description of the BWO

The BWO, which is immerged in an external guiding magnetic field, consists of a foilless diode, a resonant reflector, a seven-cavity slow wave structure (SWS) and a coaxial output system (Fig. 1).

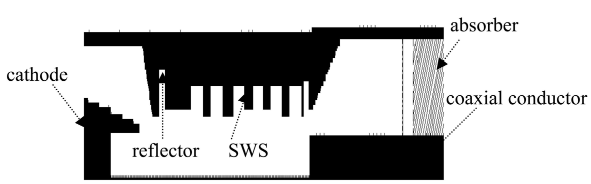


Fig. 1. Schematic of the C-band BWO.

The SWS is a corrugated waveguide whose parameters influence the dispersive curve. A microwave frequency of 7.4 GHz is achieved through the intersection of the dispersive curve and Doppler line of the electron beam (Fig. 2). In Fig. 2, $k_Z$ is the axial wave number of the microwave and $v$ is the axial velocity of the electron.

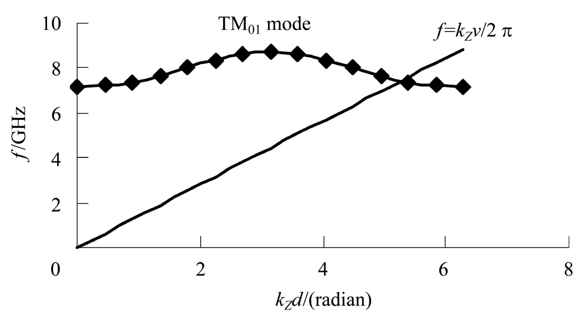


Fig. 2. Dispersive curve of the SWS and Doppler line of the electron beam.

A coaxial output system is used to enhance the beam-microwave conversion efficiency. The coaxial output system improves the reflectance of the end of the SWS [5], which promotes the interaction between the microwave and the beam and increases the output microwave power.

A Bragg reflector on the beginning of the SWS is used to completely reflect the backward wave.

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## 3 Simulation of the BWO

After conceiving the structure, the BWO is simulated with. the PIC code KARAT [6] . Within the simulation, when one of the following parameters such as a 0.83 T axial guiding magnetic field, an 80 keV electron energy and a 2.1 kA beam current is altered, all the other parameters are unchanged.

### 3.1 Influence of the electron energy

The electron energy is a crucial parameter which influences the output microwave power. There must be an appropriate energy for a given BWO (Fig. 3).

To obtain the biggest output microwave power, the electron's velocity should approximately equal the phase velocity of the microwave, so the electron energy must have an appropriate energy, or else the conversion efficiency between the electron and the microwave will lower and the output microwave power will diminish.

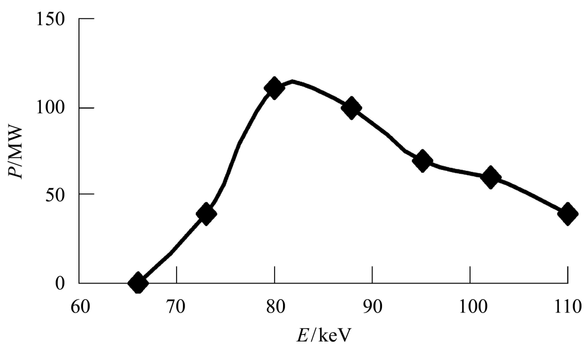


Fig. 3. Relationship between the output power and the electron energy.

### 3.2 Influence of the beam current

The beam current is another factor which influences the conversion efficiency. For the given guiding magnetic field and electron energy, there must be a special beam current corresponding to a maximum output microwave power (Fig. 4).

As shown in Fig. 4, with the increase of the beam current, the output microwave power varies like a hump. First, the output microwave power increases with the total beam energy when the current increases; Secondly, because of the reflection of the electrons which is caused by the over modulation of the electron beam, the output microwave power decreases with the continuous increase of the beam current [7].

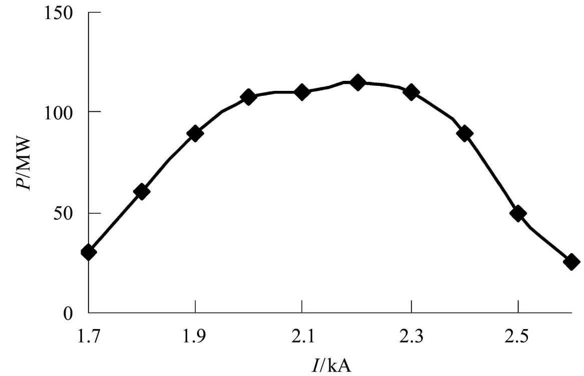


Fig. 4. Relationship between the output power and beam current.

### 3.3 Influence of the axial guiding magnetic field

The axial guiding magnetic field is the third factor which influences the output microwave power because it is used to guide the electron beam to drift through the SWS. Fig. 5 gives the relationship between the axial guiding magnetic field and the output power.

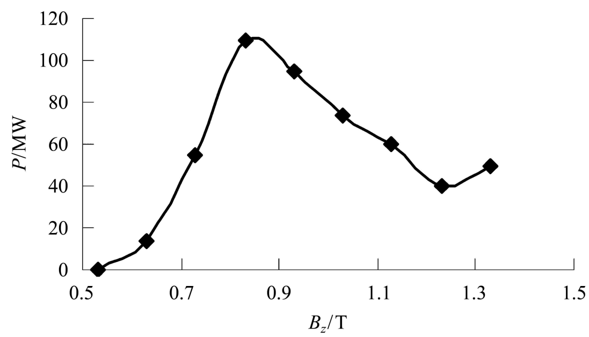


Fig. 5. Relationship between the output power and the axial guiding magnetic field.

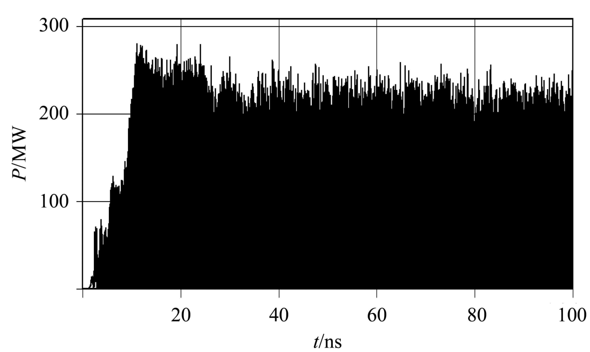


Fig. 6. Output peak power.

As shown in Fig. 5, the output power first increases with the increase of the axial guiding magnetic field because the cyclotron radium of the electron is smaller with a higher axial guiding magnetic field which avails the interaction between the electron beam and the microwave; Then the output power decreases with the continuous increase of the axial guiding magnetic field because of the cyclotron resonance.

### 3.4 Simulated result

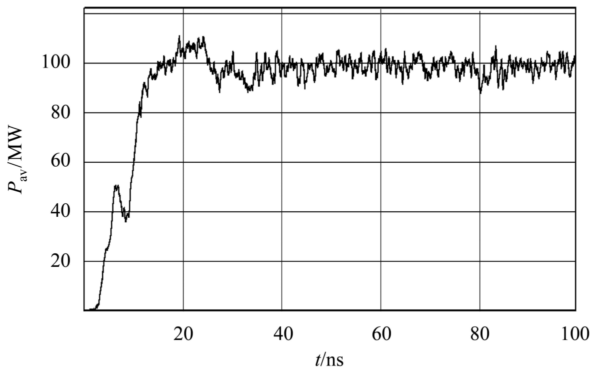


Fig. 7. Output average power.

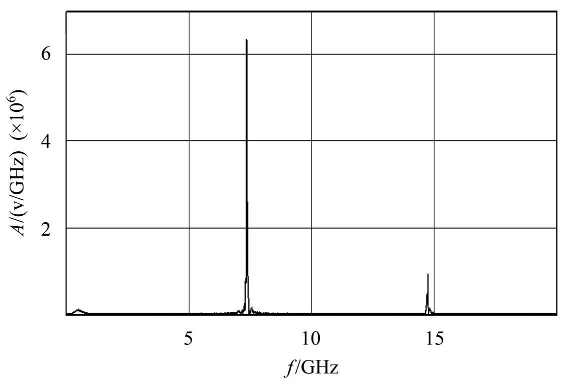


Fig. 8. FFT of the output microwave power.

When the strength of the axial guiding magnetic field is 0.83 T, the electron energy 80 keV and the beam current 2.1 kA, the following simulated results are obtained: (1) the output peak microwave power is 220 MW (Fig. 6); (2) the output average microwave power is 100 MW (Fig. 7); (3) the microwave frequency is 7.4 GHz (Fig. 8); (4) the beam-microwave conversion efficiency is about 65%.

## 4 Conclusion

A high-efficiency C-band BWO with a low impedance (about 38 Ω) is designed. When the strength of the axial guiding magnetic field is 0.83 T, and the electron energy and the beam current are 80 keV and 2.1 kA respectively, a microwave output power of 100 MW at 7.4 GHz microwave frequency with 65% conversion efficiency is achieved.

There are two reasons for the high-efficiency of the BWO. First, a Bragg reflector is used to replace the traditional cut-off neck, which avails the electron beam to travel more closely to the SWS and to interact with the superficial wave mode $TM_{01}$ of the microwave. Secondly, the existence of the coaxial output system improves the reflectance of the end of the SWS, which lets the electron transfer more energy to the microwave.

This BWO reduces the degree of the difficulty in designing the pulsed power system, which is helpful for the miniaturization of the whole HPM source and practicability of the HPM source.

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