Experimental investigation of the relativistic backward wave oscillator with a periodic guiding magnetic field

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Abstract Experiment is carried out on the accelerator Sinus-700 to investigate the Relativistic Backward Wave Oscillator (RBWO) with a periodic guiding magnetic field. When the strength of the guiding magnetic field, whose period is 4.6 cm, is 0.54 T, a microwave output power of 0.95 GW at 9.1 GHz microwave frequency is achieved. It is shown that the RBWO with a periodic guiding magnetic field is feasible.

Key words high power microwave (HPM), RBWO, periodic guiding magnetic field, accelerator

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1 Introduction

The RBWO, which needs a high guiding magnetic field [1–4], is one of the most promising high power microwave (HPM) generators. To achieve a higher energy efficiency and lower operational cost, there are two methods. One is to lower the strength of the guiding magnetic field, the other is to investigate the RBWO with a periodic permanent magnetic field (PPM).

Many investigations have been on the RBWO with a guiding low magnetic field in the last decade. A. I. Gunin achieved 0.5 GW microwave output power at 10 GHz microwave frequency with 10 ns pulse width at 0.7 T permanent magnetic field in 1998; In 2001, FAN Ju-Ping reported an 170 MW microwave output power with 8.874 GHz microwave frequency at 0.7 T guiding magnetic field [5]; In 2006, ZHANG Jun obtained an 1.2 GW X-band microwave output power at 0.6 T guiding magnetic field [6].

To testify the feasibility of the RBWO with a periodic guiding magnetic field, a particle in cell (PIC) simulation has been executed [7].

The preliminary experimental investigation of the RBWO with a periodic magnetic field is described in this article.

2 Description of the model of the RBWO

Based on the simulation of the RBWO with a sinusoidal magnetic field [7], the slow wave structure (SWS) of the RBWO is divided into two sections by a drift tube. When a relativistic electron beam (REB) travels through the first section of SWS, its velocity is modulated. Its velocity modulation is converted into density bunching gradually when REB travels through the drift tube. At last, the energy of the well-bunched REB is extracted in the second section of SWS. There is a Bragg reflector at the beginning of the SWS which is used to completely reflect the backward wave. There is also a reflector on the end of the SWS, which is used to partially reflect the forward wave so as to increase Q (quality factor) of device and decrease the strength of the guiding magnetic field.

3 Experimental investigation of the RBWO

3.1 Manufacture of the solenoid

A solenoid is manufactured to give birth to a periodic magnetic field. Fig. 1 is the axial distribution of the magnetic field when a current of 2.5 A is loaded on the solenoid.

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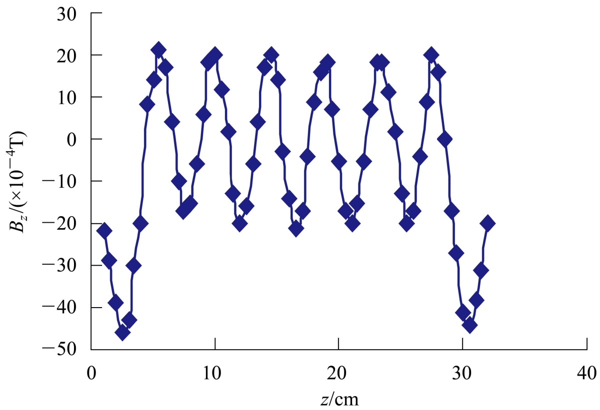

Fig. 1. Axial distribution of the magnetic.

3.2 Description of experimental system

The electron beam used in the experiment of the BWO with a periodic magnetic field is generated by the high-current electron accelerator Sinus-700 which consists of a pulse generator, a switch and a high-current electron diode. The accelerator can afford an electron beam whose energy and current are 1 MeV and 10 kA, respectively.

The electron diode and the RBWO are immerged in the periodic guiding magnetic field which is generated by a solenoid.

The RBWO generates microwave with a mode of TM_{01}, which radiates in the air through an antenna.

3.3 Microwave frequency measurement

The heterodyne technique is used to obtain the microwave frequency. Attenuated by cable and attenuators, the radiated microwave received by a receiving antenna is mixed with a fundamental, which results in an intermediate frequency (IF) signal coming from the mixer. Then the radiated microwave frequency can be deduced from the IF signal.

Figure 2 shows the typical IF signals of the same radiated microwave when fundamentals are respectively 9.4 GHz and 9.6 GHz. From Fig. 2, we can acquire the output microwave frequency of 9.1 GHz.

3.4 Microwave mode

It is difficult to directly measure the mode of the microwave, but we can deduce it from the microwave power density pattern, which reveals the relationship between the normalized power density $P/P_{\max}$ and horizontal angle Θ. The microwave power density pattern (Fig. 3) is measured for horizontal polarization in the plane at a distance of 3 m from the radiating antenna in the horizontal direction.

One can see from Fig. 3 that the mode of the microwave is TM_{01}.

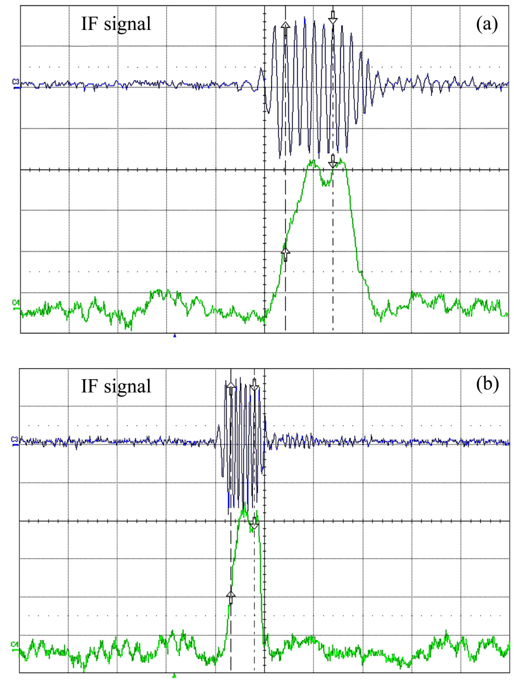

Fig. 2. Typical heterodyne signal.

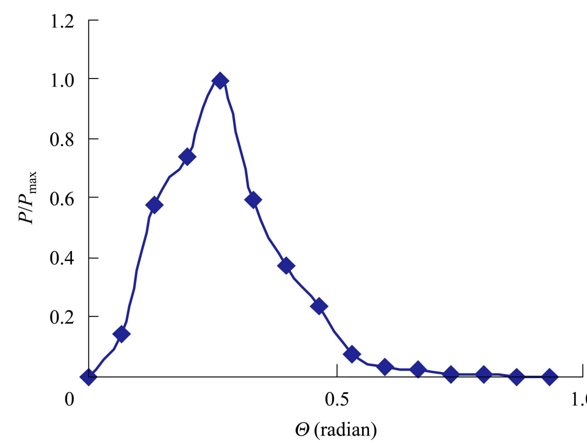

Fig. 3. Normalized power density pattern of radiation.

3.5 Relationship between the output microwave power and guiding magnetic field

In BWO, there must be a magnetic field to guide the electron beam, so the relationship between the magnetic field and the output microwave power must be investigated.

It is shown that in the experiment, when the electron energy and beam current of diode are 8000 keV and 8 kA, respectively, and the strength of the guiding magnetic field is in between 0.45 T and 0.7 T, there is a microwave radiated (Fig. 4). It can be seen from Fig. 4 that, the maximal microwave power of 950 MW is obtained when the strength of the magnetic field is 0.54 T.

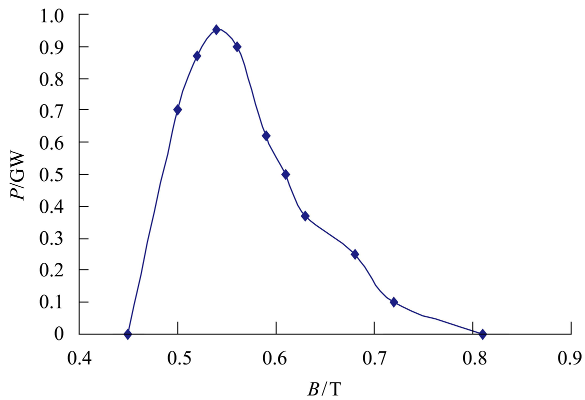

Fig. 4. Relationship between the output power and the guiding magnetic field.

4 Conclusion

The RBWO with a periodic magnetic field is experimentally investigated on the accelerator Sinus-700. The 950 MW microwave output power at 9.1 GHz microwave frequency with 13 ns pulse width is reached (Fig. 5) when the electron energy and beam current of the diodes are 800 keV and 8 kA, respectively, and the strength guiding magnetic field, whose axial period is 4.6 cm, is 0.54 T.

We can say from the experiment that it is feasible to run the RBWO under a periodic guiding magnetic field.

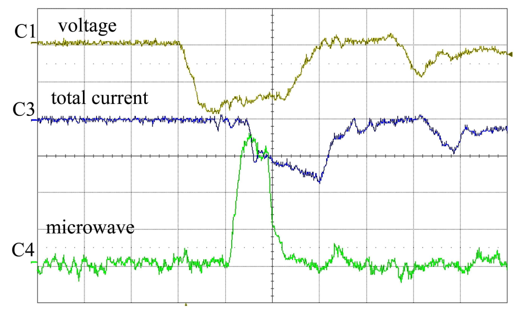

Fig. 5. Typical experimental waveform.

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