

Observation of the Dependence of Backward Wave Oscillator's Microwave Output Power on Corrugation Number

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The dependence of the backward wave oscillator's (BWO's) microwave output power on the number of corrugations is observed experimentally. The slow-wave structure (SWS) of the BWO has been designed to operate at 9.8 GHz. The SWS consists of detachable corrugated modules, and the corrugation number N can be changed from 1 up to 10. The BWO is driven by the high current electron accelerator LAX-1 (850 keV, 3 kA). The dependence of power on corrugation number is not monotonic; with 3 modules, a small output signal of 20kW level is observed; with 4 modules, a rapid increase of output power of the level of 10 MW is observed, and from 5 to 10 modules the output power appears to saturate at the power level of 100MW. These results are analyzed with a PIC Code called Magic.

Keywords: Backward Wave Oscillator, High Current Accelerator, X-band Microwave

The BWO is one of the promising candidates for producing high power microwaves which can be used for plasma heating, plasma diagnostics, and high power transmission in space. The BWO consists of a periodic, corrugated wave-guide called slow-wave structure (SWS) as shown in Fig.1, into which a high current relativistic electron beam is injected. In the present research, SWS is designed to operate at the X-band microwave region (9.8 GHz) with a driver electron beam of 850 keV, and 3kA. The SWS is fabricated so that the number of corrugated wave guide modules can be changed, i.e., the SWS consists of modules, each of which has one corrugation, and single module can be added one by one up to ten modules. The SWS is made of aluminum, and its corrugation shape is sinusoidal. The size parameters of the SWS are the same as given elsewhere[1,2]: average radius $R_0 = 13.7$ mm, corrugation period $z_0 = 15.0$ mm, and amplitude of corrugation $h = 0.28$ mm, i.e., the size of the SWS is expressed as $R = 13.7 \text{ mm} + 0.28 \cos(2\pi / 15.0)$ mm.

In the experiments, an annular electron beam was used. The beam energy was maintained at 850 keV, and the beam current was maintained at 3 kA. The electron beam was extracted from velvet or

carbon composite explosive cathodes as in refs. [1,2]. The diameter of the cathode was 16 mm, and the edge thickness was 2 mm. The microwave window was 5mm thick fused silica with diameter of 50 mm.

The radiated microwave was led into a mode converter of TM_{01} - TE_{10} , whose conversion efficiency was 95%. Through several attenuators, the microwave power was measured by a calibrated crystal detector. Figure 2 presents typical oscilloscope waveforms of the beam current, beam voltage, and microwave power. Although the half width of the beam current and beam energy is about 100ns, the half width of the microwave output was 30-50 ns throughout most of the experiments. In the

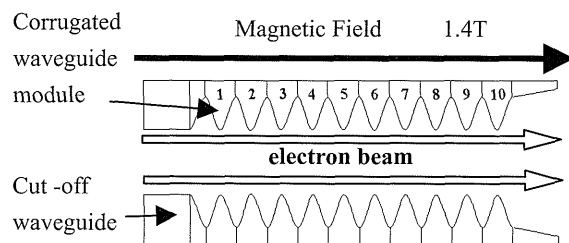


Fig.1 Schematic of SWS structure. The corrugation number is changeable from 1 to 10.

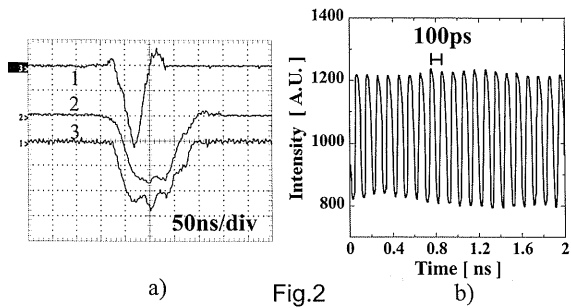


Fig.2

- a) 1: Microwave power 2: Beam voltage
3: Beam current
- b) Microwave waveform measured by high speed oscilloscope.

present paper, we refer to only peak power, and the observed pulse shortening is beyond the scope of the present study.

The microwave spectrum was obtained from the Fast Fourier Transformation (FFT) of the high-speed oscilloscope (Tektronix SCD5000) signals, as the same procedure described in ref. [1]. To verify higher mode mixing, the output wave-form was also analyzed by dispersion line diagnostics (12 m)[1], through which the waveform would change if there were any higher frequency mode. These diagnostics indicate that the output power is in the TM_{01} mode, and that the frequency of the microwave is 9.8 ± 0.3 GHz for the case from $N = 4$ to $N = 10$. Figure 3 shows corrugation number dependence of the frequency.

The dependence of power on SWS corrugation number N is not monotonic as shown in Fig.4. When the corrugation number $N = 1, 2$ no detectable power was observed. At $N = 3$ faint power at about 20-30 kW level was observed. At $N = 4$, a rapid power rise was observed. Although the current and voltage of the induction linac were stable (within 3%), power

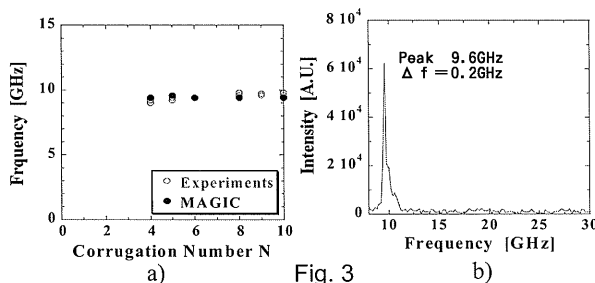


Fig. 3

- a) The corrugation number dependence of microwave frequency .
- b) Experimentally observed microwave frequency spectrum at $N = 10$.

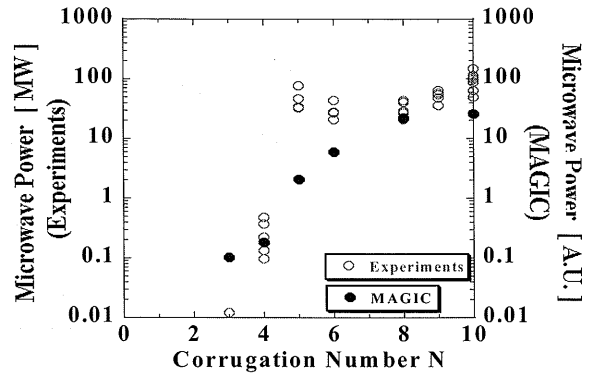


Fig.4 Dependence of microwave output power on corrugation number.

level was not stable at this number. After $N = 5$ up to $N = 10$, the power level appeared to saturate. The saturation power level was about 100 MW. A rapid rise ($N = 4$) and the saturation of output power at the early stage of the SWS ($N = 5$) appear to be an inherent characteristic of BWO oscillation with high current relativistic electron beams [4].

The computer simulation results with 2.5D particle-in-cell code MAGIC [3] are also shown in Fig. 3 and 4. In Fig.3, simulated frequencies are also plotted. In Fig.4, the simulated values of square of axial electric field component E_z^2 at the exit of BWO are plotted. The E_z^2 curve shows a similar tendency regarding power saturation.

The observed power saturation phenomena suggests that highly nonlinear processes prevail in the processes, which cannot be described by small signal linear theory. To realize the best performance of the high power BWO, an understanding of this nonlinear process is essential.

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