High Energy Beam THz Backward Wave Oscillator based on Double Corrugated Waveguide

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Abstract: *A new approach to realize THz BWOs relaxing the assembly challenge is presented. An international consortium including UC Davis, Beijing Vacuum Electronics Research Institute (BVERI), and Lancaster University is involved in the design and fabrication of 0.346 THz BWOs to replace the bulky FIR laser at the plasma diagnostic at the NSTX-U fusion device. The use of a highly energetic beam permit and a wide channel, double corrugated waveguide permit to achieve about 4 W of output power at 0.346 THz.*

Keywords: backward wave oscillator; double corrugated waveguide; electron beam; terahertz; millimeter waves

Introduction

Backward wave oscillators are an intrinsically low efficiency vacuum electron device [1]. The simple structure makes them among the most promising vacuum electron devices to generate power at THz frequency. The fabrication of BWOs in the THz regime, due to the small dimensions, is highly demanding [2 -3]. In particular, the alignment of the beam is very challenging due to the length of the interaction channel. An international consortium comprising UC Davis, Beijing Vacuum Electronics Research Institute (BVERI), and Lancaster University aims to find novel approaches to reduce the fabrication effort and the cost.

Different designs of 0.346 THz BWOs based on the double corrugated waveguide (DCW) [4] were presented to replace the bulky FIR lased at the high-k plasma scattering diagnostic at the NSTX-U fusion device. About 0.5 W output power was achieved with a 13.8 kV beam voltage, 10 mA beam current, and 100 μm beam diameter. The beam tunnel was assumed 120 μm.

The DCW was demonstrated suitable to be fabricated by nano-CNC milling [3]. However, the beam alignment is very challenging, with high risk of low yield and beam interception with the pillars.

A new approach is proposed to relax the alignment difficulties and achieve a significantly higher output power. The use of a wide diameter, high energy beam permits one to decrease the filling factor thereby reducing the alignment effort.

High energy beam BWO design

The BWO in [5] was designed with a beam radius of 50 μm, 13 kV and 10 mA. The very narrow beam makes the alignment very challenging. A new BWO with a beam, with 80 μm radius, 22 kV of beam voltage, and 30 mA was designed while keeping the beam density almost the same (Table 1). The period of the DCW was also increased to match the synchronization between the phase velocity of the wave with the high energy beam. To accommodate the wider beam, the gap between pillars was set to 220 μm, one hundred microns wider than the BWO in [5].

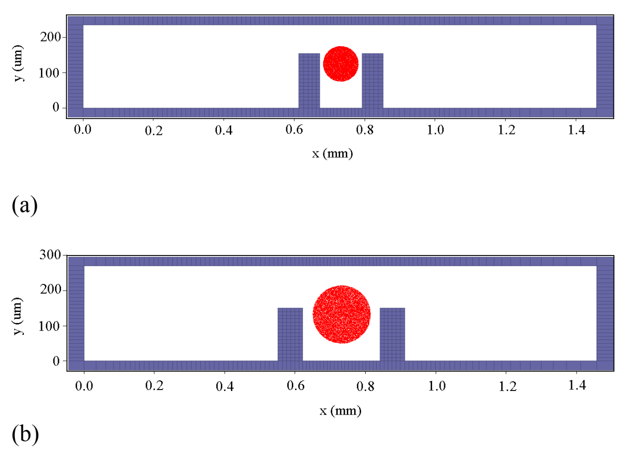

Fig.1 Cross section of beams and DCWs of the BWO [5] (a) and the new BWO (b)

This has allowed one to increase the distance from the edge of the beam to the pillar at 40 μm, in comparison to only 10 μm in [5]. As a result, the beam alignment is expected to be much easier in the new BWO. However, the increased distance from the pillar wall makes the space charge field of the beam higher, so a higher guiding magnetic field is needed to prevent the diocotron instability of the cylindrical beam propagating through the rectangular waveguide.

Table 1. Dimensions of the BWOs

	BWO [5]	New BWO
Beam voltage (keV)	12.8	22
Beam current (mA)	10	30
Magnetic field (T)	0.25	0.7
Beam radius (μm)	50	80
Pillar section (μm)	60*60	70*70
Beam channel (μm)	120	220
Pillar height (μm)	155	150
Period (μm)	140	170
Period number	116	120
Waveguide cross section (μm)	1500*235	1500*270

The dispersion curve of the DCW computed by CST-MWS is shown in Fig.2, intersecting the beam line of 22 keV at the backward wave region at approximately 0.346 THz.

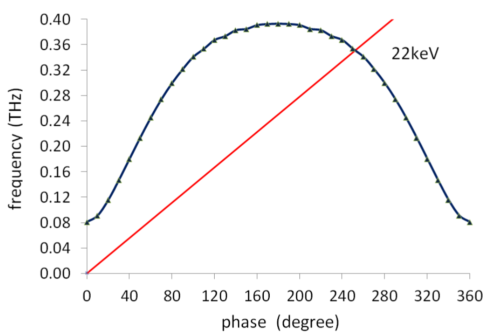

Fig.2 Dispersion curve

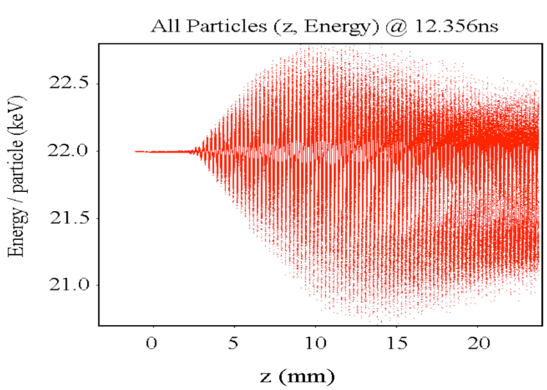

Fig.3 Beam energy after oscillation saturation

The new high energy beam THz BWO based on the DCW has been investigated by PIC simulations. Figure 3 presents the modulation and bunching of the beam. The optimized output power shown in Fig.4 is about 4.2 W, with an efficiency of 0.64%.

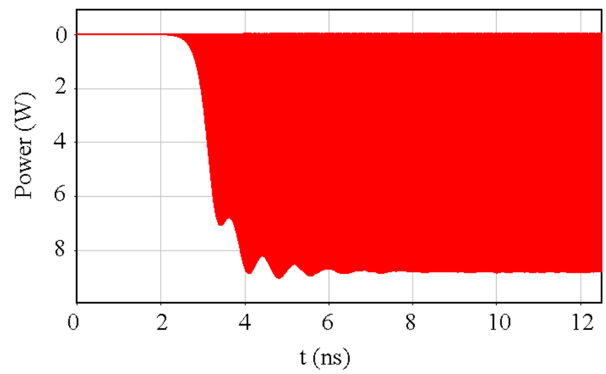

Fig.4 Output power

Acknowledgements

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