P2-20: Backward Wave Oscillators for THz Applications Based on Corrugated Waveguide

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Abstract: *Backward wave oscillators are among the most promising solutions for power generation at THz frequencies. Two 1 THz backward wave oscillators based on different topology of corrugated waveguide are compared by 3D particle-in-cell simulations.*

Keywords: Backward wave oscillator; THz; TWT; SWS.

Introduction

THz sources based on vacuum electronic principles are a viable solution for generating power at THz frequencies [1-3]. In particular, backward wave oscillators (BWOs) represent one of the most viable solutions to realize THz sources. Some examples of BWO realized with different approaches are reported in literature of [1, 2].

THz frequency range, due to the reduced wavelength and consequently reduced dimensions, can be supported only by a limited number of realizable slow-wave structures (SWSs). Corrugated waveguides have been proved to be a suitable solution as SWS for sub-millimeter wavelength range and can be realized by high-aspect ratio fabrication processes such as DRIE, LIGA or UV-SU8. Due to the electromagnetic field distribution, located over the corrugation, a sheet beam has to be chosen for the best interaction effectiveness.

A BWO based on a corrugated waveguide with the corrugation as wide as the waveguide was presented [3]. A high output power is reported making the device very promising as THz source.

In this work, a BWO designed assuming the corrugation narrower than the waveguide width, to make the assembling simpler and reducing the effect of fabrication errors, is proposed and compared to the BWO in [3] for 1 THz oscillation frequency.

BWO Comparison

The working principle of a backward wave oscillator is based on the synchronism of the electron beam with the first backward wave spatial harmonic.

Two BWOs based on different corrugated waveguides, one with the corrugation as wide as the waveguide width (Fig.1) and the other with the corrugation narrower than the waveguide width (Fig.2), are compared. The narrow corrugation SWS has been designed to get approximately the same dispersion curve and to intercept a 12 kV beam line at about 1 THz. The dimensions (Fig.3a) of the two different corrugated waveguides are listed in Table I. The structures are considered to be made of perfectly smooth copper (conductivity $\sigma = 5.99 \times 10^{7}\ \Omega^{-1} \cdot \mathrm{m}^{-1}$). The distribution of the E_z field over the corrugation is shown in Fig. 3b and Fig.3c.

A sheet electron beam 80 µm wide and 20 µm thick is adopted assuming 8 mA beam current. A uniform solenoidal focusing magnetic field of 0.9 T (about twice the Brillouin field) is imposed.

The dispersion curves of the two SWSs are shown in Fig.4 with superimposed the 12 kV beam line.

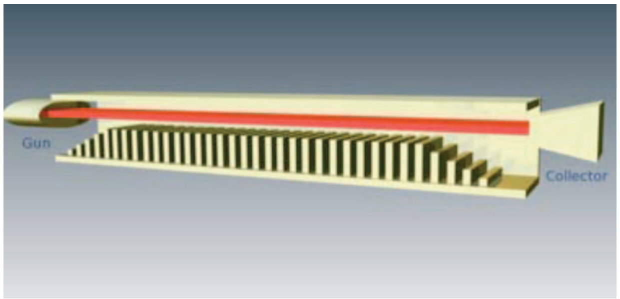

Figure 1. Wide corrugation waveguide

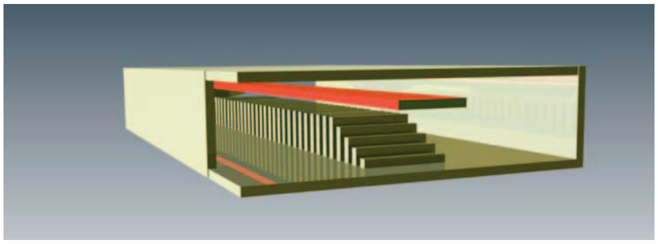

Figure 2. Narrow corrugation waveguide

The BWOs were simulated by MAGIC 3D particle-in-cell electromagnetic simulator. The wide corrugation waveguide BWO shows 190 mW output power at 1027 GHz (Fig. 5), while the narrow corrugation BWO provide 124 mW at 985 GHz (Fig.6). The electron energy as a function of the SWS length is shown in the inset in Fig.5 and Fig. 6. It is worth to note, the average energy behavior showing the amount of energy transferred from the beam to the E.M. field.

In both the cases a relevant output power is obtained. The advantage of the narrow corrugation waveguide, even if the output power is lower, is in a less critical assembling. The

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waveguide walls can be designed far enough from the corrugation so as eventual assembly errors, in particular the positioning of the top enclosure of the waveguide, do not affect the E.M. field distribution over the corrugation.

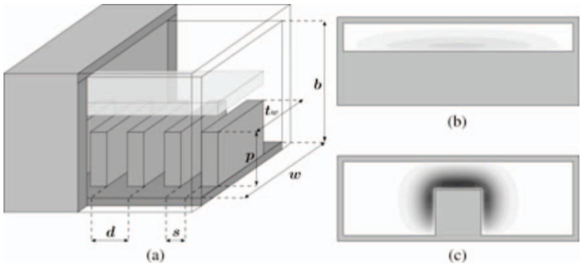

Figure 3. Schematic and E_z field distribution

Table I

Parameter	Wide corrugation (μm)	Narrow corrugation (μm)
s	25	27
d	50	50
p	60	65
t_w	240	80
b	110	110
w	240	240

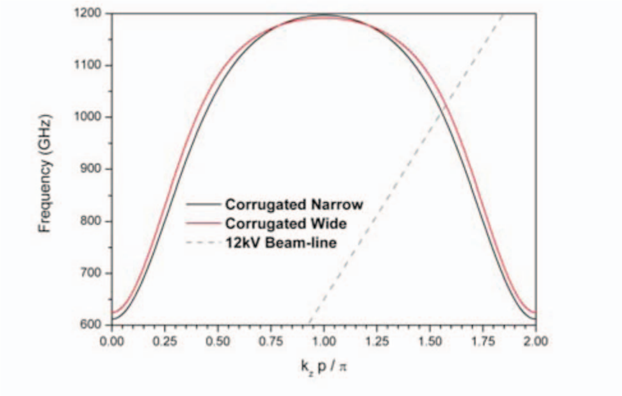

Figure 4. Dispersion curves for the two SWSs

Conclusions

A comparison between two BWOs based on different corrugated waveguide has been performed. The higher output power shown for the wide corrugation waveguide BWO is compensated by a more reliable and easy assembling of the narrow corrugation waveguide BWO. Further refinements to improve the output power of the narrow corrugated waveguide BWO are in progress.

Acknowledgment

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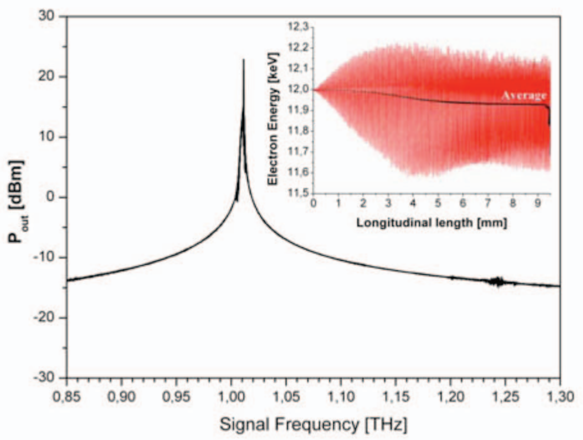

Figure 5. Output power spectrum of the wide corrugation waveguide SWS BWO

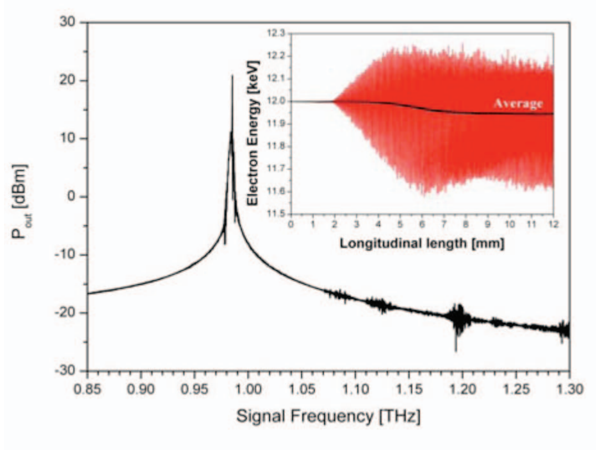

Figure 6. Output power spectrum of the narrow corrugation waveguide SWS BWO

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