Design and Microfabrication of a Double Corrugated Waveguide for G-band TWTs

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Abstract: *A G-band (210 – 250 GHz) Traveling Wave Tube (TWT) is in the fabrication stage. The TWT specifications are gain in the range 25 - 35 dB with more than 1 W output power. The double corrugated waveguide is chosen as the slow wave structure for the relatively easy fabrication. The TWT is based on a single SWS section, instead of the typical configuration with two sections separated by a sever typical at microwave frequency. The short wavelength at G-band determines the size of the parts to be less than 100 microns. The design and the fabrication had to be harmonised to achieve a high precision fabrication. A high end Computer Numerically Controlled milling machine was used. The fabrication result confirms the capabilities of the fabrication process.*

Keywords: TWT, G-band, double corrugated waveguide, millimetre waves, CNC milling

Introduction

The G-band is the region of the electromagnetic spectrum between 205 and 310 GHz. It corresponds to a valley of relatively low attenuation with about 80 - 90 GHz of useful bandwidth. This wide bandwidth is able to support tens of gigabit per second high data rate internet distribution [1]. However, amplifiers at this frequency only have a few milliwatt output power, making difficult enabling useful wireless links and to exploit the wide frequency band. In addition, the atmosphere and rain attenuation are very high.

The link budget calculation for a useful range longer than 500 m with an antenna with about 40 dBi suggests that at least one Watt is needed.

Recently, traveling wave tubes (TWT) have been introduced to enabling long links at millimetre waves above 90 GHz. The TWT multi-Watt output power capability permits one to overcome the limitations of solid state technology [1 - 4].

In this paper, the design and the fabrication of the first G-band (215 – 250 GHz) double corrugated waveguide [4] for a novel TWT, to enable multigigabit per second wireless links, will be described [5].

High precision CNC milling fabrication was used for the realisation of the complete circuit DCW [7, 8].

Double Corrugated Waveguide Design

The electron beam is operated at 12.9 kV beam voltage, 50 mA current, and 70 microns beam radius.

Those values are a compromise between the best magnetic focusing, the power supply cost, and the energy of the electrons for a relatively high efficiency. The dimensions were optimised to assure the proper synchronism of the phase velocity with the electron velocity over the 215- 250 GHz frequency band. Distinct from microwave helix TWTs, the SWS has been

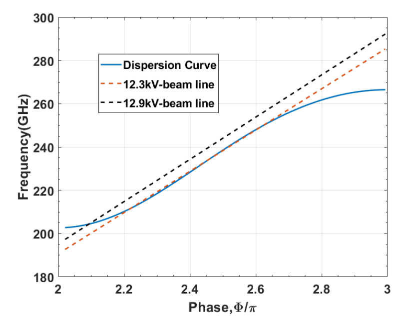

Fig. 1. Dispersion curve

designed with a single section without sever. This solution is possible because of the high losses of the slow wave structure at these frequencies. A single DCW section permits one to achieve about 30 dB gain with a stable behaviour without backward wave oscillations .

The full circuit to connect the DCW with the input and output couplers to the WR3 flanges was designed (Fig.2).

The output and input coupler include 15 rows of pillars tapered in height decreasing in direction of the flanges.

The number of periods of the DCW were then optimised to achieve about 1 W. The final circuit include 160 periods.

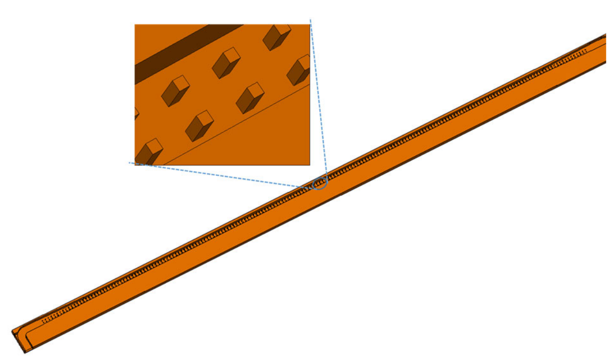

Fig. 2. Double Corrugated Waveguide G-band circuit

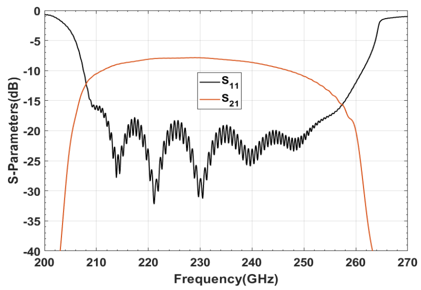

Fig. 3. S- parameters for the 160 period DCW

The S-parameters of the full circuit were computed by CST-transient solver (σ_{Cu} = 3.5×10^7 S/m). S_{11} better than -20 dB is obtained over the operating band, (Fig. 3) [5].

Particle in cells simulations were performed by CST-Particle Studio to compute the large signal behaviour of the TWT. About 30 dB gain and more than 1 W output power, with 1mW input signal are obtained over the 215 – 250 GHz band.

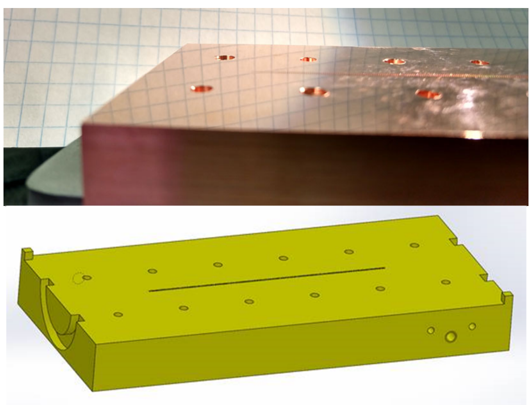

Fig. 4. Detail of the pillars and 3D drawing

DCW Fabrication

The fabrication of the circuit was performed using a KERN PYRAMID NANO CNC precision milling machine at UC Davis. The structure was built in two parts. One half with the pillars, the other with the waveguide. Oxygen Free High Conductivity (OFHC) copper stock was prepared along with precision fixtures using traditional CNC machining. First, the surfaces were made perfectly flat using a monocrystalline diamond endmill in the Kern Pyramid Nano. The pillars with a square cross section of 70 microns were then built with high spindle speed milling and utilizing microtooling of 0.1524 mm diameter. The result has been highly accurate. After the fabrication, the two halves were cleaned and bonded by diffusion bonding. The circuit was then tested for vacuum leakages, to verify the quality of the diffusion bonding.

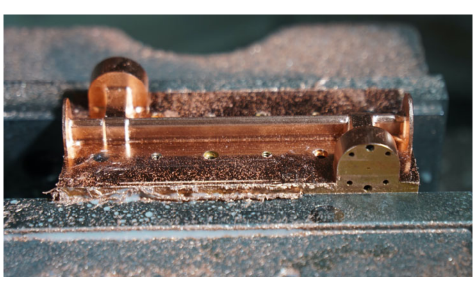

Fig. 5. CNC machining of the barrel.

Finally, the block was machined by XYZ CNC milling at , to produce the barrel with 3 mm diameter, vacuum tight, to be assembled in the TWT.

Conclusions

The design and performance of a single section G-band TWT to achieve 30 dB gain in the 215 -250 GHz range was discussed. The Double Corrugated Waveguide was chosen for the G-band TWT due to the simple fabrication and good performance. The small dimensions related to the wavelength at G-band, the high precision alignement of the parts, a diffusion bonding process vacuum tight, the delicate machining of the barrel demonstrate the substantial challenges that sub-THz TWTs pose. The fabrication of the G-band DCW TWT is in progress.

Acknowledgment

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