D-band medium power traveling wave tube

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***Abstract*—D-band (141 - 175.8 GHz) is very attractive for high capacity wireless links. However, the low power available from solid state amplifiers is not sufficient to ensure long links with 99.99% availability in the most common rain zones. Traveling wave tubes have been extensively demonstrated as the solution for satisfying the link budget. At sub-THz frequencies their fabrication is difficult and expensive. Typically, the 40 dB gain needed can be provided by two sections of slow wave structure separated by a sever. Due to the intrinsic low interaction impedance at sub-Thz frequencies, slow wave structures with high number of periods are needed. In case of metal SWS this determines long fabrication time and difficult assembly. This paper presents a short double corrugated waveguides for wide band (141 - 148.5 GHz) TWTs to provide about 26 dB gain and reduced fabrication difficulties.**

***Index Terms*—D-band, TWT, double corrugated waveguide**

I. Introduction

Wireless communications will inevitably move to the millimeter wave and sub-THz spectrum due to the abundance of frequency bands and low licensing cost [1] [2]. High data rate was fully demonstrated up to 0.4 THz, by transmitters with tens of gigabit per second (Gb/s) [3]. Unfortunately, the use of those transmitters is limited by the available transmission power of solid state amplifiers, rapidly decreasing at the increase of frequency, not sufficient to offset the high atmosphere attenuation, humidity and rain attenuation and interconnection losses. Sub-THz traveling wave tubes [4] were introduced as enabling devices in high capacity point to multipoint and point to point links in the frame of European Commission project ULTRAWAVE and TWEETHER [5] [6] and UK national projects (UKRI EPSRC DLINK). Design and fabrication of D-band TWTs were completed but some intrinsic challenges not yet fully resolved prevented to achieve a fully functional sub-THz TWT with more than 40 dB gain. The slow wave structure (both folded waveguide and double corrugated waveguide) is the most complex and time consuming part to build. The first challenge is the mechanical fabrication. It requires high accuracy, precision and the fabrication time depends on the number of periods. The second challenge is to assemble the SWS vacuum tight. Typically, it is built in split blocks that need to be bonded by solid state welding or brazing. Then, a second machining phase is needed to give the SWS the shape to support the period permanent magnetic (ppm) system. The success of this phase depends on the quality of the diffusion bonding. The period of sub-THz SWS is substantially shorter than the period at microwave due to the shorter wavelength,

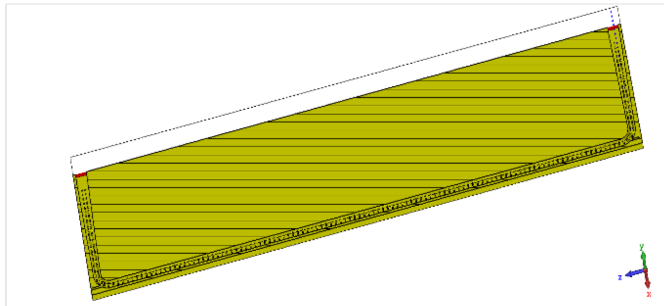

Fig. 1. Simulation model

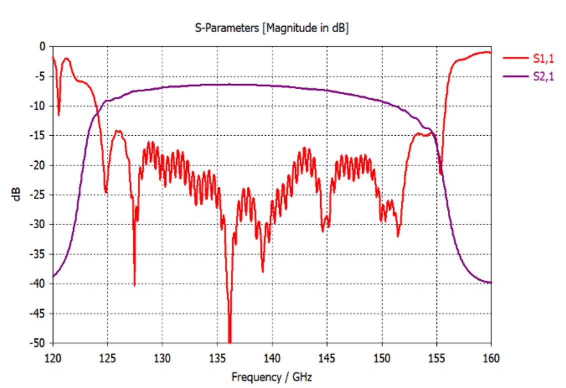

Fig. 2. Simulated S-parameters

but the low interaction impedance requires a high number of periods making the total length not so different. The tiny beam and beam tunnel diameters makes the alignment very difficult at the increase of the length. In the following, a medium gain single section D-band TWT will be described, to achieve output power at Watt level, with reduced fabrication effort.

II. D-band SWS circuit

The design of the D-band SWS was focussed to achieve the wider frequency band, possibly to use the same SWS to cover wide portion of the D-band for different TWTs. The double corrugated waveguide (DCW) single cell has similar dimensions reported in [7]. The DCW was simulated with 108 periods and input and output couplers. The simulation model is shown in Fig. 1. The S-parameters show a very wide frequency band (Fig. 2) with about 24 GHz in the range 125 - 149 GHz. The DCW was then simulated by Particle in Cell simulator.

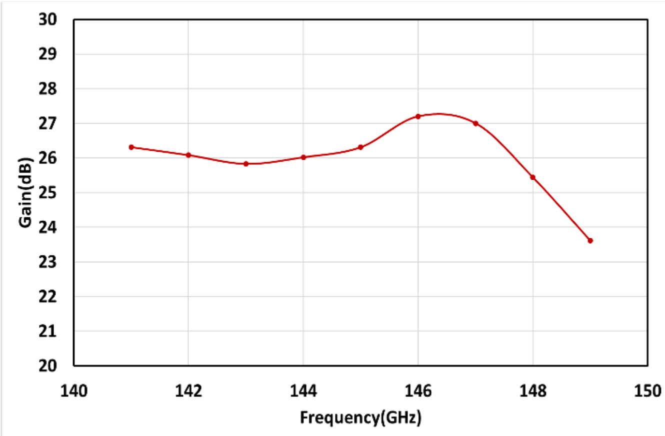

Fig. 3. Gain as a function of frequency

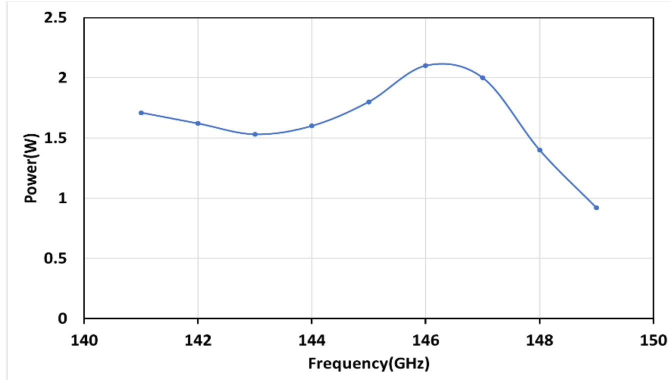

Fig. 4. Output power as a function of frequency

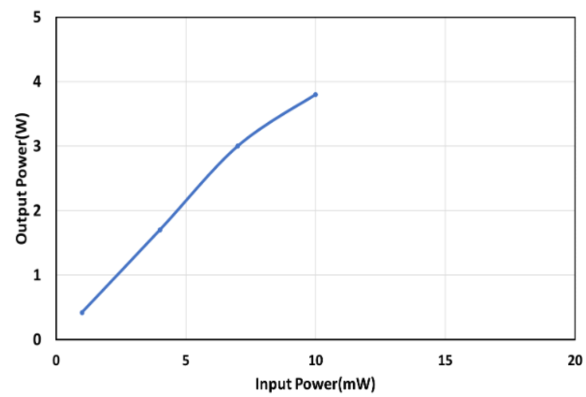

Fig. 5. Pin-Pout curve

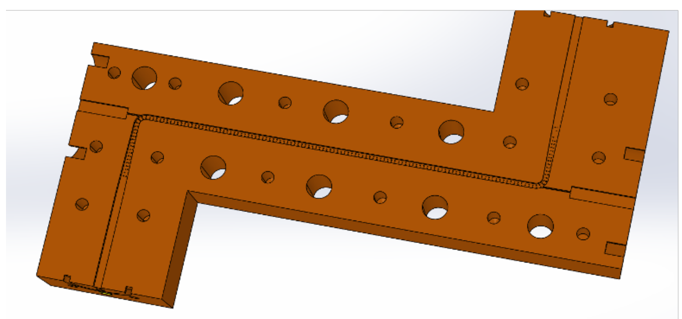

Fig. 6. Drawing of the full circuit to fabricate

The beam voltage was set at 12.7 kV. The synchronism has been optimised for the range 141 - 148 GHz. By varying the beam voltage a different frequency band can be obtained in the region defined by the S-parameters. A preliminary study was performed to define the number of period for a gain in the range 20 - 25 dB, values that should assure a stable amplification without the need of a sever. The gain and the output power are shown in Fig. 3 and Fig. 4 respectively. The gain is about 26 dB and the output power higher than 1.8 W in linear zone. The Pin - Pout curve in Fig. 5 shows that the output power close to saturation could be higher than 4 W. Assuming 6 dB back-off, the output power is 1.5 W, value more than one order of magnitude higher than available solid state amplifiers. The simulated SWS was then transferred in the technical drawing for the fabrication. The bottom block including the pillars, waveguide, couplers and beam tunnel in shown in Fig 6.

III. Conclusion

The use of a short DCW section to produce a medium gain sub-THz TWT is an option to reduce the challenges due to alignment and fabrication costs. The output power is about one order of magnitude higher than a solid state amplifier at the same frequency, making the single section TWT an enabling device for D-band wireless links.

Acknowledgment

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