Fabrication of W-band TWT for 5G small cells backhaul

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***Abstract*—The W-band (92 - 95 GHz) Traveling Wave Tube enabling the first Point to multipoint millimeter wave backhaul wireless network is in final phase of fabrication. The challenge is to build a TWT suitable for large volume fabrication to satisfy the cost constraints of network operators. Performances are targeted to provide coverage on sectors up to 90° with 1 km range. Simulations demonstrate a bandwidth of operation in excess of 5 GHz with a saturated output power of 40 W. The TWT is directly connected to a sector horn antenna.**

Keywords—TWT, W-band, 5G, folded waveguide, backhaul, access, traveling wave tube

I. Introduction

The development of 5G depends on the deployment of high density small cells to provide high capacity especially in urban environment. The challenge is to provide backhaul to the small cells with the required capillary and data rate. Fiber is not present everywhere, too expensive to deploy and needs permission of the local authority that are not always guaranteed. The only solution for capillary backhaul is the use the millimeter wave portion of the spectrum, that offer a number of very wide bands (Q-band, E-band, W-band) to support multigigabit data rate. However, the high attenuation in case of rain or humidity results in high transmission power requirements at a level of tens of Watt, not achievable by any available technology.

The EU H2020 TWEETHER project aims at demonstrating the first W-band (92 – 95 GHz) point to multipoint system for backhaul and access with high capacity. The unique performance of the system are possible for a new state of the art traveling wave tube designed to provide more than 40 dB gain and 40 W output power saturated. The traveling wave tube is based on a Folded Waveguide Slow wave structure. The various parts of the TWT have been designed and fabricated. The beam-optics is presently under test thanks to a specifically mounted "beam-tester" (beam-stick).

II. Design

The TWT is specified for the best compromise between performance and cost. The folded waveguide are realized by accurate CNC milling microfabrication. The beam parameters were chosen to assure a long lifetime compliant with the market expectations. A beam voltage of 16 kV and beam current of 70 mA assure an adequate gain and output power.

The simulation of the overall tube including SWS structure, sever and RF windows was quite demanding.

The dispersion curve with superimposed the 16kV beam line is shown in Fig. 1.

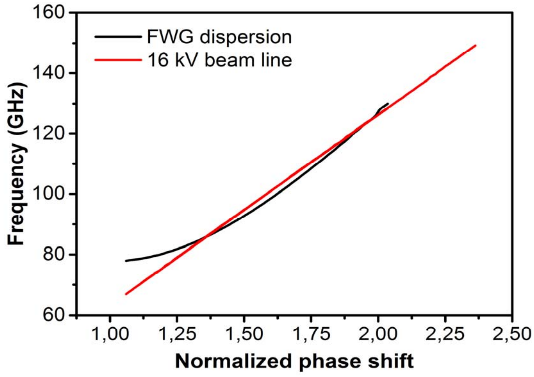

Figure 1: Dispersion of the folded waveguide and beam line

Both MAGIC3D and CST- Particle Studio were used for particle in cell simulations of the whole amplifier. The TWT uses two FWG sections separated by a sever. Both the simulators confirmed more than 40 W on the full band 92 – 95 GHz as shown in Fig. 2 The simulations included the couplers and the RF windows. Specific simulations for the design of the electron optics, the windows and the collector were performed.

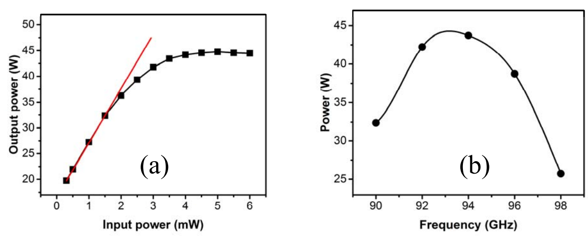

Figure 2: Simulation of (a) AM/AM transfer curve and (b) Power with 4 mW input power

III. Electron Optics

A Pierce gun is chosen with PPM focusing. Due the small dimensions of the delay line tunnel it was decided to validate the beam transmission in a specific "beam-stick" vehicle. This device is identical to the future TWT except that a simple cylindrical tunnel in copper is used instead of the folded waveguide and its RF windows. The beam-stick is mounted and is presently under test. It is shown in Figure 3.

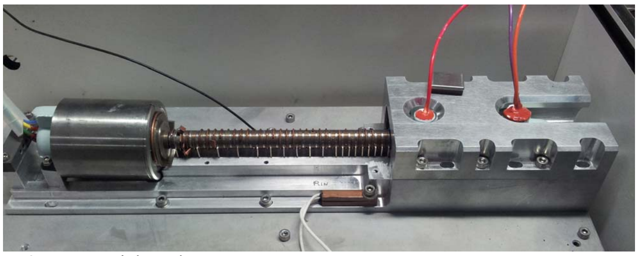

Figure 3: Beam-stick under test

IV. Delay Line Fabrication

The fabrication of a W-band TWT requires excellent geometrical tolerances and alignment. The folded waveguide has been built in two halves in OFHC (oxygen free high conductivity copper) which will later be bonded in a close waveguide. The alignment of the two parts is particularly critical due the risk of unwanted band gap in the operating bandwidth. The high fabrication precision is obtained by an accurate precise calibration of the CNC milling machine when using OFHC copper.

A test waveguide with 44 periods has been machined and tested (Figure 4). Its geometry is similar to that of the final FWG for the TWT except that it has two ports and no sever. Its purpose is to assess the machining quality, the return (S11) and propagation (S21) losses.

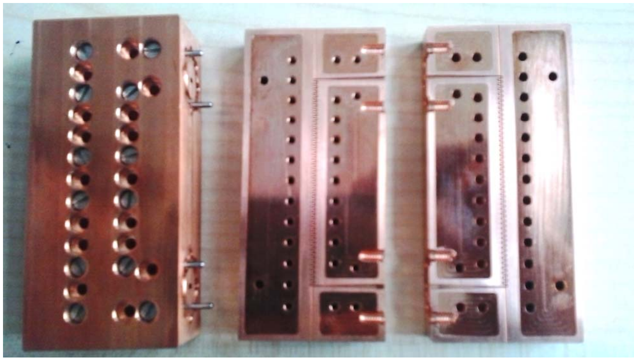

Figure 4: Test FWG in copper (assembled by screws on the left, two halves before assembling on the center and right views)

The measured return losses are 15 dB in the band of interest (Figure 5). However a narrow reflection band is visible at 94 GHz (peak). It results from a breaking of symmetry caused by machining tolerances and mis-alignement.

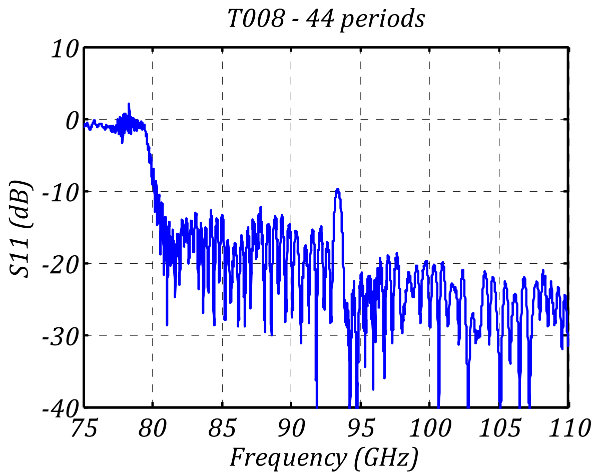

Figure 5: Measured match of the realized FWG

Measurement of the metal losses confirms the modified values for copper conductivity used in the simulations. They correspond to an equivalent conductivity on the copper wall of 2.9E7 S/m, i.e. half of ideal (pure and without roughness) copper.

V. Conclusions

The design and fabrication of the first European TWT for millimeter wave wireless backhaul for the new 5G networks has been described. Fabrication is in advanced stage.

The design satisfies system requirements. The assembly of the TWT will be shown at the IVEC.

Acknowledgment

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