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Abstract: *We report on the design and cold test validation of an overmoded TWT capable of producing power in excess of 100 Watts in the W-band and above. The TWT operates in the TM_{31} mode of a rectangular cavity and has transverse dimensions three times larger than a conventional ladder TWT. Dielectric loading of a resonant cavity was utilized to suppress lower order modes and prevent parasitic oscillations. HFSS and MAGIC3D codes were used to predict performance. An X-Ku band scaled down version of the interaction structure was built and cold tests performed on it showed excellent agreement with HFSS simulations.*

Keywords: overmoded; TWT; MAGIC3D; W-Band; ladder circuit

Introduction

TWT designs are limited in the amount of power that can be generated as frequencies reach the W-band and above. At higher frequencies the transverse dimensions of the interaction structure shrink which requires higher electron beam current density and reduces the structures ability to dissipate power. Traditionally, coupled cavity TWTs operate in a fundamental mode of the cavity. We have investigated the design of a TWT operating in a higher order mode to use larger transverse dimension of the circuit.

Overmoded Structures

By operating in a higher order mode the interaction structure's dimensions can be increased thereby the surface area available for thermal dissipation and reducing the power loss density [1]. However, overmoded operation opens the door to parasitic interactions with both lower and higher order modes. Several ideas were considered for mode suppression including, photonic band gap structures and dielectric loading. Dielectric loading was preferred for its ease of manufacture.

The goal of this work is the design of an overmoded 1-kW TWT operating near 94 GHz. Due to the historical success of the ladder circuit [2] a side coupled ladder circuit was chosen for this design (Fig. 1). While being similar to a folded wave guide TWT, a side coupled ladder circuit has the advantage of utilizing resonant cavities, allowing for mode selectivity. There are an infinite number of higher order modes, but too high a mode requires either excessive beam voltages or too fine a circuit pitch. Additionally, we wanted a mode that was axially symmetric, so that it would interact with a standard electron beam confined by an axial magnetic field. The TM_{31} mode of a rectangular cavity was chosen as the operating mode.

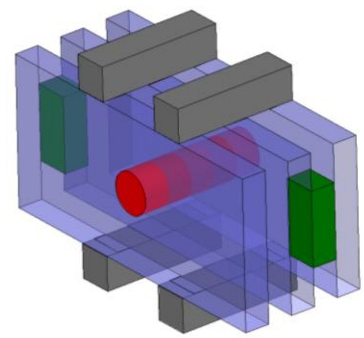

Figure 1. Unit cell of overmoded TWT illustrating the additional dielectric loading (grey) on top and bottom of the cavity, suppressing modes other than the TM_{31} mode.

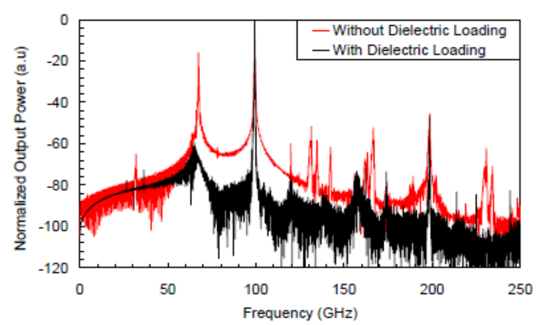

Figure 2. MAGIC3D simulation of interaction structure. The dielectric loading suppresses interaction in the lower order circuit modes.

The high-order mode has lower interaction impedance than a fundamental mode TWT. To get a saturated output power density exceeding 1 kW, more than 80 cavities were necessary. However, the choice of a TM_{31} mode and an axial electron beam meant a strong interaction with the TM_{11} mode was possible.

Computers simulations using MAGIC3D [3], seen in Fig. 2, show the TM_{11} mode, if not suppressed, leads to parasitic

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oscillations. By placing a lossy dielectric, in this case aluminum nitride, at the nulls of the TM_{31} mode significant losses can be introduced into other modes.

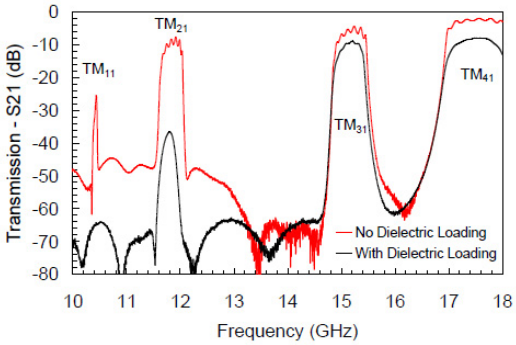

Figure 3. Results of a 15 GHz scaled cold test. The addition of dielectric loading significantly attenuates the TM_{11} and TM_{21} modes.

Using HFSS [4] the size of the loading can be optimized to fully attenuate the TM_{11} mode, leaving the TM_{31} mostly unperturbed.

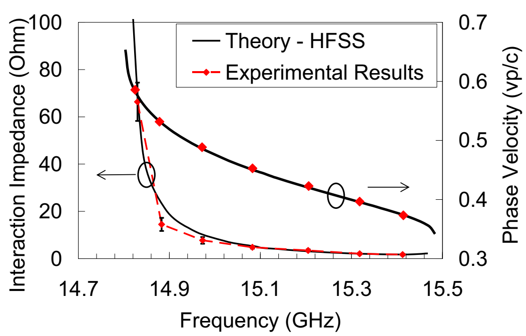

Figure 4. Results of a 15GHz scaled cold test.

HFSS was also utilized to calculate and optimize the dispersion and interaction impedance of the cavities. TWT performance was predicted using a 1D-code and had good agreement with the results from MAGIC, suggesting standard TWT design principles can be used for an overmoded TWT.

A W-band TWT was designed with a center frequency of 99 GHz. It relies on a 49 kV, 0.83A electron gun, and has a saturated output power over 1 kW with a 0.8 GHz bandwidth.

Scaled Cold Test

In order to verify the work done with HFSS an X- K_u-band cold test structure was built and tested. The addition of dielectric loading in the structure completely attenuated the parasitic, lower frequency modes, shown in Fig. 3. By performing a bead-pull experiment, interaction impedance and dispersion of the cold test structure were determined for the TM_{31} mode. The results, seen in Fig. 4, show an excellent agreement between the cold test experiment and values calculated from HFSS.

Conclusions

The overmoded circuit has many advantages over conventional circuits and the chosen dielectric loading scheme will suppress any mode competition from the lower order modes. Such an approach will be very advantageous for building sources in the terahertz frequency range.

Acknowledgements

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