Design and Measurement of a Novel Overmoded TE\textsubscript{01} Mode Converter for a Rectangular Gyro-TWT

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Abstract: In this paper, a sidewall coupler method is adopted to excite an overmoded TE\textsubscript{01} mode for the operation of a rectangular gyrotron traveling wave tube. Based on the magnetic dipole moment theory, the coupling aperture is designed and optimized. The rectangular TE\textsubscript{n0} (n=2, 3, …) modes are suppressed and the topology can also be applied to excite a TE\textsubscript{01} mode with a wider side. To verify this design, the novel Ka-band mode converter was manufactured and tested. The back-to-back measurements indicate that the port reflection is lower than -10 dB, and the transmission coefficient is great than -2.4 dB between 33 to 37 GHz.

Keywords: sidewall coupler; rectangular gyrotron traveling wave tube; overmoded mode converter.

Introduction

The gyrotron traveling wave tube (gyro-TWT) has the characteristics of high power and wideband, which have promising prospects in millimeter-wave radar and electronic countermeasures [1]. There are many different beam-wave interaction configurations of the gyro-TWT that have been designed and experimented, such as dielectric-loaded circuit [2], confocal waveguide [3], helically corrugated waveguide [4], and photonic band gap [5]. At the University of Electronic Science and Technology of China (UESTC), the hot experimental results show that the Ka-band gyro-TWT can produce 150 kW peak power, 10 kW average power with a circular dielectric-loaded RF circuit [6]. However, as the gyro-TWT develops towards higher output power (megawatt output power), the dimension of the RF circuit which is determined by the operating frequency restricts the area of the channel that allows the electron beam to be transmitted in the waveguide. So the rectangular dielectric-loaded gyro-TWT is investigated.

As shown in Fig. 1, it can be seen from the dispersion relations that when the operating mode is rectangular TE\textsubscript{10} mode, the operating frequency is only determined by the narrow side. Under a higher current, the channel area of the electron beam can be enlarged, and the electron beam current density can be reduced effectively by increasing the dimension of the wide side. With a 60 kV-48 A electron beam, the current density is about 72 A/cm\textsuperscript{2}, and the Ka-band rectangular gyro-TWT can obtain more than 1 MW output power in the simulation.

![Figure 1. Beam-wave dispersion relations in rectangular gyro-TWT.](image)

The mode converter is a part of the gyro-TWT, and its performance has a great influence on the tube. In the circular gyro-TWT, the mode converter mainly adopts sidewall coupling compared with the corrugated structure to get a high mode purity and low port reflection [7]. In this paper, a sidewall coupler method is used to excite the rectangular TE\textsubscript{01} mode with a large aspect ratio. The input microwave (rectangular TE\textsubscript{10} mode) is converted to the operating mode (rectangular TE\textsubscript{01} mode) in the RF circuit through the mode converter, and the TE\textsubscript{n0} (n=2, 3, …) modes are effectively suppressed. This structure can also easily lunch the overmoded TE\textsubscript{01} mode with a larger wide side by increasing the number of the coupling aperture. The details of design and measurement are drawn in section II.

Overmoded TE\textsubscript{01} Excitation

A. Design Principle and Simulation

As shown in Fig. 2, it is the schematic of the novel overmoded TE\textsubscript{01} mode converter with a large aspect ratio. The wide side and narrow side are 30 and 4.85 mm, respectively. The TE\textsubscript{10} mode is input from the standard Ka-band waveguide, then convert to the rectangular TE\textsubscript{01}

![Figure 2. Schematic of a TE\textsubscript{01} mode converter.](image)
mode. The Y-type power divider can guarantee the input signal divided into four signals (TE_{01} mode) with equal amplitude and the same phase. The four signals will excite the operating mode in the RF circuit. The multistaged matching is designed to improve the port reflection and the transmission coefficient. The cutoff waveguide in port 3 is applied to prevent the input microwaves into the magnetron injection gun (MIG) and affect the performance of the electron beam.

The magnetic dipole moment theory is applied to the design of an overmoded TE_{01} mode converter. The coupling apertures will produce magnetic dipoles, and when the magnetic dipoles are properly arranged on the rectangular waveguide, the rectangular TE_{01} mode can be excited. Based on this theory, a TE_{01} mode with a larger wide side can be excited by increasing the number of the coupling aperture. The TE_{m0} (m=2, 3, ...) can be effectively suppressed by optimizing the coupling aperture.

The simulation results of the mode converter are shown in Fig. 3. It can be seen that the transmission coefficient of the desired mode S_{21} is more than -0.45 dB and the port reflection S_{11} is lower than -10 dB between 33-37 GHz. The mode purity exceeds 91%. The results indicate that the novel overmoded mode converter has a good S-parameter performance and mode purity.

B. Manufacture and Microwave Measurement

Two overmoded TE_{01} mode converters made of aluminum blocks are fabricated in Fig. 4 (a). The back-to-back measurement method is adopted to verify the port reflection and transmission coefficient. The two mode converters are connected with the vector network analyzer (VNA) and tested as shown in Fig. 4 (b).

The comparison of the simulation and measurement results of the mode converter is shown in Fig. 5. It can be seen from the cold test result that the S_{11} is lower than -10 dB and it is in good agreement with the simulation result between 33 to 37 GHz. The measurement result of S_{21} is greater than -2.4 dB. The S_{21} has a difference due to the fabrication errors of the Y-type power divider.

Conclusion

In this paper, a novel overmoded rectangular TE_{01} mode converter is designed and tested. The S_{11} is lower than -10 dB and the S_{21} is more than -2.4 dB between 33 to 37 GHz in the cold test. The mode-conversion technique could also be expanded to excite the overmoded TE_{10} mode with a larger aspect ratio in the high-power rectangular gyro-TWT.

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