DESIGN OF AN X-BAND COMPACT MODE CONVERTER FOR CONVERTING TE_{10} MODE TO TE_{01} MODE*

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Abstract

This paper presents the design of a compact and efficient rectangular waveguide TE_{10} to circular waveguide TE_{01} mode converter operating in the X-band. By incorporating two choke slots, the design achieves a high-purity circular waveguide TE_{01} mode. The optimized results show that at the operating frequency of 11.424 GHz, the conversion efficiency for the circular waveguide TE_{01} mode is calculated to be approximately 100%, while the reflection coefficient is better than -50 dB. The bandwidth reaches more than 260 MHz for the transmission coefficient while the bandwidth is approximately 210 MHz for the reflection coefficient better than -20 dB.

INTRODUCTION

With the rapid development of microwave technology in accelerator systems, high-power pulse compressors have been utilized to double the energy of the Klystron. The pulse compressor is mainly based on the theory of SLAC energy doubler (SLED) [1]. The initial mode converter of the SLED directly coupled a TE_{10} rectangular waveguide into the resonant cavity, which led to mode mixing in the cavity. Therefore, by additionally designing a multi-stage mode converter, we can achieve a larger bandwidth and isolation between adjacent degenerate modes. The TE_{01n} mode in a cylindrical cavity achieves a high quality factor because its surface current has no axial component, leading to minimal wall loss [2, 3]. In addition, since the electric field vanishes at the waveguide wall, the mode can sustain higher power levels without surface breakdown[4]. Thus, The TE_{01n} mode was chosen as the operating mode of the SLED system. To ensure the purity of the storage mode, the design of an X-band compact and efficient rectangular waveguide TE_{10} to circular waveguide TE_{01} mode converter is presented in this paper.

RF DESIGN

The rectangular waveguide TE_{10}-circular waveguide TE_{01} mode converter described in this paper has a center frequency of 11.424 GHz. And it is composed of two parts: the rectangular waveguide TE_{10}-TE_{20} mode converter and the rectangular waveguide TE_{20}-circular waveguide TE_{01} mode converter, as shown in Fig 1.

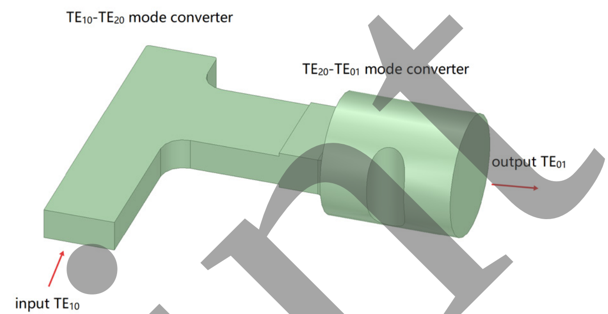

Figure 1: The rectangular waveguide TE_{10}-circular waveguide TE_{01} mode converter.

TE_{10}-TE_{20} Mode Converter

The rectangular waveguide TE_{10}-TE_{20} mode converter structure is relatively simple, it consists of a standard rectangular waveguide WR90 and a widened rectangular waveguide, with a smooth connection between the widened waveguide and the standard waveguide section. The input power is fed into Port 1, while the TE_{10} mode is converted to TE_{20} mode in the converter at Port 2. The two TE_{10} modes at Port 2 have opposite phases, resulting in the excitation of the TE_{20} mode and the suppression of the TE_{10} mode. Figure 2 shows the electric field distribution of the rectangular waveguide TE_{10}–TE_{20} mode converter after optimization. Figure 3 shows the S-parameters of the rectangular waveguide TE_{10}-TE_{20} mode converter. The TE_{10} mode is suppressed, with a transmission coefficient lower than -30 dB.

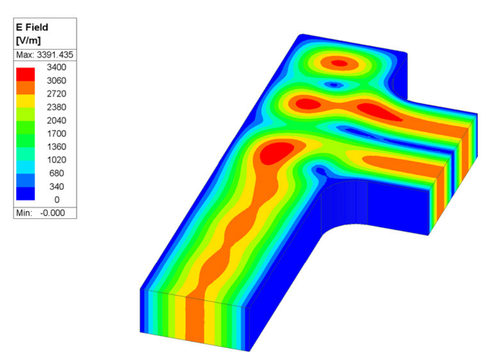

Figure 2: Electric field distribution of the rectangular waveguide TE_{10}-TE_{20} mode converter.

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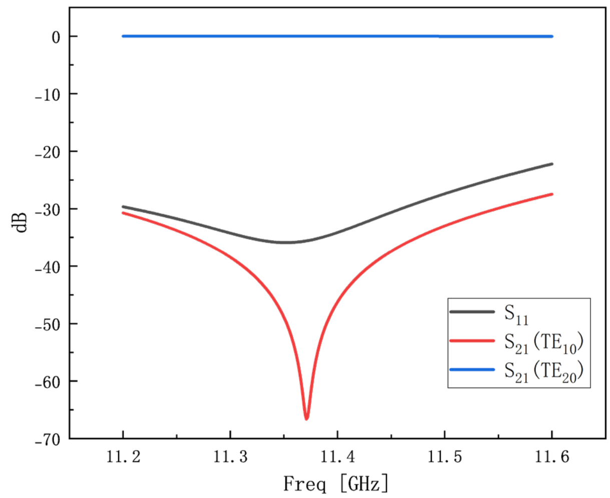

Figure 3: S-parameters of the rectangular waveguide TE_{10}-TE_{20} mode converter.

TE_{20}-TE_{01} Mode Converter

The TE_{20}-TE_{01} converter consists of a rectangular waveguide step, a circular waveguide and two choke slots. The rectangular waveguide step can reduce microwave reflections generated by the discontinuity of junction between the rectangular waveguide and the circular waveguide. Since the TE_{01} mode in a circular waveguide is not the dominant mode of the circular waveguide, it is necessary to suppress other modes during the conversion. The TE_{20} mode in a rectangular waveguide does not excite the TE_{11} mode or the TM_{01} mode in a circular waveguide. Therefore, the primary interference mode is the TE_{21} mode in a circular waveguide. In this article, two choke slots are selected. The choke slots chosen are cylinders perpendicular to the axis of the circular waveguide, and the two choke slots are symmetrical, used to cut off the axial component of the current and suppress the generation of the circular waveguide TE_{21} mode. Moreover, the introduction of the choke slots does not affect the TE_{01} mode in a circular waveguide, since there is no axial current in the TE_{01} mode of a circular waveguide. During the optimization process, it is observed that the surface electric field intensity is high at the junction between the rectangular waveguide and the circular waveguide. To reduce the surface electric field intensity and thereby achieve a higher breakdown voltage, we implemented a fillet design at the junction.

Figure 4 is the electric field distribution of the rectangular waveguide TE_{20}-circular waveguide TE_{01} mode converter after optimization. Figure 5 shows the S-parameters of the rectangular waveguide TE_{20}-circular waveguide TE_{01} mode converter. From the figure, it can be seen that the function of the choke slots is very significant. The TE_{21} mode is suppressed, with a transmission coefficient lower than -20 dB within the operating frequency range. More importantly, just as we expected, the choke slots do not affect the conversion efficiency of the TE_{01} mode and almost all the microwave energy is converted to the TE_{01} mode.

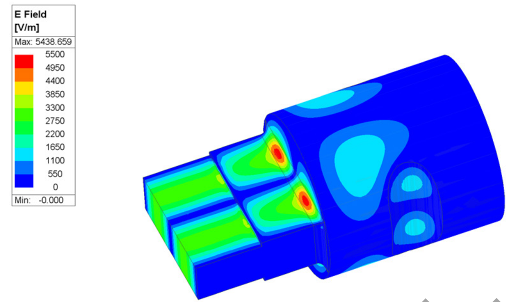

Figure 4: Electric field distribution of the rectangular waveguide TE_{20}-circular waveguide TE_{01} mode converter.

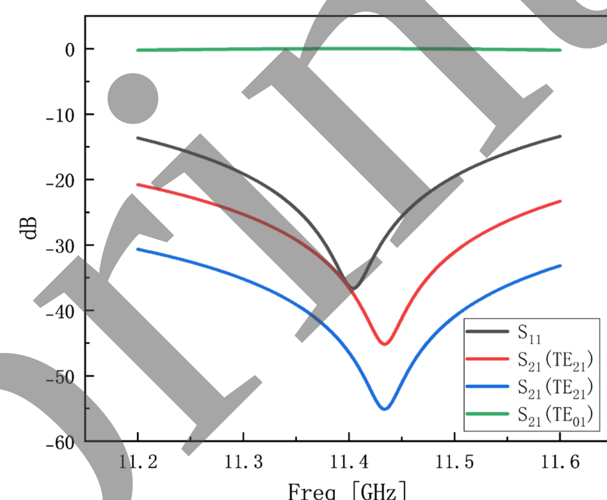

Figure 5: S-parameters of the rectangular waveguide TE_{20}-circular waveguide TE_{01} mode converter.

Simulation Results

The mode converter described in this paper is composed of two parts mentioned above. Figure 6 shows the amplitudes of the electric field of the mode converter. As can be seen, at an excitation power of 1 W, the maximum electric field intensity is approximately 5344 V/m, located at the junction between the rectangular waveguide step and the circular waveguide.

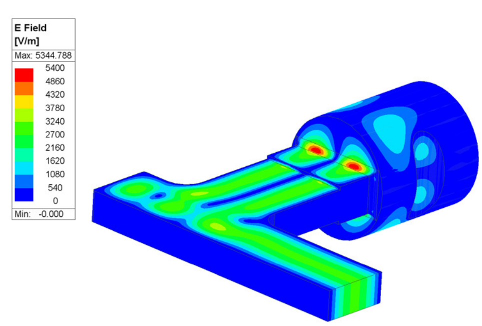

Figure 6: Electric field distribution of the rectangular waveguide TE_{10}- circular waveguide TE_{01} mode converter.

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Figure 7 shows the S-parameters of the rectangular waveguide TE_{10}-circular waveguide TE_{01} mode converter mode converter. We can see that at a frequency of 11.424 GHz, the rectangular waveguide TE_{10} mode is completely converted to the circular waveguide TE_{01} mode while the reflection coefficient is better than -50 dB, and the conversion efficiency remains high across the selected frequency range. Besides, it also shows the bandwidth reaches more than 260 MHz for the transmission coefficient greater than 99% while the bandwidth is approximately 210 MHz for the reflection coefficient better than -20 dB. Simulation results indicate that this mode converter is suitable for SLED pulse compression systems.

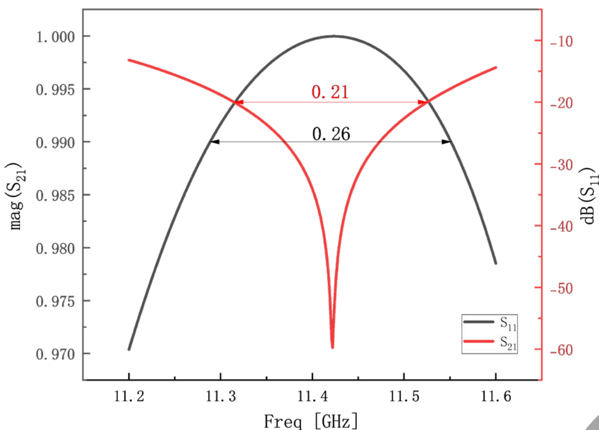

Figure 7: S-parameters of the rectangular waveguide TE_{10}-circular waveguide TE_{01} mode converter mode converter.

CONCLUSION

This paper presents the design of a compact and efficient rectangular waveguide TE_{10} to circular waveguide TE_{01} mode converter operating in the X-band. And it has a simple structure. The conversion efficiency for the circular waveguide TE_{01} mode is calculated to be approximately 100% at the operating frequency. Simulation results indicate that this mode converter is suitable for SLED pulse compression systems.

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