Excitation of a Pure TE_{mn} Mode at Low Terahertz Region

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Abstract—**This work presents a methodology of generating circular TE_{mn} mode at low terahertz region through sidewall couplings. These couplings induce magnetic dipoles. With proper arrangement on the circumference of the circular waveguide, they then jointly excite the desired mode. A model is developed to calculate the coupling strength and to analyze the mode purity. Three mode converters, TE_{21}, TE_{01}, and TE_{41}, were designed, built, and tested at W-band. Back-to-back transmission measurements exhibit excellent agreement to the results of computer simulations when the conductor loss is taken into consideration. The measured transmissions are 97%, 98%, and 95% with 3-dB bandwidths of 18.3, 24.0, and 20.2 GHz, respectively. These Y-type converters are structurally simple but machining errors are still critical. The factors affecting the performance will discuss in more details.**

I. INTRODUCTION

Researches on the terahertz region have drawn much attention in recent years with the growing terahertz technologies. The low-power, non-coherent radiation sources have created numerous applications. However, the development of the high-power, coherent radiations is still slow-moving because of the severe lack of the terahertz radiation sources as well as devices. The gyrotrons are ideal sources, especially at the low-terahertz region. The electron beam interacts with the wave through the electron cyclotron maser mechanism. A mode converter is needed to inject the desired wave pattern (mode) or to extract a wave power from a modulated electron beam. But to generate/extract the desired wave with high mode purity, high converting ratio, and broad bandwidth is extremely difficult. The improper mode-converter will excite unwanted modes which results in severe mode-competition problem and significantly hinders the progress of high-power terahertz gyrotrons.

This paper proposes an approach to generate/extract a circular TE_{mn} mode with high performance. Excitation of a circular TE_{mn} mode can be classified into two categories, according to the coupling methods involved. One is in-line coupling, and the other is sidewall coupling. The former, using a deformed waveguide structure, gradually converts a wave into the desired mode. The transition length is typically long and multiple modes can be excited during the converting process. On the other hand, the latter generally uses a smooth waveguide with coupling holes on the sidewall. The typical coupling method is the multi-hole directional coupler based on the field vector superposition theorem. Recently, the sidewall couplings around the circumference of the circular waveguide are generally accepted. A coaxial cavity which connects a rectangular waveguide and a circular waveguide is adopted and shown to be very effective. Recently, a Y-type power divider which bifurcates a wave into several proportional signals is used and shown excellent performance---wide-bandwidth and high-transmission---at Ka-band. However, the working principle is not clearly explained.

This work presents a generic approach to excite a pure circular TE_{mn} mode through sidewall couplings with the emphasis on the working principle. Coupling inducing the electric or magnetic dipoles and jointly synthesizing the desired mode will analyze in details. Based on this methodology, three mode converters, TE_{21}, TE_{01}, and TE_{41} will be designed and fabricated with great precision. These high-performance converters are demonstrated at W-band. It is especially suitable for gyrotron amplifier/oscillator applications.

II. EXPERIMENTAL RESULTS

Figure 1 shows the theory and experimental results for the back-to-back configuration. General speaking, the measured results are consistent with the HFSS simulation data. The bandwidths associated with the 1-dB and 3-dB transmission losses are 5.8 GHz and 7.0 GHz, respectively. The measured converting efficiency of a single converter is about 98.5%. The ohmic loss and the reflection account for the other 1.5%. Measurements are made using a rotatable setup to further explore the field symmetry and to examine the existence of competing modes.

Table 1 Coupling method, waveguide radius, and parasitic modes are listed for three desired modes TE_{21}, TE_{01}, and (c) TE_{41}.

Desired mode	TE_{21}	TE_{01}	TE_{41}
Couplings	Dual feed	Quad feed	Quad feed
Waveguide radius	1.74 mm	2.15 mm	3.00 mm
Parasitic modes	$TE_{11,A}$, $TE_{11,B}$	$TE_{11,A}$, $TE_{11,B}$	$TE_{11,A}$, $TE_{11,B}$
	TM_{01}	$TE_{21,A}$, $TE_{21,B}$	$TE_{21,A}$, $TE_{21,B}$
		TM_{01},	TE_{01}
		$TM_{11,A}$, $TM_{11,B}$	$TE_{31,A}$, $TE_{31,B}$
			$TE_{12,A}$, $TE_{12,B}$
			TM_{01},
			$TM_{11,A}$, $TM_{11,B}$
			$TM_{21,A}$, $TM_{21,B}$

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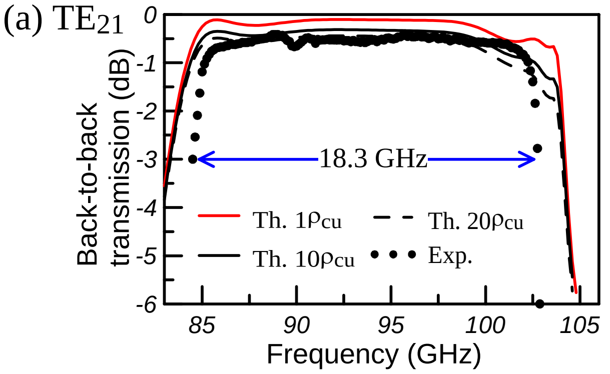

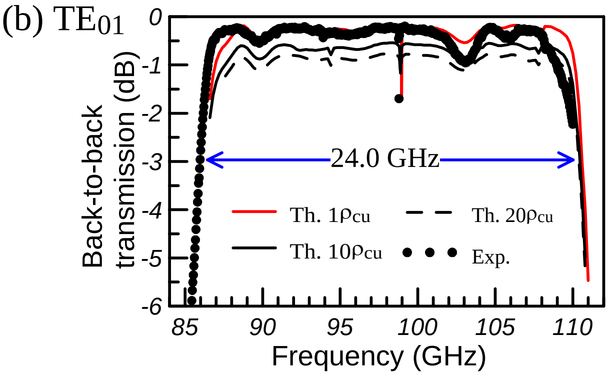

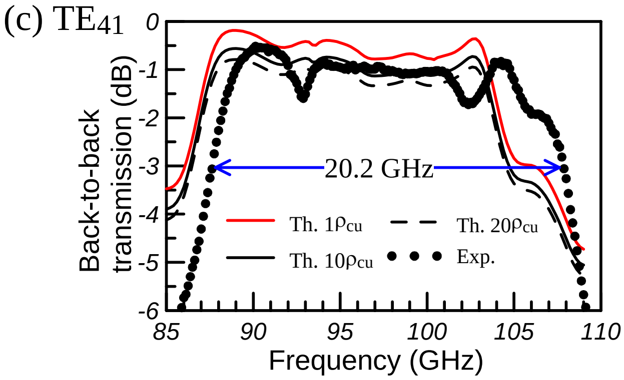

Fig.1 Back-to-back transmission for three mode converters (a) TE_{21}, (b) TE_{01}, (c) TE_{41}. The calculated results for different conductor loss are also shown.