0.22-THz Frequency-Tunable Gyrotron with Transverse Sliced Cavity

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***Abstract*—A 0.22-THz frequency-tunable gyrotron with transverse sliced cavity has been developed and tested in TRC-UESTC. The proof-of-principle experimental results indicate that radiation frequency can be varied over a 1.39 GHz range from 222.903 GHz to 224.288 GHz by adjusting the operating magnetic field. During the frequency tuning, the maximum output power was 2.85 kW with an efficiency of 5.5%. Compared with previous results of a normal cavity without transverse slices, it is demonstrated that transverse slices can suppress the mode competition and broaden the frequency tuning range. This mechanism is beneficial to the future development of high-power terahertz gyrotron.**

I. Introduction

OVER the last decades, gyrotron has always been considered as one of the most promising devices [1], which can generate high power radiation at high frequency, even in the terahertz (THz) band [2]. To overcome the narrow band of traditional high-power gyrotron, a 0.22-THz frequency-tunable high-power gyrotron operating in high-order axial modes (HOAMs) has been developed in the Terahertz Research Center, University of Electronic Science and Technology of China (TRC-UESTC). Experimental results have demonstrated that HOAMs can be successfully excited one after another in high-power gyrotron and perform a frequency-tunable characteristic[3].

In this paper, a novel interaction structure based on transverse sliced circuit is designed to suppress the mode competition and improve the frequency tuning ability. The proof-of-principle experiment of 0.22-THz frequency-tunable gyrotron with transverse sliced cavity has been carried out in TRC-UESTC and presented in this paper.

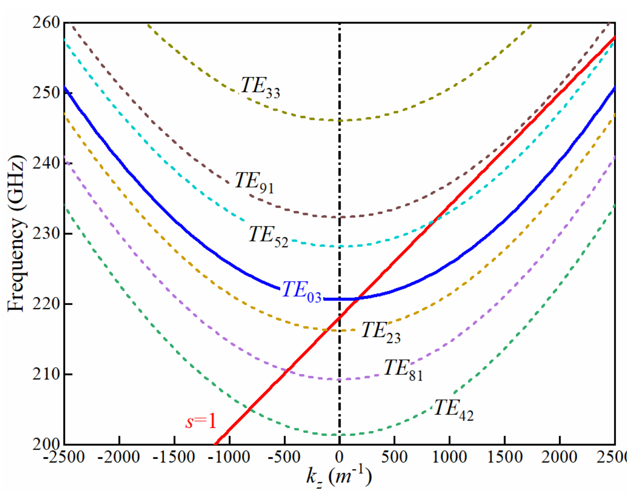

Fig. 1. Dispersion curves for a cylindrical gyrotron cavity operated in the fundamental TE_{03} mode.

II. Experimental Demonstration

According to the classical electromagnetic theory, $TE_{0,n}$ mode in cylindrical waveguide is a kind of circularly symmetric mode and its wall surface current only has the azimuthal component. In contract, the wall current for other $TE_{m,n}$ ($m \neq 0$) modes have both azimuthal and axial components. Therefore, a transverse slice is able to interrupt the wall current of the asymmetric modes but has litter effect on the $TE_{0,n}$ modes. This mode-selective mechanism has been proved by a *Ka*-band $TE_{0,1}$ gyro-BWO [4].

The previous high-power frequency-tunable gyrotron with a normal cylindrical cavity is operated in the fundamental $TE_{0,3,q}$ ($q = 1, 2, 3, 4$) mode. As shown in Fig. 1, the theoretical analysis predict that the potentially competitive modes are TE_{23} and TE_{52} modes. To suppress the mode competition and broaden the frequency tuning range, a transverse sliced interaction structure is proposed and applied into a new 0.22-THz frequency-tunable gyrotron. Fig. 2 shows the scheme of transverse sliced gyrotron cavity. The components of this new version gyrotron tube, except for the transverse sliced cavity, are almost the same as the previous gyrotron reported in [3].

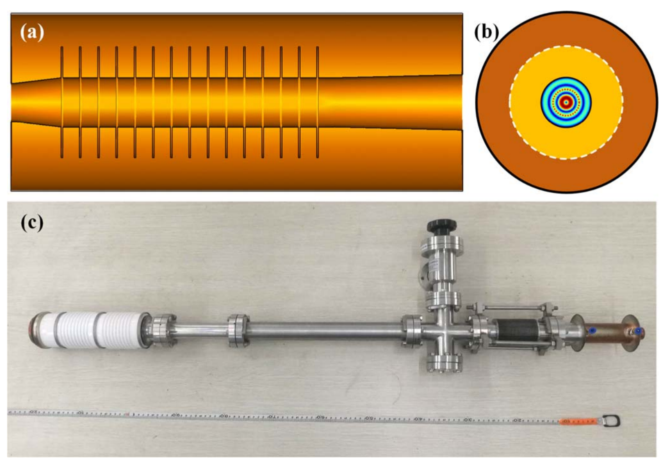

Fig. 2. Design of a 0.22-THz frequency-tunable gyrotron with transverse sliced cavity: (a) axial profile of the gyrotron cavity, (b) operation mode $TE_{0,3}$ in transverse slice, (c) photo of the gyrotron prototype.

The 0.22-THz frequency-tunable gyrotron with transverse sliced cavity has been initial tested in UESTC. During the initial experiments, the beam voltage and beam current were measured by a resistor voltage divider and Rogowsky coils, respectively. A calibrated calorimeter (Scientech, Inc. AC2500H) was utilized to measure the output power of gyrotron. The frequency measurement system was based on a 7th harmonic mixer with a corresponding frequency range of 170-220 GHz, made by the 41st Institute of China Electronics Technology Group Corporation (CETC). The intermediate frequency (IF) signal output from mixer was recorded by an Agilent oscilloscope with a standard bandwidth of 1.5 GHz and the highest sampling rate up to 4 GSa/s. Fig. 3 shows the typical recorded waveforms of beam voltage, beam current and IF signal. The beam current was estimated about 1.3 A for a fixed beam voltage of 40 kV. Fig. 3(a) shows that the waveform of IF signal detected at a lower sampling rate of 250 MSa/s kept stable during the whole pulse flat-top of beam voltage. The partial IF signal trace at a high sample rate of 4 GSa/s and its fast-Fourier-transform (FFT) spectrum, shown in Fig. 3(b), obviously illustrate that only a single frequency was detected in the voltage pulse flat-top. It is indicated that a stable single frequency oscillation was excited in the gyrotron cavity.

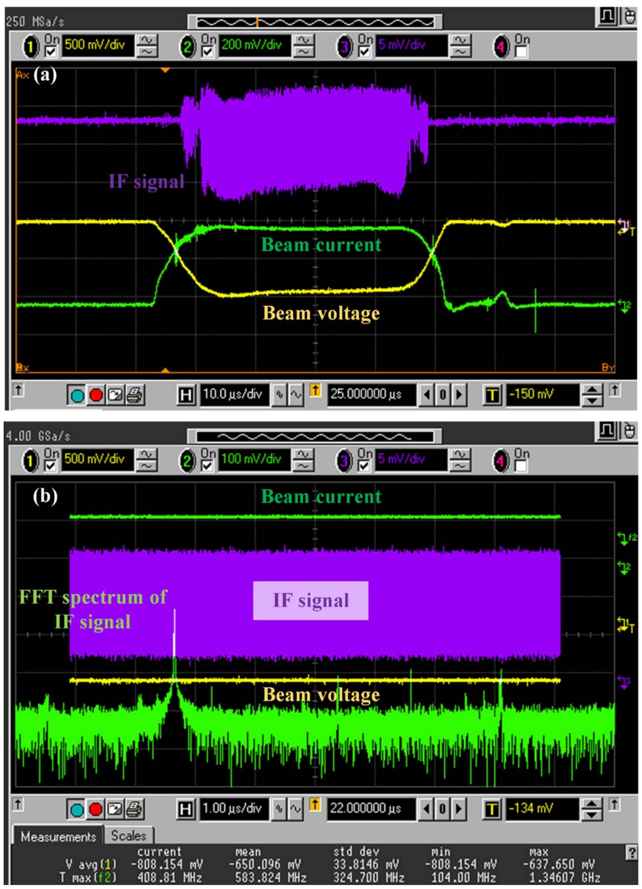

Fig. 3. Typical recorded waveforms in the gyrotron operation: (a) beam voltage, beam current and IF signal envelops detected at lower sampling rate; (b) Partial IF signal waveform detected at higher sampling rate and its FFT spectrum.

By tuning the operating magnetic field at a fixed beam voltage of 40 kV, the experimental results of radiation frequency and output power are plotted in Fig. 4. By adjusting the magnetic field B_0 from 8.27 to 8.65 T, a 1.39 GHz frequency tuning range from 222.903 GHz to 224.288 GHz was achieved. During the process of frequency tuning, the maximum power was evaluated as 2.85 kW, corresponding to an interaction efficiency of 5.5%. Fig. 4 also shows a result comparison between the gyrotron cavities with and without transverse slices. Effected by the mode competitions from TE_{23} mode at lower magnetic field and TE_{52} mode at higher magnetic field, the maximum frequency tuning range for a normal cavity without transverse slices was about 0.79 GHz, which was much smaller than that for a transverse sliced cavity. Therefore, the experimental results demonstrate that the major competitive TE_{23} and TE_{52} modes are successfully suppressed by the transverse slices and the operating TE_{03} mode performs a wide frequency tuning range.

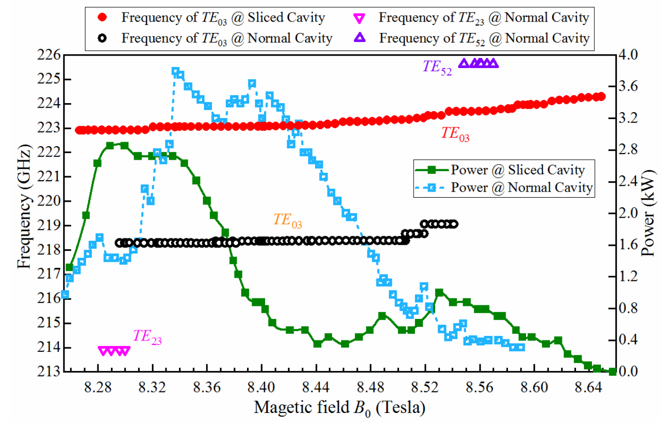

Fig. 4. Experimental results of radiation frequency and output power by magnetic tuning and comparing with the results of previous gyrotron with normal cavity.

III. Summary

In this paper, a 0.22-THz frequency-tunable gyrotron cavity with transverse slices is proposed and experimental demonstrated in TRC-UESTC. Under the initial pulse operation, the output frequency was able to varied from 222.903 GHz to 224.288 GHz, corresponding to a frequency tuning range of 1.39 GHz. Compared with the previous results of a normal cavity without transverse slices, it is demonstrated that the transverse sliced cavity can suppress the asymmetric competitive modes TE_{23} and TE_{52} effectively but has litter effect on the operating TE_{03} mode. The results of this work should be conductive to the future development of frequency-tunable high-power gyrotron.

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