Steady-state Multimode Analysis of Instability and Stabilization for a TE_{11} Mode Fundamental Gyro-TWT

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Abstract—**Based on the steady-state multimode theory, the instability and stabilization of a TE_{11} mode fundamental Gyro-TWT is discussed through increasing the power of input signal, changing the guiding center radius of electron beam and coating the microwave absorption material on the inner surface of interaction structure to suppress the TE_{21} mode second harmonic backward wave oscillation and obtain the higher amplifying gain and the larger output power for the TE_{11} mode fundamental operation with relatively low input power and microwave loss on the coated material.**

I. INTRODUCTION

Gyro-TWT can produce high output power at millimeter wavelength range with wide bandwidth, but mode competition is always a technical problem to affect operating stability. A lot of theoretical and experimental researches had ever been invested in studying the oscillation in a Gyro-TWT to improve its stability. coating microwave absorption material on the inner surface of interaction structure and adding the power of the input signal was ever used to suppress parasitic oscillations [1-3]by some experimental methods. In this abstract, Based on the steady-state multimode theory, the authors present the analytical results for improving the stability of the TE_{11} mode fundamental Gyro-TWT through increasing the input power and changing the guiding center radius to suppress the TE_{21} mode second harmonic backward wave oscillation, which is in rational agreement with the experiments ever discussed in reference [1]. However, the increase of the input power and the guiding center radius will decrease the amplifying gain and the output power. So the authors try to discuss the effect of the combination of input power, loss-loaded and guiding center variation on the stabilization of the instability for a TE_{11} mode fundamental Gyro-TWT to obtain the higher amplifying gain and the larger output power with relatively low input power and microwave loss on the coated material.

II. RESULTS

Here we only consider the mutual effect of the TE_{11} mode fundamental gyro-TWT amplification with the TE_{21} second harmonic backward wave oscillation, where $V=100kV$, $\alpha=0.85$, $L=17.46cm$, $r_w=0.26cm$, $B_0=1.254T$, $f_{TE11}=35GHz$.

At first, we set $r_c/r_w=0.09/0.26$, $I_b=0.5A$, 1A, 1.5A for calculating the output powers of the $TE_{11}^{(1)}$ mode amplification and the $TE_{21}^{(2)}$ mode backward wave oscillation without attenuating material on the inner surface of metal waveguide for different input power and guiding center radius. The results shows that the backward oscillation can be suppressed for $I_b=0.5A$ at the input power of about larger than 380W (Fig.1(a)) and $I_b=1A$ at the input power of about larger than 570W (Fig.1(b)), but it cannot completely be suppressed when $I_b=1.5A$ by adding the power of the input signal (Fig.1(c)).

And then, we set $I_b=5A$ for discussing the effect of the guiding center radius (r_c/r_w) variation on the backward wave oscillation. The results show that the backward oscillation is gradually weakened and the output power of the $TE_{11}^{(1)}$ mode is enhanced with the increase of r_c/r_w from 0.45 to 0.65 (fig.2(a) and (b)) and the backward oscillation can completely be suppressed for $r_c/r_w = 0.65$ at the input power of about larger than 75W, producing 128kW output power of the $TE_{11}^{(1)}$ mode.

After that, we set $I_b=10A$, $r_c/r_w = 0.45$, and $L_{loss}=14cm$ for discussing the effect of the conductivity variation on the backward wave oscillation. The results show that, compared with the increase of input power, the decrease of the conductivity is more effective for weakening the backward wave oscillation and the output power of the operating mode is three orders of magnitude higher than that of the backward wave oscillation. With the increase of the input power, the backward wave oscillation can completely be suppressed and the decrease of the conductivity can make the decrease of the input power for keeping the steady operation of the $TE_{11}^{(1)}$ mode (fig.3 (a), (b), (c)). At same time, the output power and the gain of the $TE_{11}^{(1)}$ mode all increase, which means that the effect of backward wave oscillation on beam-wave interaction is much more serious than the energy loss due to the decrease of the conductivity. When the conductivity lowers to 9×10^3 S/m, the gyro-TWT enters zero driving steady state, its saturated output power further increases to 239kW and the gain is over 50dB (fig.3 (d)).

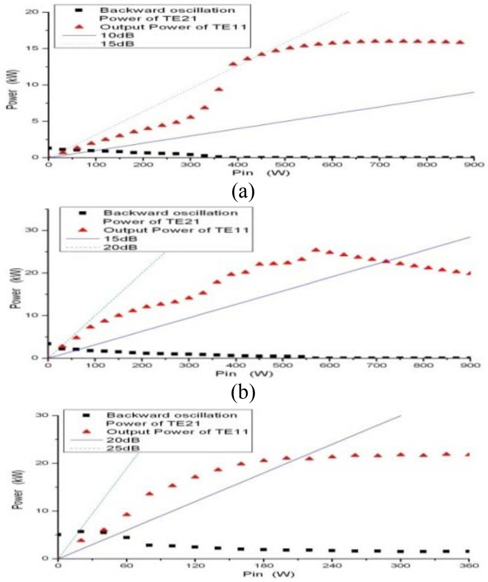
Finally, we further analyze the effect of the guiding center radius variation, which can more effectively reduce the coupling coefficient of the backward wave oscillation mode with relatively weak effect on that of the operating mode. Based on above-mentioned result, the conductivity of the zero driving steady state is 9×10^3S/m with the saturated output power of 239kW for $r_c=0.45r_w$. When $r_c=0.65r_w$, the conductivity of the zero driving steady state becomes 3×10^4S/m with the saturated output power of 253kW (Fig.4(a), (b)). Larger conductivity means that loss material absorbs less electromagnetic energy, which means the improvement of heat dissipation. At same time, the increase of the guiding center radius ($0.45r_w \rightarrow 0.65r_w$) can reduce the dropping rate of the saturated output power when the conductivity is over the critical value for keeping the zero driving steady state (Fig.4(a)).

REFERENCES

[1] Chu, K.R., et al., *Stabilization of Absolute Instabilities in the Gyrotron Traveling Wave Amplifier.* PHYSICAL REVIEW LETTERS, 1995.

[2] McDermott, D.B., et al., *Design of a W-Band TE01 Mode Gyrotron Traveling-Wave Amplifier With High Power and Broad-Band Capabilities.* IEEE TRANSACTIONS ON PLASMA SCIENCE, 2002.

[3] Garven, M., et al., *A Gyrotron-Traveling-Wave Tube Amplifier Experiment with a Ceramic Loaded Interaction Region.* IEEE TRANSACTIONS ON PLASMA SCIENCE, 2002.

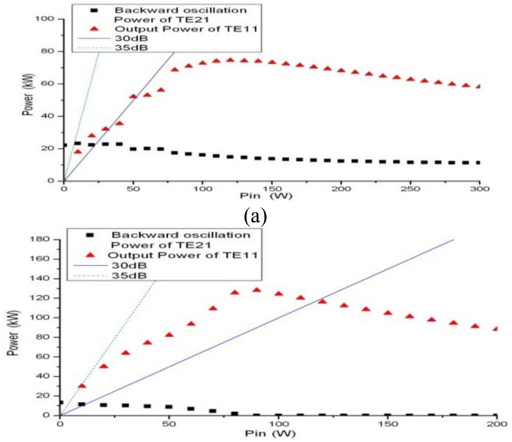


(a)

(b)

(c)

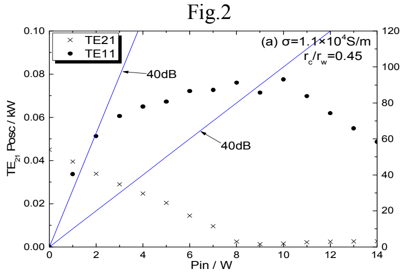
Fig. 1



(a)

(b)

Fig.2



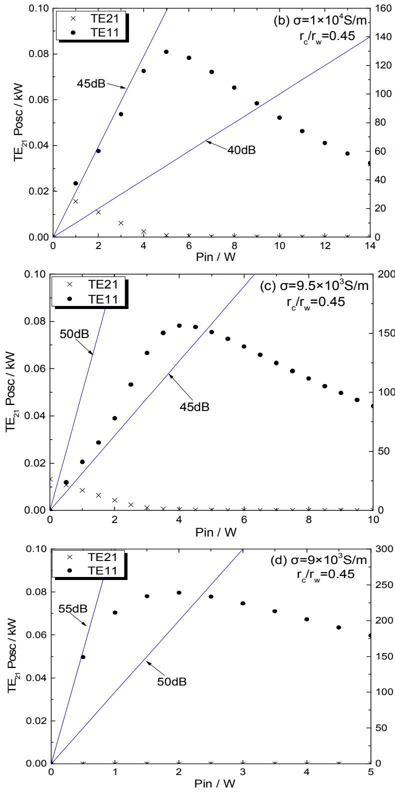


Fig.3

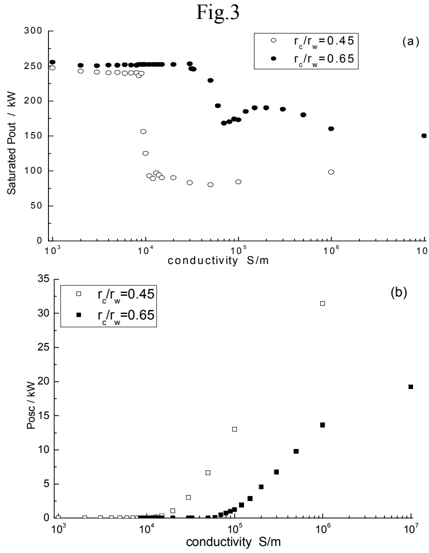


Fig.4