Preliminary Design of a Stable, Second Harmonic, 1MW, Ku-Band Gyrotron Traveling-Wave Amplifier

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Abstract—**The preliminary design results of a 1MW, Ku-band gyrotron traveling wave amplifier (gyro-TWA) are presented. Operating at the second cyclotron harmonic of the TE_{11} mode, the amplifier characterizes good stability. No distributed losses or servers are required, which could potentially allow the amplifier to be operated at high average power. Large signal simulation shows that the amplifier can generate a saturated peak power of 1.06MW with an efficiency of 26.6%, a gain of 31dB, and a 3dB bandwidth of about 1 GHz at 16.95GHz when driven by a 100kV, 40 A electron beam with 5% axial velocity spread.**

I. Introduction

HIGH power and broad bandwidth capability of gyrotron traveling wave amplifier (gyro-TWA) makes it an attractive source of coherent radiation in the millimeter and sub-millimeter wavelength ranges. gyro-TWAs could be applied very broadly, especially in radar and communication systems. Steady progress in theory and experiment has been made over an extended period of time. Major advances in gyro-TWA performances have been reported in the review papers.[1]

This paper presents the preliminary design results of a stable, second harmonic, 1MW, Ku-band gyrotron traveling wave amplifier (gyro-TWA) operating at TE_{11} mode. At frequencies as low as 17GHz, 1MW power can be produced even in the case of operating at low-order modes such as the TE_{11} mode. For operating in the second harmonic, a magnetic field of only about 0.32 T is necessary. Because a large axial velocity is beneficial for stability and wide bandwidth, the electron beam with 100 kV voltage and 1.0 velocity ratio was chosen. The interaction circuit is a circular waveguide with the radius of 5.3 mm, and the beam radius is 40% of the wall radius of the waveguide. Since the larmor radius of the electron is 2.4mm, there has no concern for the electron hitting the waveguide wall. The special advantage of the amplifier is its good stability resulting from low-order operating mode and high cyclotron harmonic, as shown in Fig. 1. For the amplifier, the possible dangerous competing oscillations include the TE_{11} mode absolute instability at the second cyclotron harmonic, the TE_{11} mode gyro-BWO at the third cyclotron harmonic and the TE_{21} mode gyro-BWO at the fourth cyclotron harmonic. Calculated by an analytic formula[2], the critical current for the absolute instability is about 90A with the operating magnetic field equal to $0.99B_g$, As shown in Fig.2. Due to weak harmonic interaction and the operating points far away from their cut off frequencies, the two gyro-BWOs are also difficuclt to be excited even the beam current is as high as 40 A. As a result, no distributed wall losses are needed to keep the amplifier's stability, which could potentially allow the amplifier to be operated at high average power.

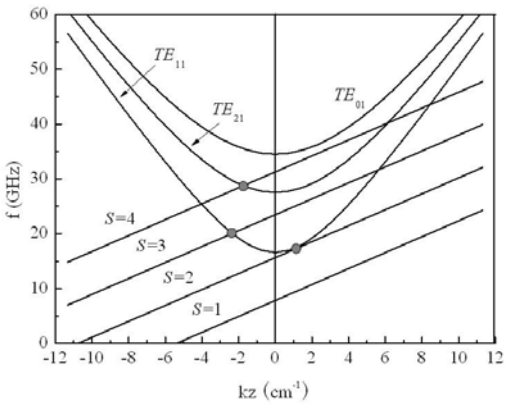

Fig. 1 Uncoupled dispersion relation of the operating mode and the competing modes.

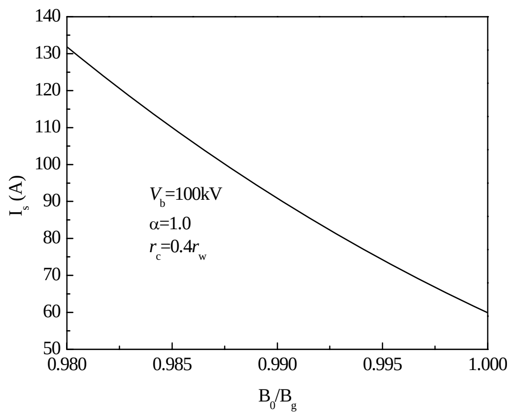

Fig. 2 Start oscillation current of the TE_{11} mode, second harmonic absolute instability.

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II. RESULTS

Self-consistent nonlinear code [3] was used to simulate the beam-wave interaction. With 600mm interaction circuit length, the calculated saturated output power and efficiency of the gyro-TWA are shown in Fig. 3, and the corresponding saturated gain is shown in Fig. 4. As shown in Fig. 3 and Fig. 4, the amplifier is predicted to generate a saturated peak power of 1.06MW with an efficiency of 26.6%, a gain of 31dB, and a 3dB bandwidth of about 1 GHz at 16.95GHz for 40 A beam current, 5% axial velocity spread.

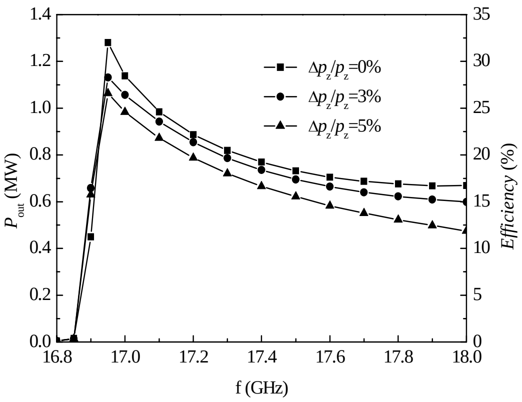

Fig. 3 predicted saturated output power and efficiency of the gyro-TWA versus frequency for different values of velocity spread.

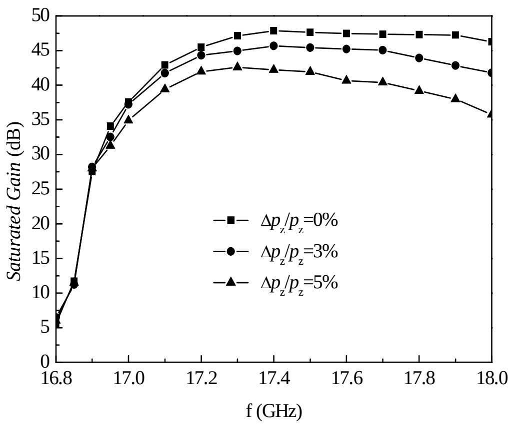

Fig. 4 Predicted saturated gain of the gyro-TWA versus frequency for different values of velocity spread.

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