RF Cavity Simulation of 0.3THz 400W Gyrotron Oscillator

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***Abstract*—The design for a 0.3THz 400W CW gyro-monotron is done and TE_{06} operating mode is chosen in the paper. The RF cavity mode field distribution and the diffraction Q value is optimized using HFSS software, so the starting current and operating magnetic field is chosen to restrain the mode competition. The simulation results including the peak output power 400W and the electron efficiency 20% in the frequency spetrum 301.1GHz are obtained by the beam-wave interaction simulation software.**

I. Introduction And Background

GYROTRON oscillator is a novel fast wave electronics vacuum devices. It can produce high pulse peak power or CW power in millimeter wave and submillimeter wave, specially in THz radiation resource. Because the THz is between the millimeter wave and the infrared, it is difficult to produce the THz radiation resource in high power wave. So the research for it has become very hot focus in foreign and home scientist. The research papers on THz gyrotron oscillator are very much including the Japan Fukui University Gyrotron FU Series and MIT report the research fruits.[1-2]

For RF cavity research on gyrotron, the linear theory method is usually used to analyze cavity mode and diffraction Q. The starting oscillation current and operating magnetic field is chosen to restrain the mode competition in the interaction. The nonlinear theory is used to analyze the interaction efficiency and cavity output power.

The paper adopts the simulation method to analyze the cavity structure. The cold cavity simulation obtains the resonance frequency and field distribution in the operating mode. By optimize the starting current and the magnetic field, an appropriate interaction operating parameter is chosen. Using PIC software, the cavity interaction is simulated to obtain the peak output power 400W and electron efficiency 20% in the frequency 301.1GHz.

II. COLD CAVITY RESULT

An opening resonance single cavity structure is designed including the input taper part, interaction cavity and output taper part. In the 0.3THz space wave-length and operating mode TE_{06}, the cavity radius is set 3.12mm. The beam guide center radius 1.34mm in the beam-wave interaction coefficient expressions calculation[3].

Using the HFSS software, the cold-cavity simulation is done to obtain the resonance frequency and TE_{06} mode field distribution and diffraction Q. The TE_{06} mode electric field distribution is viewed in figure 1.

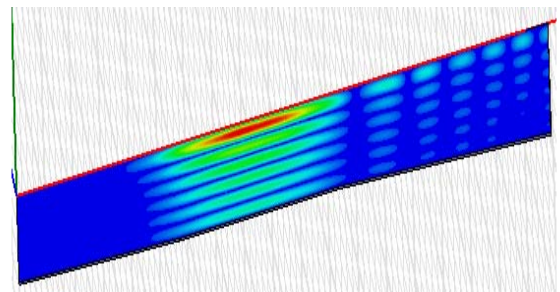

Fig. 1 TE_{06} mode field distribution by HFSS simulation

The starting current and operating magnetic field is chosen by the calculation equation to restrain the mode competition [4].

$$I_{stA} = 1.68\times10^4 \frac{\gamma_{stN}}{Q_d}\beta_\perp^4 \frac{L}{\lambda}\frac{(v_{mn}^2 - m^2)J_m^2(v_{mn})}{J_{m\pm1}^2(k_\perp R_b)} \tag{1}$$

Which $\beta_\perp$ is the ratio of the electron transversal velocity with the light speed. L is the cavity length in the Gauss field distribution. Q_d is the diffraction quality value. When the beam voltage, velocity ratio and guide center radius is set, the starting current is obtained in figure 2.

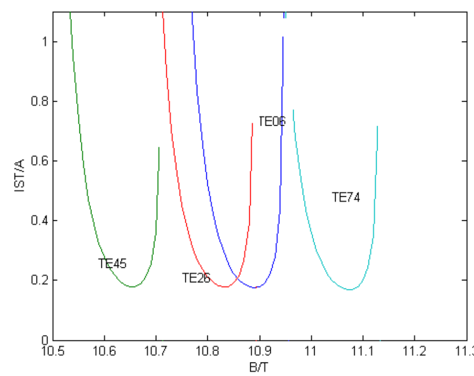

Fig. 2 Starting current as a function of magnetic field

In figure 2, the TE_{06} mode compet with TE_{26} mode, TE_{45} mode and TE_{74} mode. The starting current is chosen to restrain the other mode competition.

III. RESULT

By optimized the starting current and the operating magnetic field, the interaction parameter is chosen. The beam voltage 10kV, the beam current 200mA, so it adapt to the CW operation. The operating magnetic field 10.91T, the speed ratio 1.5 and the guide center radius 1.34mm are set in the PIC software.

The simulation runtime is about 50ns, the output mode TE_{06} work steady on output part. The peak output power is observed to obtain 400W microwave output in figure 3. The average

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output power is about 200W. The peak electron interaction efficiency is about 20%. The average electron interaction efficiency is about 10%.

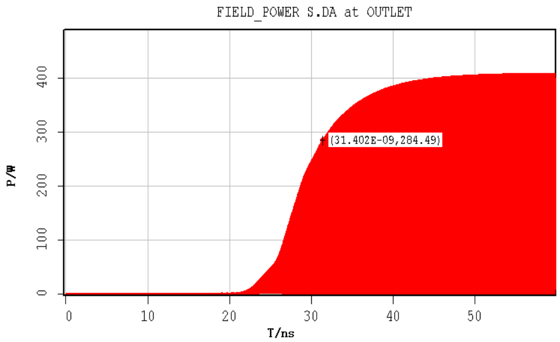

Fig. 3 the output power Vs. time

By the field FFT transform in the output part, the frequency spectrum is observed in 301.1GHz in figure 4. So the spectrum is pure in the interaction. It has no noise in the other mode competition.

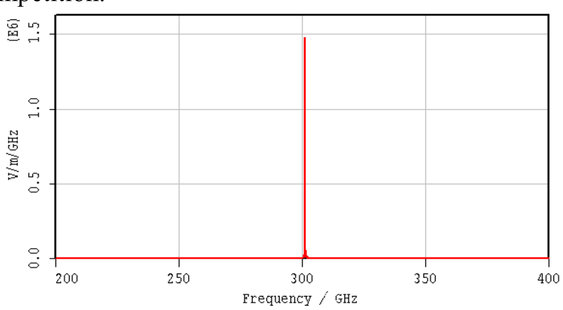

Fig. 4 output frequency spectrum in 300GHz

The paper provides some important value for the THz experiment and manufacture in the low voltage CW THz resource.

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