Design and simulation of a 0.42 THz complex-cavity gyrotron

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(Received September 19 2012)

Abstract: In this paper, the design parameters of a 0.42 *THz*, complex-cavity gyrotron are given in detail and the beam-wave interaction results are presented. It could be seen that an output power of 62.48 *kW*, 28.4% efficiency could be obtained with a 40 *KV*, 5.5 *A* electron beam(The grammar needs to be improved) when the operating magnetic is 7.95 *T* and the beam velocity ratio is 1.6.

Keywords: Complex-cavity, Gyrotron, THz

doi: 10.11906/TST.196-200.2012.12.20

1. Introduction

As one of the most powerful millimeter wave sources available nowadays, THz gyrotrons are developed widely all over the world and recognized as a bridge to fulfill the so-called “THz gap”. In order to design a high-frequency THz gyrotron, high order modes have to be chosen to maintain the size of interaction cavity and enhance the power capacity of it. One of the problems of high-order mode operation would be the mode competition operating mode and other coexisting parasitic modes. Based on the above consideration, this paper is focused on the design and simulation of a second harmonics, complex-cavity operating at 0.42 *THz*.

2. Design and simulation

A. Mode selection

For practical consideration, harmonic- operation gyrotron at 0.42 *THz* will greatly free the restriction of available magnetic fields. However, mode competition in harmonic gyrotrons is fierce and the operation mode should be carefully chosen to alleviate this problem. To maintain a proper cavity radius for power capacity, TE mode with a χ_{mp} of about 17.6 is considered where χ_{mp} is the Pth zero for TE_{mn} modes defined by $J'_m(\chi_{mp}) = 0$, and $TE_{11,2}$ is finally considered based on the mode spectra [1] of TE_{mn} modes shown in Fig. 1

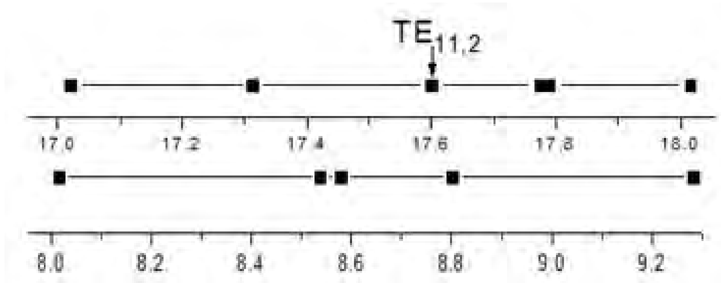

Fig. 1 Mode spectra of TE mode

B. Complex cavity structure

Fig. 2 gives the structure of the complex cavity including two cavities and Table. 1 lists the detailed parameters.

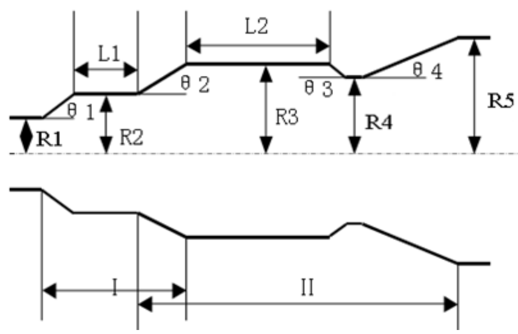

Fig. 2 structure chart of complex cavity with gradual transition

Tab. 1 Structure Parameters

R1(*mm*)	1.246
R2(*mm*)	1.473
R3(*mm*)	2.003
R4(*mm*)	1.903
R5(*mm*)	2.010
L1(*mm*)	1.785
L2(*mm*)	4.285
$\theta 1$ (deg)	33
$\theta 2$ (deg)	42
$\theta 3$ (deg)	21
$\theta 4$ (deg)	34
f（*GHz*）	420.2848
Q	9857

C. The choice of guiding center radius

The normalized coupling coefficients for the operating mode as well as the parasitic modes with the electron beam are shown in Fig. 3 as a function of the guiding centre radius(R_b). When R_b=1.73 *mm*, the coupling coefficient of cavity mode is absolutely larger compared with the parasitic modes.

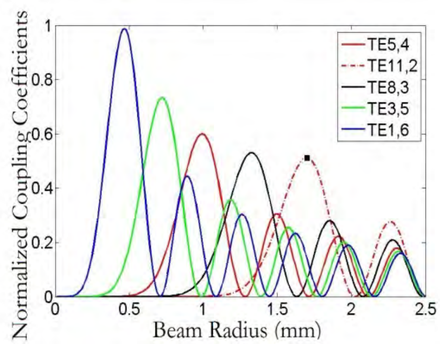

Fig. 3 Coupling coefficients for several modes as a function of R_b.

D. Starting current analysis

In the starting current analysis, the beam voltage and the beam guiding center radius are chosen to be 40 *kV* and 1.73 *mm*, respectively. Fig. 4 shows the variation of starting current with the magnet field for both the operating mode and possible parasitic modes. It could be seen that theoretically, mode competition could be eliminated when the magnetic field ranges from 7.92 *T* to 8.03 *T*.

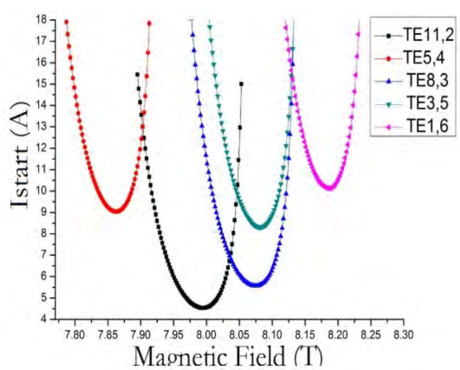

Fig. 4 Starting currents for six modes as a function of magnetic field.

E. Beam-wave interaction simulation

Simulation results with FORTRAN program are shown in Fig. 5. Field profiles of both operating modes and parasitic modes as well as the beam-wave interaction efficiency are presented. It could be seen that the normalized output amplitudes of $TE_{11,2}$, $TE_{11,1}$ and $TE_{5,4}$ are 0.06677, 0.00849 and 0.00148, respectively. The parasitic mode is well suppressed.

The beam-wave interaction efficiency is optimized to be 28.4% and the corresponding operating parameters are listed in Table. 2.

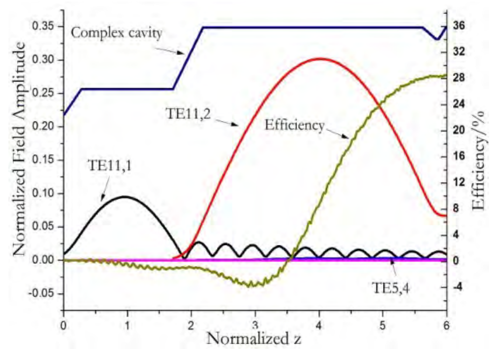

Fig. 5 Field profile and interaction efficiency

Tab. 2 Operating Parameters

Cavity Mode	$TE_{11,2}$
Harmonic	2st
Beam Voltage (*kV*)	40
Beam Current (*A*)	5.5
Magnetic Field (*T*)	7.92
Frequency (*GHz*)	420.2894
Velocity Ratio	1.6
Beam Radius (*mm*)	1.73
efficiency	28.4%
out power (*kW*)	62.48

3. Conclusion

In the above analysis, a complex cavity gyrotron is designed and the problem of mode competition is alleviated by a careful selection of the operating modes and the guiding center radius of electron beam. Finally, numerical simulation results of beam-wave interaction are presented.

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