Cold Test Design of the Open Resonant Cavity in a High-Order Mode Gyrotron

Menglong Jiao[1,2], Jirun Luo[2], Wei Guo[2], Yu Fan[2], Zheng Wen[1,2], Cheng Yang[1,2], Zhixian Li[1,2], Min Zhu[2]

1.Key Laboratory of High-Power Microwave Source and Technologies, Institute of Electronics, Chinese Academy of Sciences, Beijing, China

2.University of Chinese Academy of Sciences, Beijing, China

evata169@163.com

Abstract: *A design of the cold test for frequency, Q-factor and electric field distribution of high-order mode resonator of gyrotron with a computer control is presented. The designed results show that the difference between maximum and minimum of electric filed can clearly be distinguished, which can be applied to the measurement of the electric field pattern on crossed section.*

Keywords: cold test; electric field; mode resonator; gyrotron

Introduction

Gyrotron is a kind of high-power device using high-order mode (e.g.$TE_{28,8}$). Some of the important components in the gyrotron, such as the resonant cavity and the quasi-optical mode converter, must be cold-tested to make sure the proper functioning before they are installed. In the cold test, the high-order mode must be excited via low-power RF signal injecting into a device called mode generator. [1] The field pattern detection is vital for the design of resonant cavity to judge if the operating mode has been excited.

Problem Statement and Setup Design

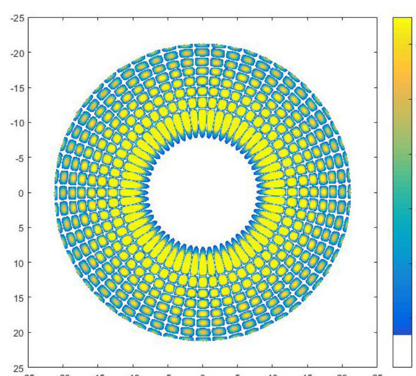

Fig.1 Ideal $TE_{28,8}$ field pattern

The computer-controlled test system for obtaining a distinct $TE_{28,8}$ field pattern as shown in Fig.1, should include a computer controlling program, a high-precision mechanically sliding units and an electric field detecting device (pick-up antenna) with a large dynamic range [2]. The pick-up antenna may have the effect on the electric field distribution of the mode, thus making the effect small enough to properly detect the $TE_{28,8}$ field is the most challenging problem.

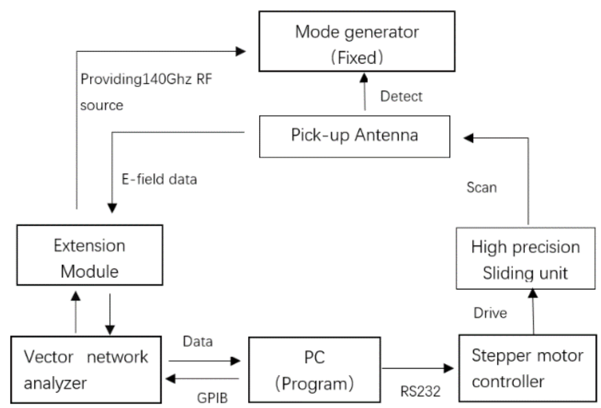

Fig.2 Schematic of computer-based test system

Design of Test System: The schematic of computer-based test system is shown in Fig.2. The whole automatic test system relies on transferring controlling command to components by a computer, which is also a data processing center. Computer program sends command via general-purpose interface bus (GPIB) and RS232 to vector network analyzer (VNA) and stepper motor controller, respectively. The pick-up antenna is fixed on the high accuracy sliding units driven by the stepper motor controller. Sliding units scan in the horizontal and vertical directions rather than azimuthal and radial for reducing setup complexity. VNA with an extension module provides 140 GHz RF signal to the mode generator, in the meanwhile, VNA also receives the field data by pick-up antenna. Finally, all the data are integrated and processed by the computer program, and then display the $TE_{28,8}$ field pattern on the computer screen.

Instruction to the Components: RF Source: The combination of a frequency expansion module with VNA provide a low-noise high frequency signal and have enough large dynamic range (~100-dB) for detecting the low-power signal lunching from the high order mode resonant cavity.

Fig.3 3D sliding units

Stepper motor controller and sliding units: Exact controllability of these two components by a computer is the basic requirement. The wavelength is about 2.14 mm, so the step length should not be over a quarter- wavelength (~0.5 mm) to detect the position of the crest in field pattern. Under the control of stepper motor controller, the stepper precision of the sliding units can reach ~0.05 mm, which is shown in Fig.3.

Pick-up antenna: A WR-7 standard rectangular waveguide is used as the pick-up antenna to receive the signal of the field. Usually, the transverse sizes of the guide may be very close to the area of the field pattern profile between half period in azimuthal direction and adjacent two field zero points in radial direction, so it is difficult to distinguish the maximum and minimum of the mode field amplitude. In order to solve the problem, a tapering circular waveguide is added to expand the output field pattern from the open resonant cavity so that the trough and crest of the field can more easily be detected.

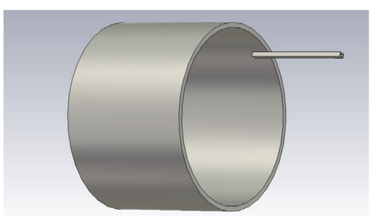

Fig.4 Simulation model

Fig.4 gives a sketch of detection model consisting of expanded cylindrical guide and pick-up antenna. The cold test system can at least distinguish the crest and trough of electric field distribution in the half period in azimuthal direction for detecting a rational field structure.

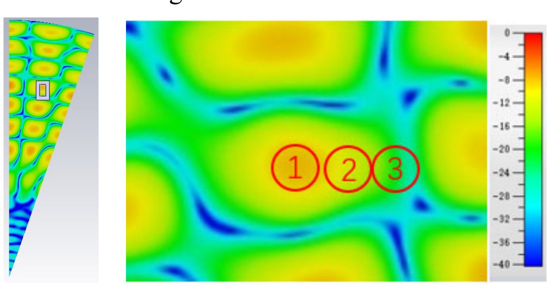

Fig.5 $TE_{28,8}$ electric field distribution in an azimuthal direction period and the positions of three detected points

Fig. 5 gives the electric field distribution of the $TE_{28,8}$ mode in an azimuthal direction period and the positions of three detected points, point 1 is the crest of the field, point 3 is its trough and point 2 is in the middle between the crest and the trough. The position and shape of the pick-up antenna is also shown in Fig. 5

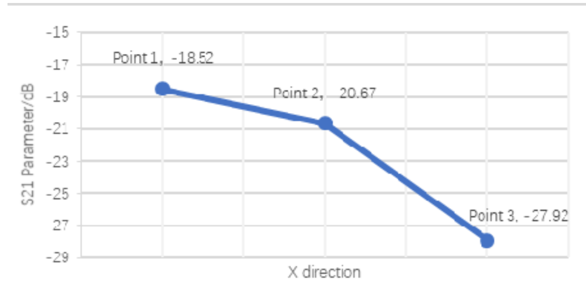

Fig.6 S_{21} Parametric curves at three points

In Fig.6, the S_{21} parameters of three points in Fig.5 are drawn. The amplitude values of the electric field detected with the pick-up antenna decrease from point 1 to 3, the field crest (point 1) is almost 10-dB bigger than the field trough (point 3), which shows that the $TE_{28,8}$ mode field pattern can be distinguished by using the standard pick-up antenna.

Conclusions

A design of the cold test of high-order mode resonator of gyrotron with a computer control has been presented. The designed results demonstrate that the TE28,8 mode field pattern, can be distinguished clearly with about 10-dB difference between the crest and trough of the mode field amplitude in the half period in azimuthal direction.

Acknowledgements

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References

1. Ruess, T., et al., "Computer-Controlled Test System for the Excitation of Very High-Order Modes in Highly Oversized Waveguides," Journal of Infrared, Millimeter and Terahertz Waves, 2019.
2. A. Arnold, G. Dammertz, and M. Thumm, "Performance measurements on high order gyrotron mode generators," in Proc IEEE ICIMW, 2004.
3. Losert, Markus, Jianbo Jin, and Tomasz Rzesnicki. "RF beam parameter measurements of quasi-optical mode converters in the mW range." IEEE Transactions on Plasma Science, vol.41, no. 3, pp. 628-632, 2013.