DESIGN OF TE_{62} MODE GENERATOR FOR W-BAND GYROTRON

Debarati Ghosh
Burdwan University
Burdwan-713104,India
ghosh.debaratiece@gmail.com

Nani Medicherla
MTRDC,DRDO
Bengaluru-560013,India
nani@mtrdc.drdo.in

R.Seshadri
MTRDC,DRDO
Bengaluru-560013.India
seshadri@mtrdc.drdo.in

***Abstract*— Gyrotron as an oscillator employ internal converters to convert the cavity interaction mode to a Gaussian output beam. A mode launcher with Quasi Optical Mirror system will convert the required Gaussian beam. Development of mode generator for the required mode helps in verifying the RF circuit design and implementation of the internal converter along with window. Cold test of internal RF circuit of Gyrotron with mode generator helps in understanding mirror alignment, mode pattern before it integrating in the gyrotron vacuum envelop. In this paper, a Coaxial TE_{62} mode generator is simulated in order to test the quasi-optical mode converter system, which would be used in a W-band gyrotron.**

Keywords*— *Gyrotron, W-band, TE_{62} mode, Non Rotating mode generator.

I. INTRODUCTION

Gyrotron is a powerful source of electromagnetic waves of very short wavelength (in the order of a few millimeters) with potential industrial and defense applications. Gyrotron can operate with a high order mode interaction cavity that is several time larger both in length and diameter than the fundamental mode of cavity. Gyrotron works based on the phenomena called Cyclotron Resonance Maser (CRM).An electron cyclotron maser employs electron cyclotron resonance and interaction with azimuthal electric field to convert the rotational energy from electron beam to microwave . At the present time, the gyrotron is a signature device for the plasma fusion applications and expanding its influence in the other areas of science and technology, like, material processing, THz spectroscopy, atmospheric analysis etc. due to various inherent advantages of millimeter and sub millimeter wave radiation over microwave radiation.

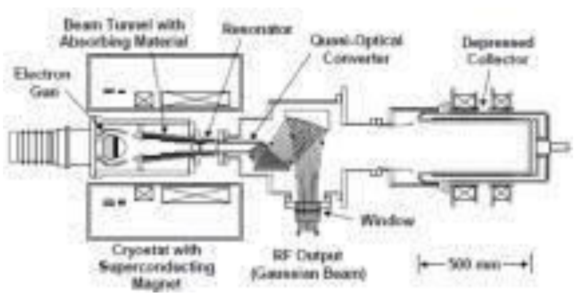

Fig. 1. Typical Gyrotron [1]

II. MODE GENERATOR

For testing of quasi optical mode converter we have to use quasi optical technique. A quasi-optical mode converter (QOMC) consists of an open-ended, non-symmetrical waveguide launcher and a series of quasi-parabolic mirrors, which are situated directly after the gyrotron's interaction circuit. QOMC should be tested for mirror alignments and designing output components after gyrotron window for proper RF beam size. To verify the design and implementation of the internal converter and RF circuit in cold test, a mode generator is needed.

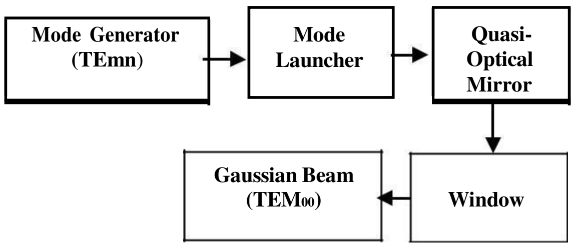

Fig. 2 Cold test setup of Mode launcher and QOMC with Mode Generator

Higher-order gyrotron-type modes have a complex electric field spatial structure. In a gyrotron, such a structure can be transformed into a linearly polarized, narrowly directed free-space (Gaussian) beam using different types of converters. Using a higher -order mode source or generator, it becomes possible to verify the design of these converters and launcher before installation in vacuum sealing of gyrotron. The design of this source uses quasi optical method. The drawback of this method is mode competition.

To avoid mode competition a cavity can be designed with a sufficiently high quality factor. The motivation for increasing the cavity quality factor is the fact that as the transverse cavity size is increased to handle higher power the coupling efficiency of beam and radiation decreases. Thus to access the high efficiency operation point it is necessary to raise the cavity quality factor (Q_d) [2].

$$Q_d = \omega\tau = \omega\left(\frac{L}{v_g}\right) = \omega\left(\frac{L}{\frac{c^2}{v_p}}\right) = \left(\frac{\omega L}{c^2}\right)\left(\frac{\omega}{\beta}\right)$$

$$= 4\pi\left(\frac{L^2}{\lambda^2}\right) \quad (1)$$

Where
Q_d = diffractive quality factor
L=effective length of cavity
v_g=group velocity
v_p = phase velocity
β = axial propagation constant
λ = wavelength at operating frequency

Due to reflection the quality factor becomes

$$Q = \frac{Q_d}{1-\rho} = 4\pi\left(\frac{L^2}{\lambda^2}\right)\left(\frac{1}{1-\rho}\right) \quad (2)$$

Where ρ is reflection coefficient

$$R_{cavity} \approx (c^*\chi_{m,p})/2^*\pi^*f \quad (3)$$

Where c is speed of light, $\chi_{m,p}$ eigen value of mode and f is operating frequency [7]

The value of R_{cavity} of mode generator is approximately 5.901mm at W-band.

A. *Types of mode Generator*

Rotating Mode Generator (RMG): A mode generator with orbital angular momentum of rotating modes is called rotating mode. One way of designing rotating mode generator is using polarization converter [3]. It is difficult because it includes various intermediate modes before the required mode existence. Another way is using coaxial cylindrical cavity with perforated wall illuminated a quasi-optical mirror [4]. The drawback of this mode generator is misalignment of the mirrors with perforated wave guide. Mode generator and poor joint assembly between the mode generator and the mode converter which may affect the mode converter's efficiency.

Non-Rotating Mode Generator (NRMG): A mode generator with no orbital angular momentum of rotating modes is called Non-rotating mode generator. In this paper we have designed a coaxial TE_{62} Non-Rotating Mode Generator.

III. DESIGN OF MODE GENERATOR(NRMG)

This converter is basically a coaxial structure for better mode separation. Outer cylindrical waveguide of mode generator consists of three sections-up-tapper (input taper), middle section (linear) and up-tapper (output section). The input taper acts as a cut-off section (L1) which prevents backward waves towards the input waveguide port and further reflections. Required TEmn mode generates mainly in the uniform middle section where RF fields reach peak values. In the uniform middle section (L2), the desired mode is excited with low loss than other modes. Last up-taper section provides enough space for desired mode to get peaking.

The inner rod is inserted at the centre of the mode-generator cavity in order to prevent excitation of neighboring modes. A WR-10 (75 -110 GHz) waveguide attached at ending of the input section directly to feed the desired frequency in fundamental mode (TE_{10}). WR-10 waveguide also working well for the same purpose without changing entire mode generator structure. The waveguide cut-off helps to enhance the mode purity and eliminate the mode competition, is placed at opposite end to ensure that the wave propagates in the desired direction. The coaxial insert also be tapered axially, uniform section (IL1) and down tapered section (IL2) which yields an additional opportunity for mode selection as shown in Fig-3.
The presence of the inner conductor influences the spectrum of mode Eigen-frequencies, which make the spectrum of the coaxial waveguide be rarefied significantly compared with the one of the cylindrical waveguide.

A. *Structure*

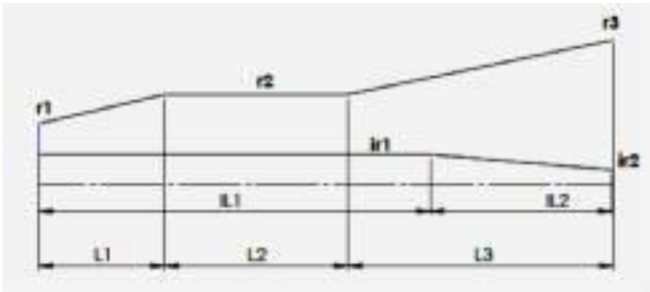

Fig.3. Geometric profile of Non-Rotating Mode Generator

B. *Design Parameter of TE62 Mode Generator*

TABLE I.

Parameter	*Specification*
Operating frequency	W-band
Q factor	989
Total Length of Mode Generator (L1+L2+L3)	87.551mm

C. *TE62 Mode Generator Simulation in CST Studio*

Mode generator is modelled as shown in Fig.4 and Fig.5 in CST microwave Studio. Full model is parameterized for easier parameter sweep and optimization of structure for better loss and Q. Input port is set for single mode excitation since input mode is fundamental mode (TE_{10}) of WR-10. Output port is set for receiving 70 modes. Infact a cylindrical wave guide produces TE_{62} as 35th mode after considering the regenerative modes.TE_{62} mode is 31st mode in sequence in this structure and it is evident from coaxial structure.

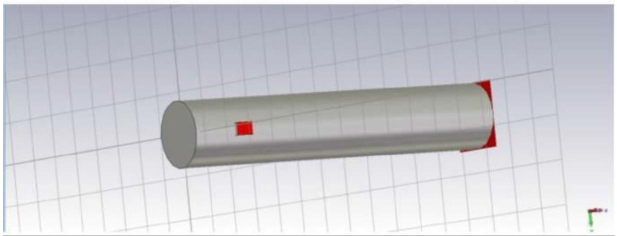

Fig.4. Model of TE62 mode generator in CST Studio

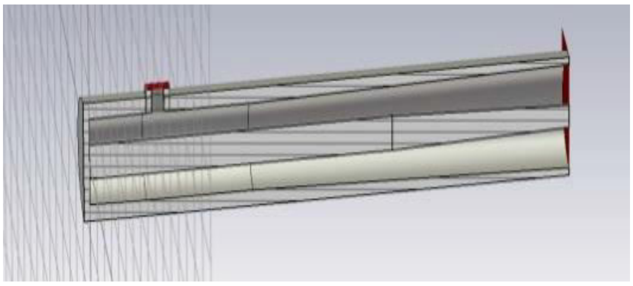

Fig.5. Cut-section of TE_{62} mode generator

D . Simulation Result

Input port is excited with TE_{10} and response is seen for 70 modes at output port of up-tapered coaxial cylindrical structure. Out of all other modes, TE_{62} is less lossy and the given structure is supporting the designed mode without any mode competition. Fig.7 is showing the field pattern of the mode. Input retrun loss is (S_{11}) -10.629dB shown in Fig.9 and insertion loss ($S_{2\,(31)\,1}$) is -5.948dB shown in Fig.8. All the structure parameters were optimized for Q (989).

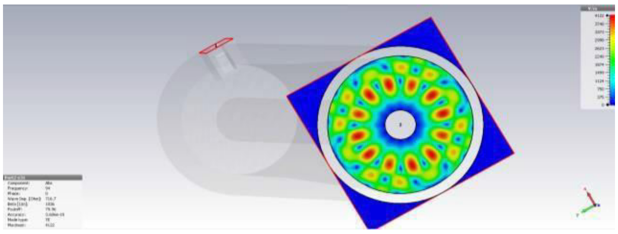

Fig.6. Mode Pattern Of TE_{62} mode

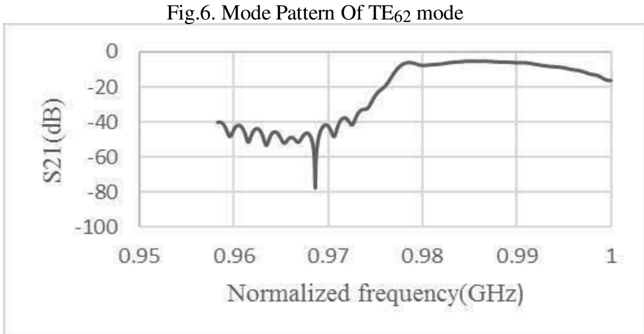

Fig.7. Insertion loss of Mode generator

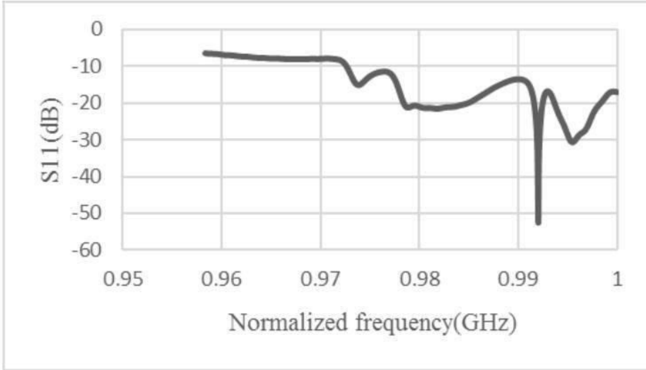

Fig.8. Input port return Loss for Mode generator

CONCLUSION

We had designed and simulated a TE_{62} mode generator. Simulation and analytical results for cavity dimensions are closely matching, Simulated results are shown in Fig.7 and Fig.8. Design parameters were optimised for better Qd and insertion loss.

ACKNOWLEDGMENT

We are grateful to Dr. S.U.M. Reddy, Director, Microwave Tube Research and Development Centre (MTRDC), Bangalore who had given us an opportunity to work on 'Design and development of W bandTE_{62} mode generator for Gyrotron' and permission to publish this work.

REFERENCES

[1] A.S.Gilmour,"Klystron,Travelling wave tubes,Magnetrons,Cross Field amplifiers, and Gyrotrons''.

[2] *R .K. Singh and P.K.Jain,* ''Ohmic Quality Factor and Efficiency Estimation for a Gyrotron Cavity, World Academy of Science, Engineering and Technology International Journal of Electrical and Computer Engineering Vol:2, No:5, 2008 .

[3] Zhi-Hui Geng, Xiao-Wan Hou, Ya-Ru Wang, Shou-Xi Xu,Gao-Feng Liu , Wei Gu and Pu-Kun Liu, Key Laboratory of High Power Microwave Sources and Technologies, Institute of Electronics, Chinese Academy of Sciences, Beijing, 100190, P. R. China ,University of Chinese Academy of Sciences, Beijing, 100039, P. R. China School of Electronics Engineering and Computer Science, Peking University Beijing, 100871,P. R. China, ''Simulation and Measurement of a W-band Circular TE62 Mode Generator for Gyrotrons''

[4] *M.Pereyaslavets,O.Braz,S.Kern,M.Losert,A.Mobius&M.Thumm*,Improvements of mode converters for low power excitation of gyrotron-type modes''

[5] N.L. Alexandrov, A.V. Chirkov et.al., ''Selective excitation of highorder modes in circular waveguides,'' Int. Journal of Infrared and Millimeter Waves, 13, pp. 1369-1385, 1992.

[6] S. G. Kim, D. S. Kim, M. S. Choe, W. Lee, J. So, and E. M. Choi, ''Cold testing of quasi-optical mode converters using a generator for non-rotating high order gyrotron modes''.

[7] P C Kalaria1, K A Avramidis, J Franck, G Gantenbein1, S Illy, I Gr Pagonakis, M Thumm and J Jelonnek,Institute for Pulsed Power and Microwave Technology (IHM),Institute of High Frequency Techniques and Electronics (IHE), Karlsruhe Institute of technology (KIT), Karlsruhe, Germany "Systematic cavity design approach for a multi- Frequency gyrotron for DEMO and study of its RF behaviour behaviour".