Design of interaction cavity for 170 GHz, 1 MW ITER Gyrotron

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Abstract: *In this paper the design of interaction cavity for 170GHz, 1MW gyrotron is presented. An in- house developed code GCOMS has been used for operating mode selection and mode competition. For 170 GHz, 1 MW gyrotron interaction cavity TE28,7 mode excite as a operating mode at the fundamental harmonic number. The Electromagnetic simulator-MAGIC, a Particle-in-Cell (PIC) code has been used for the cold cavity analysis and the beam-wave interaction. More than 1MW output power has been achieved at guiding cavity magnetic field 6.77 T.*

Keywords: Gyrotron; interaction cavity; ITER; voltage depression.

Introduction

The gyrotron is a high power microwave/millimeter wave source based on the cyclotron maser interaction between the electromagnetic wave and the gyrating electron beam under the influence of the applied magnetic field [1]. The gyrotron oscillators are widely used in the various fields of science and technology like high speed communication, material processing, biological imaging and plasma diagnostics, NMR spectroscopy, electron cyclotron resonance heating (ECRH) in the plasma fusion, etc [2].

170 GHz has been selected as the ECRH frequency in the ITER (International Thermonuclear experimental Reactor) fusion program [3]. The required output power from a single gyrotron tube at 170 GHz operating frequency for ECRH application is 1MW or more. The mode selection has been carefully studied by in-house developed code GCOMS with the aim of minimizing mode competition and restricting the excitation of undesired modes in the cavity as well as to obtain a desired power level [4]. On basis of some parameters such as voltage depression, limiting current, beam radius and cavity radius, some high order modes have been selected. For these high order modes, start oscillation current and coupling coefficient has been calculated [5]. Finally $TE_{28,7}$ is selected as the optimized operating mode.

In this paper the design of the interaction cavity for 170 GHz, 1MW gyrotron is presented. The gyrotron cavity geometry has been modeled, simulated and finally designed using the Electromagnetic simulator-MAGIC, a Particle-in-Cell (PIC) code [6]. The MAGIC simulation shows the desire output power 1MW of the gyrotron at 6.77T magnetic field with an operating mode $TE_{28,7}$ and a pitch factor of 1.5.

Design of interaction cavity

The gyrotron interaction cavity consists of three parts, the input taper (L_1), the middle section (L_2) and the output taper (L_3). The maximum beam-wave interaction takes place at the middle section of the interaction cavity. Beam radius and cavity radius has been calculated for operating mode. The design parameters of the 170 GHz, 1MW gyrotron are given in Table I.

Table1. Design parameters of interaction cavity for 170 GHz, 1 MW gyrotron.

Frequency	170 GHz
Output power	1 MW
Beam voltage	80 kV
Beam current	40 A
Cavity Radius	15.80 mm
Beam radius	8.27 mm
Length of uniform section of cavity	13 mm
Operating mode	$TE_{28,7}$
Pitch factor	1.5
Magnetic field	6.77 T

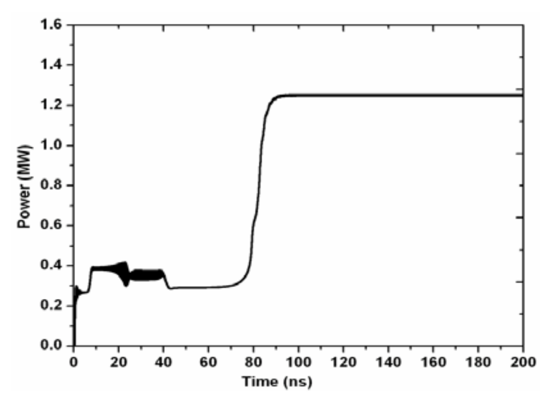

Fig.1: Output power for $TE_{28,7}$ operating mode gyrotron at the fundamental harmonic number

To analyze the mode $TE_{28,7}$ and the temporal evolution of the azimuthal beam-wave interaction, a fully enclosed conducting walls has been designed. The code provides the powerful algorithms to represent the incoming and outgoing waves, the particle emission processes, the electromagnetic fields and relativistic particles trajectories. The MAGIC code is run using the CENTERED algorithm for the relativistic electron beam-wave interaction, which yields no damping at any frequency. The cold cavity analysis illustrates the eigenfrequency, the eigenmode, and the electric field profile for the operating mode $TE_{28,7}$

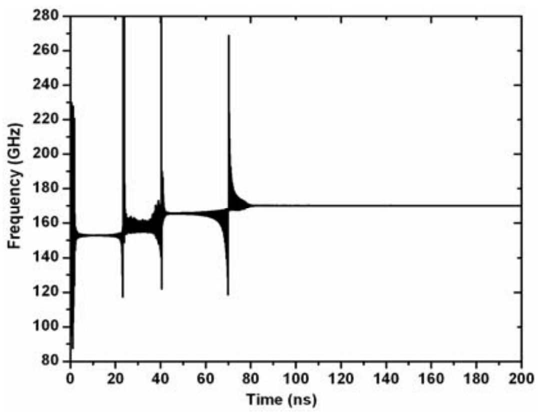

Figure 2: Frequency as a function of time forTE$_{28,7}$ mode gyrotron

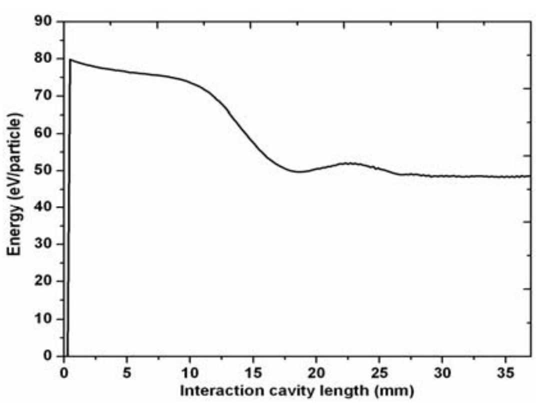

Fig. 3: Profile of electron energy in the interaction cavity for $TE_{28,7}$ mode gyrotron

Figure 1 and 2 show the output power and frequency response of the interaction cavity with respect to time. The output power and the frequency achieve the steady state after 95 ns of the start operation. To check the power growth and frequency stability in the cavity, the simulation has been run upto 200 ns. Figure 3 shows the electron energy profile w. r. t interaction cavity axial position. The maximum energy of the electrons is transferred to the RF at the cavity center. Results show the desire output power of 1MW and frequency of 170 GHz of the gyrotron at 6.77 T magnetic field with an operating mode $TE_{28,7}$ and a pitch factor of 1.5.

Conclusion

The $TE_{28,7}$ mode is chosen as the operating mode for the designed gyrotron interaction cavity. PIC Simulated results show the output power of 1.25 MW at the magnetic field of 6.77 T, beam voltage of 80 kV, beam current of 40A and pitch factor of 1.5. The interaction efficiency is more than 35%.

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