STUDIES ON A 170 GHz, 1.0-1.3 MW, CW CONVENTIONAL CAVITY GYROTRON

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Abstract— **Design studies of a 1.0-1.3 MW, CW gyrotron operating at 170 GHz, for ECRH in the international thermonuclear fusion experiment (ITER) is presented. Mode competition and mode selection procedures have been carried out for various candidate modes to choose a probable cavity operating mode. The present study includes cold cavity and self-consistent design calculations. The initial results are indicating that an output power of over 1.3 MW can be achieved at 170 GHz with $TE_{34,9}$ or $TE_{36,10}$ as the operating cavity mode.**

I. INTRODUCTION

Gyrotrons are high power microwave sources widely employed for electron cyclotron resonance heating (ECRH) of plasmas, and in other industrial and scientific applications [1]. Recent experiments at FZK, IAP and JAEA [2,3] suggest that conventional cavity gyrotrons delivering in excess of 1 MW power at frequencies ranging from 140-170 GHz operating with very high order volume modes can successfully be realized. As a consequence of those efforts, we consider to see the design feasibility of a 1.0-1.3 MW, CW power level at 170 GHz with a conventional cavity configuration. This has provided the basic impetus to carry out this work. In addition, since the frequency of operation is 170 GHz, the present magnet system and power supply at FZK is sufficient to permit preliminary experiments on such a device to be performed. In the present work, the feasibility of a conventional cavity gyrotron at 170 GHz capable of giving power in excess of 1.0-1.3 MW, CW, operating in a higher order asymmetric volume mode is presented. The design goals are given in Table-1.

Table 1: Design goals and parameters

Frequency	170 GHz
Cavity output power	≈ 1.0-1.3 MW (CW)
Quality factor (diffraction)	≈ 1000
Beam current	≈ 40-50 A
Beam voltage	≈ 80-85 kV
Magnetic field at interaction	≈ 6.7-6.9 T
Beam velocity ratio	≈ 1.20
Total output efficiency	≈ 33 % (without SDC)
Estimated wall losses	< 2 kW/cm^2
Total losses	< 8 %

After a careful mode selection procedure, a few operating modes are chosen which are capable of giving a high-quality solid beam output through a synthetic diamond window with a suitable dimpled-wall quasi-optical launcher. This will reduce the technical complexities connected with high diffraction losses (stray radiation) inside the device. The realization of such a high power gyrotron will help satisfy the ECRH and other heating and stabilization needs of ITER and other similar tokamak installations.

II. DESIGN STUDIES

Rigorous mode selection procedures that involve the modes that support an advanced quasi-optical mode converter and with less fundamental competitors suggest two modes, namely, the $TE_{34,9}$ or $TE_{36,10}$ and they have been chosen to carryout the initial feasibility studies. By choosing suitable conventional cavity geometry for these modes, self-consistent computations (SELFC) are carried out and output power and efficiencies are computed (see Table-2). This will give an initial impetus on the power-efficiency realization for a given set of beam parameters and magnetic field. Plots of diffractive quality factor (Q_D) times coupling coefficient versus frequency for the main mode with all the competing modes is shown in Figs.1-2. In addition, time-dependent computations (SELFT) are carried out self-consistently considering various competing modes along with the main mode and the results are shown in Figs. 3-4.

Table 2: Cavity geometry and typical self-consistent results

Mode	$TE_{34,9}$	$TE_{36,10}$
L_1 / L_2 / L_3 (mm)	14 / 17 / 18	14 / 17 / 18
θ_1/ θ_2 / θ_3 (deg)	2.3 / 0 / 3.0	2.3 / 0 / 3.0
R_{cav} / R_b (mm)	19.95 / 10.0	21.63 / 10.58
Q_D	967.80	979.89
U_b (kV)	81	82
I_b (A)	42	50
B (T)	6.781	6.795
η (%)	34.44	29.62
P_{out} (kW)	1172	1214
$^*\rho_{cav}$ kW/cm^2	2.02	1.46

(*enhancement factor of 2.0 included)

Further investigations to consolidate the design concept are in progress at the time of the preparation of this paper.

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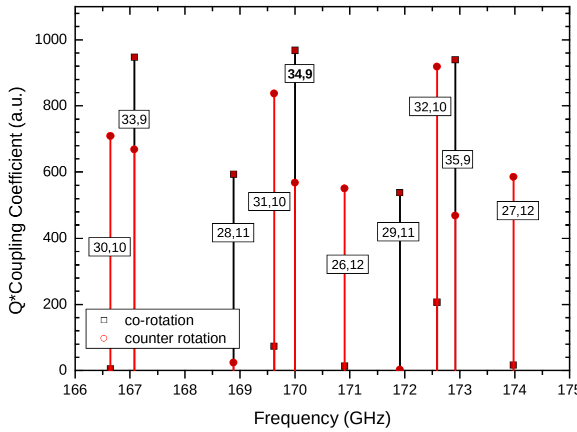

Fig. 1: Q times coupling coefficient versus frequency for various competing modes. Here the main mode is taken to be $TE_{34,9}$.

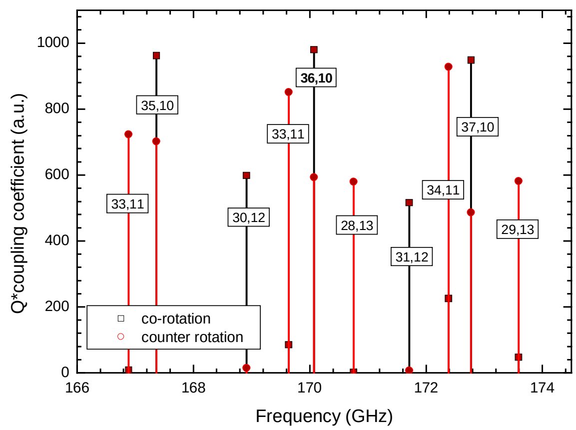

Fig. 2: Q times coupling coefficient versus frequency for various competing modes. Here the main mode is taken to be $TE_{36,10}$.

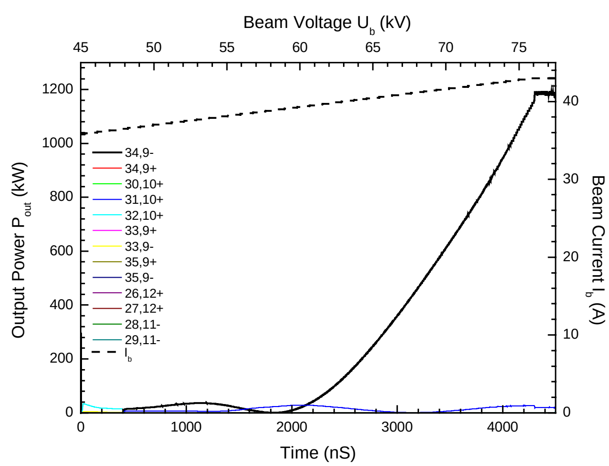

Fig. 3: SELFT simulation results for a $TE_{34,9}$ mode conventional cavity gyrotron considering the probable competing modes. Here, I_b = 44 A, B_0 = 6.781 T, and U_b = 45-77.5 kV (α varies accordingly).

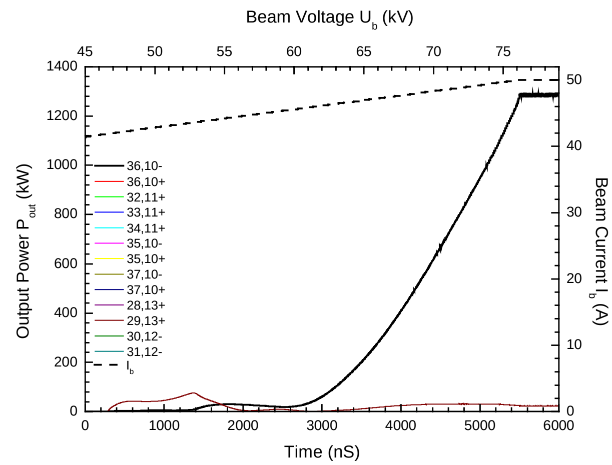

Fig. 4: SELFT simulation results for a $TE_{36,10}$ mode conventional cavity gyrotron considering the probable competing modes. Here, I_b = 50 A, B_0 = 6.795 T, and U_b = 45-79 kV (α varies accordingly).

III. CONCLUSIONS

From these studies, it is evident that one can realize a 1.0-1.3 MW, CW at 170 GHz operating with a high volume mode conventional cavity gyrotron and all the modes considered can oscillate independently over a wide range of nominal parameters without many problems with other competing modes. The modes considered in this paper have set an example for such feasibility. However, one would like to have the stray radiation minimized inside the device; losses will be reduced and damages will be averted if a suitably optimized output system is employed to reduce such stray radiation. The convenient solution is to employ an advanced dimpled-wall quasi-optical mode converter. A thorough exercise has to be carried out to freeze this design feasibility and a feasibility design study of the quasi-optical launcher with suitable mirror system has to be carried out and that work is in progress.

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