

FEASIBILITY STUDIES OF A 140 GHz, ≈ 2.4 MW, CW GYROROTRON CAVITY

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Introduction

In this work, we present feasibility studies on a 140 GHz, ≈ 2.4 MW, CW, conventional cavity gyrotron, as a potential alternative for the existing gyrotron systems for W-7X type machines. This is a logical extension of our earlier work on similar gyrotron operating at 140 GHz.

Motivation & Scope

- # Megawatt class CW gyrotrons operating at 140 GHz were successfully developed and demonstrated.
- # There is a need to investigate the feasibility of a 2.0 MW back-up gyrotron for the ECRH of fusion plasmas in WS7-X like machines.
- # Also, it is a logical sequel of our earlier studies on high power gyrotrons (both conventional and coaxial versions) operating at 140 GHz.
- # It has been opted to employ a weakly-tapered, open-ended, conventional hollow cavity resonator instead of a complex coaxial geometry.
- # Latest version of Gyrotron Design Studio (GDS-V.2024) has been used for the computer simulations.

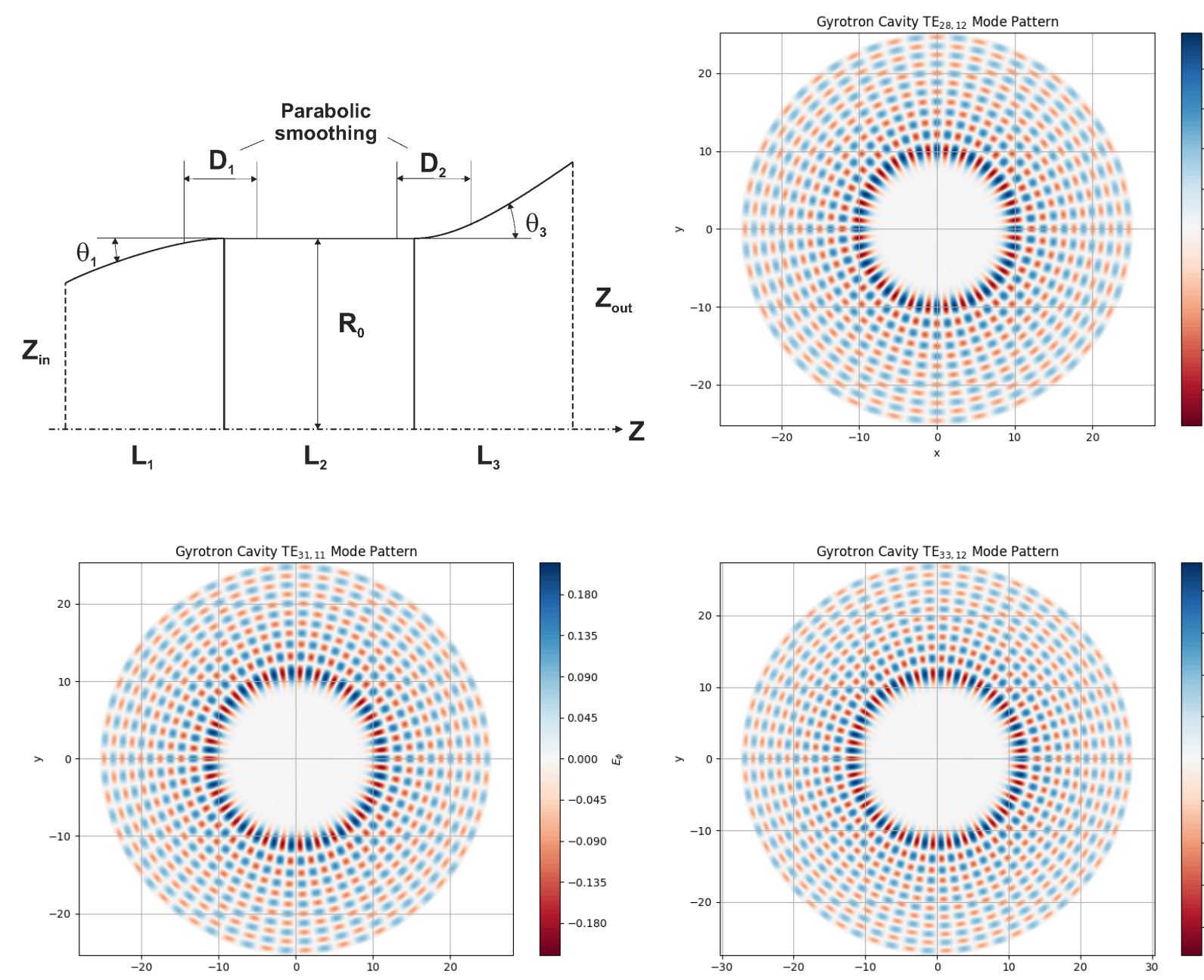
Design Goals & Parameters

Frequency	140	GHz
Output power	≈ 2.3 -2.5 MW	CW
Diffraction Q	≈ 1200 -1800	
Beam current (I_b)	≈ 62 -69	A
Beam energy (U_b)	≈ 80 -88	keV
Magnetic field at interaction	≈ 5.50 -5.58	T
Velocity ratio (α)	≈ 1.25 -1.35	
Total output efficiency	≈ 40	%
Estimated wall losses	≈ 1.0 -2.0	kW/cm ²
Overall losses	< 10	%

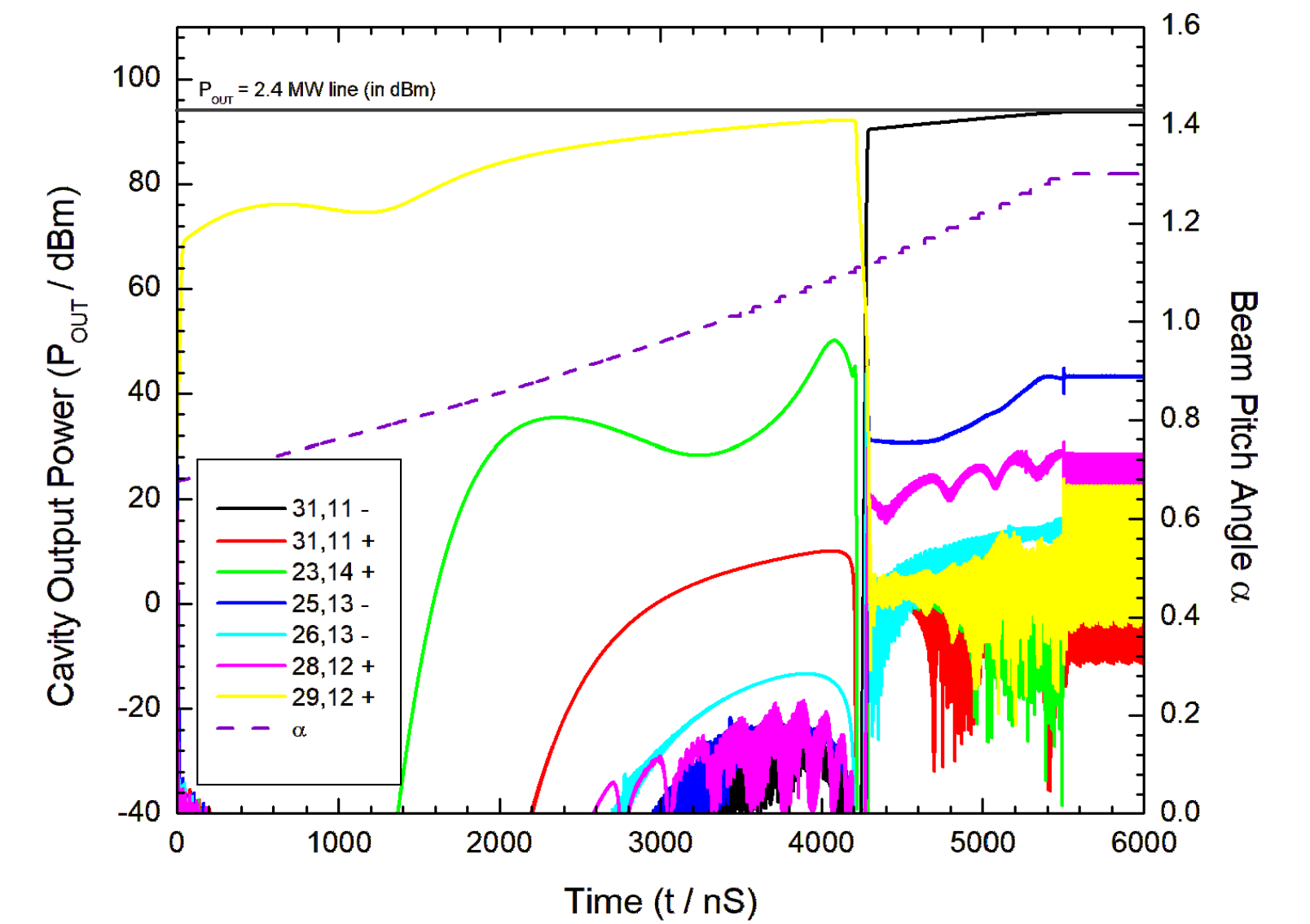
Mode Selection

- Modes with eigenvalues, typically, between 65 and 85 are scanned keeping in view the basic design constraints and considerations.
- For the mode selection, two important rules are observed to choose a suitable mode. The first one is the mode which supports a dimpled wall quasi-optical mode converter with $\Delta m = 3$ perturbation for azimuthal focussing. For this, one should have a mode with $m/\chi_{m,p} \approx 0.5$ or $360^\circ/\varphi \approx 3$.
- Of course, the another consideration is stability with respect to competing modes.
- The numbers indicate that the modes TE_{28,12}, TE_{31,11}, TE_{33,12} would be a good choice to work with.

Results: Cavity Schematic & Operating Mode Patterns



Results: TE_{31,11} Mode

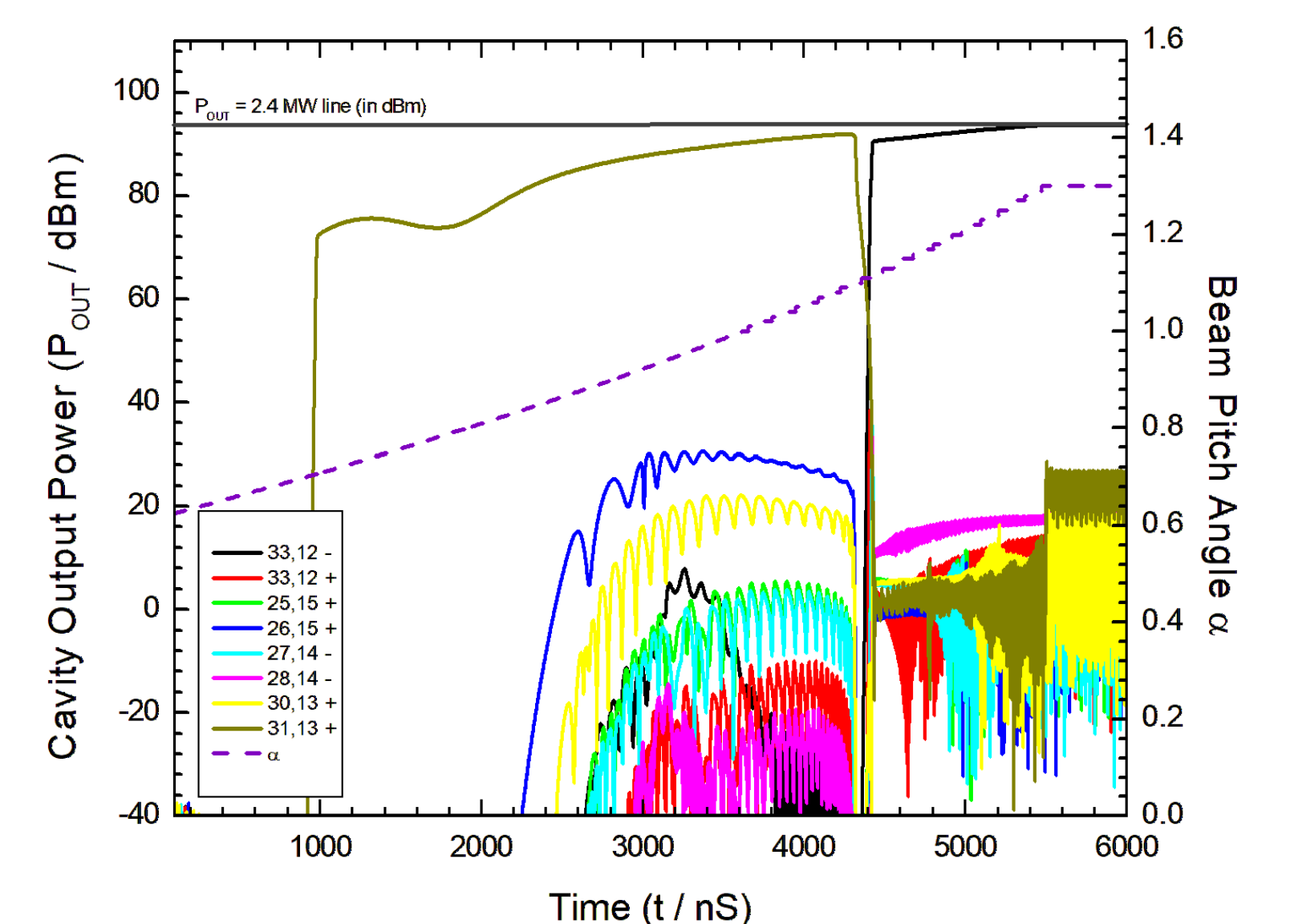


Here, $U_b = 45$ -82 kV, $I_b = 65$ A, $B(T) = 5.55$ T and α varies accordingly.

Cavity Geometry & Single-mode Self-consistent Results

Operating Mode	TE _{28,12}	TE _{31,11}	TE _{33,12}
$L_1/L_2/L_3$ (mm)	16/17/16	16/17/16	16/17/16
$\theta_1/\theta_2/\theta_3$ (°)	3.0/0/2.5	3.0/0/2.5	3.0/0/2.5
D_1/D_2 (mm)	5/5	5/5	5/5
R_{cav} (mm)	25.22	25.35	27.38
R_b (mm)	10.04	11.10	11.80
F (GHz)	140.05	140.049	140.06
Q_D	1251	1253	1276
U_b (kV)	82	82	82
I_b (A)	65	65	65
Beam pitch (α)	1.3	1.3	1.3
B(T)	5.56	5.56	5.57
η (%)	43.50	43.30	41.70
P_{out} (kW)	2317	2305	2224
ρ_Ω (kW/cm ²)	1.90	1.90	1.70
I_L (A)	106.05	113.14	111.84
V_d (kV)	11.61	10.41	10.61
σ_{cav} (S/m)	2.23E+07	2.23E+07	2.23E+07

Results: TE_{33,12} Mode



Here, $U_b = 45$ -82 kV, $I_b = 65$ A, $B(T) = 5.57$ T and α varies accordingly.

Conclusions

Key Findings

- Initial feasibility design studies indicate that such an operation is very much feasible to achieve cavity output powers up to around 2.4 MW with interaction efficiencies $\approx 40\%$ with the selected modes (i.e., TE_{28,12}, TE_{31,11}, TE_{33,12}).
- All competing modes are below 40 dBm of output power level for the operation with and TE_{28,12} & TE_{31,11} modes where as the competing modes are below 30 dBm level for the operation with the TE_{33,12} mode.
- All the computations are carried out with the latest version of Gyrotron Design Studio.

Outlook

- The frequency is ≈ 140 GHz, and if the cavity is deformed in hot conditions, then one may anticipate a small change in frequency and rising of other modes!!
- We are at present investigating the cavity hot conditions using a suitable multi-physics simulation code!!
- Further studies on the aspects of RF-Behaviour are in progress at present!!

References

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