Analysis of RF oscillations in coupled-cavity TWT at millimetre-wave band

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Abstract — Analysis of RF oscillation of a coupled-cavity traveling-wave tube is carried out at millimetre-wave band by using 3D numerical simulation code CST-Particle studio. The complete interaction structure was modelled including sever, RF input/output couplers and windows as close to experimental set-up. The simulation was carried out for fundamental and higher order modes, the start oscillation current was estimated from the simulation, which is very important parameter to be studied in the preliminary design of the TWT.

Index terms: coupled-cavity, millimetre-wave, slow-wave structure, traveling-wave tube.

I. INTRODUCTION

Coupled-cavity traveling-wave tube (CC-TWT) promises high peak power and moderate bandwidth at millimeter-wave band [1], [2]. 3D numerical simulation of a Ka-band CC-TWT was reported by J. R. Legarra, *et. al* [3], [4] and by Hae Jin Kim, Hyoung Jong Kim and Jin Joo Choi to estimate the output power and gain [5]. But RF oscillation analysis of the CC-TWT which includes sever, RF couplers and window is not yet reported. In this present work, RF oscillation analysis of a complete coupled-cavity interaction structure is carried out which includes severs, RF couplers and window as close to experimental TWT.

II. NUMERICAL ANALYSIS

The coupled-cavity analyzed in the present work consists of double coupling slot and the cavity is square in cross section. The cavities are having circular ferrule and beam tunnel. The coupling slots are rectangular in shape and staggered as shown in Fig.1.

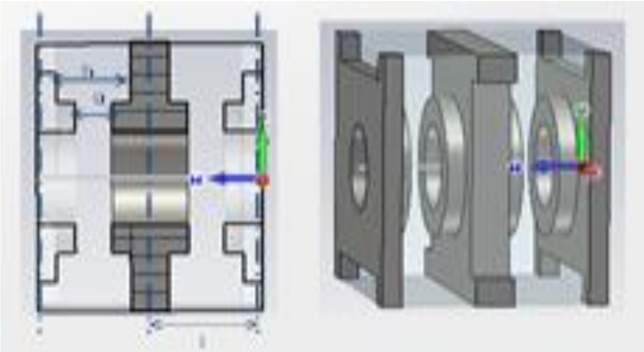


Fig.1 3D model of a double slot CC-SWS.

The complete 3D model of a CC-SWS along with sever, input/output couplers and RF window is shown in Fig. 2. The complete CC-SWS is divided into two sections. A sever cavity is placed in between two sections. The sever cavity consists of lossy ceramic at both sides to attenuate the RF signal. The tapered impedance transformer is used for input/output couplers. A waveguide RF window are attached to both ends of the couplers.

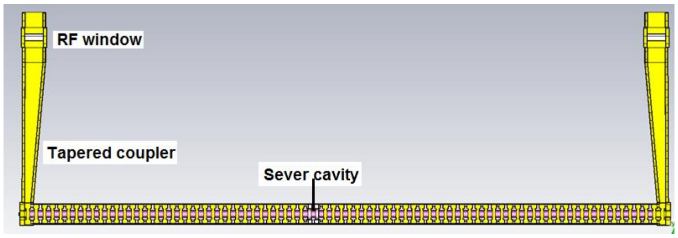
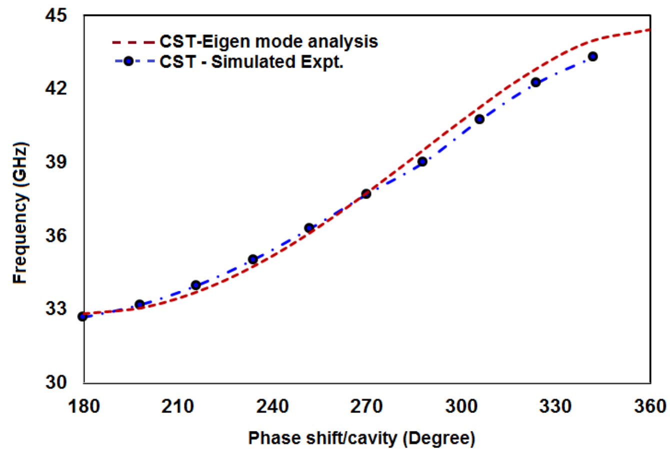


Fig.2 3D model of a complete CC-SWS including sever, RF input/output couplers and windows.

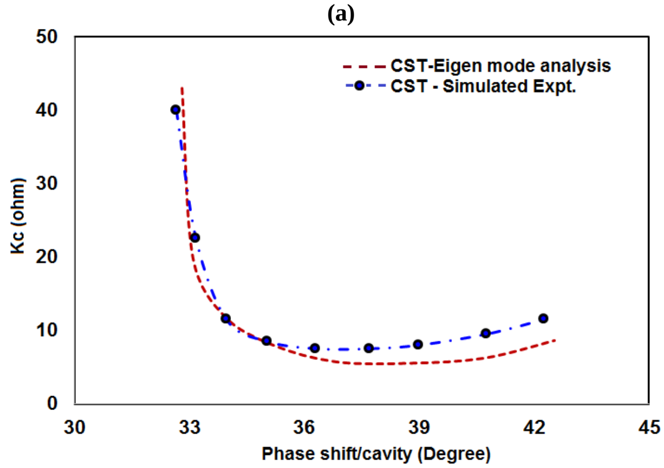
The cold circuit parameters such as dispersion, interaction impedance and VSWR characteristics are analysed initially using CST-Microwave studio [6] to finalize the beam operating parameters following the approach reported in [5]. Based on cold circuit analysis, the electron beam parameters are estimated. Beam-wave interaction analysis was carried out using CST-Particle studio [6]. Electron beam was launched at the starting of the CC-SWS for the operating voltage of 20 kV, assuming 50% beam filling factor. A constant magnetic field of 0.25 T was considered along the beam axis. The electron beam current was increased from 600 mA to 2 A in the step of 200 mA without any RF input signal to find out the start oscillation current. Both the input/output port signals are monitored for the total simulation time of 10 ns for each run.

III. RESULTS AND DISCUSSIONS

The simulated cold circuit results are shown in Fig.3 for dispersion and interaction impedance characteristics and in Fig. 4 for VSWR characteristics of input/output sections. The simulated electron trajectory plot is shown in Fig. 5 and output port signal plot is shown in Fig.6, Fig.7 and Fig.8 for the fundamental TE_{10}-, higher order TE_{02}/TE_{20}- and TE_{11}- mode respectively. The Stat oscillation current Vs. output power and frequencies for these different port modes are given in table-1.



(a)



(b)

Fig.3 Comparison of (a) dispersion and interaction impedance characteristics

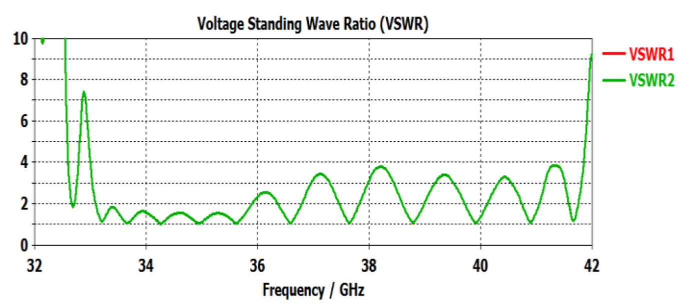


Fig. 4 Input/output section VSWR plot

Table-1 Simulated Parameters

Sl. no	mode	I_{osc} (A)	F_{osc} (GHz)	P_{osc} (W)
1	TE_{10}	1.0	40.03	0.80
2	TE_{02}/ TE_{20}	2.0	67.0, 80.7	0.16
3	TE_{11}	2.0	42.0, 47.0, 75.0,80.0,85.0	0.04

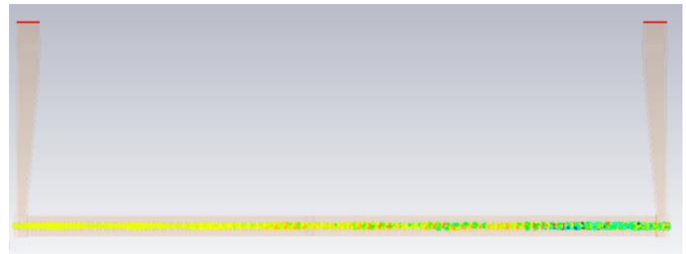
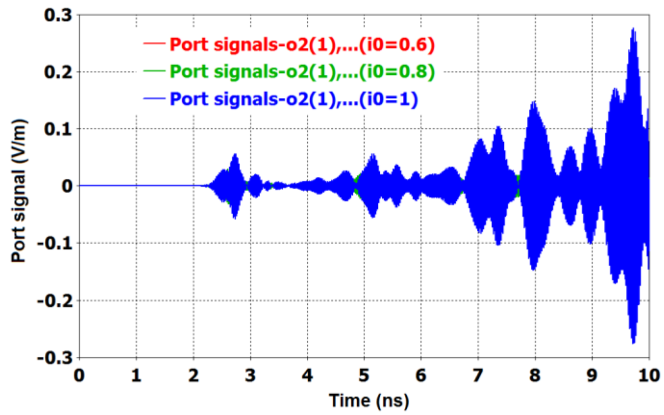
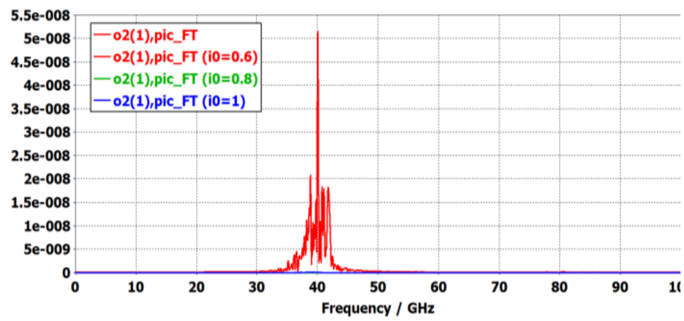


Fig. 5 Electron trajectory plot

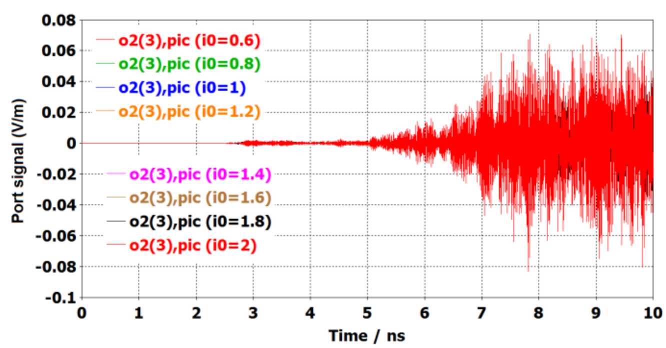


(a)

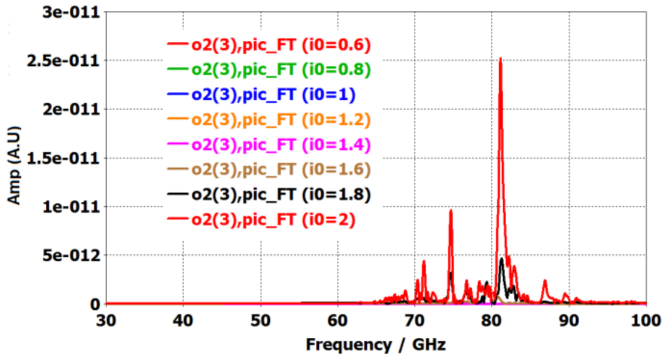


(b)

Fig. 6 simulated (a) output port signal for mode TE_{10} (b) FFT of the output port signal for TE_{10}

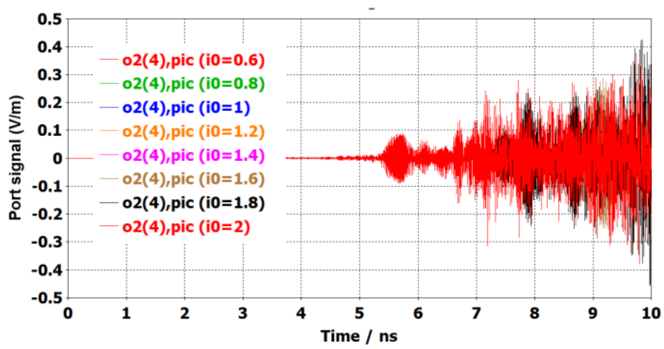


(a)

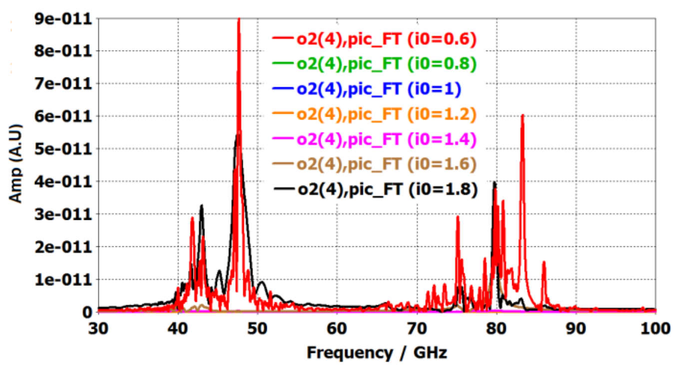


(b)

Fig. 7 Simulated (a) output port signal for mode TE_{10} (b) FFT of the output port signal for TE_{20} & TE_{02}



(a)



(b)

Fig. 8 Simulated (a) output port signal for mode TE_{11} (b) FFT of the output port signal for TE_{11}

IV. CONCLUSION

Analysis of RF oscillation of mm-wave coupled-cavity travelling-wave tube is carried out to study the oscillation characteristic, which is presently under development, Operating current of TWT is the 0.65A; start oscillation current is estimated along with oscillation power and frequency which is very much essential to be studied before RF testing the TWT. From the present analysis we understood that there is sufficient margin is there for the operating current from start oscillation current for our required operating bandwidth.

V. ACKNOWLEDGEMENT

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