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Study of Side Coupled Modulation Cavity for High Power Microwave Application

Anamika Raj
Dept. of Electronics and Communication
NIT Patna
Patna, India
anamikaraj703@gmail.com

Manpuran Mahto
Dept. of Electronics and Communication
NIT Patna
Patna, India
mmahto@nitp.ac.in

Saket Kumar
Dept. of Electronics and Communication
MIT Muzaffarpur
Muzaffarpur, India
saket@mitmuzaffarpur.org

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Abstract

In this paper, we have studied the side coupled modulation cavity as an RF interaction structure of the reltron. In this modulation cavity beam wave interaction takes place. Using CST Eigenmode solver a beam absent simulation of the modulation cavity has been carried out. Since the side coupled modulation cavity is made of three re-entrant cavities, the modulation cavity provides three resonant modes i.e. 0 mode, π/2 mode and π mode. Here, π/2 mode is the desired mode of the operation and it is obtained at 2.896 GHz at 10mm coupling depth. One of the major advantages of the side coupled modulation activity is that it can be made the frequency tunable. To predict this behavior we have varied the coupling depth of the cavity and obtained the frequency for all the three resonating modes.

Index Terms—reltron, electron velocity, modulation cavity, eigenmode simulation

I. Introduction

The Reltron is a high power microwave tube and it is the family member of the microwave tube [1]. The working principle of reltron is similar to the klystron but the bunching process is different in the reltron and also reltron does not require external dc magnetic field to direct the electron, it has self magnetic behaviour. In reltron bunched beam are re- accelerated so in the reltron electron velocity increases and hence increasing the energy [2]. Reltron uses velvet cathode which can generate the current density greater then $1KA/cm^2$. Reltron is a microwave oscillator, which can generates hundred of megawatt of power in the frequency range of 0.5-12 GHz. The principal operating mode of the device is TM_{01}. Reltron does not require mode converter at output extraction cavity. The high voltage sources are used to operate the reltron. Initially reltron was operated with Marx generator. The electron beam is pre-modulated in the first grid space of the modulation cavity then the second grid spacing. In the first grid induced gap voltage is high. So, it forms virtual cathode in the second grid [3]. Once the virtual cathode is formed the oscillation phenomenon takes place as the electron reflected back towards the cathode and again reflected back towards the virtual cathode. The efficiency of electron in reltron is obtained

Identify applicable funding agency here. If none, delete this.by taking the ratio of average kinetic energy to initial electron beam energy.

II. Model Description

The reltron consists of modulation cavity, post-acceleration gap, extraction cavity, beam dump etc. Here we are modeling the modulation cavity that consists of

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main cavity, coupling cavity, grids, idlers. During the construction of modulation cavity as per design in [4] main cavity, inner radius= 38.5mm, outer radius =41.5mm as thickness is 3mm, Zmin=0mm and Zmax=59mm. In coupling cavity inner radius is 23mm and outer radius is 26mm. Add coupling and the main cavity,then cut1. And after cut1 add three grids and add all with the main cavity. Then cut2 from the main solid. The coupling cavity has two idler that make the re-entrant cavity. Idlers are used for the frequency tuning and having dimension outer radius=8mm, inner radius=0mm, y-dimension=57.5mm, Zmin=14.75mm, Zmax=24.25mm and spacing between the idlers are 8mm. Add the small cylinder having dimension inner radius=10mm, outer radius=12mm, Zmin=22.75mm, Zmax=32.75mm. Add the cover to the main cavity and the coupling cavity.

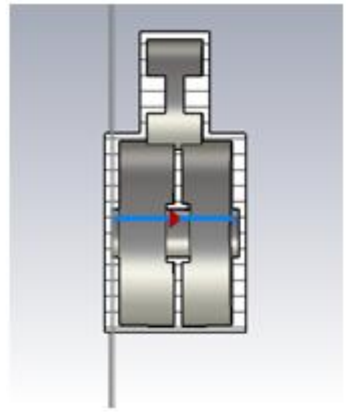

Fig. 1. Reltron model

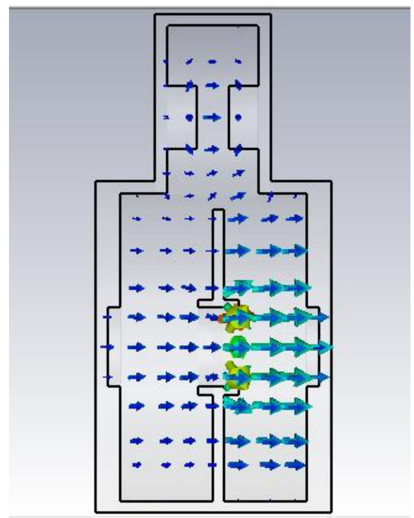

Fig. 2. 0 mode

III. Bunching Process

Here, we are taking the dc velocity of the electron as v_0. and accelerates the dc velocity of electron at. Again this velocity is re-accelerate at the equation, and we get the final accelerated velocity of the electron at the extraction output cavity of the reltron. Equation" 5" gives the first modulated velocity and equation" 9" gives the re-accelerating velocity.

v_0 = dc velocity of electron
$v(t_1)$ = modulated velocity at time t_1
$v(t_2)$ = modulated velocity at time t_2

$$\frac{1}{2}mv^2 = eV_0 \; (conservation of energy) \quad (1)$$

$$v = \sqrt{\frac{2eV_0}{m}}$$

$$v(t_1) = \sqrt{\frac{2e}{m}(V_0 + V_1 sin(\omega t_0))} \quad (3)$$

$$v(t_2) = \sqrt{\frac{2e}{m}(V_0 + < v(t_1) >)} \quad (4)$$

$$v(t_1) = V_0[1 + \frac{V_1\beta_1}{2V_0} sin(\omega t_0 + \theta_g/2)] \quad (5)$$

2.979 GHz at 10mm coupling depth. Here we are inserting a table for varying the coupling depth and we get resonance frequency for the different mode of the reltron.

$$\beta_1 = \frac{sin\theta_g/2}{\theta_g/2} \quad (6)$$

Similary,

$$v(t_2) = \sqrt{\frac{2e}{m}[V(t_1) + V(t_2)]} \quad (7)$$

$$v(t_2) = \sqrt{\frac{2e}{m}[V_1\beta_1 sin(\omega t_1 + \theta_g/2) + V_2\beta_2 sin(\omega t_1 + \theta_{g1}/2)]} \quad (8)$$

$$= V_0[V_1\beta_1 sin(\omega t_1 + \theta_g/2) + V_2\beta_2 sin(\omega t_1 + \theta_{g1}/2)] \quad (9)$$

$$\beta_2 = \frac{\sin\theta_g l/2}{\theta_g l/2}$$

SIMULATION RESULT

To perform the beam absent simulation, we are using eigen-mode simulation. In modulation cavity interaction of RF with electron beam. The eigenmode simulation is a mode matching technique. In CST eigenmode solver is used for beam absent simulation for studying the electromagnetic behaviour. The modulation cavity has three resonant frequency of 0, due to three cavities. In 0 mode, electric field in main cavity and coupling cavity are in the same direction. In this mode frequency is 2.878 GHz at 10mm coupling depth. In $\pi/2$ mode, electric field in the main cavity field are opposite in phase. And it shows negligible effect in coupling cavity. In this mode frequency is 2.896 GHz at 10mm coupling depth. In π mode, electric field in the main cavity and in the coupling cavity are in opposite direction. In this mode frequency is

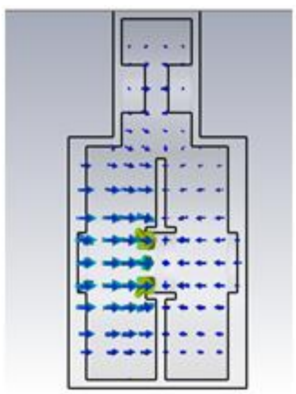

Fig. 3. pi by 2 mode

TABLE I
SIMULATION RESULTS

S.No	Coupling Depth	0 Mode	? /2 Mode	? Mode
1	8mm	2.890	2.910	3.000
2	10mm	2.878	2.896	2.979
3	12mm	2.839	2.877	2.974
4	14mm	2.807	2.872	2.973
5	16mm	2.774	2.871	2.972

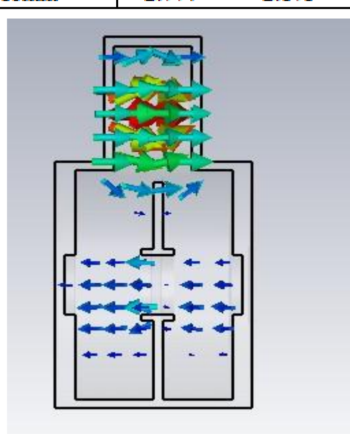

Fig. 4. pi mode

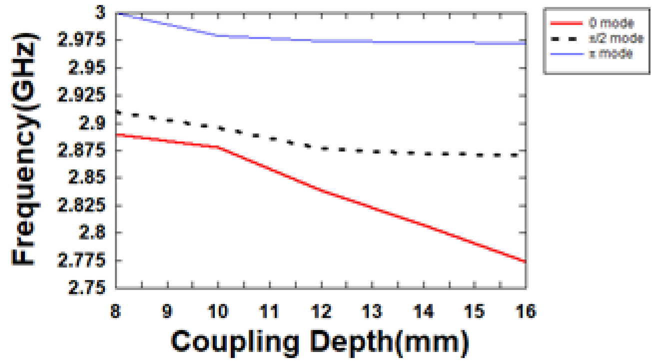

Fig. 5. Modes result

IV. CONCLUSION

Hence, we have successfully studied the side coupled modulation cavity using a disk hole in place of metal grids. As a result less electron beam interception takes place which enhance the device life. The Eigenmode simulation predicts that the operating frequency of the modulation cavity to be 2.89 GHz. This work can further be extended by reducing the operating voltage of the reltron.

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