STUDY OF CYLINDRICAL REENTRANT OUTPUT CAVITY FOR 350 MHz KLYSTRON

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Abstract

The Particle in Cell (PIC) simulation of a 350 MHz klystron output cavity is carried out. The CST Particle Studio module which enables a mutual coupling of the charge movement and the electromagnetic field is used to investigate the interaction between bunched electron beam and the output cavity of klystron. The parameters of the klystron used in the investigation were: beam power 200W, beam voltage 32 kV and beam current 6.25A with efficiency around 50%. The Gaussian particle source emits series of Gaussian bunches with static magnetic field superimposed to the PIC simulation to compensate the bunch divergence due to space charge effects. The output power (wave amplitude) is directly recorded by the waveguide ports. After performing a discrete Fourier Transformation of the time signal, the corresponding frequency spectrum is obtained. It shows a peak around 350 MHz which was the design value for this klystron.

INTRODUCTION

A klystron is a device to amplify microwave and/or radio frequency signals. The outstanding specifications of klystron are high output power, high gain, high reliability. The output resonator is the last stage (cavity) of a klystron, the input fed at input port of the first stage (cavity) is amplified by subsequent stages and amplified signal can be coupled out by waveguide ports. Since only the output resonator as a part of the klystron is simulated, a Gaussian emission model is used to define an already bunched particle beam.

CST Studio Suite is a powerful 3-D electrodynamic code for the simulation and design of microwave devices. The Particle Studio module is used here for the investigation of the interaction between a bunched electron beam and the output cavity of a klystron. The simulation is performed with the Particle in Cell (PIC) code of CST PARTICLE STUDIO (CST PS). The code enables a mutual coupling of the charge movement and the electromagnetic field. The objective of the study was to understand the way in which the cavity and bunch parameters affect the efficiency of power transfer from the bunches to the cavity. The R&D activity for Klystron development is in progress at RRCAT. Preliminary specifications for the development in-line are given in Table1.

Table 1: Klystron Specifications

Parameter	**Value**
Operating frequency	350MHz
Output Power CW	100kW
Beam voltage	32kV
Beam current	6.25 A
Beam micro Perveance	0.915
Efficiency	50 %

MODELING AND SIMULATION

The parameters of the klystron used in the investigation were: beam power 200W, beam voltage 32 kV and beam current 6.25A with an efficiency around 50%. The geometry, a cavity with an output waveguide attached, is shown in Fig. 1

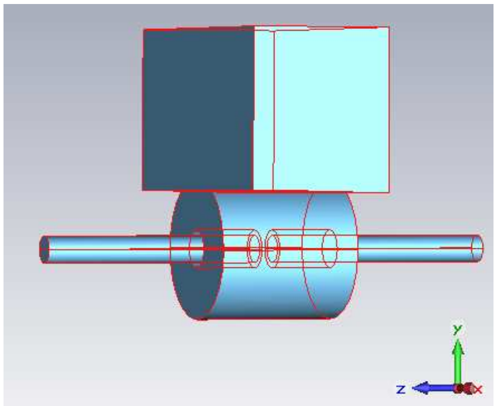

Figure 1: CST PS model of the output cavity.

For the purposes of the study an idealized bunch was defined in terms of the distribution and velocities of the electrons as they emerged from the penultimate cavity. A velocity distribution of 5% of the maximum velocity is assumed in a bunch. It was assumed that the charge density between the bunches was negligible and that the initial bunch length was assumed to fill the cavity length.

The particle source is defined to be Gaussian type. The emission surface has to be picked and then the particle properties such as mass, charge, initial energy etc. can be modified. A series of Gaussian bunches is emitted. Static magnetic fields, can be superimposed to the PIC simulation. These fields can be either homogeneous, cylindrically symmetric with arbitrary longitudinal dependency, or precalculated by an CST EM STUDIO simulation of an arbitrary coil geometry. In this case a homogeneous field is used to compensate the bunch divergence due to space charge effects (see figure 2).

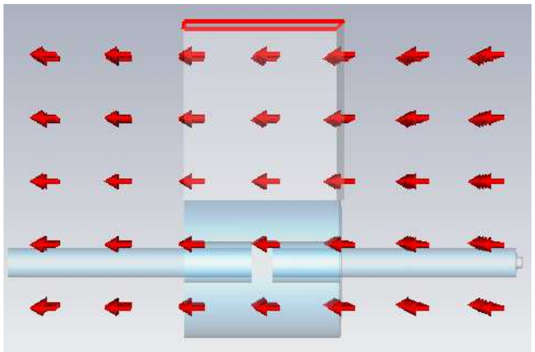

Figure 2: Superimposed static magnetic field to compensate the bunch divergence due to space charge effects.

RESULTS

Figure 3 shows the port dominant mode at resonance frequency 350 MHz. It can easily visualized to be TE_{10}.

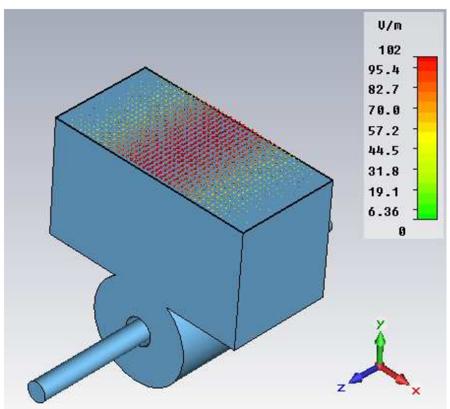

Figure 3: E-field distribution for dominant mode at resonance frequency.

Figure 4 shows the particle trajectories of the simulated bunches. The colour indicates the energy distribution of the particles inside the bunch. The time varying amplitude of the bunch current has a Gaussian distribution. The spatial distribution of the charged particles is defined to be uniform over the emission surfaces cross section. The time dependent field and particle monitors also show the space charge effect on the bunches.

The output power (wave amplitude) is directly recorded by the waveguide ports. After performing a discrete Fourier Transformation of the time signal, the corresponding frequency spectrum is shown in figure 5. It shows a peak around 350 MHz which was the design value for this klystron.

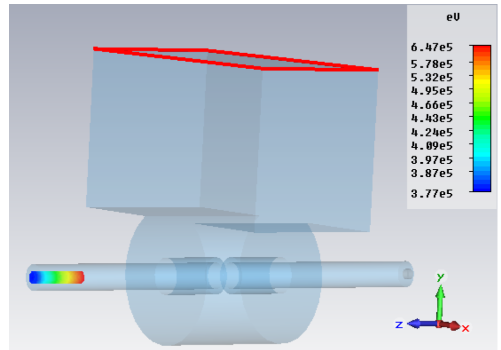

Figure 4: An electron bunch travelling in beam tube.

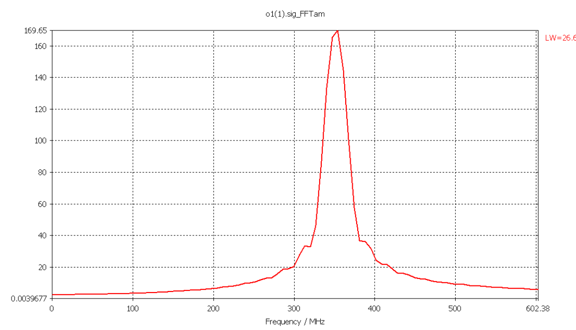

Figure 5: Frequency spectrum of the output signal at waveguide port.

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