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Design and Simulation of Electron Gun for a Multibeam Klystron

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Abstract. This paper represents the design of multi-beam (sixty-beam) electron gun and focusing system for high power, compact klystron. The beam voltage is 4 kV with a total beam current of 513 (8.55 x 60) mA which is equally divided among sixty-beam. Each beam has a perveance of 0.033 μP making a total gun perveance of 2.02 μP corresponding to a total beam power of more than 2 kW. The cathode radius is7 mm and individual emitter radius is 0.2 mm having current density 6.7 A/cm2. The design has been accomplished using OPERA 3D code. All beamlets have individual anode as well as BFE and a common focusing system. Potential difference between cathode and anode is 4 kV. A magnetic field of 1200 Gauss is applied along the beam axis. A major challenge for the development of multi-beam klystron is design and technology for the focusing of off-axis beamlets because off-axis beams are at various azimuths.

1. Introduction

The basic principle of operation of any microwave tube is the effective interaction between the electron beam and the electromagnetic wave in an interaction region. Therefore electron gun plays a vital role in the design and development of any microwave tubes. For new generation microwave tubes like multi-beam klystron electron beam of desired shape, energy and current density and its focusing is really a challenging task. Since the drawbacks of the single beam klystron like high operating voltage, narrow bandwidth and more weight cannot be eliminated due to some physical limitations or technical restrictions. Therefore, concept of multi-beam electron gun has been introduced. The multi-beam klystrons (MBKs) are the only microwave amplifiers that fulfil the most of present demand of users, such as high power, high efficiency, large bandwidth, low noise and low-voltage operation, as compared to conventional single-beam klystrons. Due to these features MBK is used for ground-based, airborne and space-based radars, radio-communication and high energy particle accelerators [1]-[7].

In an MBK each beamlet propagates along its own individual path through the RF section consisting of two or more cavity resonators. The most important advantage of an MBK is that the current and perveance per beamlet are low while total current and perveance remain high in this device. For higher electronic efficiency and gain of device bunching should be more, which can be achieved by low perveance per beamlet. Further, the overall higher perveance allows a lower voltage operation yielding higher beam power and RF power as compared to conventional single beam klystron. In addition, the reduced operating voltage significantly decreases the cost of the power supply system and reduces the device length thereby making the device more compact. Moreover, the multiple-beam devices are designed with lower cavity shunt impedance as compared to single-beam devices resulting in a broader bandwidth [2], [8].

Figure 1 An example of 4 kV sixty-beam electron gun consists of sixty emitters (radius = 0.2 mm) on a common plate with sixty electrically isolated BFE (again a common plate) as well as sixty individual anodes constructed on a common plate has been taken for study and focused with a common solenoid.

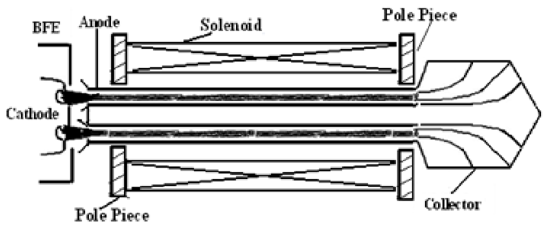

Figure 1. Schematic of sixty beam stick tube

Table 1. Gun design parameters

Parameter	Value
Cathode voltage	-4 kV
No. of beamlets	60
Total beam current	513 mA
Total beam perveance	2.02 μP
Individual beam perveance	0.033 μP
Cathode diameter	14.4 mm
Cathode loading	6.7 A/cm^2
Beam waist radius	0.15 mm
Beam throw	2.75 mm

2. Electron Gun Design

In this section we discuss how to format the title, authors and affiliations. Please follow these instructions as carefully as possible so all articles within a conference have the same style to the title page. This paragraph follows a section title so it should not be indented.

2.1 Objective of the sixty beam electron gun

The main objective of designing the multi beam electron gun is to replace a single beam high perveance (1.2 μP), high voltage (6 kV) electron gun with low perveance (0.033 μP) and low voltage (4 kV) compact multi beam electron gun. An effort has been made to design sixty beam low perveance electron gun using 3D code OPERA. Initially solenoid focusing has been planned to achieve the sixty-beam focusing with minimum beam scalloping and at later stage permanent magnet can be tried.

2.2 Sixty-beam gun topology

The gun design parameters of multi-beam electron gun are shown in Table 1. A sixty beam electron gun with planer cathode has been simulated using OPERA 3D code [9]. The electron gun employs a concentric packing topology with four PCDs 12.8 mm, 9.6 mm, 6.4 mm, and 3.2 mm having emitters 24, 18, 12, and 6 respectively as shown in figure 2(a) and is expected to produce 513 mA at its nominal operating voltage of 4 kV. The cathode radius is 14.4 mm and individual emitter radius is 0.2 mm having current density 6.7 A/cm2. All beamlets have individual anode as well as BFE and a common focusing system. Potential difference between cathode and anode is 4 kV. A magnetic field of 1200 Gauss is applied along the beam axis. Figure 2 (b) illustrates one quadrant of the basic topology of the optimized sixty beam electron gun design, which includes sixty planer emitters set within a cathode mask, an sixty-aperture focus electrode, and an sixty-aperture anode.

Figure 3(a) shows the beam trajectories in a full gun geometry and beam tunnels with a guiding magnetic field of 1200 Gauss. Total beam current is 513 mA (8.5 mA×60) at a voltage of 4 kV corresponding to a total beam power of more than 2 kW and magnified view of their corresponding graph trajectories on different PCDs are shown in figure 3(b). The computed beam-throw and beam-waist radius are 2.75 mm and 0.15 mm, respectively. Confined flow focusing system has been chosen to have better focusing, resulting in higher value of output RF power. The end-on views of electron trajectories corresponding to figure 3(a), is shown in figure 4(a). It has been observed that the beamlets are laminar and within the initial beam-to-tunnel fill factor at the beam waist. The achievement of this sixty beam electron gun is that the beam cut off in single beam takes place when BFE is biased with negative 300 V with respect to cathode while in case of multi-beam it takes place at negative 100 V as shown in figure 4(b) [10].

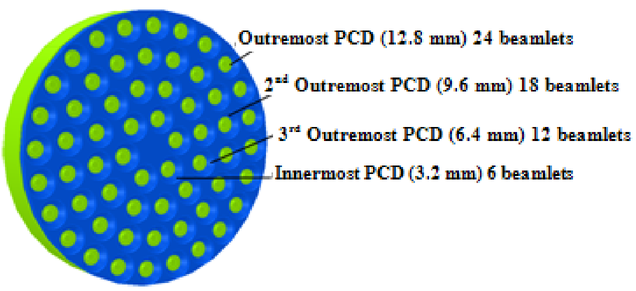

Figure 2(a). Sixty emitters and BFE on a common plate

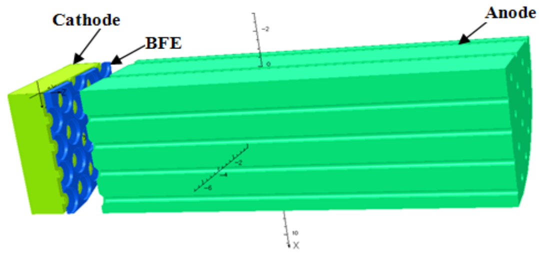

Figure 2(b). Quarter section of multi-beam electron gun

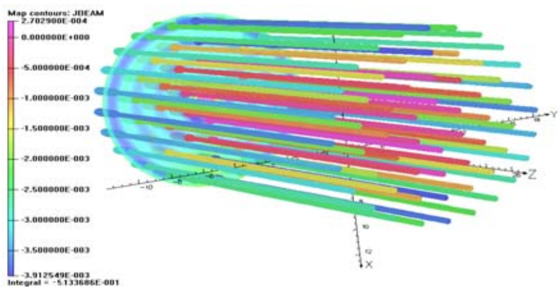

Figure 3(a). 3D view of electron trajectories with magnetic field

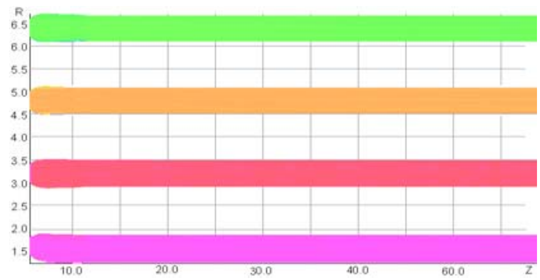

Figure 3(b). Electron trajectories graph on different PCDs with magnetic field

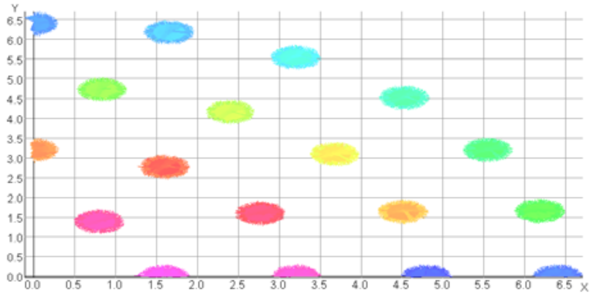

Figure 4(a). 3D view of electron trajectories with magnetic field

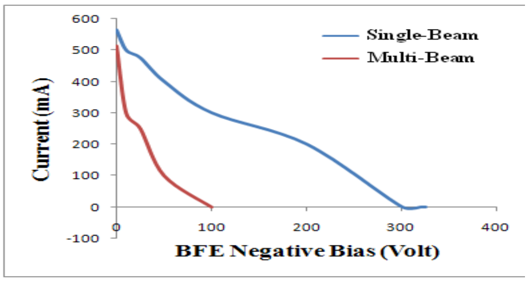

Figure 4(b). Electron trajectories graph on different PCDs with magnetic field

3.Conclusion

A sixty beam electron gun with individual beam perveance 0.033 μP and total beam perveance 2.02 μP has been designed to replace the single beam electron gun of 1.2 μP, operating at beam voltage 6 kV and 564 mA current. It has been observed that emission of electrons take place from the edge of emitter but it can be controlled by applying negative potential at beam focusing electrode and at a particular potential beam completely cut off or no emission of electrons takes place.

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