Design of Magnetron Injection Gun for 140GHz, 1MW Gyrotron

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***Abstract*—This paper presents the design simulation of a triode type MIG for 140GHz, 1MW gyrotron operating at $TE_{28,8}$ mode. Primarily, the basic design equations have been used for the estimation of initial gun parameters and the beam trajectory simulation has been carried out by using the EGUN code. The simulated results for gun geometry and beam trajectory show that a good quality of electron beam is generated with a low velocity spread 2.42% at the velocity ratio (α) = 1.34.**

***Keywords*—electric field on cathode, gap factor, beam compression ratio, velocity ratio, beam spread.**

I. Introduction

The magnetron injection gun (MIG) is a key component used in the gyro-devices and it produces an annular electron beam from the thermionic cathode in presence of the external magnetic field [1-2]. The most preferable gun is a triode magnetron injection gun (TMIG) which consists of a cathode and two anodes and has good control over the beam parameters. The qualitative design of MIG depends on the good quality of the gyrating electron beam and it could be decided by the axial beam velocity spread and beam velocity ratio (α) [3-5]. This paper presents the design of a TMIG for a gyrotron operating at 140GHz and capable to deliver the power 1MW with operational $TE_{28,8}$ mode. Initially, the gun parameters have been estimated by the basic design equations [6-7] and after that, the beam trajectory simulation is done by using the EGUN [8]. The design study of TMIG for 140GHz, 1MW gyrotron has been proposed with the short pulse power supply and this work may be beneficial for the futuristic plans of INDIA.

The primary design inputs are listed in Table I. The other design input parameters are estimated with the help of basic design equations by using a computational approach and such parameters are listed in Table II.

II. Magnetic Field Profile

A rough estimation of the device length can be made by looking at the magnetic field profile [1, 6, 7]. Fig. 1 present the magnetic field from the gun to the cavity centre. The required magnetic field for 140GHz gyrotron is 5.75 Tesla on the cavity center.

III. Simulation and Results

The numerical simulation of 140GHz, 1MW triode type MIG (TMIG) is presented by using beam trajectory code EGUN. The optimized gun geometry and beam trajectory profile are shown in Fig. 2 and 3, while the optimized results are listed in Table III. The optimized design results show a good quality electron beam generation with a velocity spread

TABLE I
Primarily Design Inputs for 140GHz TMIG

S.No.	Parameters	Design Values
1.	Frequency of Operation	140GHz
2.	Beam Voltage (V)	80 – 90kV
3.	Beam Current	38 – 42A
4.	Output Power (P)	1MW
5.	Velocity Ratio (α)	≤ 1.5
6.	Beam Compression Ratio	$\approx 20 - 32$
7.	Operating Mode	$TE_{28,8}$
8.	Cathode-Anode Distance	$\approx$ 15mm
9.	Velocity Spread	$\leq 5\%$
10.	Emitter Cathode Angle	$\geq 25^0$

TABLE II
Computationally Obtained Parameters

S.No.	Parameters	Design Values
1.	Cathode Radius	50mm
2.	Slant length (l_s)	6.06mm
3.	Magnetic field at cavity center (B_0)	5.75T
4.	Compression ratio (f_m)	31
5.	Magnetic field on Cathode (B_c)	0.1854T
6.	Cavity Radius	20.48mm
7.	Beam Radius (at first maxima)	10.03mm

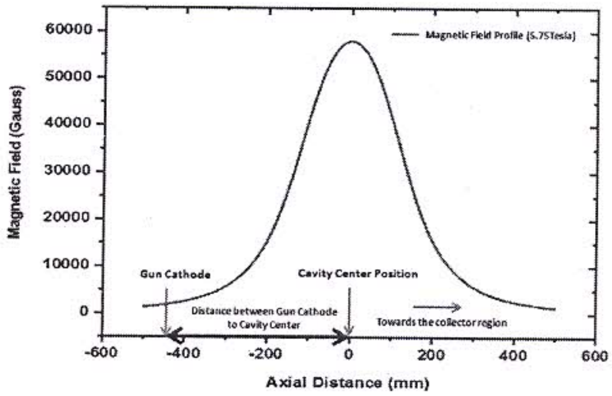

Fig. 1. Optimized Magnetic Field Profile from the Cathode to the Cavity Centre.

= 2.42%, and the velocity ratio = 1.34. Fig. 4 and 5 present the variation in beam spread and velocity ratio with changes in modulating voltage and beam voltage respectively which gives the parametric control to generate a good quality of electron beam.

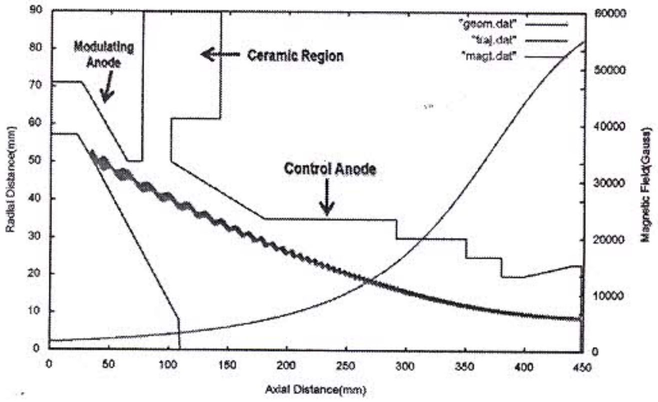

Fig. 2. TMIG Simulation on EGUN (Electron Beam Trajectory Program).

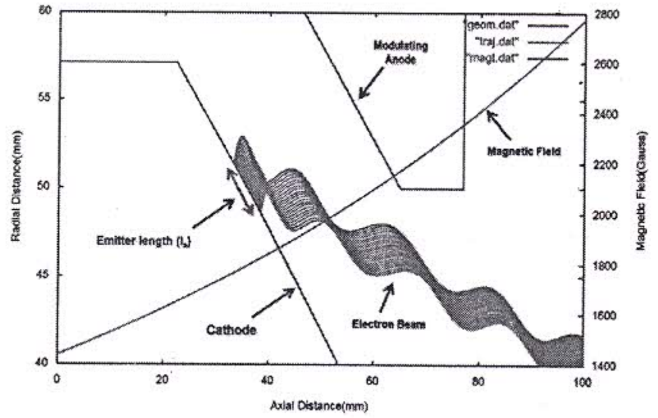

Fig. 3. Electron beam Emission from Emitter (with desired Quasi-Laminar Flow)

TABLE III
FINAL OPTIMIZED PARAMETER FOR TMIG

S.No.	Parameters	Obtained Values
1.	Beam Current	40A
2.	Accelerating voltage	86kV
3.	Modulating anode Voltage	60kV
4.	Magnetic field at cathode	0.1854T
5.	Beam compression ratio	31
6.	Beam radius (interaction)	$10.0mm$
7.	Larmor radius (interaction)	$0.192mm$
8.	Cathode radius	$50mm$
9.	Cathode angle	28^0
10.	Veloctly ratio (α)	1.34
11.	Velocity spread	2.42%

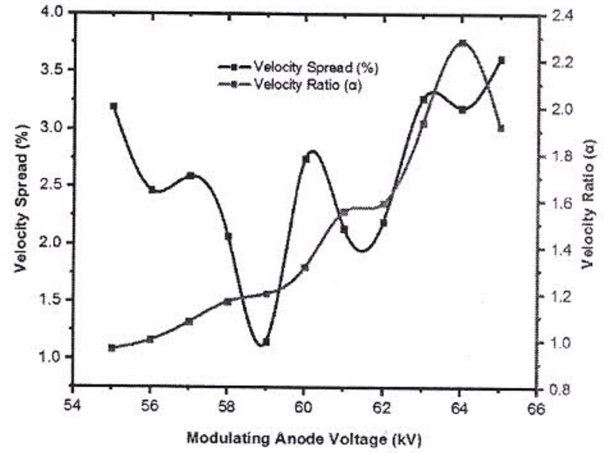

Fig. 4. Effect of Modulating Anode Voltage on Velocity ratio and spread.

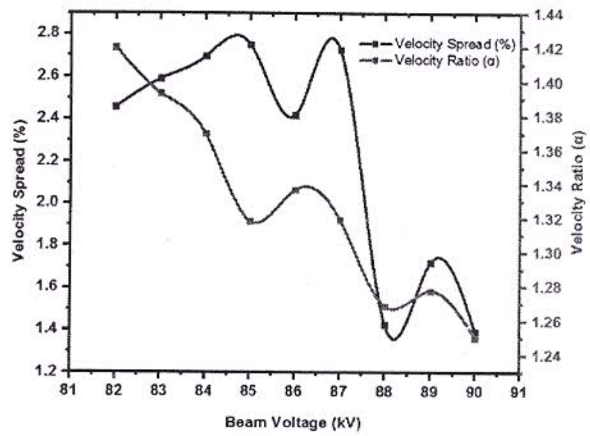

Fig. 5. Beam Voltage Effect on Velocity ratio and spread.

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