Particle-In-Cell (PIC) Simulation of Spatial-Harmonic Magnetron (SHM)

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Abstract: *RF Vacuum Electronic Devices (RF VEDs) have been the most promising milestones for radio-wave and microwave generation at high power and high frequencies for decades. Spatial Harmonic magnetrons (SHMs) with cold secondary emission cathodes have proved to be an efficient solutions to the viability of magnetrons at high frequency. The paper presents a 3-D Particle in Cell (PIC) simulation of a D-Band (140 GHz) SHM using CST particle studio (CST-PS).*

Keywords: Spatial Harmonic Magnetrons, Compact Terahertz devices, 3D Particle-In-Cell Simulation, Beam-wave interaction, CST Particle Studio.

I. Introduction

Spatial Harmonic Magnetrons (SHMs) have been a technical breakthrough in the development of a variant of magnetron, utilizing a spatial harmonic of the RF field of a non-π (usually a π/2 mode or a neighboring one) for its operation [1]. These magnetrons have facilitated various advantages of increased dimensions of resonant system even at higher frequencies, increased mode separation, reduction of dc magnetic field, thermal and operational stability with extended lifetime using cold cathodes [2]. Vehicle guidance system, meteorological and navigational high resolution radars, environmental monitoring systems, desktop charge particle accelerators, compact terahertz (THz) devices for chemical and biological reagents are some of the possible applications for such high frequency magnetrons [3]. The paper introduces a brief review in section I. The 3-D PIC simulation details of a D-band (140 GHz) SHM is summarized in section II. Section III contains the simulation results and discussions. Section IV concludes the paper.

II. Simulation & Analysis

Single harmonic approximation approach [4] is used to find the initial geometrical parameters of a vane type anode of the designed SHM. On the finalization of the anode structure and its dimensional parameters summarized in Table.1, a simulation model is designed in CST microwave studio [5]. Later a cold secondary emission (CSE) cathode, end caps, an iris coupled $\lambda_g/4$ output section and a WR-6 waveguide is added to complete the SHM simulation model. The SHM utilizes a CSE cathode which requires the modelling of suitable secondary emission coefficient (δ) (Fig.2). This is done by coding eq.1, 2, 3 in MATLAB obtained from various secondary emission models [6]. In addition the operating voltage and the applied magnetic field deciding the operating point is obtained by solving Hull- Hartree equation (eq.4) in MATLAB (Fig.3). These inputs (simulation model, secondary emission characteristics, Operating voltage and magnetic field) are then given to the CST-PS. The nonlinear beam wave dynamics in CST particle studio reveals interesting insight into the interaction mechanism of spatial harmonic magnetrons.

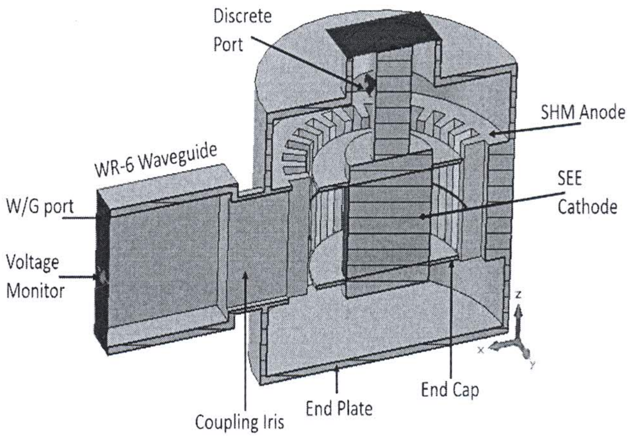

Figure 1: Simulated Model of SHM in CST-Particle Studio.

$$\delta_r = 0.47(1 - e^{-2.3\omega_o}) \tag{1}$$

$$\delta_{ts} = \begin{cases} \sqrt{5\omega_o} & , \quad \omega_o < 0.3 \\ 1.39 - 0.8(0.8 - \omega_o)^2 & , \quad 0.3 \le \omega_o < 1 \\ 1.57e^{-0.24\omega_o} & , \quad \omega_o \ge 1 \end{cases} \tag{2}$$

$$\delta = \delta_r + \delta_{ts} \tag{3}$$