Study of Thermionic Emission Microscope for Multi-Beam Cathode

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Abstract— **Thermionic emission microscope (THEM) is an important analytical research tool for studying the electron emission uniformity of a thermionic cathode. The criticality of its design and development stems from the need to characterize the inhomogeneous emission nature of the impregnated cathode surface. In this paper, a design of the lens and the deflection plates is presented for a multi-beam cathode (MBC). To understand the electron optics of THEM with lens and deflection plates system, simulations were carried out using the simulation tools CST Particle Studio software. The present MBC contains 19 protruding buttons-each acting as an independent emitter, whose image is projected onto the screen for study.**

*Keywords— **Thermionic emission microscope (THEM), Multi-beam klystron (MBK), Multi-beam cathode (MBC), Single beam cathode (SBC), Electrostatic lens, Immersion lens, CST Particle Studio***

Introduction

Klystrons are always in demand for the major source of high power RF in many applications such as particle accelerators, experimental reactors, radars, satellites and wideband high-power communication devices. The historical growth in klystron technology from past 70 years since WWII shows that the output power increases tremendously. Recent applications of high-energy such as super-conducting linear accelerators demand high power klystrons with high efficiency (> 70%) and long pulse duration (an order of 1ms). The peak power delivered by a long pulse Single-Beam Klystron (SBK) is limited by the high voltage that its gun can withstand. A lower cathode voltage is desirable to ensure reliable operation without gun arching or voltage breakdown.

However, in a SBK, the balance of output power, voltage and efficiency altogether is nearly impossible, since the perveance determines the relationship of all other operating parameters and even an achievable maximum efficiency of the tube. The concept of multiple-beam klystrons (MBKs) was proposed in 1950s in both the Russia and in France [1]–[3]. MBKs have many advantages such as low operating voltage, high perveance, small and light weight in design. Microwave tube researchers now a day have paid more attention to Multi-beam klystron (MBK) with growing need of high power and high frequency [4]-[7]. As the name implies, in MBK, multiple electron beamlets propagate in a separate, parallel beam tunnel, but interaction with electric fields takes place in common cavity. Due to this, the perveance of the individual beamlet would be low; and thus providing stable-beam propagation and efficient beam-wave interaction with negligible space-charge effects that could debunch the beam, while the total beam current would be high, thus having high-power and broad-bandwidth operation. Characterization of multi-beam cathode (MBC), becomes very necessary to check weather each beamlet has uniform emission distribution from the button of cathode. For this purpose THEM is used for MBC characterization.

THEM is a characterization tool to study the emission uniformity of a thermionic cathode [8]-[9]. The surface of a dispenser cathode is composed of low work function sites, which dominate the emission, surrounded by high work function sites. A schematic diagram showing the various subsystems of THEM is shown in Fig. 1.

The system has (a) an electrostatic immersion lens to produce the image of cathode emission; (b) deflection plates to deflect the beam; and (c) Faraday cage to collect the elemental currents. The image of the cathode is magnified by applying suitable voltages to the cathode.

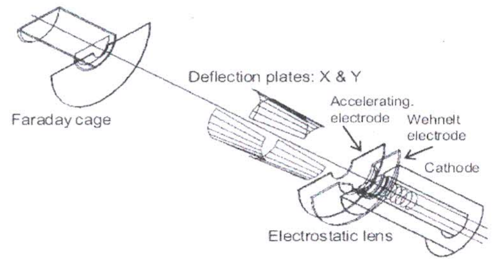

Fig. 1. Schematic layout of THEM

The cathode is operated under saturated conditions; and, the image is formed at the screen (elemental current captured through faraday cage and plotted in computer using in-house software package) due to the electrons emitted by the cathode surface. The single beam cathode (SBC) has a smooth planar surface while the MBC has several miniature buttons, contributing to the multiple beamlets emanating from individual buttons, which are projected from the main body of cathode. In this work characterization of MBC was done using CST particle studio.

Simulation Study

Planner cathode and THEM have been designed using CST particle studio and image has been obtained at the screen. After building the concepts, MBC containing 19 buttons were designed and characterized using THEM with suitable Lens structure and applied voltages.

(i) Planar Cathode Characterization

For planer cathode designing, parameters for cathode as well as THEM has been taken as given in table 1.

TABLE 1
PARAMETERS USED TO DESIGN SBC

Parameter	Value
Cathode Dia.	5.4 mm
Accelerating electrode Aperture	4.95 mm
Operating voltage	19kV

The various sub-components of THEM lens has been shown in Fig. 2 (a) & (b).

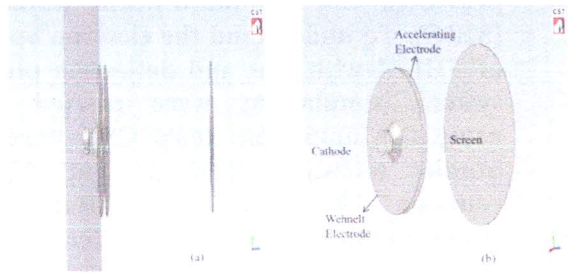

Fig. 2. THEM design using: (a) side view (b) front view

The electron trajectory for above designed geometry has been simulated and the results are shown in Fig. 3 (a) & (b).

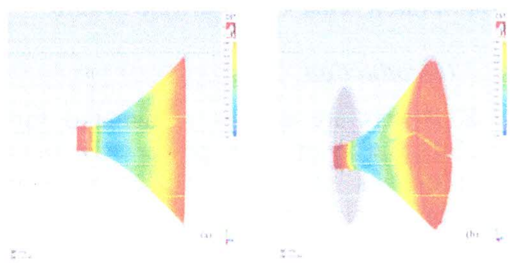

Fig. 3. Electron trajectories: (a) side view (b) front view

(ii) Multi-Beam Cathode Design

The design available with us for a SBC cathode of diameter 5.4 mm has been modified to handle multi-beam cathode containing 19 buttons each of diameter 0.6 mm.

An MBC pellet with 19 miniature buttons was designed in CST with parameters given in table 2.

TABLE 2
PARAMETERS USED TO DESIGN MBC

Parameter	Value
Base metal dia.	5.4 mm
Button dia.	0.6 mm
Interspacing between two buttons	0.4 mm
Accelerating electrode Aperture	4.95 mm
Operating voltage	19 kV
Deflection voltage	± 1 kV
No. of buttons	19

The designed MBC pellet is shown in fig. 4.

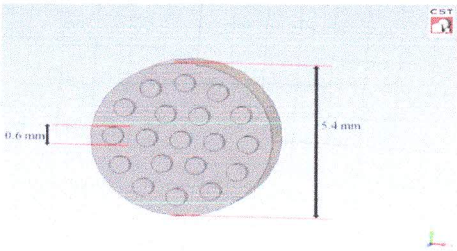

Fig. 4. MBC geometry of 19 buttons

Designed THEM geometry with and without deflection plate has been shown in Fig. 5. The upper and the right side plate have been given positive voltage supply and rest two has been given negative power supply.

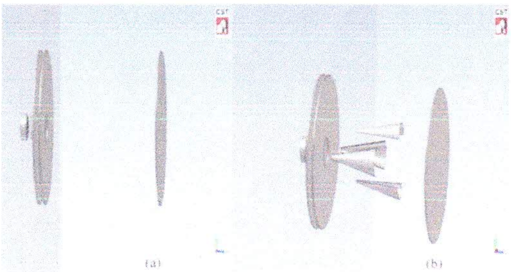

Fig. 5. THEM design of MBC: (a) without deflection plate (b) with deflection plate

Electron beam trajectory for designed THEM trajectory has been shown in Fig. 6. From figure individual beamlet can easily be visualized and deflection of beam can also be seen clearly.

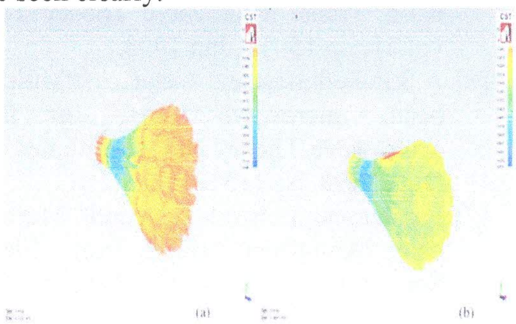

Fig. 6. Electron trajectories of MBC: (a) without deflection plate (b) with deflection plate

Conclusions

Simulations performed here in this work will be helpful for understanding field distribution for lensing action and electron emission laminarity in the electrostatic lens system. Simulated results clearly depicts that it is possible to characterize the multi-beam cathode assembly using THEM. The emission distribution of individual buttons could also be studied. To visualize the complete picture of MBC, the electrostatic lens has to be tailored according to the diameter of the MBC.

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