A Design Approach to Characterize Multibeam Cathode using Thermionic Emission Microscope

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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 inhomogeneous emission nature of impregnated cathode surface. In this paper, a design approach of lens and deflection plates is described for a multibeam cathode (MBC). The design of lens is carried out using 2D TRAK and the design of deflection system using OmniTRAK 3D to ensure required deflection of beam without losing laminarity and beam interception with deflection plates. The simulation studies show that THEM could be used as an effective tool to study MBC.

Index Terms: THEM, 2D TRAK, MBC, OmniTRAK 3D.

1. INTRODUCTION

THEM is a research tool to study the emission uniformity of a thermionic cathode. The surface of Dispenser cathode is composed of low work function sites, which dominate the emission, surrounded by high work function sites. A schematic diagram showing various subsystems of THEM is shown in Fig. 1. The system comprises of (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, typically, –8 kV to the cathode. The cathode is operated under saturated conditions; and, the image is formed at the screen due to the electrons emitted by the cathode surface. The basic difference between a THEM and a SEM is that in the former the object is the emitting area whose image is magnified through lens system; while, in the later, the object could be any specimen whose secondary emission image is observed.

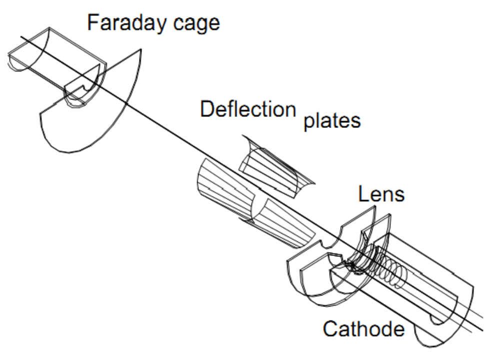

Fig.1 Schematic Layout of THEM

The single beam cathode has a smooth planar surface. However, in the case of MBC; the individual beamlets are generated out of several miniature cathodes which are projected from the main body of cathode. The present simulated studies show that MBC could be studies using THEM.

2. DESIGN AND SIMULATION

The simulation is carried out in two stages by: (a) TRAK (2-D model), and (b) OmniTrak (3-D model) - both of which are suited for the study of charged particle optics.2-D model has been used for simulation of lens system and for obtaining electron trajectories; while, 3-D model has been adopted to incorporate deflection plates to find out the extent of image deflection, which is not possible through 2-D model.

2.1 DESIGN OF ELECTROSTATIC LENS

The simplest immersion lens may consist only of a single aperture at positive potential for accelerating the electrons. The necessary convex curvature can be given to the equipotential by introducing a second electrode at higher potential. This electrode is often, but not necessarily, kept at negative potential relative to the cathode (C) and is known as the beam-focusing electrode (BFE). The other one, known as anode (A), is kept at positive potential in order to accelerate the electrons. The essential requirement is that the potential of the anode (A) be high enough to create a greater field between anode and the BFE than that of BFE and the cathode. Here the object (cathode) is deeply immersed in the field, and thus, electrons enter the lens with almost zero velocity. These electrons are extracted from the cathode under the influence of the applied potentials, and have initially only the velocity of thermal emission.
The electrostatic lens parameter such as refractive index, focal length and condition for beam convergent can be explained from simple optical phenomena.

2.2 DESIGN OF DEFLECTION PLATE

By providing two sets of deflecting systems at right angles to each other, it is thus possible to scan any desired area of the screen. The requirements of the deflecting system are (i) deflection should be proportional to the deflecting voltage and (ii) Deflecting field should introduce no distortion of the spot. When the deflection exceeds a certain value, neither of these two requirements are fulfilled in practice. For small deflections (much less than beam diameter at the screen), deflection goes in proportion to the applied voltage.

Let an electron of velocity v_1 enters a homogeneous field 'E' of length 'l' between the parallel plates spaced at distance 's' apart as shown in figure-2.
Time of electron in the field is $t = l/v_1$ and
Acceleration in the direction of the field= Ee/m,
Therefore velocity in the direction of the field= Eet/m.

Also angle of deflection= tanα = $\frac{velocity\ in\ field\ direction}{velocity\ in\ axial\ direction}$

Therefore the total deflection D = $\frac{ElL}{2V_1}$.

These expressions show that the deflection varies with the deflecting field E. Since E = $\frac{V}{s}$ where V is the voltage on the plates, the deflection sensitivity then becomes

$\frac{D}{V} = \frac{lL}{2sV_1}$ mm/volt.

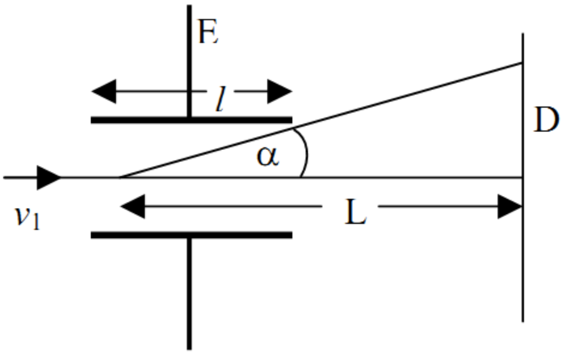

Fig.2 Deflection path of electron beam

For this simulation two packages are used TRAK (2-D model) and OmniTRAK (3-D model). The 2-D model has been used for simulation of lens system and for obtaining electron trajectories; while, the 3-D model has been adopted to optimize deflection plates to find out the extent of image deflection.

3. RESULTS & DISCUSSIONS

The potential curve, equipotential lines and lens system with electron trajectories for multibeam cathode with five emission regions are shown in fig.3, fig.4 and fig.5 respectively.

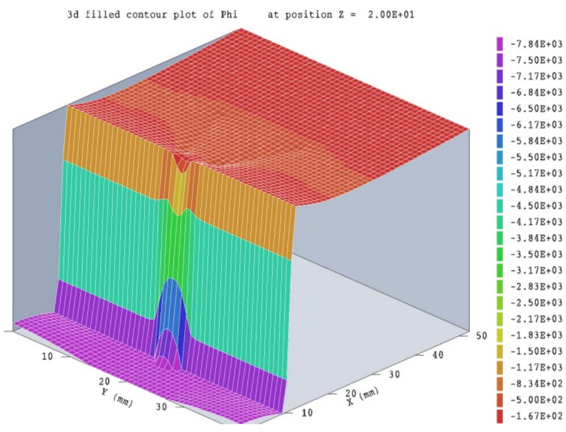

Fig.3 Potential curve with respect to distance z

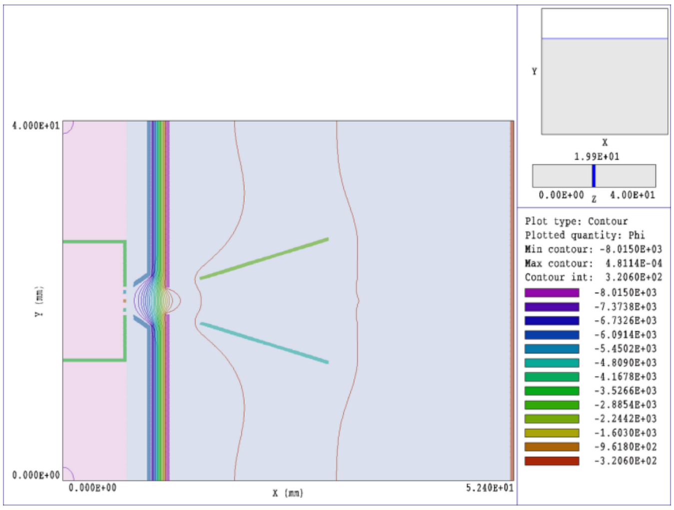

Fig.4 Equipotential lines

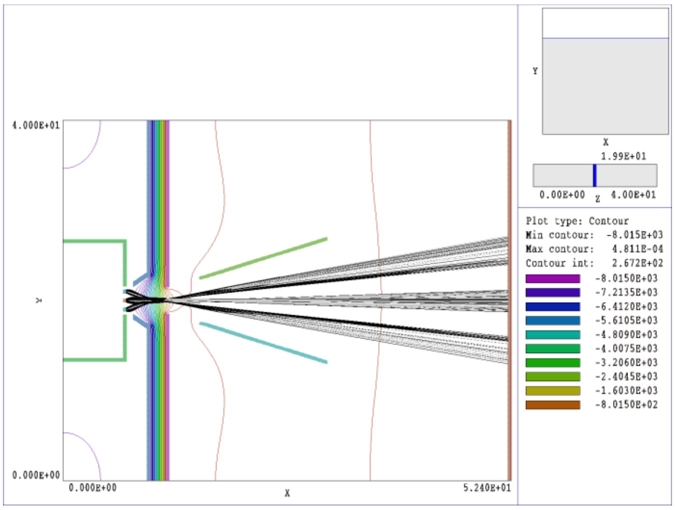

Fig.5 Lens system with electron trajectories

From fig.6 a clear difference between an emissive and non emissive regions could be visualised. Same surface area was taken for all the three cases, Fig 6 (a), (b) and (c). In Fig 6(a) whole surface is considered as single emiting region and one image is formed on the screen. while in fig 6(b) and 6(c) multiple emitting regions are modelled to show the electron trjectory from a MBC surface. In Fig 6(b) we are getting the image which shows the emmision from all five regions whereas Fig 6(c) shows one poor emitting region in the image.

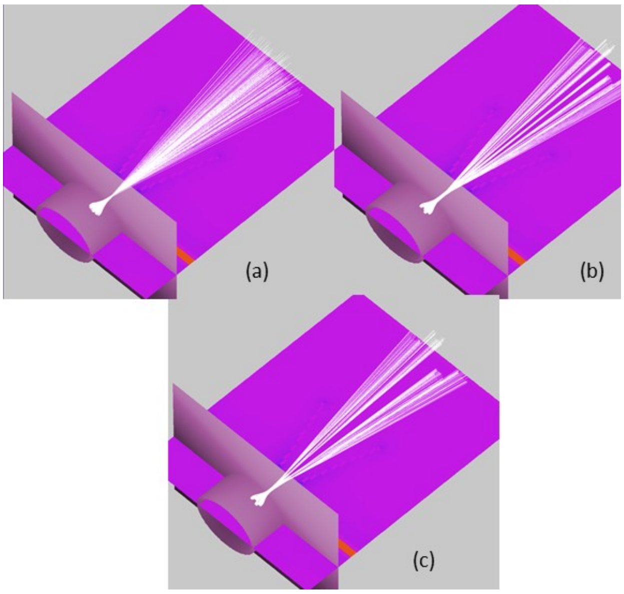

Fig.6 Cathode, with emission from (a) whole surface (b) five emitting regions and (c) five emitting regions with poor emission from one region

4. CONCLUSIONS

In this work, theoretical values of the design parameters are calculated using analytical formula derived in section-2. All the parameters are also optimized using TRAK simulation software. From this study we can summarize that THEM can be a useful tool for characterization of MBCs.

5. REFERENCES

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