Simulation Study of electron beam profile near the aperture of hollow cathode for high current density electron beam generation using COMSOL

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INTRODUCTION:

- Sheet electron beam source is highly useful for generation of high current density electron beam as required for high power sub-THz radiation source
- The dimension of sheet electron beam source plays a major role in efficient sheet electron beam generation
- Optimization study of sheet electron beam source for different aperture shape and size has been performed

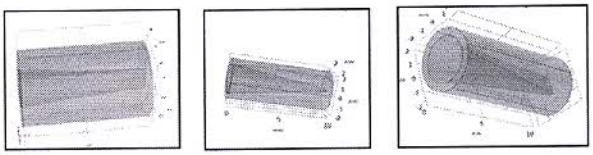


Figure 1. (a) Elliptical, (b) Circular and (d) Rectangular electron beam

COMPUTATIONAL METHODS:

Charged Particle tracing interface and Electrostatic interface has been used for the simulations.

Charged Particle Tracing interface:

The Charged Particle Tracing (cpt) interface has been used to model charged particle orbits under the influence of electromagnetic forces. The physics interface solves the equation of motion for charged particles.

A Newtonian formulation has been used therefore, the particle position is computed using Newton's second law:

$$\frac{d}{dt}(m_p \mathbf{v}) = \mathbf{F}$$

where m_p is the particle mass (SI unit: kg), v is the particle velocity (SI unit: m/s), and F is the total force exerted on the particle (SI unit: N).

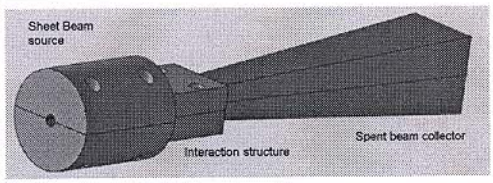
Electrostatic interface:

The physics interface solves Gauss' Law for the electric field using the scalar electric potential as the dependent variable.

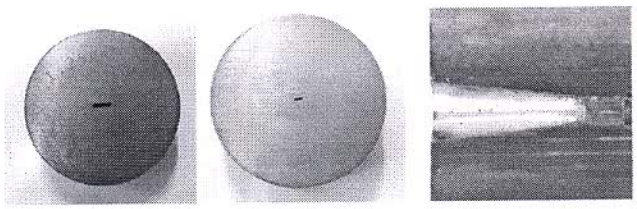
RESULTS: The current density obtained for the different shapes of apertures as per the different shapes of the electron beam is as shown in table 1.

Type of beam	Current Density (A/cm^2)
Circular beam	134
Elliptical beam	381
Sheet beam	410

Table 1. Comparison of current density for different shapes of electron beam



DEVELOPMENT WORK: Based on the simulation results, electron beam adapter regions have been fabricated where circular aperture has been down tapered to sheet aperture.



(a) (b) (c)

Figure 2. (a) Front view, (b) Rear view of adapter region and (c) adapter region on cut view on two different plates

- Dimensions for the sheet beam's aperture have been chosen based on the optimization results of hollow cathode geometry[4].
- Optimization study has been performed using Comsol

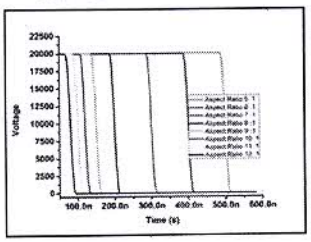


Figure 3. Comparison of voltage with time for different aspect ratios

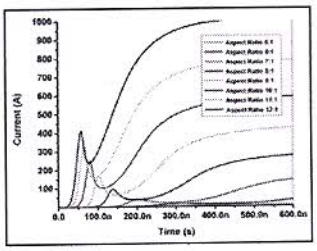


Figure 4. Comparison of current with time for different aspect ratios

CONCLUSIONS

- The sheet aperture was found to have the highest current density followed by the elliptical aperture and the cylindrical aperture has the lowest current density.
- The sheet electron beam source is capable of producing highest current density and suitable for sub-THz generation

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