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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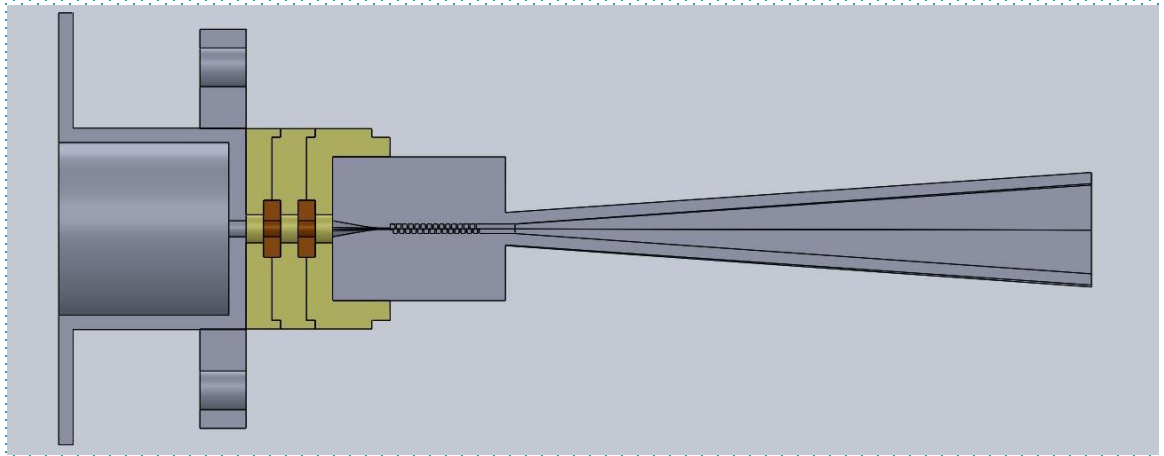
OUTLINE

- Motivation
- Introduction
- Computational methods
- Results
- Development work
- Conclusion

MOTIVATION

- Development of a high power and portable terahertz source
- Strategic and NDE applications
- Plasma assisted Backward Wave Oscillator (0.1 THz)

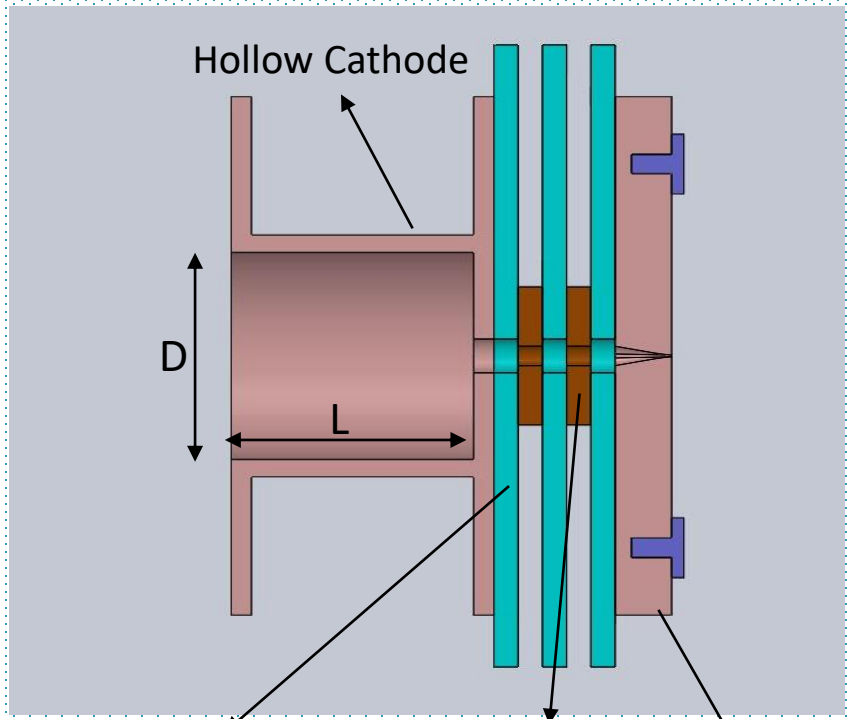


Schematic of the Terahertz source

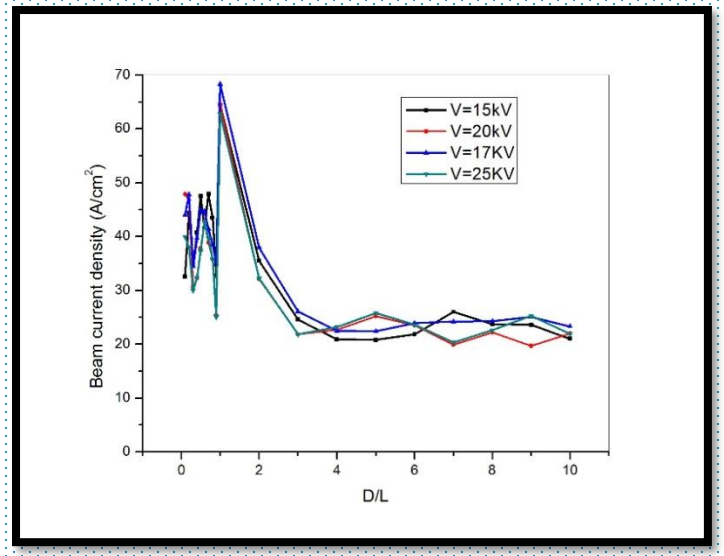
- High current Density electron beam is required for greater interaction which thereafter leads to a high power terahertz signal

ELECTRON GUN

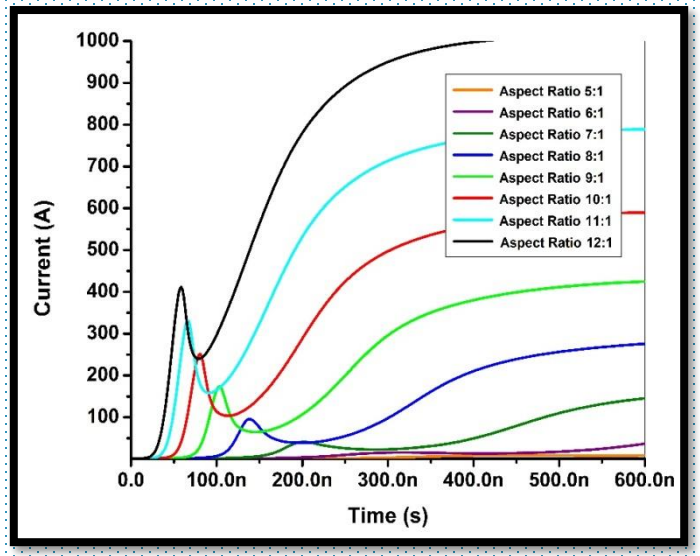
The hollow cathode parameters i.e., D/L ratio and the dimensions of the aperture have been optimized based on previous simulations using COMSOL*.



Schematic of electron gun



Variation of beam current density for different D/L ratio at different applied voltages

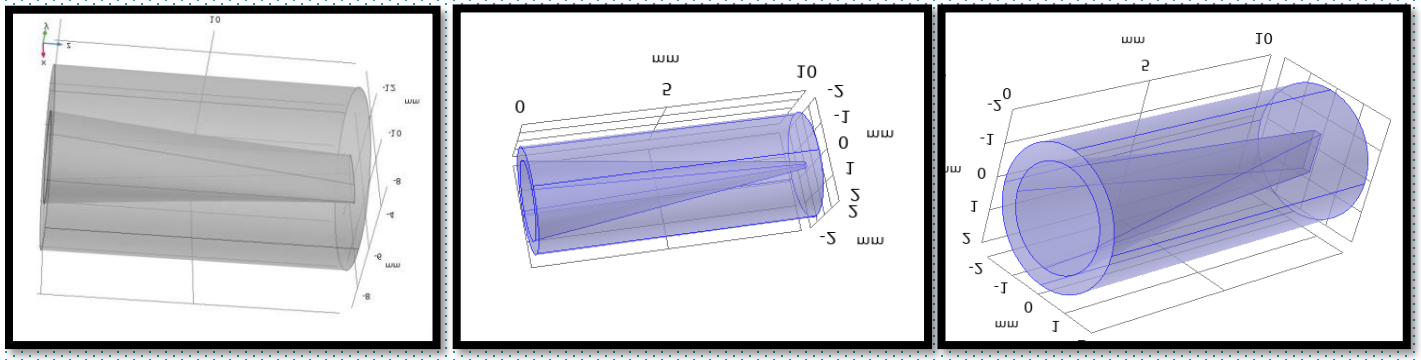


Comparison of current with time for different aspect ratios

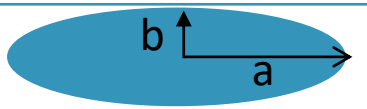
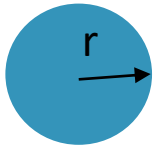
* **"Design approach for a miniaturized pseudospark based high current density sheet electron beam source", Nikita Gurjar**, et. al. , doi. 10.1109/TED.2019.2934229, **IEEE Trans. Electron Devices**.

INTRODUCTION

- High current density electron beam source is highly useful for the generation of high current density electron beam as required for high power sub-THz radiation source
- Optimization study of electron beam source for different aperture shape has been performed for constant area 0.31 mm² and adapter length 10mm



(a) Elliptical, (b) Circular and (c) Rectangular aperture

Type of aperture	Dimensions
 Elliptical	a= 1.05mm b= 0.25mm
 Circular	r= 0.3mm
 Rectangular	a= 1.25mm b= 0.25mm

Dimensions of the different apertures

COMPUTATIONAL METHODS

Charged Particle tracing interface and Electrostatic interface found inside the Particle Tracing Module 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:

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

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:**

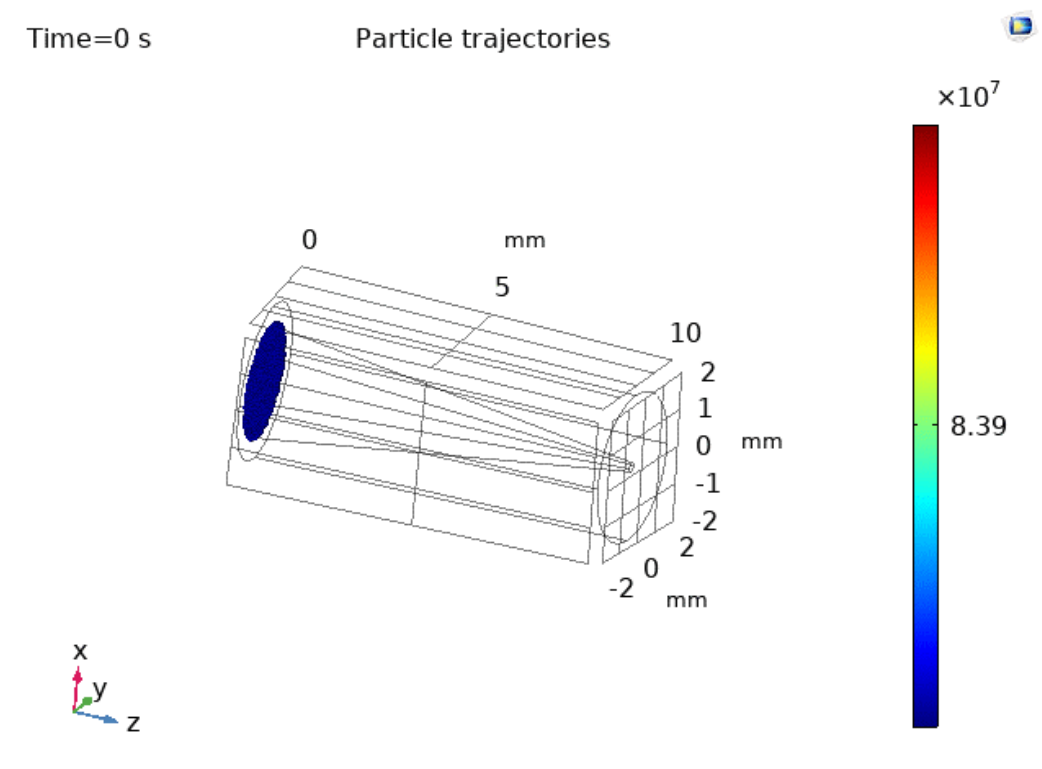
The physics interface solves Gauss' Law for the electric field using the scalar electric potential as the dependent variable.

RESULTS

- The current density obtained for the different shapes of apertures as per the different shapes of the electron beam is as shown in the following table:

Shape of aperture	Current Density (A/cm^2)
Circular aperture	134
Elliptical aperture	381
Rectangular aperture	410

Comparison of current density for different shapes of the aperture



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)

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

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

PUBLICATIONS USING COMSOL

- “Design approach for a miniaturized pseudospark based high current density sheet electron beam source”, **Nikita Gurjar**, Afaque M. Hossain, Rishu Singh, R. K. Sharma, V. P. Anitha, Raj Singh and Niraj Kumar, **vol. 64(10)**, **IEEE Trans. Electron Devices,** 2019**.**
- “Influence of Rectangular Aperture Aspect Ratio on Sheet Beam Generation ”, **Nikita Gurjar**, M. Afaque Hossain, R. K. Sharma and Niraj Kumar, **IEEE-IVEC 2019**, **doi. 10.1109/IVEC.2019.8745011**, 28th April - 1st May 2019.
- “Simulation Study of High Current Density Miniaturized Pseudospark Based Sheet Electron Beam Source”, **N. Gurjar**, M.A. Hossain, V. P. Anitha, R. Singh and N Kumar, **Plasma 2018**, December 2018.

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1. G. X. Shu, H. Yin, L. Zhang, J. P. Zhao, G. Liu, A. D. R. Phelps, A. W. Cross, and W. He, “Demonstration of a Planar W-band, kW-level Extended Interaction Oscillator Based on a Pseudospark-sourced Sheet Electron Beam,” IEEE Electron Device Lett., vol. 39, pp. 432-435, 2018, DOI. 10.1109/LED.2018.2794469.

2. “Design approach for a miniaturized pseudospark based high current density sheet electron beam source”, Nikita Gurjar, et. al. , doi. 10.1109/TED.2019.2934229, IEEE Trans. Electron Devices.

3. N. Kumar, R. P. Lamba, A. M. Hossain, U. N. Pal, A. D. R. Phelps, and R. Prakash, “A tapered multi-gap multi-aperture pseudospark-sourced electron gun based X-band slow wave oscillator,” Appl. Phys. Lett., vol. 111, p. 213502, 2017, DOI. 10.1063/1.5004227.

4. Particle Tracing Module User’s Guide, COMSOL 4.3, www.comsol.co.in

THANK YOU