Design and Optimization of a 1.3 GHz Gridded Thermionic Electron Gun for High Intensity Compact Superconducting Electron Accelerator (HICSEA)

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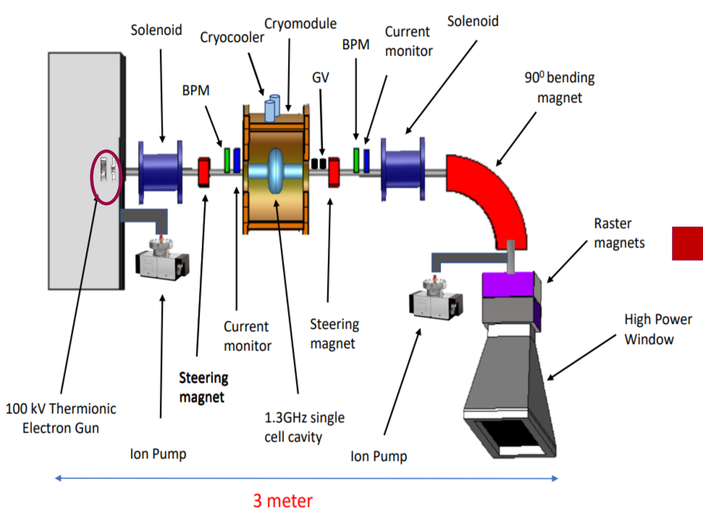
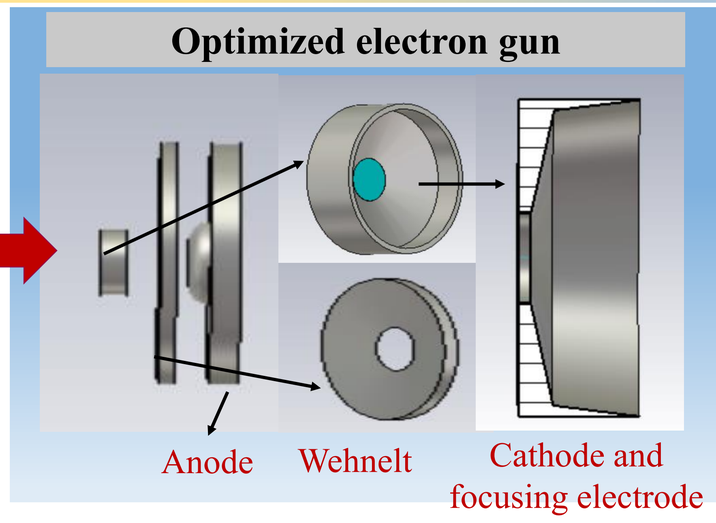
Abstract

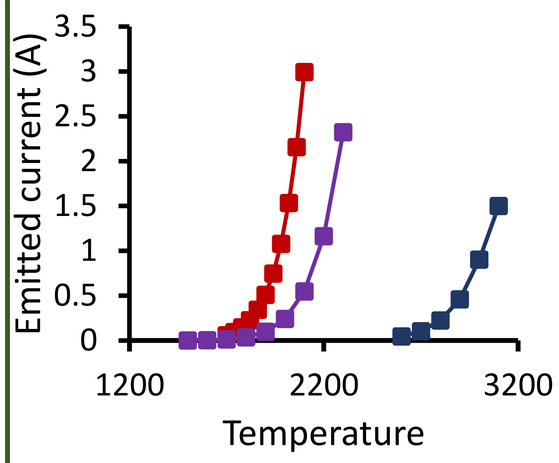
The design and optimization of the proposed gun aims to drive a conduction cooled SC electron accelerator that will be used to treat contaminants of emerging concern in water bodies. The gun geometry is Pierce-type and optimized for beam current of 1A with LaB6 as cathode material at cathode potential of -100 kV. The final optimized cathode radius and angle of inclination of the focusing electrode is found to be 1.5 mm, and 770 respectively. For an emittance compensation electrode, the optimized values for thickness and potential are 2 mm and -50 kV respectively, and separation between cathode and compensator is 8 mm. Beam dynamics calculations have been performed with self-developed particle tracking code that assumes space charge interactions and imported fields. The beam dynamics simulations show that with an initial pulse length of 50 ps having a bunch charge of 5 pC, the pulse length of the bunch reduces to 33 ps. The diameter, transverse and longitudinal emittance obtained are 1 mm-mrad, 5 mm-mrad and 2.8 mm respectively.

Proposed System





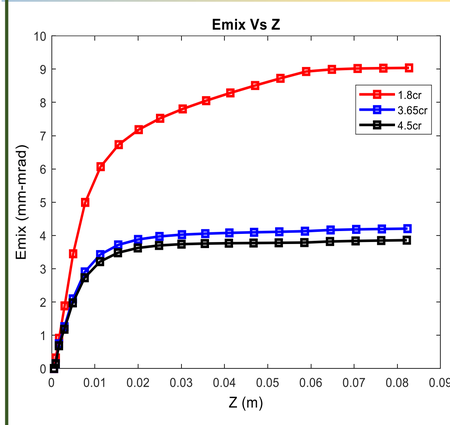
Cathode material study

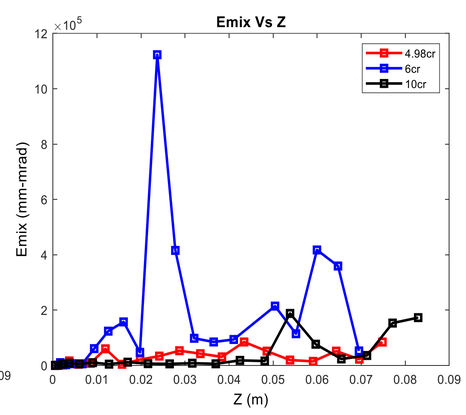


Material chosen: LaB_6

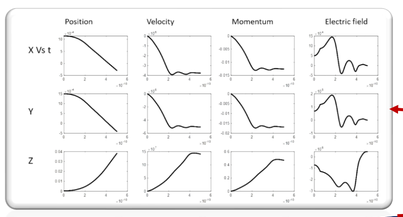
- Requirement of higher vacuum (10^{-7} torr)
- Lower evaporation rate ($2.2x10^{-9}$ g/cm^2/s) at 1800k
- Longer life time (1000 hr)
- Lower operating temperature (1700 K)
- Melting point = 2483k [2]

Beam dynamics

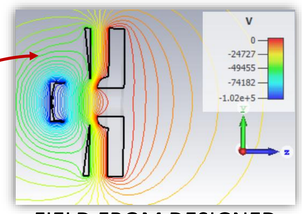




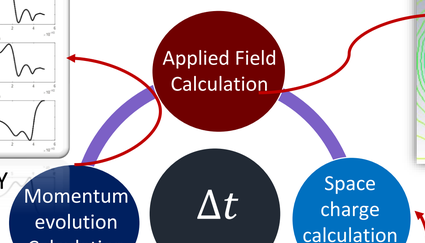
RMS Norm. Transverse Emittance at mesh density of 1.8, 3.65, 4.5, 4.98, 6, 10 crores

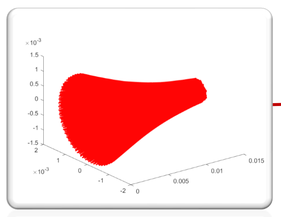


SINGLE PARTICLE TRAJECTORY



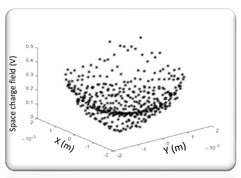
FIELD FROM DESIGNED GEOMETRY



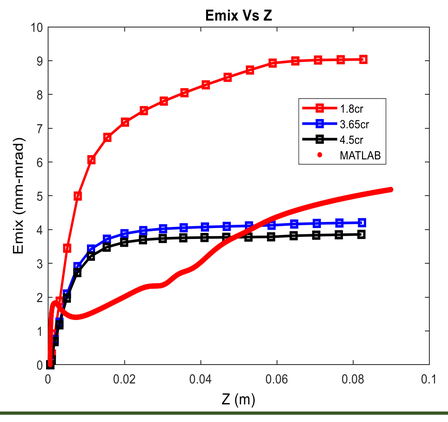


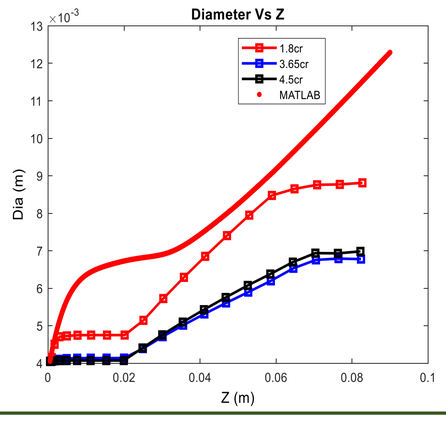
MULTI-PARTICLE TRAJECTORY

$F = q(E_a + E_{SC})$



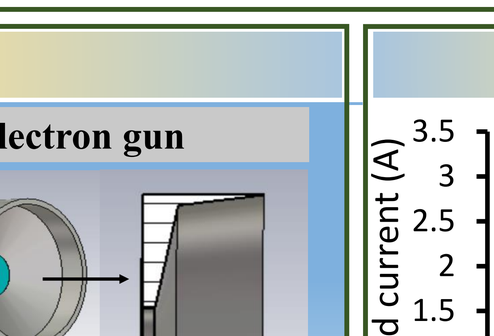
FIELD FROM PARTICLE DISTRIBUTION

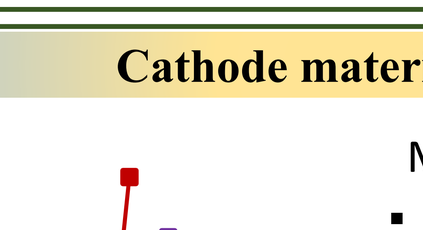


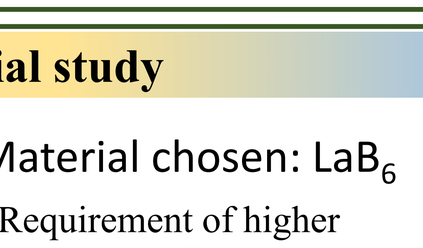


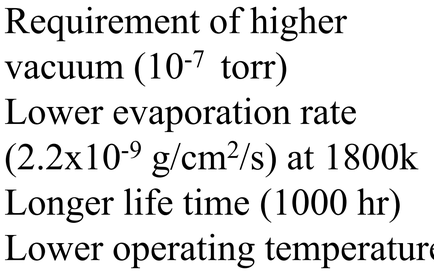
RMS Norm. trans. emittance and diameter of the beam compared between CST & script results

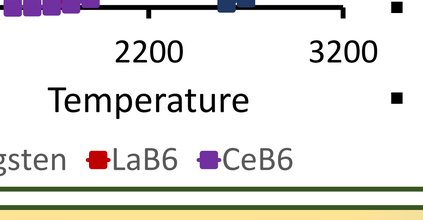
Design and optimization

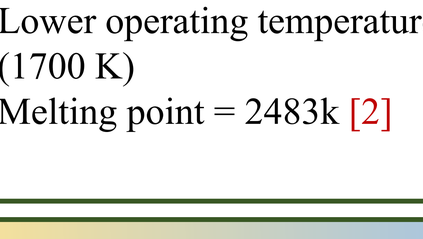




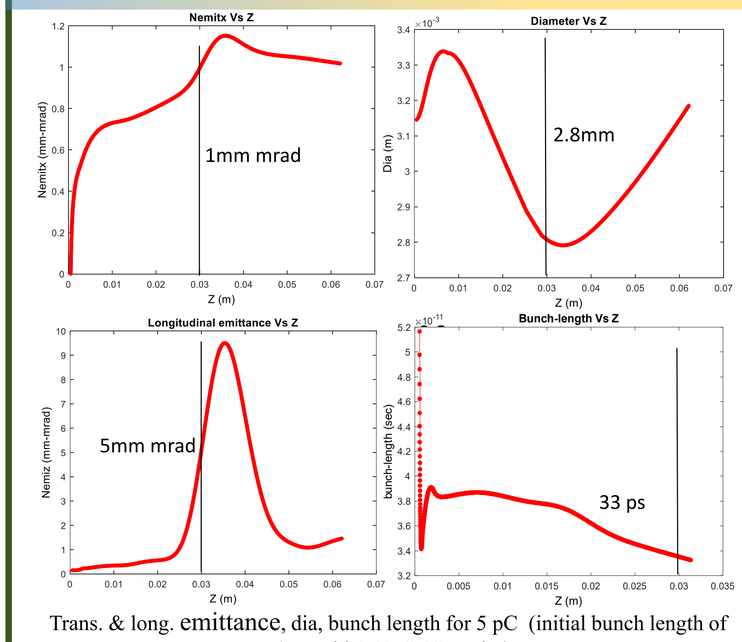








Results



Trans. & long. emittance, dia, bunch length for 5 pC (initial bunch length of 50 ps with MATLAB codes)

Parameters	Values
Cathode material	LaB_6
Cathode radius	1.5 mm
Pierce angle	77^0
Cathode Potential	-100 kV
Cath-Wehnelt distance	12 mm
Wehnelt thickness	2mm
Wehnelt Potential	-50 kV
Gun length	30 mm
Transverse emittance	1 mm-mrad
Longitudinal emittance	5 mm-mrad
Beam diameter	2.8 mm
Bunch length	33 psc

References

[1] electron beam irradiation impurity degradation - Bing images

[2] Lanthanum and Cerium Hexaboride (LaB6 and CeB6) Cathodes (laboratoryresource.com.au)

Acknowledgement

Author would like to acknowledge the help of Pragya Nama, Manisha Meena, Pankaj Kumar (IIT Bombay) for frequent discussions and analysing the results

Conclusion

- A thermionic gridded electron gun is designed and optimized.
- Particle track code developed using MATLAB to solve discrepancies observed with CST.
- Beam dynamics results for bunch of 50 ps, 5 pC are RMS norm trans. & long. emittance at gun exit of 1 & 5 mm-mrad respectively, bunch diameter 2.8 mm, and bunch length 33 ps.