# Optimization of Helicon in HIIPER Space Engine using Charged Particle Tracing Module


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**INTRODUCTION**: Helicon Injected Inertial Plasma Electrostatic Rocket (HIIPER) is a deep space propulsion system consisting of 3 stages – Helicon plasma generation, inertial electrostatic confinement (IEC) plasma extraction and magnetic nozzle (MN) for thrust generation. Current experimental setup consists of the first two stages. Charged particle tracing is used to simulate the ion movement within the quartz tube to figure out sections of ion loss. Ion parameters at the downstream end of the tube are also plotted as a function of input radio frequency (rf) power.

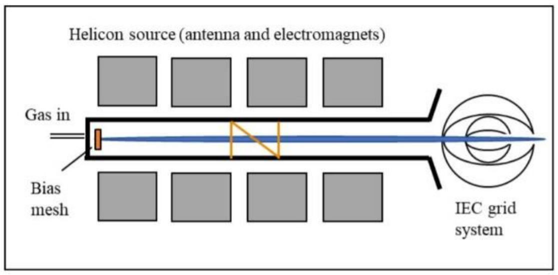


**Figure 1**. HIIPER Schematic

**COMPUTATIONAL METHODS**: The model consists of the following parts: Magnetic fields (mf), plasma, electromagnetic waves and charge particle tracing. Helicon waves are used to generate plasma but not explicitly included in results. The figures below show the computational diagram and the model flowchart of the study.

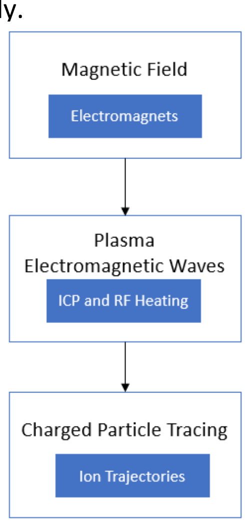


**Figure 2**. Computational Chart

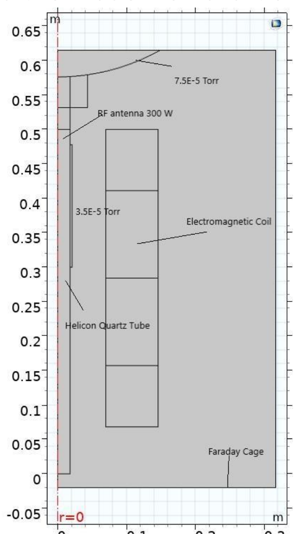


**Figure 3**. Model Diagram

**RESULTS**: Simulations are carried out for four different rf powers – 10 W, 300 W, 1000 W and $10^6$ W. The first two are the minimum and maximum levels available in the HIIPER experimental setup, 1000 W is a possible upgrade to the setup and $10^5$ W is theoretical requirement for an actual deep space thruster. The following results are achieved under 90 Gauss electromagnetic field:

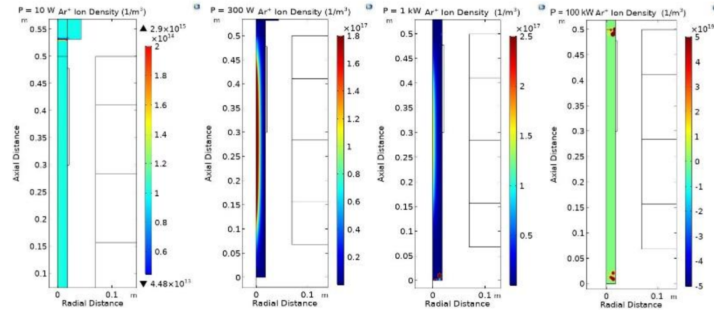


**Figure 4:** Ion Densities at (a) 10 W, (b)100 W, (c)1 kW & (d) 100 kW

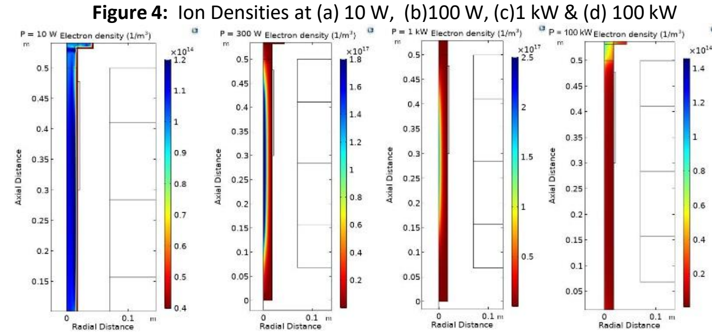


**Figure 5:** Electron Densities at (a) 10 W, (b)100 W, (c)1 kW & (d) 100 kW

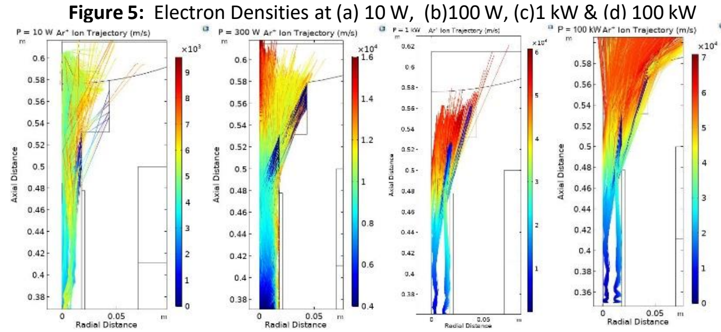


**Figure 6:** Ion Trajectories at (a) 10 W, (b)100 W, (c)1 kW & (d) 100 kW

**CONCLUSIONS**: Ion densities of the order $10^{17}$ $m^{-3}$ can be observed at the 300 W to 1 kW rf power range. Langmuir probe experiments done at 300 W have shown similar magnitudes of ion densities. The ion densities do increase at 100 kW power at specific positions, but the average remains same as that for the kW range. Particle trajectories are plotted to study the location of ion losses in the current helicon setup. As can be seen from the results, the ions are lost to wall at the downstream end of the helicon tube. With increase in rf power, the percentage of high energy (kinetic energy) particles hitting the wall also increases considerably. This concludes that the increase in rf power doesn't impact ion density as much as it impacts the ion velocity (kinetic energy).

**REFERENCES**:


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