Optimization of a Low Power ECR Thruster Using Two-Frequency Heating*

Benjamin Wachs and Benjamin Jorns

University of Michigan, Dept. of Aerospace Engineering, Ann Arbor, MI, USA
(bwachs@umich.edu, bjorns@umich.edu)

Magnetic nozzle thrusters offer many ideal attributes for low-power in-space propulsion. The technology operates by heating a plasma using radiofrequency or microwave power and accelerating this plamsa through an expanding magnetic field. This architecture avoids many of the limitations inherent to more mature thruster technologies such as Hall effect and gridded ion thrusters. For instance, it does not require plasma contacting electrodes, can operate using only a single power supply, and enables the use of reactive propellants. However, for over a decade, laboratory experiments using this technology revealed poor thrust efficiencies (~1%) at low input powers (< 100 W), largely negating many of its potential advantages [1].

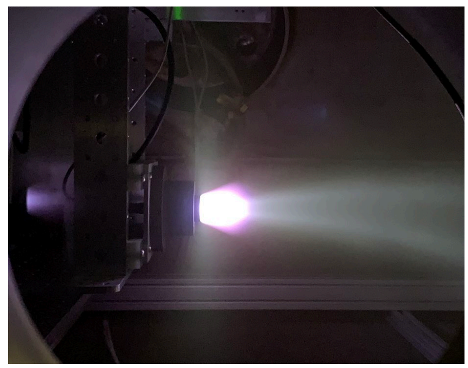

Figure 1 – ECR thruster firing at 20 W on the PEPL thrust stand.

This trend was recently reversed in experiments using Electron Cyclotron Resonance (ECR) as the heating source for magnetic nozzle thrusters. These thrusters have demonstrated efficiencies above 10% with specific impulses over 1000 seconds while operating at 30 watts, almost an order of magnitude greater than previous studies using helicon or ICP plasmas [2]. While these results show that magnetic nozzle thrusters can be competitive with established propulsion technologies, much work is left to further improve efficiency.

Here, we present the initial results of an optimization experiment aiming to improve performance by adding a second input frequency to the ECR heating. This two-frequency heating is commonly used in ECR ion sources but has not yet been implemented in thrusters [3]. Our experiment uses a set input power and flow rate and divides the power evenly between the two frequencies. Each input frequency can be adjusted from 800-2500 MHz. We use a thrust stand to directly measure the output thrust and efficiency.

By introducing a second frequency, we have formed a two-variable global optimization problem with parameters f_1 and f_2, which makes testing each possible point prohibitively time consuming. We therefor use a surrogate-based global optimization algorithm to choose new test points based on previous outputs from the thrust stand.

* This work was supported by NASA Space Technology Research Fellowship grant 80NSSC17K0157.

References

[1] S.N. Bathgate, M.M.M. Bilek, and D.R. Mckenzie, Plasma Sci. Technol. **19**, 083001 (2017).
[2] T. Vialis, J. Jarrige, A. Aanesland, and D. Packan, J. Propul. Power **34**, 1323 (2018).
[3] Z. Q. Xie and C. M. Lyneis, Rev. Sci. Instrum. **66,** 8 (1995).