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

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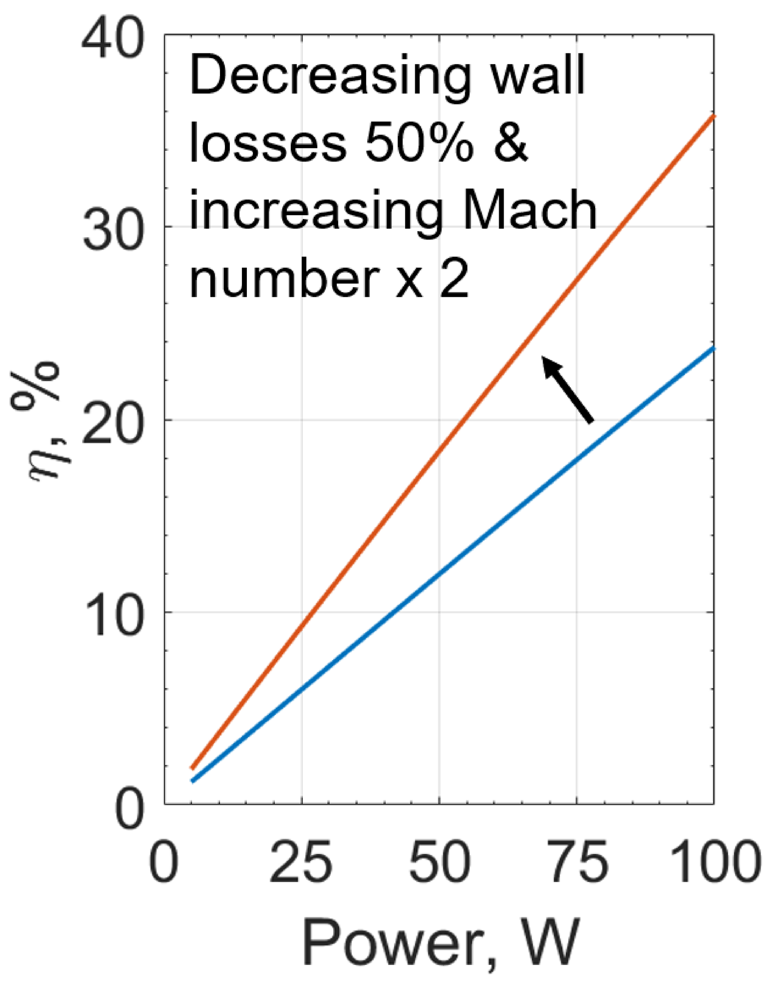
Motivation

Magnetic nozzles enable simple thruster designs, low system masses, and can use a variety of propellants, making them well suited for small satellite applications [1].

Efficiency at low powers has typically been worse than existing systems such as gridded ion and Hall effect thrusters [2]. However, global models indicate that efficiency can be increased to competitive levels by lowering wall losses and increasing the magnetic nozzle thermal efficiency.

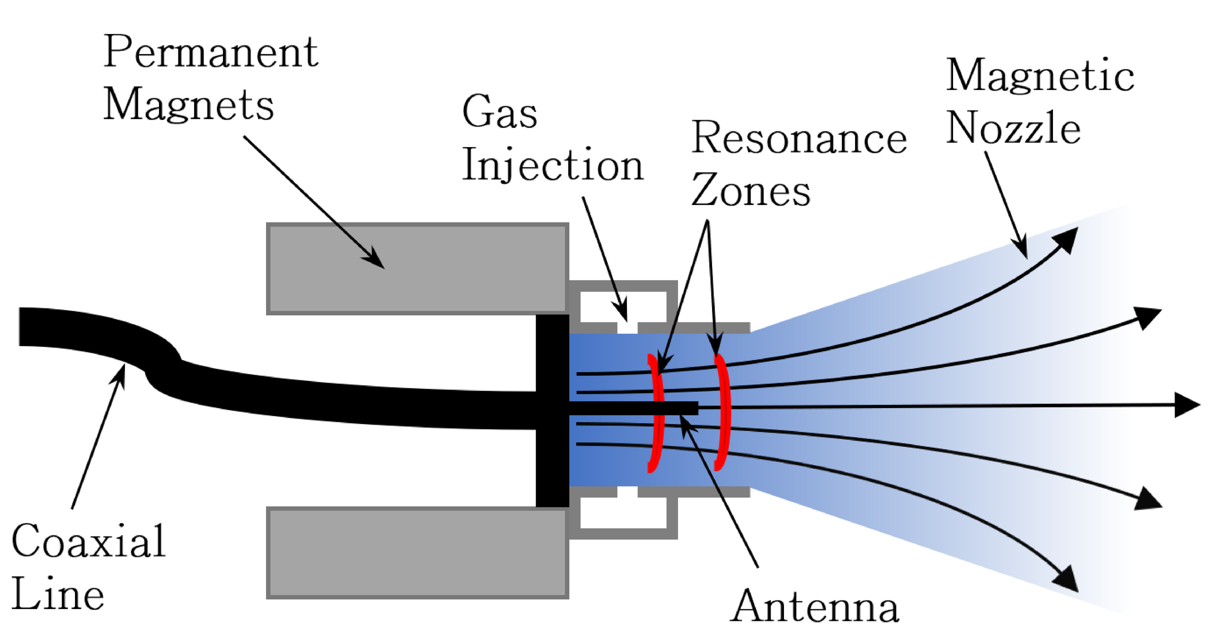


Efficiency predicted by a 0-D thruster model

While previous studies have optimized these thrusters by modifying geometry and magnetic field topology, in this experiment we use custom input waveforms to improve performance. This enables rapid iteration through many test points.

Two-Frequency Heating

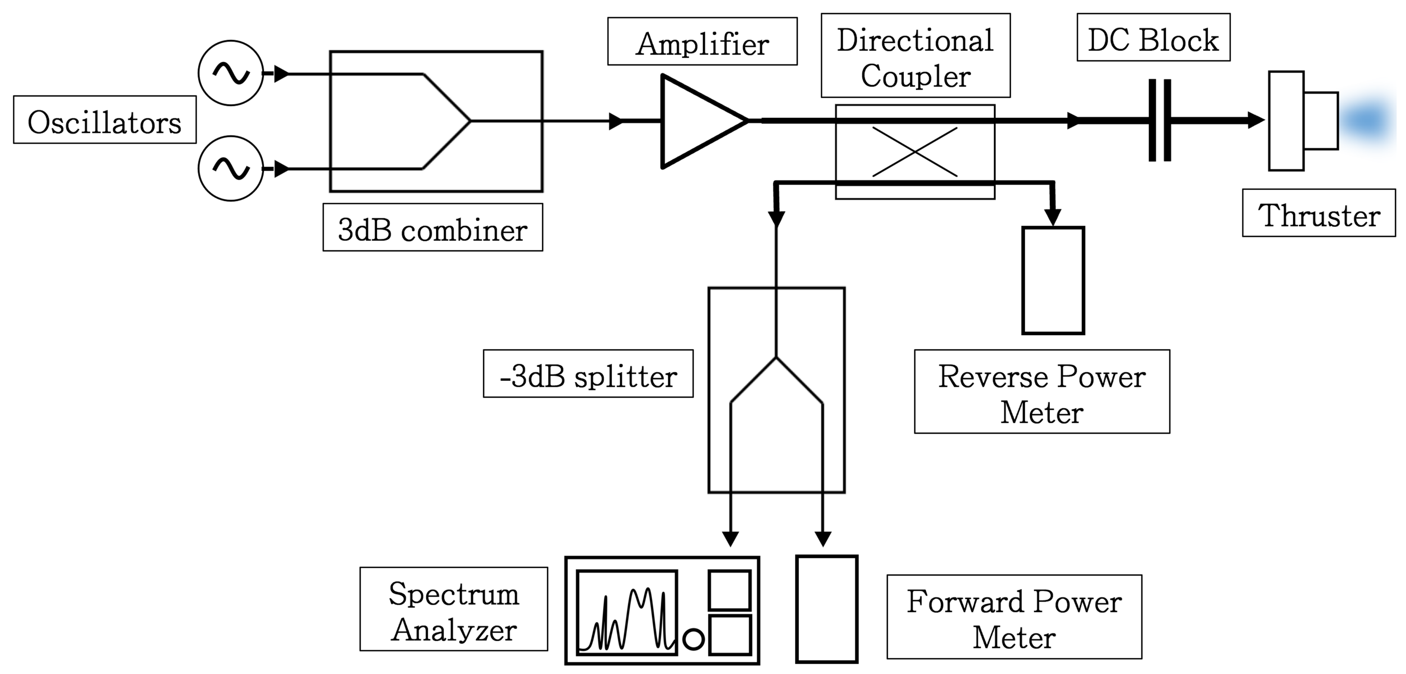
This technique, developed for highly charged ion sources, adds a second frequency to a typical ECR discharge, creating two resonance zones. It has been shown to suppress instabilities and increase ion yield; however the underlying physics is not fully understood [3].



Schematic of ECR Thruster showing resonance zones

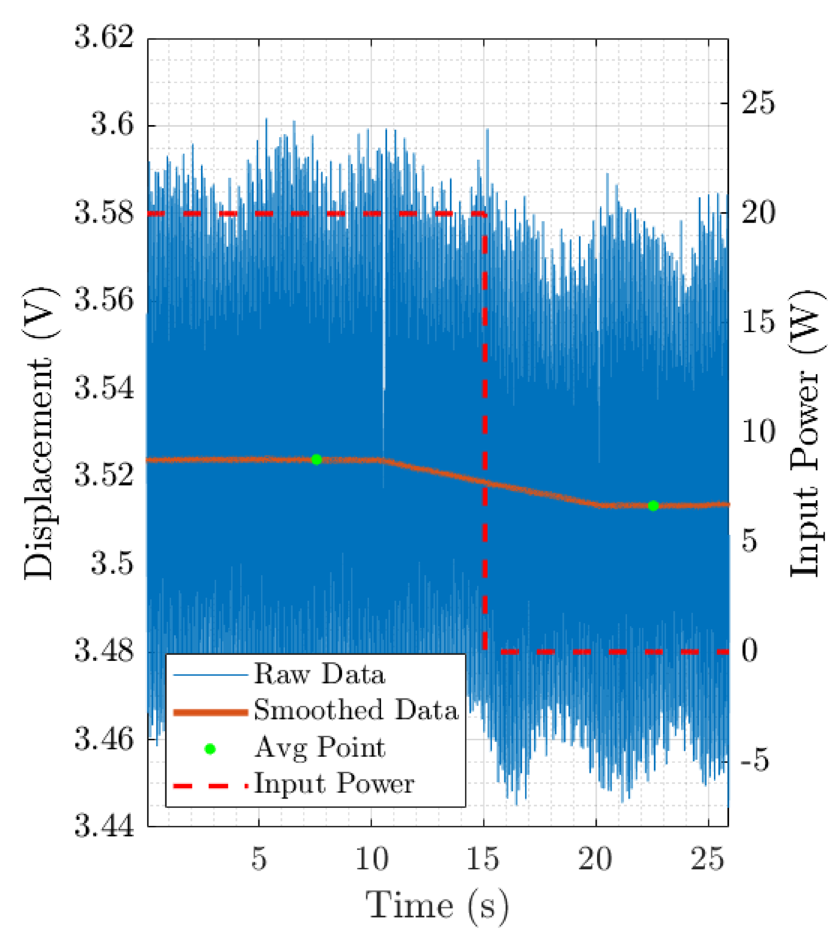
Experimental Setup

We use a coaxial ECR thruster based on experiments at ONERA [2]. The input signal is generated by two microwave signal generators controlled by a computer interface. The system bandwidth is 800-2500 MHz. Power is read by RMS power meters and a spectrum analyzer. Absolute thrust is measured using a thrust stand that includes a wireless microwave power coupler to avoid cable deformation.



Schematic of the microwave setup

ECR Thruster on PEPL Thrust Stand



Thrust Measurement Output

Optimization Technique

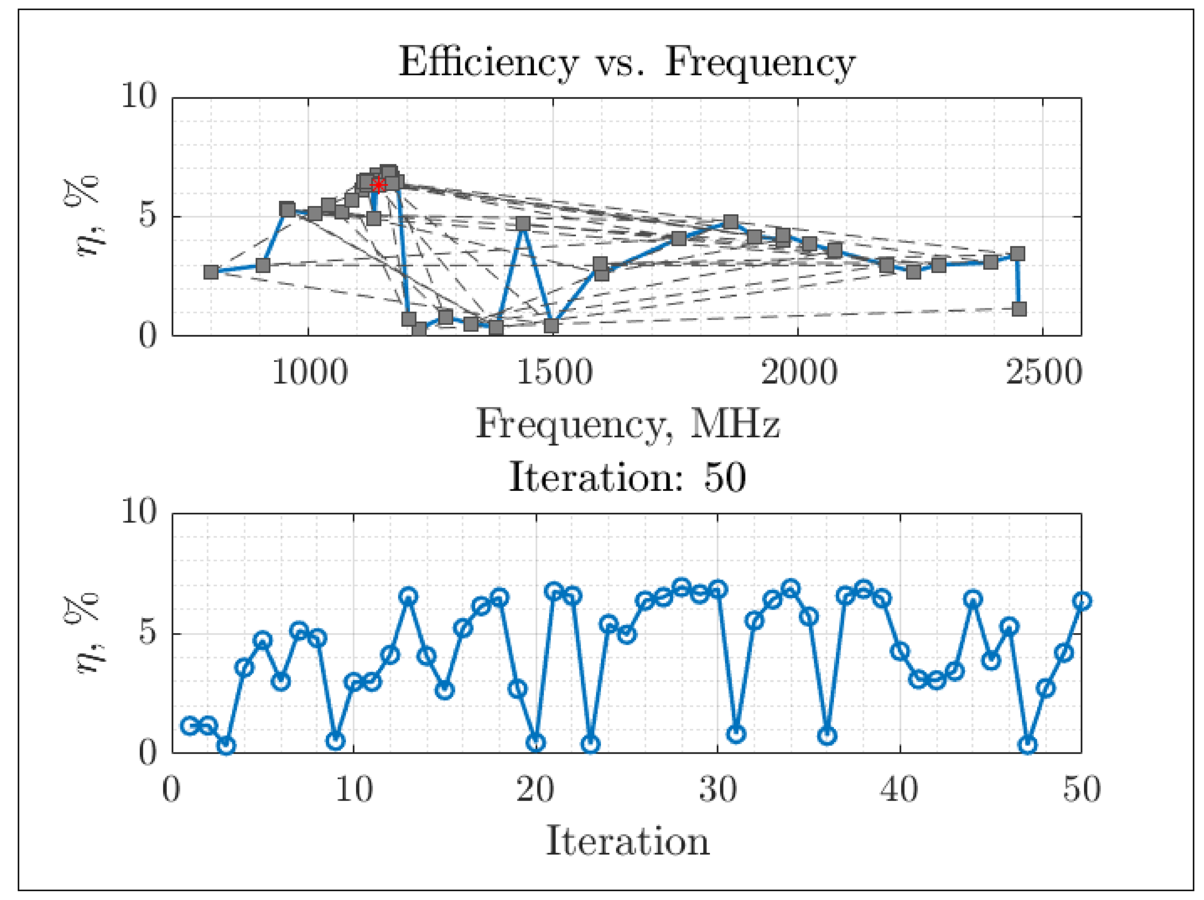
We ran two preliminary experiments:

- 1 frequency fixed power: 20 W
- 2 frequency fixed power: f_1 15 W, f_2 5 W

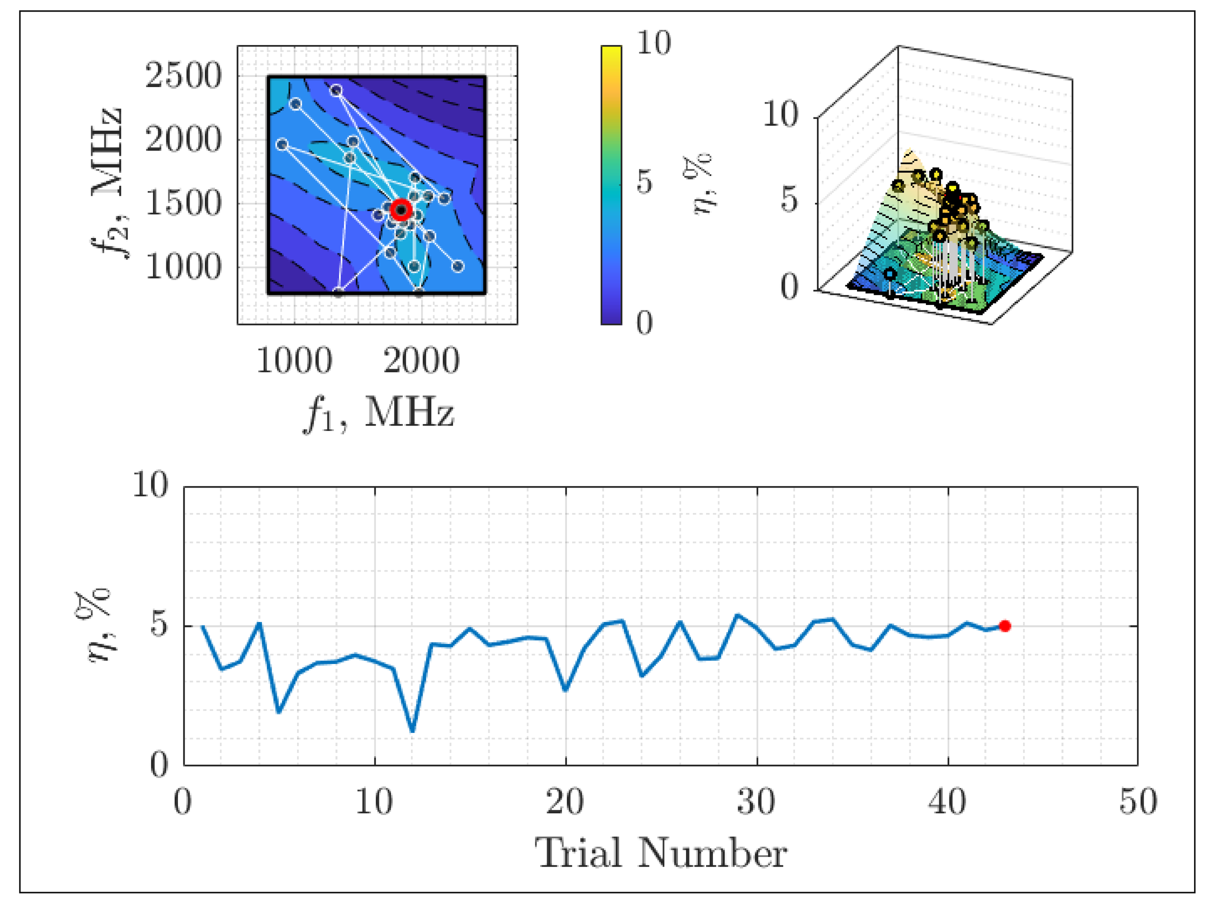
The thrust at each point was fed into a surrogate-based global optimization algorithm that selected each new test point [4].

Results

One Frequency



Two Frequency



Conclusions & Future Work

While the initial two-frequency data does not show as high thrust efficiency as single frequency heating, most majority of the design space remains unexplored. Upcoming experiments will involve many times more data points to address this issue.

Acknowledgments

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