Channel interaction in a 100-kW class Nested-channel Hall thruster

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Introduction

Nesting the channels of Hall thrusters allows scaling to high powers (hundreds of kW) while maintaining a compact device footprint.

The X2 was a proof-of-concept thruster developed at the University of Michigan in 2009. It is a 10-kW thruster and has had a full performance characterization [1].

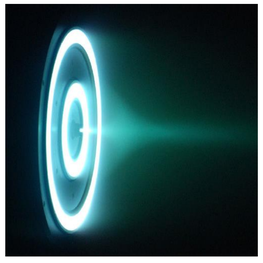

Figure 1: The 2-channel X2 Nested-channel Hall thruster.

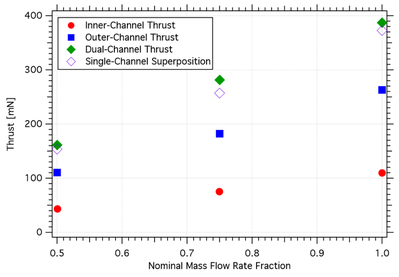

Figure 2: A boost in thrust was found when running channels together.

The X3

A nested channel Hall thruster:
- based on the design of the X2
- with 3 channels
- up to 200 kW of discharge power
- weighing over 250 kg
- about 1 m in diameter
- new: fired first in Sept. 2013

The X3 was developed jointly between the Plasmadynamics and Electric Propulsion Laboratory at the University of Michigan, NASA, and the Air Force Office of Scientific Research [2,3].

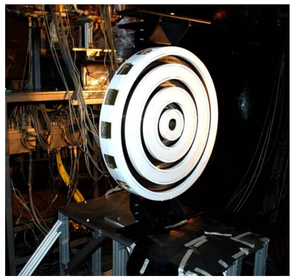

Figure 3: The X3 prior to first firing.

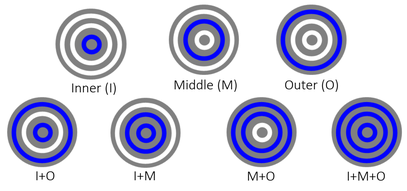

Figure 4: The channels of the X3 can be run separately or together, giving the thruster 7 operational modes.

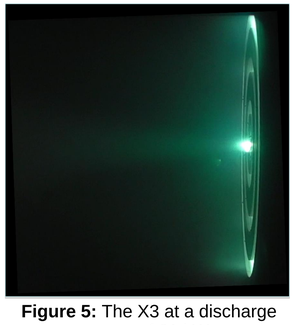

Figure 5: The X3 at a discharge power of 61 kW.

X3 Channel Interaction

Less propellant was necessary to maintain constant current density when running multiple channels of the X3 than the sum of propellant flow rates of the channels running alone.

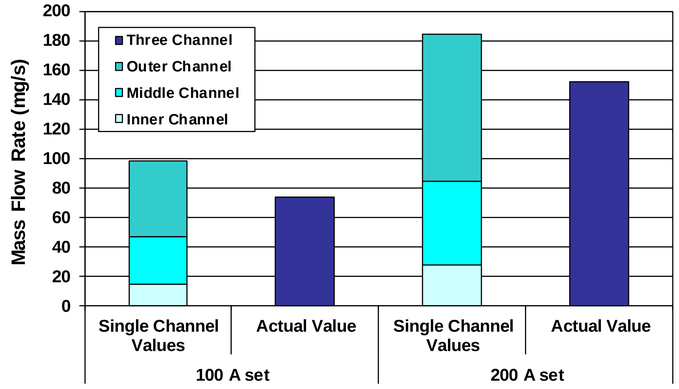

Figure 6: The propellant flow rate data, which illustrates the savings seen in 3-channel mode.

The propellant flow rate needed to maintain current density was 26% less than the sum of the single channel values in the lower current density case, and 18% less in the higher current density case.

Additionally, the breathing modes (the frequencies at which the discharge current in each channel oscillates) tend to converge to a single value when operating multiple channels, providing more evidence of channel interaction.

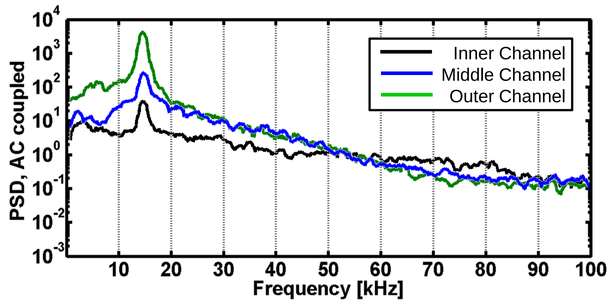

Figure 7: An example of the breathing modes of each channel converging to a single value (here, 14.7 kHz) when operating together.

Conclusions, Questions, and Future Work

Conclusions:
- The channels are interacting by some unidentified mechanism.
- The behavior matches what was seen with the X2.

Questions:
- What is the mechanism causing this channel interaction?
- Can this be leveraged to design the next generation thruster to be even more efficient?
- When the breathing modes converge, is there a phase delay?

Future work:
- Reach a discharge power of 200 kW.
- Perform a full thruster characterization, including plasma plume studies and thrust measurements.
- Collaborate with a modeler to fully capture the underlying physics.

Acknowledgements

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References

[1] Liang, R., "The Combination of Two Concentric Discharge Channels into a Nested Hall-Effect Thruster," Ph.D. Dissertation, University of Michigan, 2013.
[2] Florenz, R., et al., "First Firing of a 100-kW Nested-channel Hall Thruster," IEPC-2013-394, 33rd International Electric Propulsion Conference, Washington, D.C., October 6-10, 2013.
[3] Hall, S., et al., "Implementation and Initial Validation of a 100-kW Class Nested-channel Hall Thruster", AIAA 2014-3815, 50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Cleveland, OH, July 28-30, 2014.

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