Stabilized Z-Pinch Fusion Driven Electromagnetic Propulsion

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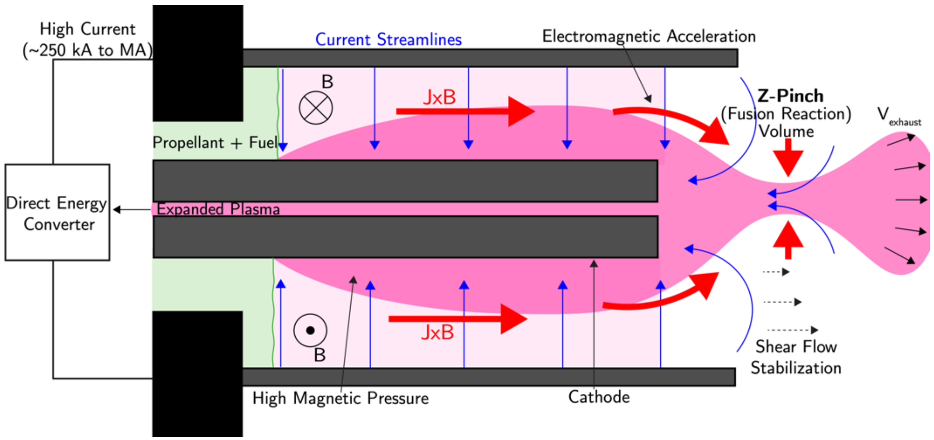

Schematic of a z-pinch stabilized fusion driven electromagnetic propulsion system. The system is compact, modular, and utilizes a flowing z-pinch and electromagnetic acceleration mechanism that can generate scalable thrust, specific impulse, specific power, and the temperatures that are required to drive fusion reactions.

Research Objectives

This project will build and assess the potential for a z-pinch fusion driven electromagnetic propulsion concept to operate as a candidate architecture for space exploration. Specific research objectives during the project include:

1) Develop, fabricate, and characterize the scalability of a z-pinch fusion driven electromagnetic propulsion system.
2) Perform laboratory proof-of-concept testing of a prototype with increasing peak currents (up to 500 kA) to quantify the scalability in thrust, specific impulse, magnetohydrodynamic stability, specific power, plasma temperature, and the number of fusion reactions.
3) Develop a magnetohydrodynamic simulation framework to extrapolate from laboratory testing to space mission planning. This includes system level design of how to extract energy from fusion reactions to create a sustained source of propulsion.

Innovation: The concept combines electromagnetic acceleration with a shear stabilized z-pinch that can generate the plasma conditions that are necessary to drive fusion reactions (i.e., temperatures > 1 keV). The scheme is compact and amenable to laboratory testing.

Technology Readiness Level: Project starts at TRL 2 and will end at TRL 3.

Approach

A z-pinch fusion driven electromagnetic propulsion system will be designed, fabricated, and tested using a combination of experimental testing and numerical models. Specific plans include:

1) Fabricate proof-of-concept thruster with an integrated shear flow stabilized pinch. Demonstrate performance scaling of the thruster to peak currents where fusion reactions can occur (~ 500 kA) .
2) Measure thrust and specific impulse of the thruster as the peak current is increased. Measurements will be performed using neutral propellant (i.e., Ar) and mixtures of neutral propellant and deuterium to demonstrate fusion reactions (i.e., D-D fusion).
3) Quantify plasma temperature and neutron yield of the thruster during operating conditions.
4) Demonstrate shear flow stabilization at increasing peak currents within the z-pinch.
5) Develop a magnetohydrodynamic simulation framework to connect laboratory testing with extrapolated conditions of interest for space mission planning.

Potential Impact

This propulsion concept combines electromagnetic propulsion with a stabilized z-pinch that is scalable to fusion conditions. Benefits include:

1) The concept creates a pinch that can generate plasma temperatures that are necessary for sustained fusion reactions. This means the propulsion system can leverage fusion energy for high specific powers (~ 1-10 kW/kg). It is also scalable to generate sustained thrusts of 10^5-10^6 N and specific impulses of ~ 10^5-10^6 s with peak currents of ~ 500 kA. Together these capabilities would offer an unprecedented performance envelope for space propulsion.
2) The concept leverages a Lorentz force to accelerate gas flows, sustain a z-pinch, form sheared velocity profiles, and generate thrust. This axial acceleration also acts to stabilize the z-pinch against magnetohydrodynamic instabilities.
3) The concept is compact, modular, and amenable to laboratory testing. The theoretical foundation of the idea is built upon an electromagnetic thrust mechanism that has been demonstrated in orbit and a stabilized z-pinch scheme that has demonstrated the production of fusion reactions in a laboratory facility. This makes scaling and assessing its potential as a thruster feasible during a funded period.