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Title

Integration and Testing of a High Temperature Superconductor Magnet with a Central Cathode Electrostatic Thruster

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Abstract

High temperature superconductor (HTS) materials have long been perceived as futuristic solutions to many problems in space, including magnetic shielding from cosmic rays [1], energy storage and power delivery [2], and propulsion applications requiring very high magnetic fields [3]. Some types of electric propulsion devices show improved performance when operating in higher magnetic fields [4] [5], and superconductor magnets can create higher fields than any other technologies [6]. There have recently been advances in combining superconductor technologies with thrusters to improve performance [7] [8]. However, traditional superconductor systems are designed for laboratory rather than in-space conditions, and as a result the existing supporting technologies are typically of laboratory scale [7]. To date, there are no publicly available examples of a fully developed superconductor magnet system operating in space, let alone one operating as part of a plasma thruster. Furthermore, the ground testing of superconductor plasma thrusters has thus far relied upon laboratory scale subsystems, such as convective cooling systems with a cryogen such as helium or liquid nitrogen to prevent the superconductor overheating and quenching. Replacing these subsystems with space-ready alternatives is a key milestone on the path to in-space deployment. In this study, a high temperature superconductor magnet was integrated with a plasma thruster of the central-cathode electrostatic type. The thruster performance parameters such as thrust, specific impulse and efficiency were shown to improve at high fields. The magnet's thermal design was experimentally validated, with cryogenic conditions maintained at fields of over 1 Tesla. This magnet was not cooled using conventional convective methods: instead, it was conductively cooled using a single stage Stirling cycle cryocooler via a copper thermal bus. This allows the compact, lightweight cooling subsystem to operate at power on the scale of 100W and with room temperature heat rejection, which could be integrated with a spacecraft's radiator panels in the future. This empirical evidence shows that a spaceflight-capable superconductor

magnet device is thermally and energetically feasible. It also demonstrates the virtue in utilizing an HTS magnet system to supply a magnetic field to a plasma thruster.

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