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LASER BASED ELECTRON DENSITY MEASUREMENTS IN A RING-CUSP MAGNETOSHEATH

Abstract

Gridded ion thrusters are the proven choice for deep space science missions, such as NASA's Deep Space 1 and Dawn spacecraft. Ion engines are also used on Department of Defense and commercial satellites for station keeping and orbital plane changes. The advantages of ion thrusters are their extremely long operational lifetimes and the highest efficiency of any propulsion system. Their main drawback is the low thrust density. Increasing the thrust density would enable rapid orbit transfers of satellites and reduced trip time for cargo missions supporting human exploration of Mars. My research involves investigating a novel methodology that improves the thrust production capacity of ion thrusters. NASA's state of the art ion thrusters employ ring cusp magnetic circuits to increase electron confinement and improve ionization efficiency. The majority of the discharge current is collected through the magnetic cusp structure. This makes the magnetic circuit choice crucial to ion thruster performance. Magnetic circuits are typically designed through trial and error or by rules of thumb founded in flight heritage. The goal of this work is to gain physical insight into the processes occurring at the magnetic cusps and elucidate how those processes impact not only the plasma conditions in the bulk discharge, but also efficiency and stability. The space charge limit imposed by the beam extraction grids is given by the Child-Langmuir limit, but this limit is not immutable. The limit is derived assuming zero ion velocity. By accounting for velocity the limit is increased. Therefore, by generating ion velocity directed towards the grids, the space charge limit, and thus the thrust density can be increased. My previous work has explored a method for producing ion velocity and the associated performance improvements [1]. Here, I present work which further investigates this method using a laser diagnostic, called Laser-Collisional Induced Fluorescence (LCIF), which is used to measure the 2D spatial distribution of electron density and temperature within the discharge. I attempt to answer the question of how bulk plasma properties change in response to local modifications to current collection at the cusp magnetosheath. From a practical standpoint, I also the address the question of what magnet geometry is best to achieve optimum ion thruster performance (e.g. high density, uniformity, and a broad stability envelope). [1] Arthur, N. A. and Foster, J. E., J. Vac. Sci. Technol. A. 35, 021310, 2017.