Operating the Helicon Double Layer Thruster in a Space Simulation Chamber

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***Abstract*—A prototype of the helicon double layer thruster (HDLT) is designed and manufactured. Initial tests with the thruster mounted on a small vacuum chamber (pumping speed of $700\ \mathrm{l}\cdot\mathrm{s}^{-1}$) show successful operation in xenon with the formation of the double layer which generates a low divergence ion beam, which is the source of thrust. The prototype is subsequently inserted inside a much larger space simulation chamber (pumping speed of $7000\ \mathrm{l}\cdot\mathrm{s}^{-1}$). A high-density blue mode is found when increasing the RF power above 380 W, and measurements with a Langmuir probe give an estimated density of $10^{12}\ \mathrm{cm}^{-3}$ in the thruster. An image of the HDLT operating in the high-density blue mode is presented.**

***Index Terms*—acceleration, ion beams, plasma engines, propulsion.**

PARTICLE acceleration in expanding "collisionless" plasmas can be applied to electric propulsion, particularly for deep space missions [1]. Low-pressure high-density wave-excited plasma sources, such as the Helicon source, exhibit good efficiency [2]. The recently found current-free electric double layer in a helicon source [3], [4] is the base of the helicon double layer thruster (HDLT), which is a new long-life electrodeless magneto-plasma thruster. In this paper, we present an image which combines three photos of the HDLT prototype operating in a high-density xenon blue mode discovered in the CORONA space simulation chamber at the European Space Agency (ESA)'s development center, i.e., the European Space Research and Technology Centre.

The previously described HDLT prototype [5] was initially mounted on the CHI KUNG experimental system [6] with a pumping speed of $700\ \mathrm{l}\cdot\mathrm{s}^{-1}$. In xenon, a low divergence ion beam formed by acceleration in the potential drop of a current-free double layer was easily observable using a retarding field energy analyzer [5]. The results were consistent with a recently developed model [5], [7].

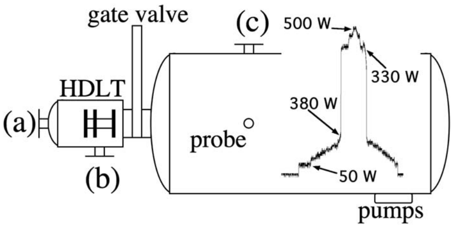

Fig. 1. Schematic of the HDLT mounted in the hatch of the CORONA space simulation chamber. The inset shows the density jump obtained at about 380 W in xenon for a pressure of 7×10^{-5} mbar and also a maximum magnetic field of about 140 G inside the thruster (same plasma appearance throughout the high-density mode).

The HDLT prototype was subsequently tested in ESA's CORONA system shown in Fig. 1, which consisted of a 1.4-m-long 1.1-m-diameter hatch attached via a 0.8-m-diameter gate valve to the 5-m-long 2-m-diameter CORONA chamber equipped with a system of primary, turbomolecular, and cryogenic pumps. The pumping speeds in the hatch and CORONA were 7000 and $12\,000\ \mathrm{l}\cdot\mathrm{s}^{-1}$, respectively. Subsequent to initial plasma tests in xenon, a Faraday cup, which is mounted on a rotating arm and positioned on the main axis 1.8 m downstream of the thruster (probe on Fig. 1), was operated as a Langmuir probe with a bias of -40 V. The HDLT was tested for various pressures, and although a clear ion beam could not be observed in the ion saturation current, a new high-density plasma mode was discovered in the 2×10^{-5} to 2×10^{-4} mbar range (inset in Fig. 1). It had a maximum density in the center at a pressure of 5×10^{-5} mbar which, if extrapolated back to the source assuming a $1/R^2$ expansion, yielded a source plasma density of over $10^{12}\ \mathrm{cm}^{-3}$, correlating well with that expected from the input power of about 500 W.

The image shown in Fig. 2 corresponds to three photos taken by using a SONY DSC-T1 five-megapixel digital camera via the three ports shown in Fig. 1, respectively, with the HDLT operating in the high-density mode (500 W and 7×10^{-5} mbar). The round frames were created by using Adobe photoshop. Top pane (a) shows the back view of the HDLT with the white to blue circles of the high-density mode measured with the probe.

Middle pane (b) is a side view of the HDLT showing the two copper solenoids and the thermal radiation plates. The pink/purple color corresponds to the background plasma in the CORONA chamber. A "white" plasma is seen at the thruster's exit plane. Bottom pane (c) clearly shows the blue reflections of the high-density plasma generated in the HDLT, as well as the rotating arm supporting the Faraday day cup and immersed in the purple background plasma. Unfortunately, this diagnostic

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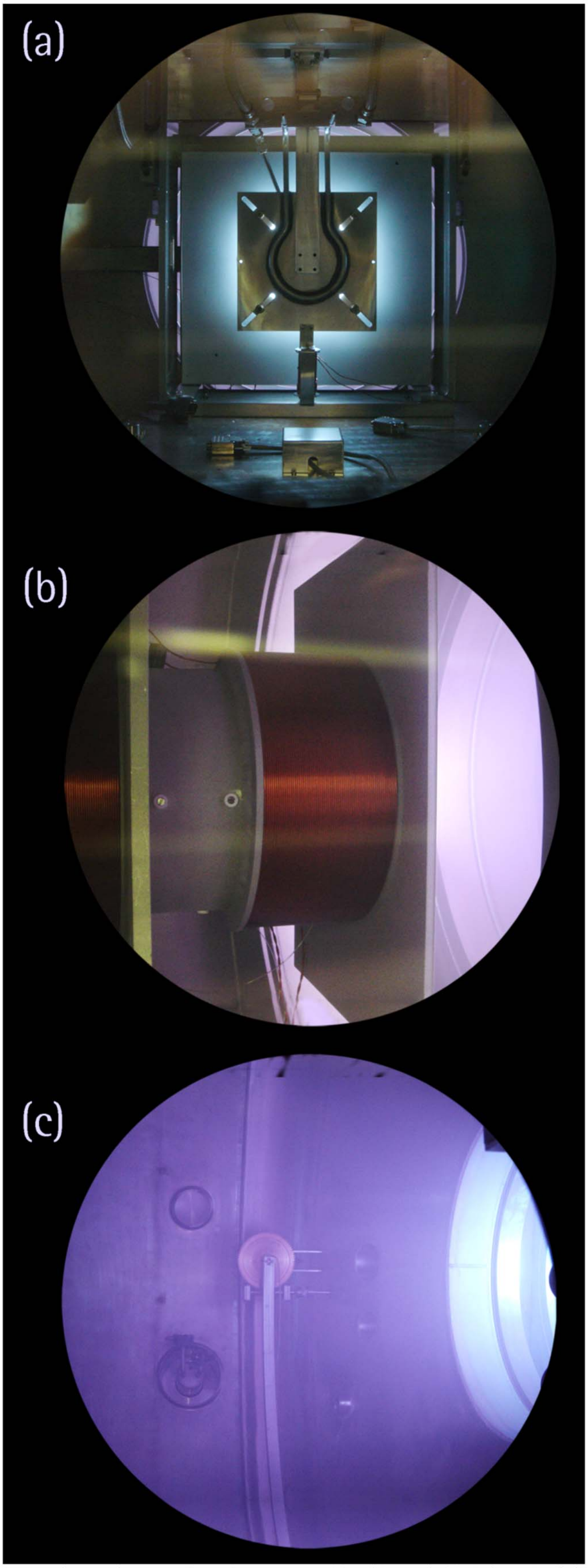

Fig. 2. Three photos taken from ports (a), (b), and (c) (Fig. 1) of the HDLT operating in the high-density xenon mode.

could not be positioned closer to the HDLT itself, and no other diagnostic was available to get any clear evidence of the double layer.

In conclusion, the image of an HDLT operating in a space vacuum chamber under full cryo-pumping provides useful information on the high-density xenon blue mode which complements preliminary results obtained by using a Langmuir probe. Recently, experiments at The Australian National University with the HDLT immersed in a hatch identical to that of the CORONA's system, but with a pumping speed of 330 $\mathrm{l \cdot s^{-1}}$, have shown clear evidence of the ion beam in argon using an energy analyzer [8]. The image in Fig. 2 provides an important visual reference. Future testing under full cryo-pumping is needed to establish databases as extensive as those obtained with ion gridded thrusters and Hall thrusters, which are two other types of electric propulsion systems which have already successfully been used for space missions [9].

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