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Experimental Study of Additional Plasma Acceleration Method Using Rotating Magnetic Field Method in Electrodeless Plasma Propulsion

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Electric thruster has been widely being developed and launched recently. As conventional thrusters, e.g., ion gridded engine and Hall thruster, are hot topics because these conventional thrusters have possibilities to realize future space missions such as deep space exploration, human space mission to the Mars, and SSPS (Space Solar Power System). Especially, a number of institutes and research groups all over the world are focusing on the Hall thruster because of the salient increment of the performance nowadays. However, these thrusters have a fatal problem; erosion of electrodes (girds) to generate and accelerate a plasma. The problem makes the realization of the future missions impossible.

As one of the solutions, electrodeless plasma propulsion methods are being proposed all over the world. In this thruster scheme, a plasma does not contact with electrodes directly, leading to a long operation time of the electric propulsion. Among the electrodeless thruster concepts, we are proposing Rotating Magnetic Field (RMF) acceleration method as an addition of the plasma acceleration scheme in a typical RF (Radio Frequency)/helicon plasma thruster systems [1]. Originally, this RMF technique has been used to maintain the Field Reversed Configuration (FRC) [2], which is a way to create magnetically confined plasma in the field of the plasma fusion research as an azimuthal current drive method. The use of the RMF method in this electric propulsion systems is to generate an axial Lorentz force derived by a cross product of the current and a radial component of divergent B-filed applied by the use of a dc B-field source such as permanent magnets or electromagnets (see Fig. 1). Note that our present status is to clarify the RMF current drive phenomena inside of a relatively low temperature plasma in our proposed RF/helicon plasma thruster scheme, and optimization of this additional plasma acceleration effect.

We are focusing on the azimuthal current drive mechanisms. In particular, the current drive can be conducted by a non-linear effect, i.e., the Hall term effect, which is also used in the Hall thruster, and the current has both dc and ac components. From the spatial diagnostics of the oscillating component of the RMF, we previously derived the spatio-temporal current profiles oscillating with the second harmonic of the applied RMF current frequency [3].

We changed some operation parameters relating the RMF plasma acceleration effect, propellant gas pressure, the plasma generation power, the RMF current amplitude, and the current frequency [4]. Needless to say, plasma parameters such as an electron density and temperature are also important to determine the acceleration efficiency of the RMF method.

In this conference, the dependences of the plasma parameters on some operational conditions are shown and discussed, as well as the spatial RMF configurations with the original and secondary frequencies. Moreover, ion flow under the RMF scheme is also an interesting content. Argon Laser Induced Fluorescence (LIF) measurement was conducted to clarify the absolute velocity increment and the flow structure owing to the RMF. Figure 2 shows an example of the IVDF (Ion Velocity Distribution Functions) w/ RMF application in the axial middle of the RMF antennas. Here, the IVDFs will be also presented to explain the RMF plasma acceleration effect, comparing with those w/o RMF.

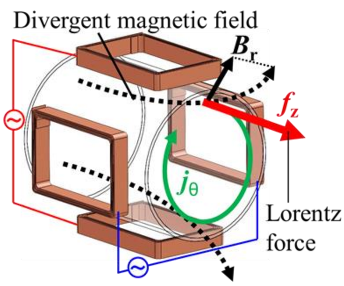

Figure 1 Schematics of RMF plasma acceleration scheme.

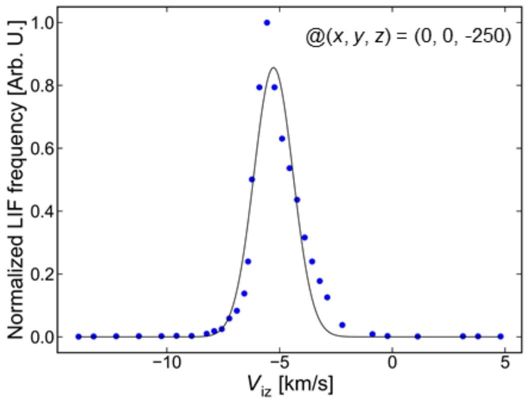

Figure 2 Example of ion velocity distribution function in the axial middle of the RMF antennas.

References

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