8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Development of a Small RF Plasma Thruster Using Rotating Magnetic Field Plasma Acceleration Method

T. Furukawa[1], Y. Morishita[1], D. Kuwahara[2], H. Takeno[1], and S. Shinohara[3]
[1] Department of Electrical and Electronic Engineering, Kobe University
[2] College of Engineering, Chubu University
[3] Tokyo University of Agriculture and Technology
e-mail (speaker): tak_furukawa@diamond.kobe-u.ac.jp

Industry and academia are launching many small satellites because of low-cost manufacture and short-term development [1]. Accordingly, miniature electric propulsion has attracted and developed worldwide. It is equipped with a small satellite and CubeSat [2]. Miniature ion engines and pulsed plasma thrusters have already been utilized in space missions [3,4].

To satisfy demands in the small satellites concerning erosion of acceleration grids in practical electric propulsions, small-diameter, radio frequency (RF) plasma thrusters with a magnetic nozzle (MN) are one of the promising approaches. Electrons mainly take charge of the thrust generation mechanism in the presence of the MN, and the physical behavior in expanding plasma has been investigated [5,6]. Among the RF plasma thruster concepts, we are proposing the rotating magnetic field (RMF) plasma acceleration method [7,8] to enhance thrust performance with an additional acceleration effect. This RMF method drives an electron azimuthal current via the Hall-term effect, and an axial Lorentz force is generated in the presence of a radial component of the MN. Afterwords, ions increase their axial momentum because of ambipolar electric field caused by the axial transit of electrons. Thus, net plasma acceleration is obtained in the downstream of the MN. We aim to enhance the thrust performance by applying the RMF acceleration effect to a small RF thruster scheme.

Figure 1 shows a newly developed small-diameter RF plasma thruster simulator with an RMF antenna. This simulator has a stepped-shaped discharge tube, and its inner diameter is 27 mm in the small tube region. A background pressure is reached to 8×10^{-4} Pa using a turbomolecular pump and a rotary pump connected to a stainless vacuum chamber, as shown in Fig. 1. A one-turn RF antenna and two-phase, two-coil per phase RMF antenna are equipped for plasma generation and acceleration, respectively. An electromagnet is used as an external static magnetic field source, and the RMF antenna position is determined by considering the MN configuration. A cross-sectional view of the RMF strength and field lines is shown in Fig. 2. A centered, open black circle indicates the discharge tube wall. Almost all field lines have radial components inside the tube, and the field strength of 60 G on the z-axis is obtained at an AC current amplitude of 90 A_{pp} applied to the RMF antenna.

Plasma parameters are measured with an electrostatic probe inserted from a branch tube at $z = -135$ mm in this simulator. In addition, optical emission spectroscopy (OES) measurement is conducted to estimate the electron density in the RMF antenna region qualitatively.

We will introduce the developed small RF thruster device with the RMF antenna and show the dependence of the RMF strength on the plasma parameters and acceleration effect in the small thruster scheme at this annual conference.

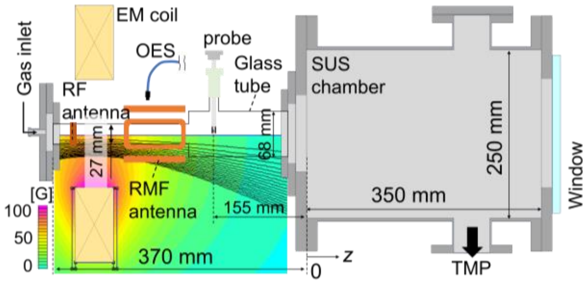

Figure 1 Cartoon of the developed small RF thruster simulator with the RMF antenna. The color contour map shows the magnetic field's strength with field lines using an electromagnet.

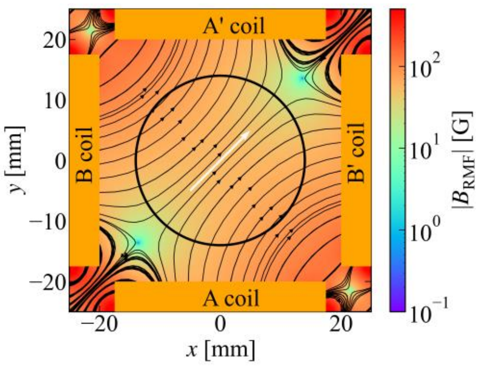

Figure 2 The two-phase, two-coil per phase RMF antenna with a color contour map of the magnetic field strength and field lines.

References

[1] J.R. Kopacz *et al*., Acta Astronaut. **170** (2020) 93.
[2] K. Lemmer, Acta Astronaut. **134** (2017) 59.
[3] J. Asakawa *et al*. Trans. Jpn. Soc. Aeronaut. Space Sci. **16** (2018) 427.
[4] H. Koizumi *et al*. Trans. Jpn. Soc. Aeronaut. Space Sci. **14** (2016) Pb_13.
[5] K. Takahashi, Phys. Rev. Lett. **117** (2016) 225003.
[6] J.M. Little and E.Y. Choueiri, Phys. Rev. Lett. **117** (2016) 225003.
[7] S. Shinohara *et al*., IEEE Trans. Plasma Sci. **42** (2014) 1254.
[8] T. Furukawa *et al*., Phys. Plasmas **28** (2021) 07350.