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m = 0半周期加速法を使用した無電極電気推進機の電磁加速効果の検証
Investigation of electromagnetic acceleration effect in electrodeless electric thruster using m = 0 half-cycle acceleration method

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Electric plasma thruster system has been developed and utilized for space propulsion owing to its higher fuel efficiency by one order magnitude than that of typical chemical one. Practical plasma thruster systems, e.g., ion gridded engine and Hall thruster, have some problems including limitation of operational lifetime and contamination inside the discharge room due to erosion of acceleration electrodes. The fatal issues result in a difficulty of future long-term space missions such as deep space expedition and manned space probe to Mars.

Electrodeless radio frequency (RF)/helicon[1] plasma thruster[2,3] concept is being studied because this type of thruster does not have direct interaction between plasma and the electrodes. The plasma is generated by using an external RF antenna wound outside the discharge chamber. The generated plasma is accelerated by a magnetic nozzle effect composed of diamagnetism, E×B current drive, and electron detachment form the nozzle. The present maximum thruster efficiency is 20%,[2] although it is still a low performance compared to the practical level.

As one of the novel additional electrodeless plasma acceleration methods, m = 0 half-cycle plasma acceleration is being proposed and applied to a typical RF thruster.[4,5] The m = 0 method aims to enhance an electromagnetic force, f_z, by driving an azimuthal current j_θ, inside the plasma in the presence of a radial component of the magnetic nozzle, B_r, as shown in Fig. 1. The j_θ is induced owing to the electromagnetic induction. Note that the "half-cycle" means that the acceleration phase exists for a half period of the m = 0 current frequency, since the induced current direction changes at every half period. In the acceleration phase, increasing rate of the ion velocity up to 110% was obtained in the downstream of the acceleration antenna, using a 20-mm i.d. plasma source and the applied ac current of 600 A_{pp} with less than several kHz.[6]

In this conference, the electromagnetic acceleration effect on the plasma, varying the m = 0 applied ac current amplitude and the dependence of the acceleration effect on the operational condition will be presented. Thruster size is also important for the performance improvement and here, a new 70-mm i.d. stepped-shape quartz tube is used. Three directional time-varying components of the m = 0 magnetic field and plasma parameters, e.g., Fig. 2, are measured to evaluate the current induction and the magnetic field penetration experimentally.

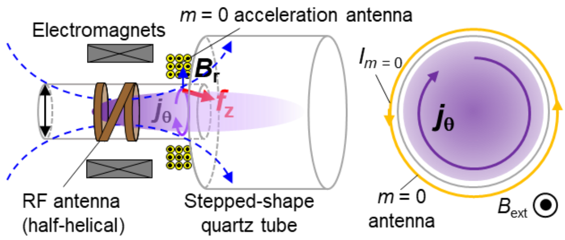

Fig. 1 Schematic of the m = 0 plasma acceleration method.

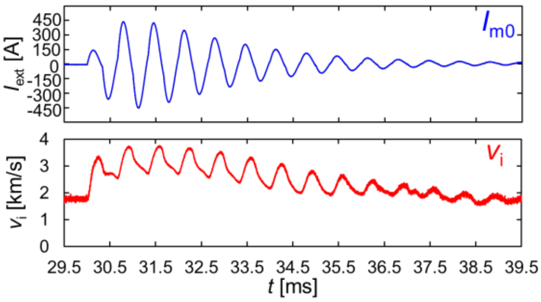

Fig. 2 Example of time evolutions of the applied m = 0 coil AC current and measured ion velocity.

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