# Effect of a cusp magnetic field provided by a permanent magnet array on a magnetic nozzle plasma thruster performance

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A magnetic nozzle (MN) radio frequency (rf) plasma thruster has been actively investigated over the last few decades [1,2]. Because no electrodes are exposed to the plasma, it is expected to provide a longer lifetime even at a higher power level than mature electric propulsion devices. The thrust efficiency of the MN rf thrusters has been improved year by year and recently increased to about 30% [3].

In the MN rf plasma thrusters, the thrust is generated when the gaseous propellant ionized by the rf plasma source is spontaneously accelerated by the expansion process in the MN and ejected at high velocity into space [2]. The physics and thrust generation mechanisms within the MN and plasma sources have been investigated [2], and it has been found that energy and momentum losses at the plasma source wall cause the poor thrust efficiency [2,4]. Therefore, it is essential to suppress the wall losses to improve performance. Recent experiment showing the 30 % efficiency has utilized a cusp magnetic field, which can be formed by locating the additional upstream solenoid in addition to the downstream solenoid, to suppress the plasma loss to the source wall [3].

Replacing the solenoid with permanent magnets would reduce power and weight and simplify the structural design for practical application of the MN rf plasma thrusters [5]. In this study, the upstream additional solenoid is replaced by a permanent magnet array, while maintaining the downstream solenoid providing the MN. The thrust and the ion saturation current profiles are measured under the following three conditions of "no cusp field", "cusp field by the two solenoids", and "cusp field by the permanent magnets array" to verify the effectiveness of the permanent magnets array.

Figures 1 shows the schematic diagrams of the experimental setup tested here. The source tube is continuously attached to a cylindrical stainless steel diffusion chamber. The plasma source configuration with no cusp field and with cusp field by two solenoids are drawn in Fig.1(a) together with a pendulum target plate for qualitative assessment of the impulse bit. The calibration procedure of the target technique follows the previous thrust measurement [6], where the axial displacement of target is measured by a light emitting diode (LED) displacement sensor. The impulse bit is obtained from the calibration coefficient and the LED sensor output. When pulsing the rf power with the pulse width δt, the thrust can be obtained by dividing the measured impulse bit by δt. Figure 1(b) shows the plasma source configuration with a cusp field by the permanent magnets array and the Langmuir probe. The permanent magnets array consists of NdFeB magnets and is designed to have an axially movable structure.

The results show the increase in the thrust by locating the cusp field inside the source even for the permanent magnet array, providing the better system efficiency than the two solenoids configuration. Detailed results will be described in the presentation.

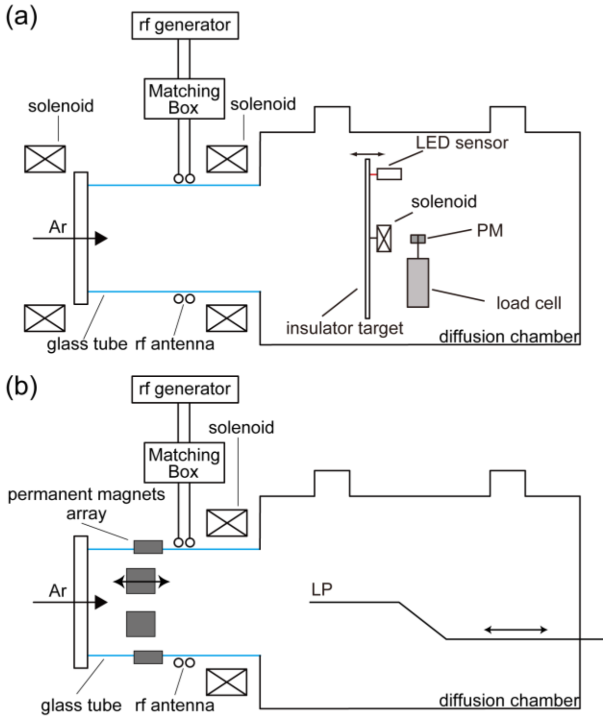


**Figure 1**. Schematic diagram of (a) the plasma source configuration with "no cusp field", with "a cusp field by two solenoids", a pendulum target plate, (b) the plasma source configuration with "a cusp field by permanent magnets array", and the LP.

References
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