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Advanced Electrodeless Propulsion using High-Density Helicon Plasma Source

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High-density (~10^{13} cm^{-3}), low electron temperature (a few to several eV) helicon plasma sources using an rf frequency range are very useful, and they can be utilized in many fields. This is because high-density helicon plasmas can be produced with a broad range of external operating parameters such as a fill pressure, magnetic field strength, and its field configuration, as long as the excitation frequency is between an ion and an electron cyclotron frequencies.

We have been developing various kinds of these sources and characterizing them to control plasmas as required: e.g., very large- [1-3] or very small-area [4,5] sources have been developed, and applying these sources to a space propulsion system with a concept of an electrodeless condition (no direct contact between a plasma and electrodes) [5,6] is encouraged due to the longer life operation expected. Here, although electric propulsion systems can strongly exceed the chemical systems in their specific impulse (the ratio of exhaust velocity to the gravitational acceleration), most of the present electric systems are suffering from problems of a short lifetime caused by the erosion of the electrodes and of an impurity contamination.

Here, we will overview our studies on electrodeless, helicon plasma thrusters under the HEAT (Helicon Electrodeless Advanced Thruster) project [2,5,6]: characteristics of very large or small (diameter) sources, and plasma thrust performance mainly using middle sized sources [5-7] (see Fig. 1). In addition, some trials of electrodeless, additional acceleration methods proposed such as rotating magnetic field and m = 0 half cycle schemes [5,6] (Fig. 2 shows various proposals).

In verifying our acceleration schemes, diagnostics are also important [6], and, e.g., a plasma thrust, an ion flow velocity, and a neutral/electron particle densities were measured by using a thrust stand [7], a Mach probe, a laser with a Laser Induced Fluorescence (LIF) method [8], and a Langmuir probe. Additionally, spectroscopic measurements using a high-speed camera with optical filters, and two types of spectrometers were executed.

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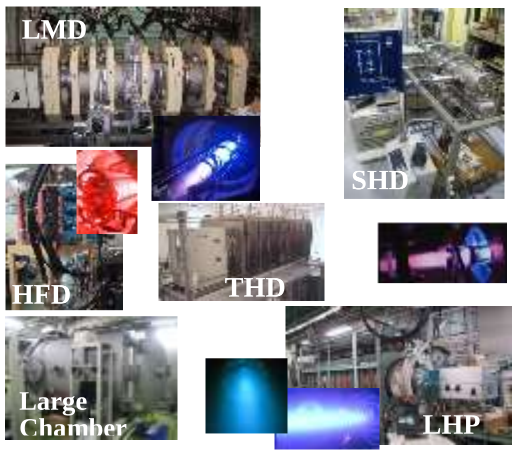

Figure 1 Examples of various, unique helicon sources developed in addition to vacuum chambers to carry out the thruster experiments.

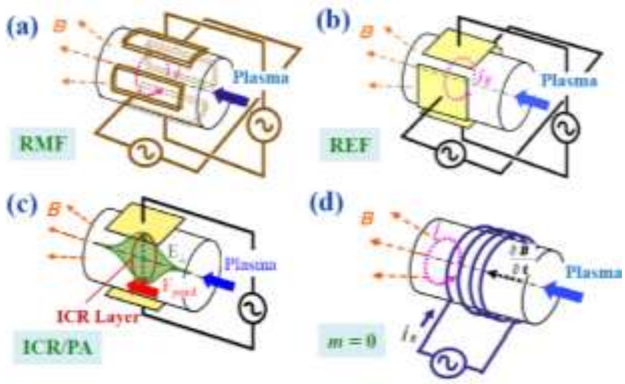

Figure 2 Examples of electrodeless plasma acceleration schemes proposed: (a) RMF (Rotating Magnetic Field) acceleration, (b) REF (Rotating Electric Field) acceleration, (c) ICR (Ion Cyclotron Resonance) and PA (Ponderomotive Acceleration), and (d) m = 0 half cycle acceleration.