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回転磁場によるプラズマ加速の評価
Estimation of Plasma Acceleration in Rotating Magnetic Field Method

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Development of electric plasma propulsion system is a notable topic for a realization of more sophisticated space missions than the current status. As one of the obstacles to the progressive approach, erosion of electrodes (metal grids) is a fatal issue, which can be typically seen in conventional electric thrusters, e.g., ion gridded and Hall thrusters. The erosion results in a limitation of the operation life time and a degradation of the thruster performance, leading to difficulty of further deep space missions or manned space probes.

"Electrodeless" plasma acceleration concept, e.g., helicon plasma thruster [1], can be a next generation plasma propulsion system, expected to overcome the above issue, since there are no electrodes, contacting directly with a plasma, in the plasma generation and acceleration stages. As an additional electrodeless plasma acceleration, we are proposing Rotating Magnetic Field (RMF) [2] plasma acceleration method [3], combining a helicon plasma source [4], under the Helicon Electrodeless Advanced Thruster (HEAT) project [5]. The RMF current drive method has been used successively in a magnetically confined plasma fusion research. Thus, this application to electric propulsion systems is an unprecedented and challenging study. Note that we are mainly conducting the proof of the principle of the RMF acceleration method at the present stage.

In the RMF acceleration scheme, an azimuthal electron current, j_θ can be induced by means of nonlinear effects, i.e., the Hall-term effect. An axial Lorentz force f_z can be generated in the presence of a radial component of an external divergent B-field source, B_r, leading to an axial electromagnetic plasma thrust.

Figure 1 shows a top view of our present experimental scheme, Large Mirror Device (LMD) with a developed two-dimensional (2D) scanning instrument. Two sets of opposing coils were used as RMF induction antennas. The rotating magnetic field B_{RMF} is induced by applying an ac current I_{RMF} to the coils with current phase difference ϕ between the two-set of them. Here, we measured spatiotemporal, three directional RMFs, which are oscillating with an RMF current frequency f_{RMF}, to investigate the RMF penetration condition into plasma [6], based on the Milroy's expression [7]. In addition, second harmonic components of B_{RMF} were obtained to deduce the time-varying azimuthal current density $\tilde{j}_\theta$ with twice of f_{RMF}. According to the theoretical current induction method, the amplitude of the $\tilde{j}_\theta$ is equivalent to that of j_θ. Hereby, we could estimate f_z value through a surface integral of the obtained j_θ. Dependences of $\tilde{j}_\theta$ on three ϕ values (-90, 0, and 90°) were also examined to clarify the RMF current induction method. Here, we demonstrated the electromagnetic acceleration effect employing the RMF method, by 2D spatial measurement. The detailed study will be provided in our presentation.

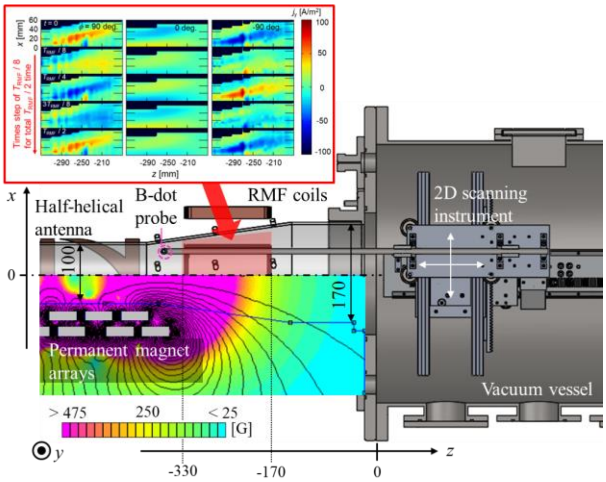

Fig. 1: Experimental scheme of RMF acceleration.

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