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Laboratory Experiment of Traveling Magnetic Field Acceleration Method for Electrodeless RF Plasma Thruster

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Abstract
Electric propulsion using electrical energy is employed for changing the trajectory of space crafts. The lifetime issue of space craft by contamination and failure of the electrode of electric propulsion has been known. Electrodeless plasma thruster which the electrode completely non-contacts to the plasma has capability of solving this problem. Particularly, Electrodeless RF (Radio Frequency) thruster is studied, which is one of typical electrodeless thrusters. The RF thruster consists of static magnetic coil and radio frequency system. Plasma is generated by RF discharge and accelerated by magnetic nozzle. However, the thrust efficiency accelerating plasma only by magnetic nozzle is less than 10% which is much lower than other practical use thruster of over 60%.
Some previous researches proposed and researched the additional acceleration method. For instance, it was reported that VASIMR engines utilizing Inductive Cyclotron Resonance (ICR) heating has achieved 72% of thrust efficiency with 200kW input power. Acceleration by REF (Rotating Electric Field) was proposed and achieved 2 mN with 2.1 kW input power with 260 s specific impulse(1). Enough performance for a space propulsion is still obtained only with high input power. On the other hand, it is reported that a thruster utilizing Travelling Magnetic Field (TMF) have 23% of thrust efficiency researched in 1965(2). RF magnetic field propagating to one direction is called the TMF. The TMF of high magnetic field strength confines the plasma (including ion and electron) and acts as a piston pushing the plasma downstream, consequently the plasma is accelerated to the velocity close to the traveling velocity of the TMF which is usually within the range 10^4 – 10^5 m/s. Recently, it is tried to apply lower input power of 300W to the thruster in Stanford university. In this method, however, there are deceleration phase in steady operation and high magnetic field is needed to confine the plasma.
As a solution for these problems, This paper describes a new additional electrodeless plasma acceleration method using a technology in nuclear fusion to achieve high performance(3). According to the research of Fukuda and Matsuura, they calculate the energy absorbed efficiency to electron from the TMF and estimated that the best phase velocity is nearly equal to thermal velocity of electron which is within the range 10^5– 10^6 m/s. schematic diagram of the new acceleration method is shown in Fig.1. The TMF propagating to the axial direction trap electrons which thermal velocity close to the phase velocity of the TMF. Electron slight slower than TMF get momentum from the TMF While faster electron give momentum to the TMF. Slower electrons are usually dominant so that electrons are accelerated as a whole. Consequently, ambipolar electric field is induced by the velocity difference between ion and accelerated electron, and ion is accelerated by this electric field.
In this method High efficiency of 65% has been expected from theoretical calculation. The TMF system has been constructed (Fig.2) as laboratory experiment model, where the model 7.57% is expected. It was observed that the effect of the TMF by photograph of plasma emission. We will discuss in Mach number to prove acceleration. Also, we will measure electron temperature and electron number density by Langmuir probe to investigate the plasma generation effect by TMF.

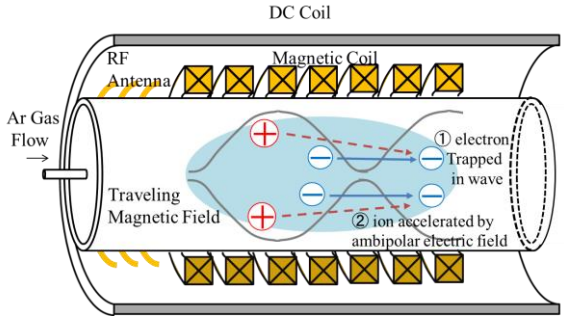

Fig.1 Schematic of electrodeless acceleration

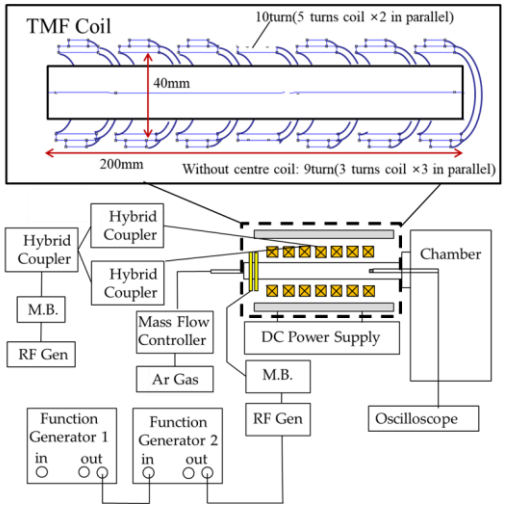

Fig.2 Experimental Setup.

References

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