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Experimental and numerical studies on the thrust generation for laser-fusion-powered spacecraft

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Many researches have been performed on inertial confinement fusion (ICF) such as implosion, plasma heating, hydrodynamic instability, and other advanced designs of fusion pellet. On the other hand, we have been studying the spacecraft propulsion system based on nuclear fusion, as one of the application of ICF technology. The interaction between high-temperature plasmas and magnetic field is observed in various physical phenomena, for example, in laboratory magnetic confinement fusion, fusion reactor wall, and laboratory experiments to study astrophysical phenomena such as collisionless shocks and magnetic reconnection [1-6]. Furthermore, the magnetic field can convert the plasma thermal energy to kinetic energy to generate thrust for space propulsion systems. This is one of the strong candidates as the thrust system of laser fusion rocket (LFR), in which a high-temperature fusion plasma is controlled by a magnetic field. We demonstrated this thrust generation experimentally by using high-power laser-produced plasma and pulse-powered strong magnetic field. In addition, numerical simulations have been developed to investigate quantitative thrust performance, energy-scaling, and the validity of the experimental results. The magnetic nozzle, which is used as a key component of this thrust system, can be modified and applied to control plasma flow.

This spacecraft concept has originally been proposed and investigated by researchers at Lawrence Livermore National Laboratory [7-8]. Previous numerical and theoretical works [9] have shown that LFR produces both large impulse and high specific impulse which are required for manned interplanetary spaceflight. We have estimated thrust performance such as momentum efficiency [10], the design for thruster, pellet, and propellant [11,12] by using hybrid PIC and hydrodynamic simulations.

We have recently performed experiments with laser-produced ablation plasmas to demonstrate the magnetic thrust chamber systems: development of strong magnetic field device [13], the direct measurement of an impulse [14], ion extraction [15], a diamagnetic cavity formation [16], observation of plasma deceleration which result in the thrust generation [17].

In this talk, we summarize previous numerical and experimental studies as well as recent experiments with high-power laser Gekko-XII at Osaka University. We also discuss future prospects of this fusion-powered spacecraft estimated from recent results.

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