Numerical Study of Ionization Structure and Shock Wave Propagation Toward Flight Performance Improvement of Beaming Propulsion

Report Number: R18EACA17
Subject Category: JSS2 Inter-University Research
URL: https://www.jss.jaxa.jp/en/ar/e2018/9096/

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Abstract

Technique to improve a thrust performance is proposed by reproducing electromagnetic wave propagation, discharge structure, and shock wave propagation structures inside a beaming propulsion vehicle.

Reasons for using JSS2

Utilization of JSS2 is required to reproduce a multiscale physics of the electromagnetic wave, plasma, and shock wave propagations because a computational cost is very large.

Achievements of the Year

A coupling calculation between the electromagnetic wave, plasma, and shock wave propagations was conducted by solving Maxwell's equation, reaction diffusion equation for an electron transport, and neutral gas dynamics equation. An interaction between the plasma and electromagnetic wave was captured, which reproduced the plasma propagation toward the electromagnetic wave source. A discrete plasma structure was formed because of a wave standing. A strong Joule heating was obtained at the plasma front, which generated a strong shock wave. A positive thrust was obtained because a positive pressure of the shock wave interacted with the thruster wall.

Publications

- Peer-reviewed papers

1) Masayuki Takahashi and Naofumi Ohnishi, "Gas Propellant Dependency of Plasma Structure and Thrust Performance of Microwave Rocket," Journal of Applied Physics (accepted).

2) Masayuki Takahashi and Naofumi Ohnishi, "Gas-Species-Dependence of Microwave Plasma Propagation under External Magnetic Field," Journal of Applied Physics, Vol. 124, 173301 (2018).

- Non peer-reviewed papers

1) Masayuki Takahashi and Naofumi Ohnishi, “Numerical Study for Flight Performance Improvement of Beamed-Energy Propulison,” Proceedings of 26th Space Sciences and Technology Conference, 2N16 (2018).

2) Masayuki Takahashi and Naofumi Ohnishi, “Numerical Study of Discharge and Thrust Generation in a Microwave Rocket,” AIAA Paper 2019-1242 (2019).

- Oral Presentations

1) Masayuki Takahashi and Naofumi Ohnishi, “Numerical Study for Flight Performance Improvement of Beamed-Energy Propulsion,” 26th Space Sciences and Technology Conference, Oct. 24-26, 2018, Kurume.

2) Masayuki Takahashi and Naofumi Ohnishi, “Numerical Study of Dishcarge and Thrust Generation in a Microwave Rocket,” AIAA Science and Technology Forum 2019, Jan. 7-11, 2019, San Diego, USA.

3) Masayuki Takahashi, Manabu Myokan, Akiya Kubota, Francesca Gnani, Henny Bottini, Akira Iwakawa, Naofumi Ohnishi, and Akihiro Sasoh, “Flow Separation Control and Lift-to-Drag Ratio Improvement Using Repetitive Laser Pulses,” Plasma Application and Hybrid Functionally Materials 2019, March 8-11, 2019, Naha.

- Poster Presentations

1) Masayuki Takahashi and Naofumi Ohnishi, “Numerical Study of Millimeter-Wave Discharge and Application to Launching System for Small Satellites,” 43rd International Conference on Infrared, Millimeter and Terahertz Waves, Sep. 9-14, 2018, Nagoya.

2) Masayuki Takahashi and Naofumi Ohnishi, “Fluid Modeling of Microwave Plasma Under an External Magnetic Field,” APS Gaseous Electronics Conference 2018, Nov. 5-9, 2018, Portland, USA.

3) Masayuki Takahashi and Naofumi Ohnishi, “Propellant Species Dependence of Plasma and Shock Wave Structures in a Microwave Rocket,” 2nd Asia-Pacific Conference on Plasma Physics, Nov. 12-17, 2018, Kanazawa.

Usage of JSS2

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	2 - 100
Elapsed Time per Case	20 Hour (s)

Resources Used

Fraction of Usage in Total Resources[*1] (%): 0.11

Details

Computational Resources		
System Name	Amount of Core Time (core x hours)	Fraction of Usage*2 (%)
SORA-MA	956,242.16	0.12
SORA-PP	0.00	0.00
SORA-LM	0.00	0.00
SORA-TPP	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2 (%)
/home	476.84	0.49
/data	9,765.63	0.17
/ltmp	1,953.13	0.17

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	0.00	0.00

*1: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

*2: Fraction of Usage: Percentage of usage relative to each resource used in one year.