Evaluation of Coaxial Short-pulse Laser-assisted Pulsed Plasma Thruster

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Keisuke Sato, Tosikai Oi, Hideyuki Horisawa
Department of Aeronautics and Astronautics, Tokai University

Abstract: An objective of this study is to improve the thrust performance of a laser-assisted pulsed plasma thruster. In this study, to verify the thrust performance of laser-assisted pulsed plasma thruster in ablation with low laser energy of 50 mJ and 100 mJ and establish for the optimum operate condition, an impulse bit measurement and mass shot measurement were conducted. To estimate the thrust performance of a short-pulse laser-assisted pulsed plasma thruster, impulse bit measurement and mass shot measurement were conducted. Form the results, Measured impulse bit increased to linearly in all case of laser energy. Measured mass shots were 1.39 to 1.89 μg/shot assuming the origin of the mass flow is only from the propellant. Mass shot increased with discharge voltage with the increase of laser energy, although the increase of charge energies was less effective.

1. Background

1.1 What is LA-PPT

Laser Propulsion + **Pulsed Plasma Thruster**

Laser-Assisted Pulsed Plasma Thruster

- Simple and compact systems
- Various materials can be used for propellant
- Significant thrust controllability
- High Isp or Thrust characteristics

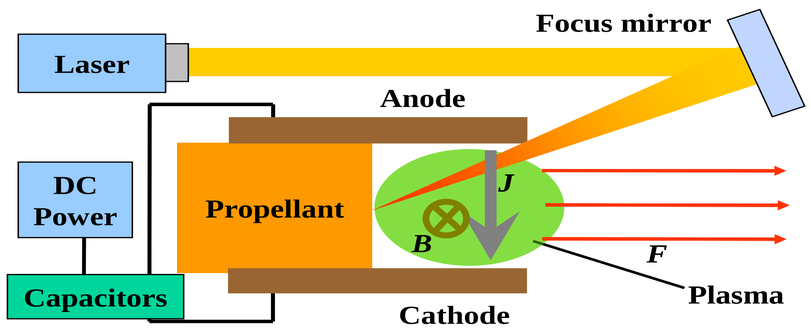


Fig 1. Laser-Assisted Pulsed Plasma Thrsuter

1. **Laser beam irradiated on solid propellant**
2. **Plasma accelerated through laser ablation**
3. **Electric discharge current flows through Plasma**
4. **Magnetic field induced by discharge current**
5. **Plasma accelerated by Lorenz Force**

1.2 Research motivation

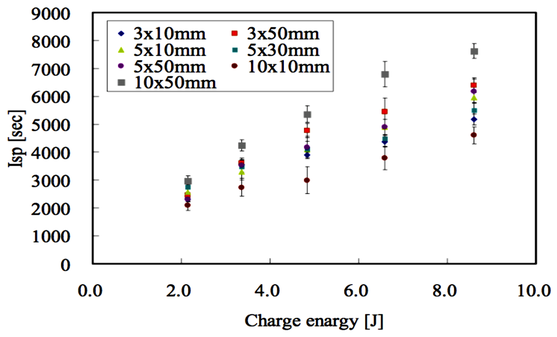


Fig 2. Variation of specific impulse with charge energy

Previous report

-Specific impulse increase with charge energy
-The highest specific impulse of 7200

◆Performance of Short pulse cases ⇒ **?**

Objecetiv

1. To confirm advantages of high-voltage operation
2. To confirm high-peak power operation & to reduce thermal loss to thruster

➡ **Examination of high-voltage, short-pulse operation**

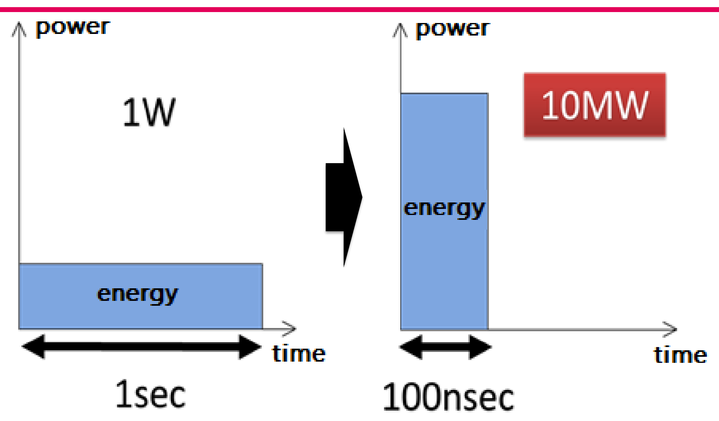
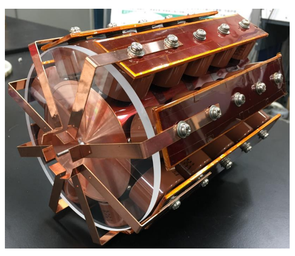


Fig 3. Effect of Short pulse operation

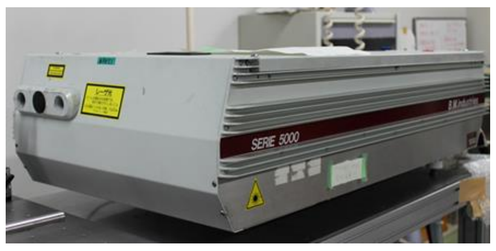
2. Experimental setup

2.1 Experimental device



Channel length	5mm
Channel width	10mm
Channel gap	15mm
Electrode material	Cu
Cathode rod diameter	3m
Cathode rod material	Mo
Propellant material	Al2O3
Body	Al2O3

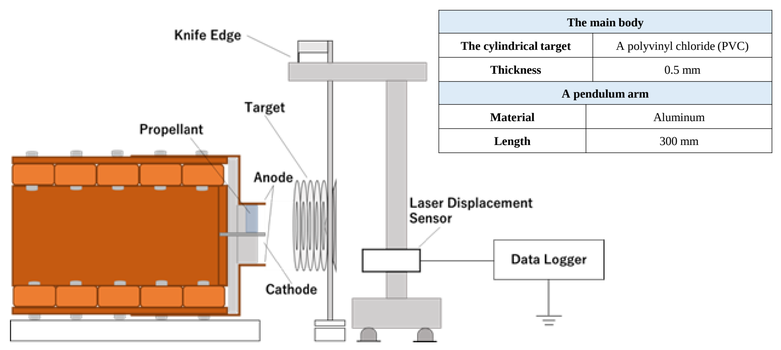
Fig 4. Short-pulse laser Assisted Pulsed Plasma Thruster



Wave length	1064 nm
Pulse width	5 ns
Pulse energy	400 mj

Fig 5. Nd Yag laser

2.2 Impulse bit measurement



The main body	
The cylindrical target	A polyvinyl chloride (PVC)
Thickness	0.5 mm
A pendulum arm	
Material	Aluminum
Length	300 mm

Fig 6. Schematic of an impulse bit measurement system

To measure an impulse bit of a short-pulse LA-PPT, the impulse bit measurement was conducted using a cylindrical target thrust stand shown schematically.

2.3 Mass shot measurement

Fig 7. KEYENCE VK-X200

To the mass shot measurement, the amount of mass loss was calculated using a confocal laser microscope (KEYENCE,VK-X200). A typical number of pulse shots for the measurement was 2000.

3. Result

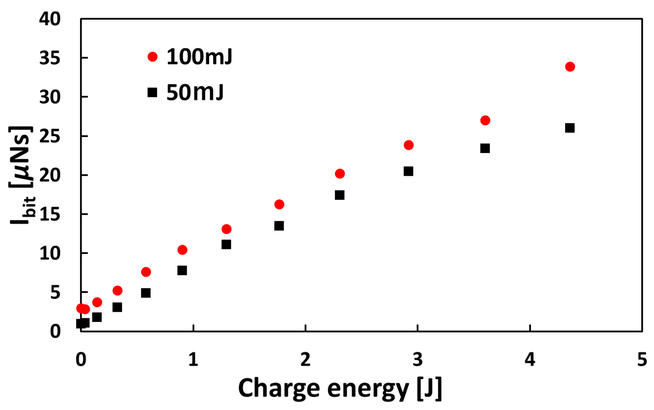


Figure 8 Impulse bit measurement

Figure 9. Acquired wave from impulse bit measurement(as an example)

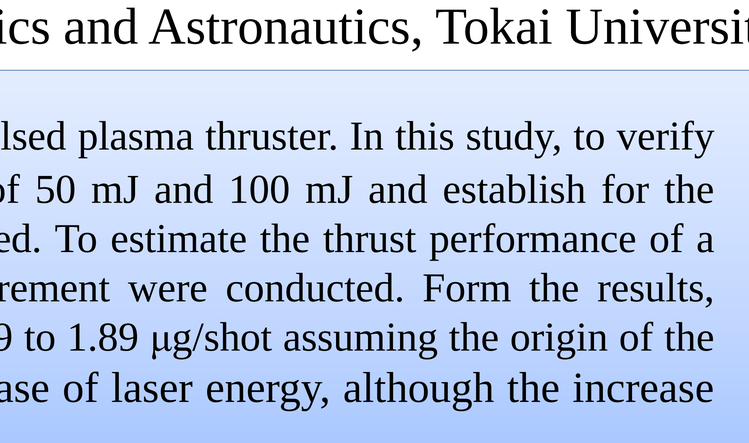


Figure 10. Mass shot measurement result (propellant only)

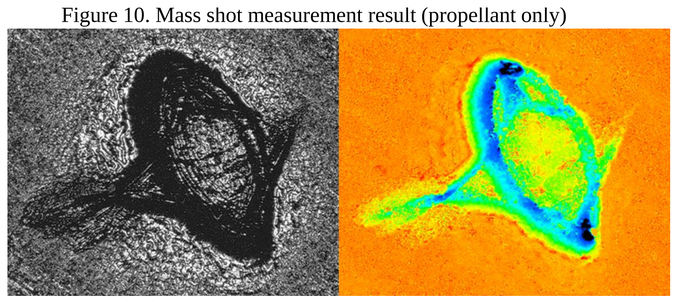


Figure 11. Crater image (laser light intensity / height)

Impulse bit measurement

- The increase of both laser energies and charge energies is effective in augmenting the impulse bit.
- The increase of laser energies is more effective than that of charge energies in increasing impulse bits.

Mass shot measurement

- The mass shots of propellant (except those of electrodes) vary from 1.39 ~ 1.89 μg/shot.
- Larger the laser energy, the more mass shot.
- Mass shot decrease with increasing charging energy.

4. Conclusion

In this study, to verify the thrust performance of laser-assisted pulsed plasma thruster in ablation with low laser energy of 50 mJ and 100 mJ and establish for the optimum operate condition, an impulse bit measurement and mass shot measurement were conducted.

- Measured impulse bit for laser energies of 50 mJ and charge voltage of 11 kV were 33.9 μNs to the maximum.
- Impulse bit increased to linearly in all case of laser energy.
- Measured mass shots were 1.39 to 1.89 μg/shot assuming the origin of the mass flow is only from the propellant.
- Larger the laser energy, the more mass shot.
- Mass shot decrease with increasing charging energy.