



# Plasma dynamics of 1 kHz repetitive laser ion source

Kazuki Igarashi, Momoka Iwasa, Kazumasa Takahashi, Toru Sasaki, Takashi Kikuchi  
Nagaoka University of Technology, Japan

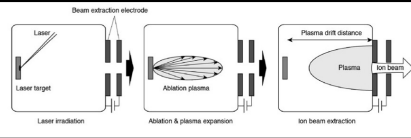


## Introduction

### Repetitive laser ion source

#### Laser ion source<sup>[1]</sup>

Compared to conventional ion sources, the plasma density is high. Therefore, high current ion beams can be easily generated.



#### Repetitive operation

#### Application

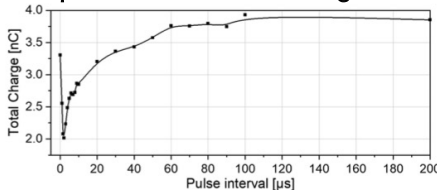
- Ion implantation<sup>[2]</sup>
- Spot scanning for medical accelerator<sup>[3]</sup>

#### Requirement

- High dose<sup>[4]</sup>
- High repetitive operation<sup>[5]</sup>

### Issues of repetitive operation using laser ion source

#### Interaction between the generated plasmas lowers total charge. <sup>[4]</sup>



#### Obstruction of ion transport by particles remaining in a chamber.

It is necessary to measure the ablation plasma generated by the repetitive operation of a laser.

## Purpose

Study on the effect of a high repetition rate operation of a repetitive laser ion source on ion production

- ▶ Generation of ablation plasmas with a 1 kHz repetitive laser
- ▶ Simultaneous measurement of impulse, ion current density, and drift velocity
  - Impulse: Pressure sensor
  - Ion current density: Faraday cup
  - Drift velocity: TOF measured with a Faraday cup
- ▶ Estimation of ion production efficiency

## Experimental setup

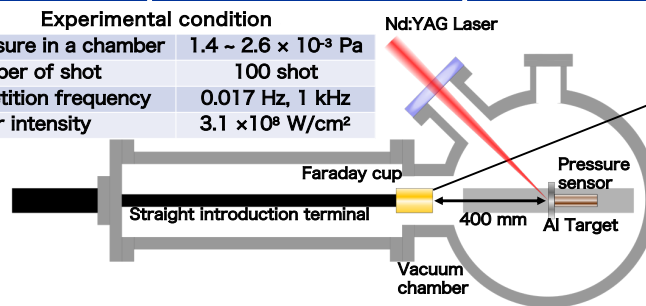
Ablation plasma of Al is generated using a high repetition rate Nd:YAG Laser.

Time-resolved measurement of an impulse  $I$ , ion current density  $J_i$ , and drift velocity  $v_d$

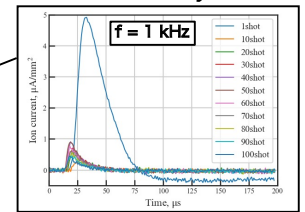
- Ablation mass:  $m_a$
- Number of ions:  $N_i$
- Number of all particles:  $N_{all}$
- Ionization efficiency:  $\eta_i$

#### Experimental condition

Pressure in a chamber	$1.4 \sim 2.6 \times 10^{-3}$ Pa
Number of shot	100 shot
Repetition frequency	0.017 Hz, 1 kHz
Laser intensity	$3.1 \times 10^8$ W/cm <sup>2</sup>



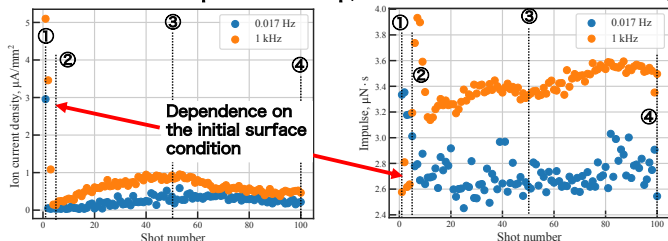
#### Ion current density with TOF



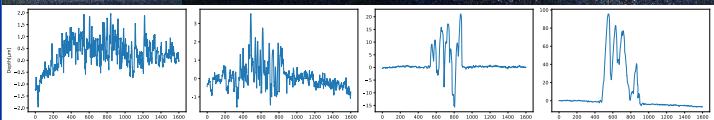
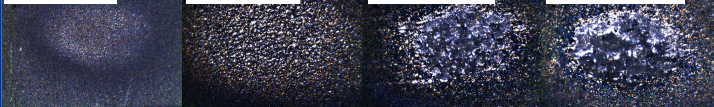
- Peak values of ion current density
- Drift velocity

## Results and Discussion

### Dependence of ion current density and impulse on shot number and repetition freq., surface condition of Al target

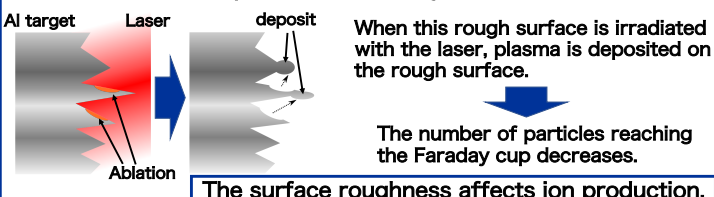


① 1st shot ② 5th shot ③ 50th shot ④ 100th shot



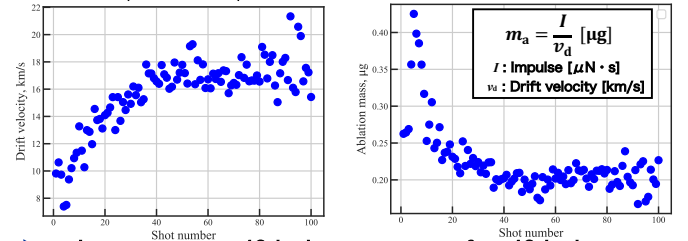
▶ For the repetitive operation from 0.017 Hz to 1 kHz, ion current and impulse are similar trend of repetition frequency.

▶ The surface becomes rougher and rougher with each shot, and the raised area is up to about 90 μm by 100th shot.



The surface roughness affects ion production.

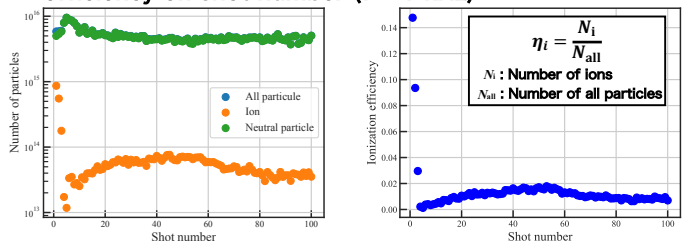
### Dependence of drift velocity and ablation mass on shot number ( $f = 1$ kHz)



- ▶  $v_d$  increases up to 40th shot, saturates after 40th shot.
- ▶  $m_a$  decreases up to 40th shot, remains constant after 40th shot.

The dependence of the ablation mass and drift velocity changed after the 40th shot. This may be due to the difference in surface composition and influence of the surface condition during laser irradiation.

### Dependence of number of particles and ionization efficiency on shot number ( $f = 1$ kHz)



- ▶ The generated plasma is composed of nearly neutral particle.
- ▶ 1~4 shot: Rapid decrease, 4~100 shot: Maximum at 58 shot

The dependence on the surface condition, the ionization efficiency decreases with irradiation to the same point.

## Conclusion

- ▶ Until repetition frequency of 1 kHz, there is no effect of repetitive operation of the laser ion source.
- ▶ Repetitive operation of the laser ion source roughen the target surface.
- ▶ The mass and number of particles ejected from the Al target are affected by the surface roughness.
- ▶ Ionization efficiency is almost constant 2 %.