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ScienceDirect

Energy Procedia 131 (2017) 354–358

Energy Procedia

www.elsevier.com/locate/procedia

5th International Symposium on Innovative Nuclear Energy Systems, INES-5, 31 October – 2 November, 2016, Ookayama Campus, Tokyo Institute of Technology, JAPAN

# Behavior of Laser Ablation Plasma During Transport in Multicusp Magnetic Field Using Different Targets for Laser Ion Source

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**Abstract**

To obtain laser ion sources with high current and long pulse, a method of applying multicusp magnetic fields to confine laser ablation plasmas has been proposed. The behaviors of the laser ablation plasmas during transporting in the multicusp magnetic fields are investigated by experiments using two types of multicusp magnetic field and the targets of aluminum, copper, and lead. To understand the behavior of the ablation plasma, numerical calculations for ion trajectory were also performed. The results indicate that the distance which a plasma proceeds until the appearance of the effect of the magnetic field on the plasma behavior at the center axis could be explained by ion motions affected by the azimuthal magnetic field.


Peer-review under responsibility of the organizing committee of the 5th International Symposium on Innovative Nuclear Energy Systems.

*Keywords:* Laser ion source, Ablation plasma, Multicusp magnetic field, Heavy ion inertial fusion

## 1. Introduction

Laser ion sources (LIS) have been expected to be used for a driver of heavy ion inertial fusion (HIF) [1] and high energy density physics [2,3] because of their capability of supplying high current ion beams. A pulsed ion beam is

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Peer-review under responsibility of the organizing committee of the 5th International Symposium on Innovative Nuclear Energy Systems.
10.1016/j.egypro.2017.09.467

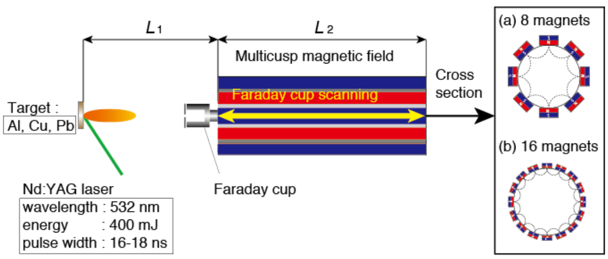


Fig. 1. Schematic of experimental setup and cross section of the multicusp magnets.

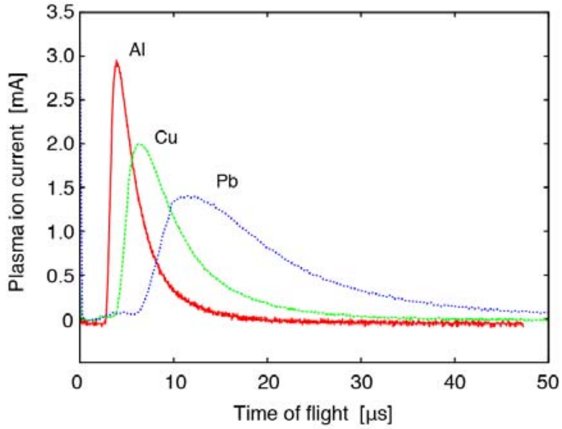


Fig. 2. Ion current waveforms measured at 220 mm from the laser target for Al, Cu, Pb without the magnetic fields.

Table 1. Configurations of multicusp magnetic field for experiments.

| Type of magnetic field | (a) Small multicusp field | (b) Large multicusp field |
|---|---|---|
| Number of magnetic cusp | 8 | 16 |
| Distance between target and magnetic field $L_1$ [mm] | 250 | 220 |
| Length of magnetic field $L_2$ [mm] | 300 | 900 |
| Drift tube inner diameter $D$ [mm] | 54 | 108 |

generated using a pulsed laser and the pulse width can be controlled by changing the drift distance of the ablation plasma between a laser target and an extraction electrode in the LIS. However, the ion current density decreases with extending drift distance due to the plasma expansion. To transport the plasma for a long distance keeping high ion density, various magnetic guiding of the ablation plasma have been investigated [4-6], which shows that some guiding methods give ion current waveforms fluctuation. To obtain stable confinement of the plasma, we have proposed plasma guiding with a multicusp magnetic field [7]. The results showed that ion current of ablation plasmas generated from a copper target increase in the multicusp magnetic field. However, the increase of ion current does not start at the position of the injection into the magnetic field. To understand why plasma needs to proceed some distance until the density enhancement starts, we investigated the behavior of plasmas transported in the magnetic field for various materials such as aluminum (Al), copper (Cu), and lead (Pb) using two types of multicusp magnetic field. The results were compared to calculations of ion trajectories in the magnetic field.

## 2. Experimental setup

The experimental setup is shown in Fig. 1. A Nd:YAG laser ($4\times10^2$ mJ/16-18 ns) with a wavelength of 532 nm was used for generation of ablation plasmas. The laser spot area was set to be 0.12 $cm^2$ and the power density on a target was estimated to be $10^8$ W/$cm^2$. The laser intensity produces singly ionized ions dominant plasmas [8]. Neodymium magnets were arranged around a drift tube for generating the multicusp magnetic field. The magnetic flux density of magnets is 0.2 Tesla on the surface. A Faraday cup biased at -60 V was used to measure the ion current of ablation plasmas and the aperture diameters of 0.5 and 1.0 mm were used for experiments for small and large multicusp magnetic field, respectively. The Faraday cup can be moved along center axis of the drift tube to measure the ion current as a function of the plasma drift distance. The pressure in chamber was kept at order of $10^{-4}$ Pa. Plates of Al, Cu, and Pb were used as laser targets to compare the behavior of ablation plasmas transported in magnetic field. The experiments were performed using two types of multicusp magnetic field configurations, which are indicated in Table 1.