LIS IN LOW POWER DENSITY FOR RHIC-EBIS*

Kotaro Kondo†, Brookhaven National Laboratory, Upton, NY 11973, USA;
RIKEN, Saitama, 351-0198, Japan
Takeshi Kanesue, Kyushu University, Fukuoka 819-0395, Japan
Robert Dabrowski, City College of New York, NY 10031, USA
Masahiro Okamura, Brookhaven National Laboratory, Upton, NY 11973, USA

Abstract

The Electron Beam Ion Source (EBIS) project at Brookhaven National Laboratory is a new heavy ion pre-injector for Relativistic Heavy Ion Collider (RHIC) and NASA Space Radiation Laboratory science programs. Laser Ion Source (LIS), which can supply many heavy ion species using solid targets, is a candidate of a primary ion source provider for RHIC-EBIS. LIS experiment with 5 Hz operation, which is required practically in RHIC-EBIS, was demonstrated to understand the beam property for long operation time. High laser power density decayed the peak current and ion yield with operation time and did not keep the surface of target flat. On the contrary, the beam in low laser power density kept the performance in long operation time.

INTRODUCTION

The Electron Beam Ion Source (EBIS) project at Brookhaven National Laboratory progresses in the place of Tandem Van de Graaff accelerators as the heavy ion pre-injector for Relativistic Heavy Ion Collider (RHIC) and NASA Space Radiation Laboratory (NSRL) science programs[1, 2]. It is demanded to supply beams with different ion species to multiple users for 4 ∼ 6 months.

Laser Ion Source (LIS) has a powerful potential as a primary ion source provider for RHIC-EBIS because low charge state, low emittance and high ion yield with defocused Nd: YAG laser were shown[3], and the design study with solenoid was reported[4].

Practically, 5 Hz operation in RHIC-EBIS for several months is required, however, there are little information of LIS in long time operation. We investigated beam property and target consumption for the laser power density with 5 Hz repetition rate in 1 hour operation.

EXPERIMENTAL SETUP

Figure 1 shows a picture of the experimental setup with long laser path. In this experiment, an aluminum target (45 mm × 45 mm with 1 mm thickness) in the vacuum chamber was irradiated by a Nd: YAG laser at 1064 nm with 7 ns pulse length. The partially defocused laser by a convex mirror (f = 2500 mm) generated 6 mm spot size on Al target and a incident angle between laser path and beam line was 30°. It is desirable that the location of the optics (window) in LIS is far from the vacuum target chamber to keep from damage by laser ablation. In this experiment, the laser path from window to vacuum chamber was about 2 m as shown in Figure 1.

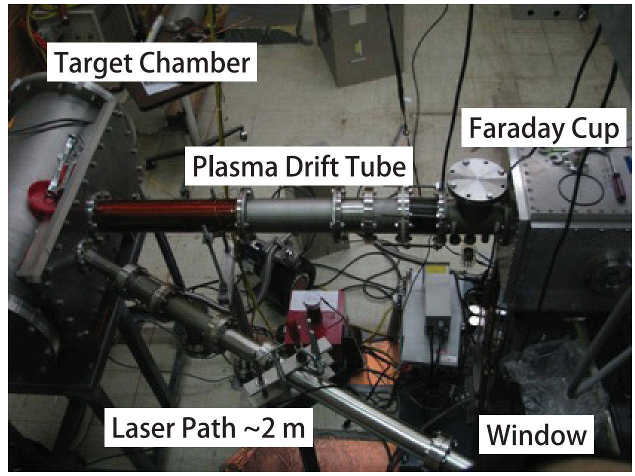

Figure 1: LIS experimental setup with long laser path between window and Al target.

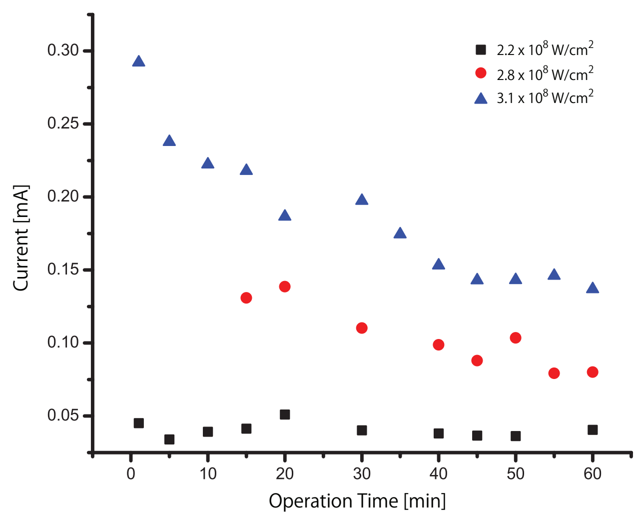

Figure 2: Beam current vs operation time for 3 types of laser power density with 5 Hz repetition ratio.

We had 3 different conditions of laser power density: 2.2×10^8, 2.8×10^8, and 3.1×10^8 W/cm^2 for this experiment. We can assume that all supplied ions were singly charged in the laser power density based on previous

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† kkondo@bnl.gov

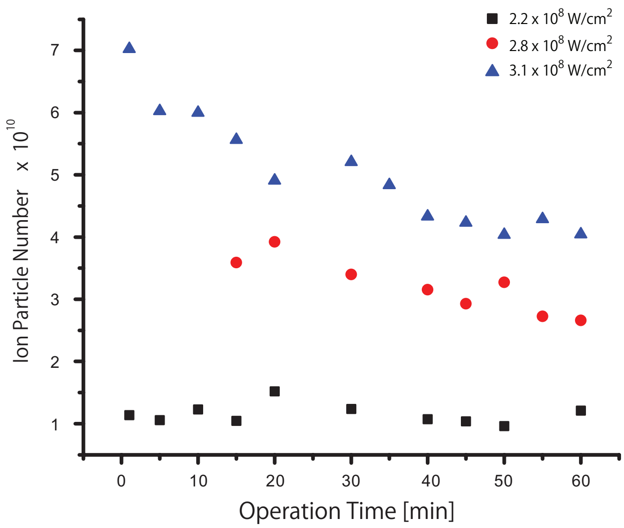


Figure 3: Number of particles vs operation time for 3 types of laser power density with 5 Hz repetition ratio.

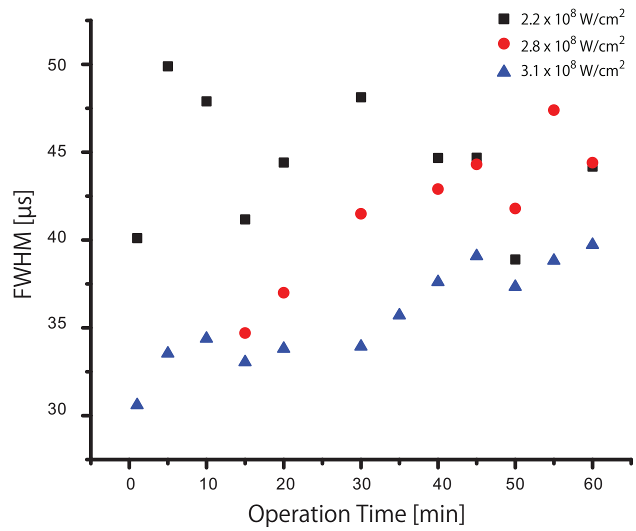


Figure 4: FWHM vs operation time for 3 types of laser power density with 5 Hz repetition ratio.

experiment[5].

Faraday Cup (FC) with 5 mm aperture was located at 1.95 m from the Al solid target to measure the beam current. The suppressor voltage of FC was controlled from 1.5 to 5.3 kV for avoiding a discharge inside FC. In the voltage region, there was no change of the FC signal.

RESULTS AND DISCUSSION

Beam Current and Ion Number

A relation ship between beam current at FC and the operation time, for laser power density is shown in Figure 2. In high power density of 3.1×10^{8} W/cm^2, beam current was significantly reduced by 50 % with operation time. The decay of beam current were also observed in 2.8×10^{8} W/cm^2. On the other hand, the beam current kept constant over 1 hour operation in the low power density of 2.2×10^{8} W/cm^2.

As well as beam current, the ion particle number per 1 laser shot with operation time is shown in Figure 3. The behavior is similar to Figure 2. These experimental results show that low laser power density condition is suitable for supplying constant beam property.

Beam Pulse Width

Figure 4 represents Full Width at Half Maximum (FWHM) of the beam with the operation time. Although the FWHMs of initial operation were shorter length in 2.8×10^8 and 3.1×10^8 W/cm^2, they became wider with the operation time.

In low power density of 2.2×10^8 W/cm^2, the FHWM seems to keep constant. As well as beam current and total ion number, FWHM in low power density condition is steady for the long operation.

Consumption Target

The weight of Al target for each laser power density was measured before and after the experiment with 1 hour oepration. Total plasma particle number, which corresponds to the consumption weight, for the laser power density is shown in Figure 5. These results show that the consumption amount is increasing with the laser power density.

Target Condition

Al target surfaces in 2.2×10^8 and 3.1×10^8 W/cm^2 are shown in Figure 6. The surface in high power density is rougher than that in low power density where beam property can keep constant for long operation. The surface condition make ablation plasma condition different, that causes

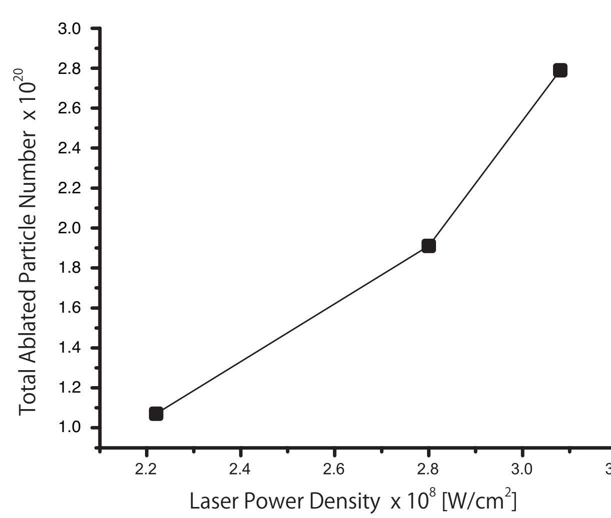
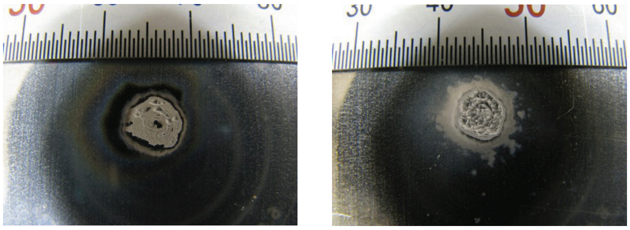


Figure 5: Ablated particle number in 1 hour operation vs laser power density.



(a) 2.2×10^8 W/cm^2 (b) 3.1×10^8 W/cm^2

Figure 6: Al surface conditions after 1 hour operation with 5 Hz.

the change of beam property such as current, ion number and FWHM.

CONCLUSION

We investigated beam property of laser ion source under 5 Hz laser irradiation in 1 hour. The peak current and ion particle number in high power density were decreased with the operation time. Pulse length (FWHM) in high power density became wider with the long operation. After the experiment, there were many bubbles on Al surface especially in high laser power density. These experimental results show the ablation plasma profile is sensitive to the surface condition. Laser power density is as low as possible, that is significant for RHIC-EBIS.

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