Interaction of plasmas in laser ion source with double laser system†

Y. Fuwa,[*1,*2] S. Ikeda, [*1,*3] M. Kumaki, [*1,*4] M. Sekine, [*1,*5] D. Cinquegrani,[*6] M. Romanelli,[*7] T. Kanesue,[*8] M. Okamura,[*8] and Y. Iwashita[*9]

A laser ion source can provide intense and low-emittance pulsed ion beams. For these advantages, various applications have been studied, such as DPIS (Direct Plasma Injection Scheme) to RFQ (Radio Frequency Quadrupole) Linac[1)] and a seed-ion beam provider for the EBIS (Electron Beam Ion Source) at BNL (Brookhaven National Laboratory)[2), 3)]. The laser ion source functions on a simple principle. Figure 1 shows the schematic layout of a laser ion source. Laser irradiation with an energy density above the target's ablation threshold generates plasma. This plasma drifts to an extracting electrode and an ion beam is formed. A change in the laser power density on the target can adjust the produced ions' charge states and the expanding velocity of plasma.

In conventional laser ion sources, a nano-second laser has been used. With single nano-second laser irradiation, thermal mechanisms are the dominant processes in plasma production and it results in a Maxwellian ion energy distribution. Since the plasma expands in three dimensions in the drift region from the target to the extracting electrode, an ion beam pulse width is proportional to the drift length L, and the peak ion beam current is inversely proportional to L^{-3}. Therefore, if we need a longer beam pulse width, the total peak current is steeply decreased.

A multi-pulse laser system may be used to elongate the ion beam pulse length or to intensify the beam current. To test the feasibility of these ideas, a double-pulse laser system was used in BNL.

Previous research showed that a multiple laser shot scheme is useful in extending the ion beam pulse length for a low-charge state mode. However, if the interval between the two laser is less than 10 μs, the observed current profile is not just sum of two laser plasmas[4)]. In this research, we carried out a more detailed study for the case in which the interval between laser pulses was less than 10 μs, in order to understand this phenomenon.

In our experiment, each laser energy on the target was 560 mJ at maximum and the laser spot was an ellipse of height 3 mm and width 4 mm. The estimated laser power density of each laser shot was between 10^8 and 10^9 W/cm^2,

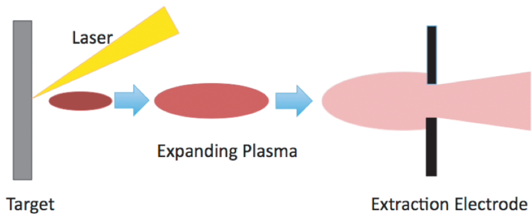

Fig. 1. Schematic layout of a laser ion source

and the induced charge states of ions were mostly single.

Ion current was measured using a Faraday cup. Two lasers were operated with various intervals of trigger timing range from 0.1 μs to 10 μs. In the measured current profile, a prominent peak that does not correspond to any single laser's current profile was observed. Figure 2 shows a typical result. This peak had a maximum peak current for the laser interval from 1 μs to 1.5 μs and the peak height was multiplied five times. This peak appears to have formed owing to the interaction between the second laser and the neutral vapor or particles produced by the first laser.

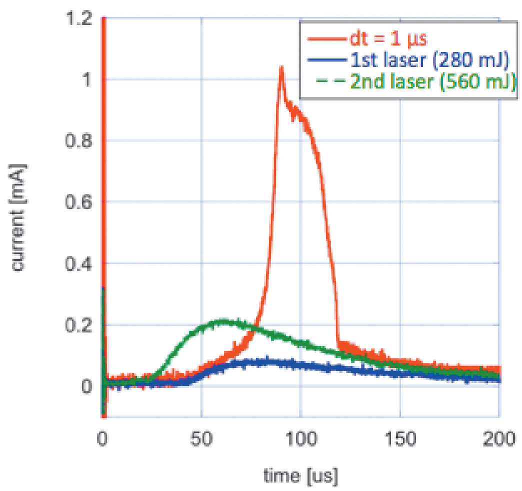

Fig. 2. Comparison of the measured ion current profile between single-laser plasma (blue and green plots) and double-laser (red plots).

References
1) M. Okamura et al.: Rev. Sci. Instrum. **79**, 02B314 (2008).
2) J. G. Alessi et al.: Rev. Sci. Instrum. **81**, 02A509 (2010).
3) K. Kondo et al.: Rev. Sci. Instrum. **81**, 02B716 (2010).
4) M. Okamura et al.: Rev. Sci. Instrum. **83**, 02B308 (2012).

† Condensed from the article in Rev. Sci. Instrum. **85**, 02B916 (2014).
*1 RIKEN Nishina Center
*2 Graduate School of Science, Kyoto University
*3 Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology
*4 Research Institute for Science and Engineering, Waseda University
*5 Department of Nuclear Engineering, Tokyo Institute of Technology
*6 Nuclear Engineering and Radiological Science, University of Michigan
*7 School of Applied and Engineering Physics, Cornell University
*8 Collider-Accelerator Department, Brookhaven National Laboratory
*9 Institute for Chemical Research, Kyoto University