



BNL-93645-2010-CP

Angular distribution of laser ablation plasma

Kotaro Kondo

**Brookhaven National Laboratory, Upton, NY 11973 USA
RIKEN, Saitama, 351-0198, JAPAN**

Takeshi Kaneshue

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

Presented at the First International Particle Accelerator Conference (IPAC'10)
Kyoto, Japan
May 23-28, 2010

Collider-Accelerator Department

Brookhaven National Laboratory

P.O. Box 5000
Upton, NY 11973-5000
www.bnl.gov

Notice: This manuscript has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. Department of Energy. The publisher by accepting the manuscript for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

This preprint is intended for publication in a journal or proceedings. Since changes may be made before publication, it may not be cited or reproduced without the author's permission.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Angular distribution of laser ablation plasma*

Kotaro Kondo[†], Brookhaven National Laboratory, Upton, NY 11973, USA; RIKEN, Saitama, 351-0198, JAPAN
Takeshi Kanetsue, 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

An expansion of a laser induced plasma is fundamental and important phenomena in a laser ion source. To understand the expanding direction, an array of Langmuir probes were employed. The chosen ion for the experiment was Ag^{1+} which was created by a second harmonics of a Nd-YAG laser. The obtained angular distribution was about ± 10 degree. This result also indicates a proper positioning of a solenoid magnet which enhances ion beam current.

INTRODUCTION

A laser ion source (LIS) is the powerful ion source which enables us to utilize high current high charge state heavy ions. In spite of this, it has been difficult to control ion pulse duration since the pulse duration can only be adjusted by changing a distance between the laser target and the ion beam extraction point, called plasma drift length. If the plasma drift length is varied, the ion current density at the extraction point is also changed drastically and the optimum extraction condition cannot be preserved. Recently we developed a new technique to control the ion pulse duration by using a solenoidal field. An axial magnetic field traps an expanding plasma from a laser ablation and an ion current density can be adjusted with the various plasma drift length. Thus the ion pulse duration can be changed to meet demands[1]. However the solenoid scheme introduced a new issue. Historically, in a laser ion source, the only center part of the expanding plasma was used as an ion beam. On the other hand, by applying a solenoid field, we can correct the diverging expanding plasma more efficiently. The characteristics of the off centered plasma became more important. Then the angular distribution of a laser ablated plasma was investigated. Figure 1 shows a geometric acceptance of a solenoid magnet installed in a typical setup of direct plasma injection scheme.

EXPERIMENTAL APPARATUS

Ion beam and laser condition

As a laser target material, silver was used since it is relatively easier to produce stable laser plasmas. To simplify the experiment, single charge state ions were created by choosing a low laser power density on a target. Figure 2 shows a foot print of the multiple laser shots on the pure

*This work was partially supported by the U.S. Department of Energy and the National Aeronautics and Space Administration.

[†]kkondo@bnl.gov

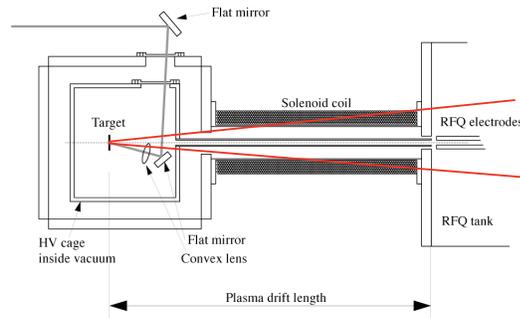


Figure 1: Solenoid with DPIS.

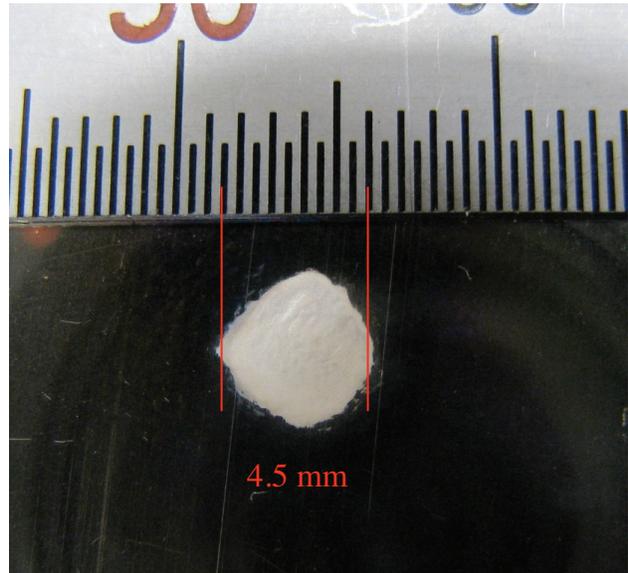


Figure 2: Silver plate used as target.

silver plate. The laser spot diameter was measured as 4.5 mm. The used laser was Nd-YAG laser with a second harmonics crystal (wave length : 532 nm) with 416 mJ of laser power. The laser pulse duration was measured as 6.1 ns as indicated in Figure 3. The estimated laser power density was $4.3 \times 10^8 \text{ W/cm}^2$. At this laser power density, most of all the ions are expected to be singly charged[2].

Detectors

Eleven Langmuir probes were used to detect the ion currents in the expanding plasmas. Each sensing area has a round shape and its diameter was 3.33 mm. The probes were biased at 50 V and the measured signals were within

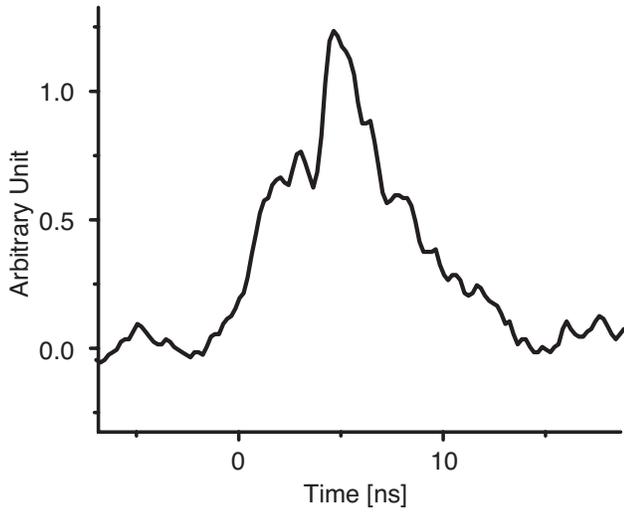


Figure 3: Laser pulse profile.

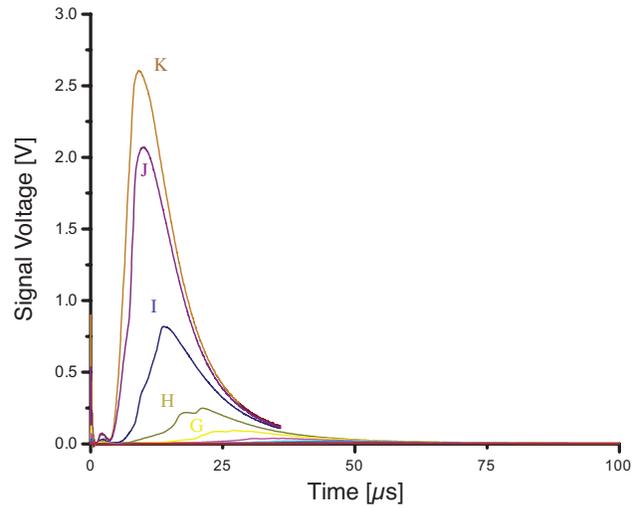


Figure 5: Current distribution in linear scale.

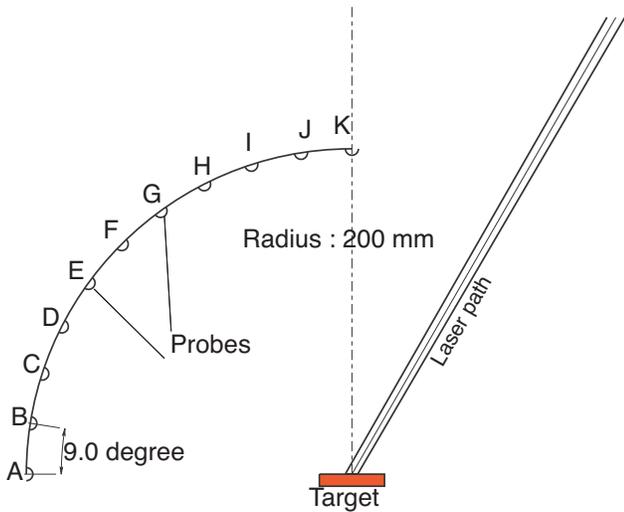


Figure 4: Probe layout.

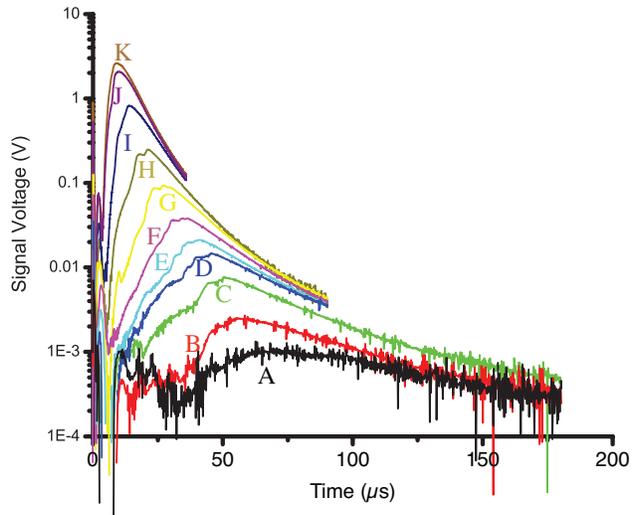


Figure 6: Current distribution in log scale.

ion saturation region. The array was installed horizontally and each detector position was at every 9 degrees as explained in figure 4. The incident angle of the laser path was 30 degrees respect to the normal to the target surface.

RESULTS

The induced voltages at a 50Ω terminating register are shown in figures 5 and 6. The both graphs are the identical but the vertical scales were different, linear and logarithm. 1 V reading corresponds to 230 mA/cm^2 . At the position "K", the normal position, the maximum current was observed as expected. At the angle of more than 30 degrees, the current was significantly reduced. In the horizontal scales, the laser lights were used as trigger signal at $t = 0$. The plasma expansion velocity is slower at deeper angle position.

Figure 6 indicates higher energy ions have sharper di-

rectivity. Figure 7 shows the directivity of the plasma expansion. The each point represents the peak value of the recorded current. To maximize the ion capturing efficiency, $\pm 10 \sim 15$ degrees of the acceptance seems reasonable.

ACCEPTANCE OF SOLENOID

The current enhancement by a solenoid is severely affected by the positioning of the solenoid[3]. For instance, as shown in Figure 8, to determine a position of a solenoid which has 75 mm of the inner diameter, it may installed at 213 mm from the laser target to have ± 10 degrees acceptance (140 mm for 15 degree).

CONCLUSION

Using Ag^{1+} plasma, angular distribution was measured by an array of Langmuir probes. The ion dense angle is $\pm 10 \sim 15$ degrees. A solenoid for current enhancement

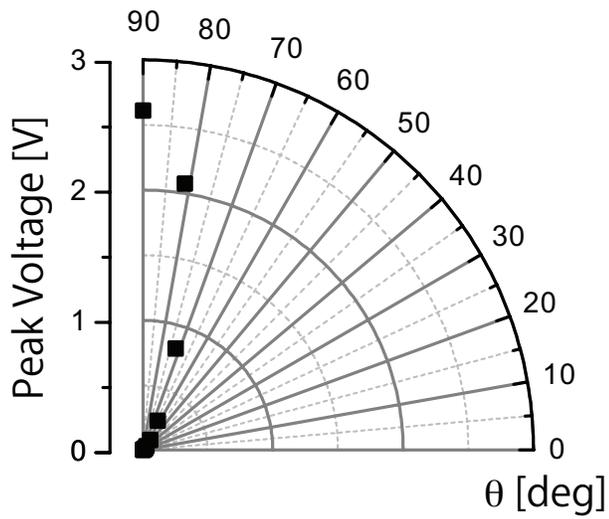


Figure 7: Directivity of plasma expansion.

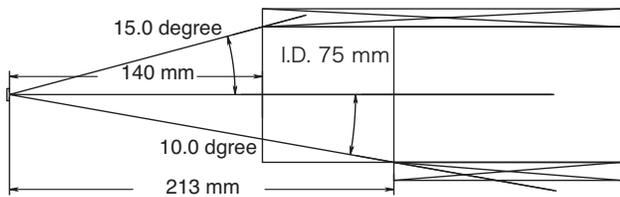


Figure 8: Solenoid positioning.

can be positioned to accept the dense part of the expanding plasma. Ion beam extraction and acceleration with the DPIS will be tested near future to confirm the obtained results.

REFERENCES

- [1] M. Okamura, A. Adeyemi, T. Kanesue, J. Tamura, K. Kondo and R. Dabrowski, *Review of Scientific Instruments*, **81**, 02A510 (2010).
- [2] T. Kanesue, J. Tamura, and M. Okamura, *Proceedings of EPAC 08*, 2008 p. 421.
- [3] T. Kanesue, R. Dabrowski, M. Okamura, and K. Kondo, TH-PEC077 in these proceedings.