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Angular distribution of laser ablation plasma

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DISCLAIMER

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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 ablatioin 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.

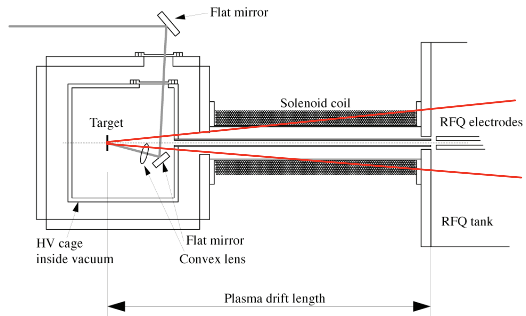

Figure 1: Solenoid with DPIS.

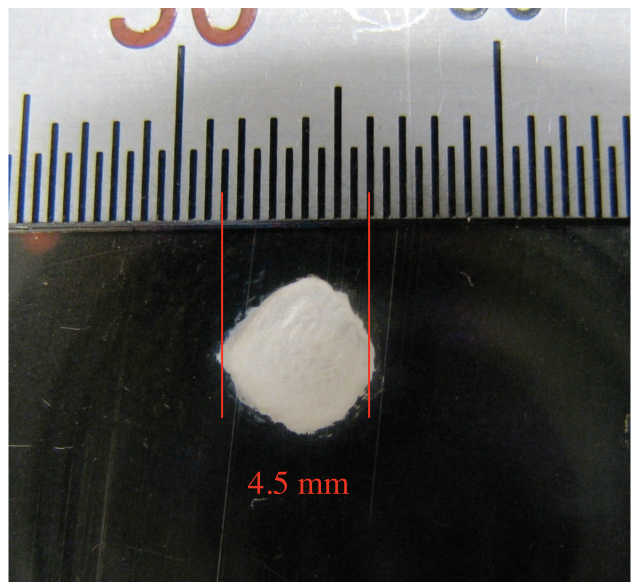

Figure 2: Silver plate used as target.

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 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 4.3×10^{8} 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

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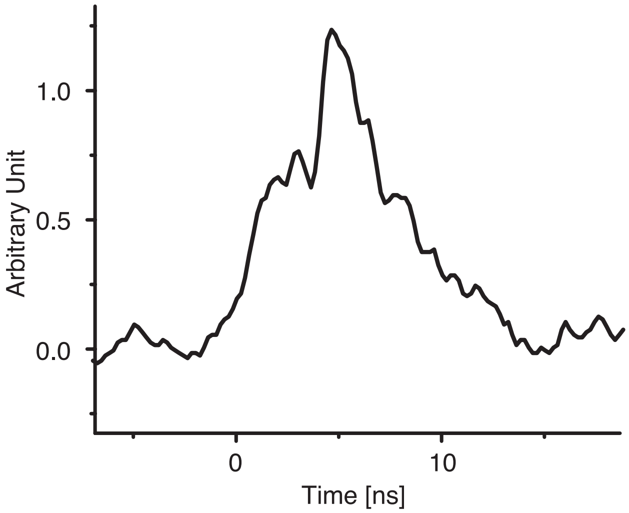

Figure 3: Laser pulse profile.

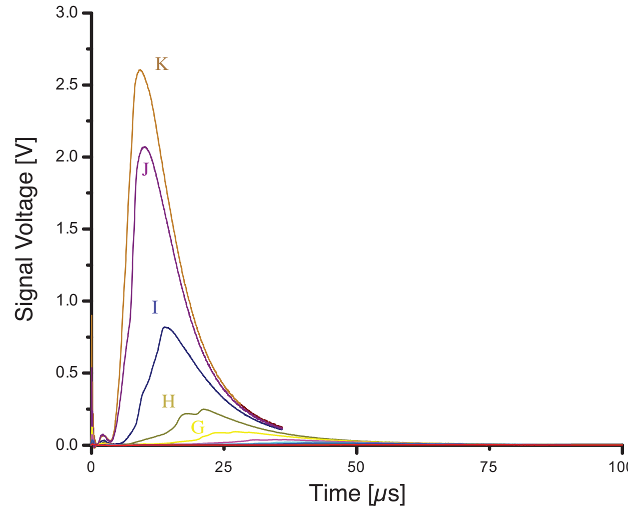

Figure 5: Current distribution in linear scale.

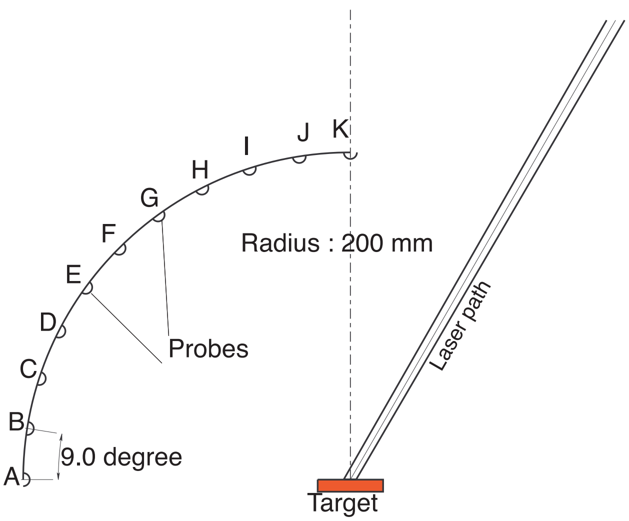

Figure 4: Probe layout.

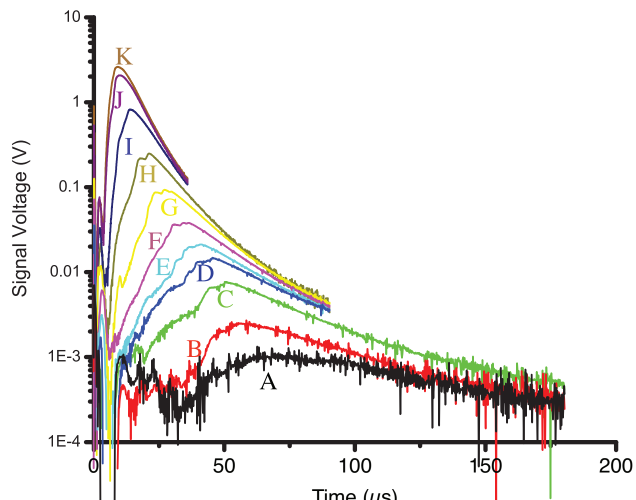

Figure 6: Current distribution in log scale.

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 50 Ω terminating register are shown in figures 5 and 6. The both graphs are the identical but the vertical scales were different, linear and legalism. 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 directivity. 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 $\pm$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

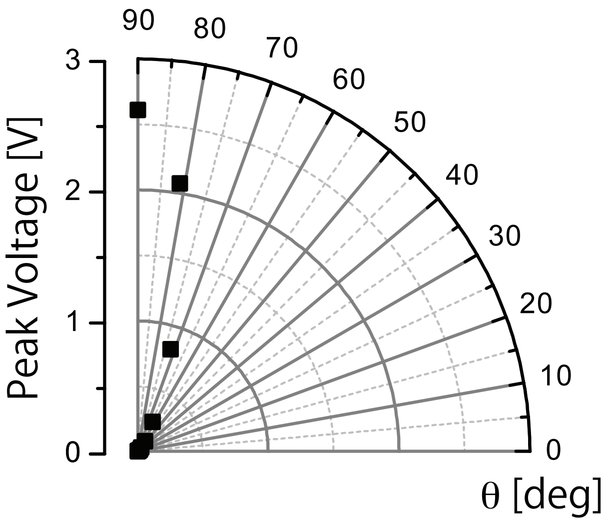

Figure 7: Directivity of plasma expansion.

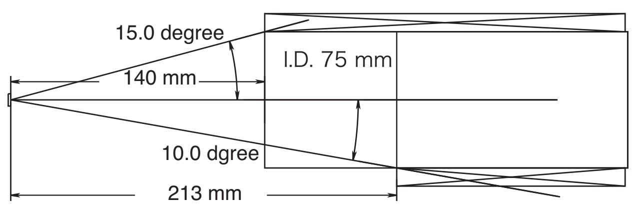

Figure 8: Solenoid positioning.

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.

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