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Study on Behavior of Laser Ablation Plasma Produced in Magnetic Field
磁場中で生成されたレーザーアブレーションプラズマの挙動の検討

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A laser ion source is expected as a high-flux and low charge state ion source for realizing heavy ion inertial confinement fusion. To realize high-flux ion sources, the laser ablation plasma control by an external magnetic field behind a target has been considered. Laser ablation plasmas were generated by irradiating a Q-switched Nd:YAG laser to a copper target in the magnetic field produced by a neodymium magnet. Angular distributions of plasma ion current were measured with a Faraday cup. The results indicate that the directivity of peak ion current enhances with the magnet.

1. Introduction

To realize heavy-ion-beam (HIB) inertial confinement fusion (ICF), high-flux and low charge state ions are required. Conventional ion sources are difficult to provide heavy ions with high-flux. A laser ion source has been expected as a high-flux ion source for realizing HIB ICF. However, the plasma density in the laser ion source decreases due to a plasma expansion along drift distance. To solve this problem, suppressing plasma expansion in the transverse direction using magnetic field applied by solenoids [1,2] or permanent magnets [3] has been considered.

Although the previous results indicate that the plasma ion current increases using the magnetic fields, a part of the laser ablation plasma injected into the magnetic field after expansion is guided. To control the whole ablation plasma, we examine to apply divergence magnetic field to region of plasma generation. The divergence magnetic field has been applied to aerospace thrusters as a magnetic nozzle and increasing plasma flux can be expected. To consider the possibility to control the behavior of the ablation plasma with the divergent magnetic field, we have investigated the angular distribution of the plasma ion current.

2. Experimental setup

Figure 1 shows a schematic of experimental setup. The laser was used for a second harmonics of Nd:YAG laser (wavelength: 532 nm) with the energy of 407 mJ and irradiated on a copper target. The pulse width of the laser was 16-18 ns (FWHM). It was sufficiently short compared with time scale of the plasma expansion (~μs). The area of the laser spot was measured as 0.06 cm^2. The estimated laser

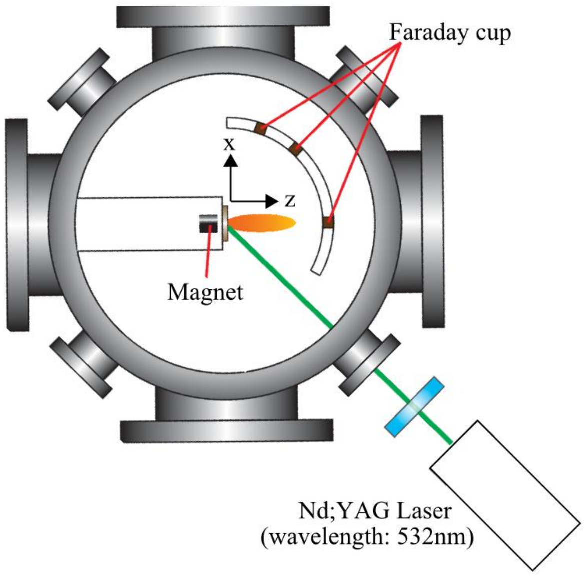

Fig. 1 Schematic of experimental setup.

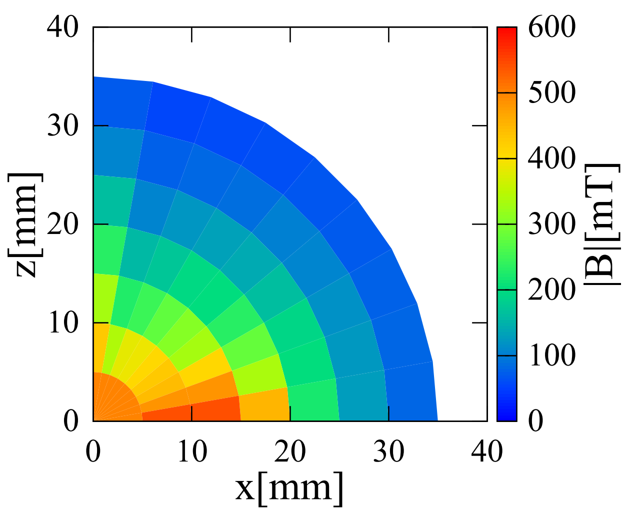

Fig. 2 Distribution of magnetic flux density.

intensity was 4×10^8 W/cm^2.

The external magnetic field was generated with a neodymium magnet (W30 mm×D30 mm×H30 mm). Magnetic flux density on the magnet center is 497 mT. The magnet was set at behind the target. Figure 2 shows the distribution of magnetic flux density as function of the distance from the surface of the magnet.

A Faraday cup was set at 57 mm downstream of the target to measure the ion current. The Faraday cup was biased at -60 ~ -120 V to extract ions from the plasma and has the aperture of Φ = 1 mm. The angle of the Faraday cup was varied at 0, 40, and 70 deg from the front of the target to investigate the angular distribution of the expanding plasma.

3. Results and discussions

Figure 3 shows comparisons of ion current without and with the magnet. The time at t = 0 indicates a trigger signal from the laser. From the comparison between with and without the magnet, the ion current at 0 deg with magnet is about 1.7 times larger than that without the magnet. The ion currents at the other angles decreased by applying the magnetic field as shown in Figs. 3(b) and (c).

Figure 4 shows the angular distribution of the expanding plasma. Each plot indicates a peak ion current of the waveform. We can see that the directivity of peak ion current increases by the applied magnetic field.

4. Conclusion

To consider the possibility to control the behavior of the ablation plasma using magnetic field, we have measured the angular distribution of the plasma ion current. The results indicate that the directivity of peak ion current was improved by magnetic field.

References

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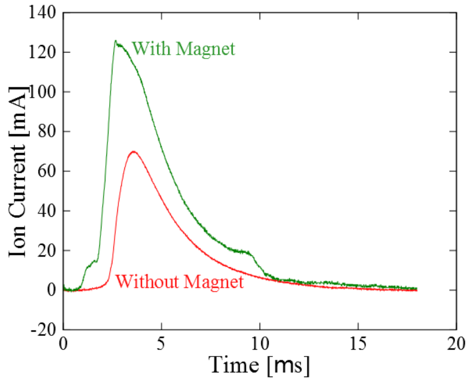
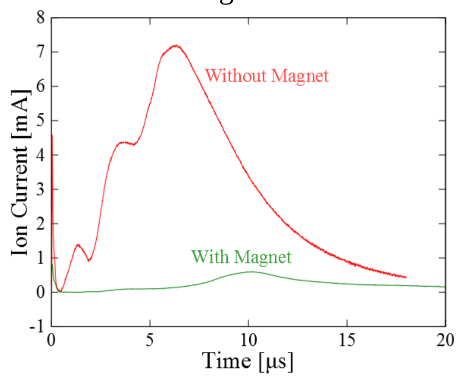
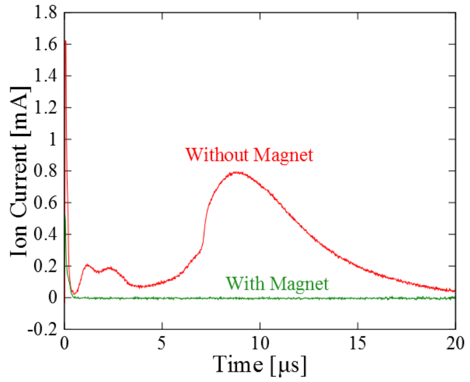


(a) Ion current at 0 deg from the front of target



(b) Ion current at 40 deg from the front of target



(c) Ion current at 70 deg from the front of target

Fig. 3 Comparison of ion currents between without and with magnet at (a) 0 deg, (b) 40 deg, and (c) 70 deg.

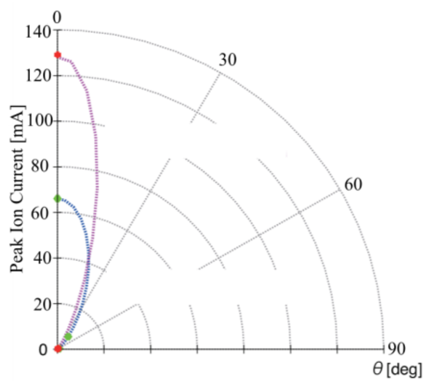


Fig. 4 Angular distributions of peak ion current without and with magnet.