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Investigation of the effect of solenoidal magnetic field on Fe plasma flux for application to laser ion source

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Laser ablation plasma has been studied as a highly charged ion source for nuclear physics experiments[1)] and as a high flux ion source for heavy ion inertial fusion,[2)] and it is used as an ion source at Brookhaven National Laboratory[3)]. In a typical configuration of the source, plasma flux at an extractor varies as a function of time. The time-dependent flux results in the changes in the ion beam current and its optics within a beam pulse. To prevent the changes, we propose to apply a pulsed magnetic field. Enhancement of the flux after passing through a static solenoidal magnetic field was observed[4)]. The enhancement depended on the magnetic intensity. Therefore, if we apply the fast-rising magnetic field in accordance with the transient flux level of the plasma, we will be able to make the flux level flat.

To predict the optimal pulsed magnetic field, we first investigated the effect of a static magnetic field that was driven by quasi-stationary current during the plasma passing through the coil. We scanned a biased ion probe detecting plasma flux transversely or normal to the plasma drifting direction by applying a magnetic field.

Figure 1 is a brief schematic diagram of the experimental setup. A Nd:YAG laser irradiated an iron target with a pulse width of 6 ns and intensity of 4.0×10^8 W/cm^2. At this irradiation level, the laser mainly produces singly charged ions in the chamber evacuated to 4×10^{-4} Pa. The coil was driven by a pulse circuit. During the plasma passing through the coil, the decrease in magnetic flux density was less than 10 % and we can regard the magnetic field as almost constant during the interaction. A 2-mm-diameter aperture and a metal mesh whose transparency was 90.3 %, were grounded and placed in front of the probe.

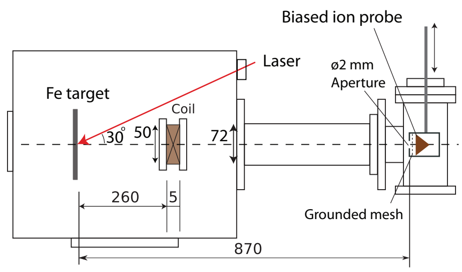

Fig. 1. Schematic of experimental setup for transverse scan of ion flux distribution

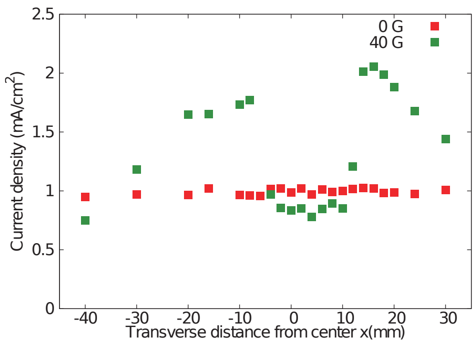

Fig. 2. Transverse flux distribution with and without magnetic field

Figure 2 shows the transverse distribution of plasma flux whose longitudinal velocity v_z is 14 mm/μs at 870 mm away from the target. v_z was estimated by division of the distance by the time of flight. Horizontal axis is the distance x from the center axis. Each point is an average of 3 data. The red squares are data with no magnetic field and green ones are in the presence of magnetic field. The magnetic flux density at the center of the coil is estimated to be 40 G using a simulation code(OPERA). When the magnetic field was applied, two peaks and decrease in the flux near the center axis were observed. The formation of two peaks around $x =$ -15 and 20 mm means that the plasma collected around the radius. The collection indicates that the magnetic field had focusing force that increases nonlinearly with increasing x. On the other hand, the decrease in the flux around the center ($x = 0$ mm) may mean that the magnetic field does not converge the plasma within a certain value of x. The difference in the magnetic field effect on the plasma with respect to x may result from the shape of the magnetic field. We need to investigate this difference in order to increase the ion flux with minimum emittance growth. The discussion of the enhancement mechanism will help optimize the parameters of pulsed magnetic field.

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