Response of an axial magnetic field to injection of laser ablation plasma

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An ion source using laser ablation plasma can provide various types of heavy ion pulsed beam with relatively simple configuration, such as the source operated in the Brookhaven National Laboratory.[1)] In addition to this advantage, the plasma is expected to become a high current ion source because of the high density and high drift velocity. To achieve this, guiding of the expanding plasma with axial magnetic field is necessary and the mechanism needs to be made clear. During the above interaction, the magnetic field is distorted by the plasma while the distortion generates magnetic pressure affecting the plasma dynamics. The distortion is determined by a competing process between the convection by the plasma and the diffusion into the plasma. In the case of laser ablation plasma, both effects play some roles and vary within the plasma plume due to the distribution of the conductivity and the plasma velocity. Therefore, the magnetic field should evolve within the plume while giving rise to a structure within the plume. Hence, we investigated the response of an axial magnetic field against the plume injection with a magnetic probe, and then compared the result with plasma behavior.

Figure 1 shows the experimental setup. We produced the plasma plume using a 4×10^8 W/cm^2 Nd:YAG laser from an iron target in a chamber evacuated to 4×10^{-4} Pa. A coil 50 mm in diameter and 5 mm in length was placed at a distance of 260 mm from the target to generate the magnetic field that was 65 G at the center. A disk with a 14-mm-diameter aperture was placed between the target and the coil to define the plasma plume diameter. A magnetic probe was placed in the coil. A 20-turns pickup coil 6.4 mm in diameter and 2.0 mm in length was attached to the probe edge. By integrating the voltage signal from the probe, we measured the variation in the longitudinal component of the magnetic field. We also measured the plasma ion current density at a distance of 740 mm with a biased ion probe.

From the current density measurement, we found that the head of the plasma plume is preferentially guided and directed. In addition, the plume was estimated to pass through the coil from 5 to 30 μs.

Figure 2 shows the field response ΔB_z as a function of the distance from the coil center z at various time (8, 10, 14 μs) from the laser pulse. At any given point of time, ΔB_z was negative in $z < 0$ and positive in $z > 0$. The absolute value of ΔB_z in $z < 0$ was larger than in $z > 0$, and additionally, ΔB_z changed from negative to positive in $z > 0$. These results mean that the magnetic field was distorted asymmetrically with respect to the midplane of the coil. On the other hand, ΔB_z in $z < 0$ in earlier time was smaller than that in later time. This means that the head of the plume distorts the field to a greater extent. Because the head is faster than the tail, this indicates that the different convective effect depending on the velocity leads to the different distortion within the plume.

The larger distortion by the head and the preferential guiding of the head as mentioned above show that the difference of the distortion results in the difference of the guiding effect.

From the investigation, we found that the magnetic field evolves within the plume asymmetrically, which leads to structure in the plume.

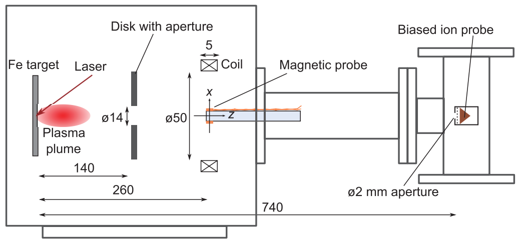

Fig. 1. Schematic of the experimental setup for magnetic field measurement.

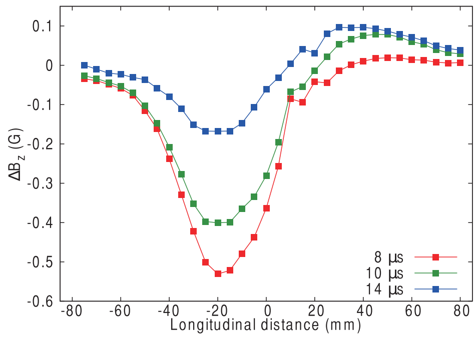

Fig. 2. Variation of magnetic field ΔB_z as a function of the distance from the coil center z at various time (8, 10, 14 μs) from the laser pulse.

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Reference
1) T. Kanesue *et al.*: *Proceedings of IPAC2014, Dresden, Germany*, p 1890 (2014).