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（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	創造エネルギー　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　理学　）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Heavy ion accelerators have applications in a variety fields of science and technology such as nuclear physics experiments, cancer therapy, and energy drivers of heavy ion inertial fusion. For the accelerators, high current and low emittance ion source is desired because these parameters determine the power level, the reaction rate, the energy deposition, and/or the accelerator size. The ion source performance is expected to be improved by using laser ablation plasma. By a high power laser irradiation on a solid surface, a hot and dense plasma is produced. Then the plasma expands adiabatically while obtaining high drift velocity and decreasing the temperature. In typical static ion sources, since both intrinsic beam emittance and beam current density depend on the temperature, there is a trade-off between high beam current and low emittance. On the other hand, when the drift velocity dominates the plasma ion current density, the current density is proportional to the drift velocity and does not depend on the thermal velocity. Therefore, the plasma is expected to be a high current and low emittance source while avoiding the trade off.

However, some issues remain in the expansion phase of the ablation plasma. In a typical configuration, the ablation plasma drifts to an extraction electrode while expanding. The longitudinal width of the plasma determines the pulse width of the extracted beam. Thus, the plasma has to be transported for a long distance. Without external field in the expansion phase, the plasma also expands transversely. As a result, only ions within a small solid angle can be injected into an aperture of the extraction electrode while most of the ions escape out. In addition, the plasma ion current density varies drastically within the plasma plume. Because the shape of a boundary between plasma and ion beam in an extraction electrode depends on the difference of the plasma ion current density and the Child-Langmuir current density for the electrode, the variation of the plasma ion current density leads to beam divergence and emittance growth. To overcome those issues, control of expansion of the plasma is essential.

Some researchers reported that laser ablation plasma is guided by axial magnetic field, and as a result, the extracted beam current is enhanced. Therefore, the guiding is considered to be useful for the plasma control. On the other hand, any discussions in the previous studies are limited within phenomenological understanding. In order to control the plasma for novel ion source, we need to make the interaction process between the plasma and axial magnetic field clear.

Typically, behavior of magnetic field interacting with plasma is described by the induction equation of magnetic field. The equation shows that the behavior is determined by the competing process between the convection by the plasma flow and the diffusion into the plasma due to the plasma resistivity. To characterize the behavior qualitatively, a magnetic Reynolds number, R_m is defined by the ratio of the diffusion time to the characteristic time of the plasma flow. When a plasma plume is injected into magnetic field, if $R_m >> 1$, the field is completely excluded from the ablation plasma while the plasma is guided by the magnetic pressure. In this case, the interaction can be described by the snow-plow model. On the other hand, if $R_m << 1$, the plasma is magnetized, and the ions and the electrons are guided along the magnetic field while both are attracted.

In the case of the interaction between laser ablation plasma and magnetic field, R_m is usually around 1, and therefore, both the convective and diffusive effects play some rolls. In other words, the plasma should be partially magnetized and partially convective. In addition, the plasma velocity, the density, and the temperature vary within the plasma plume. As a result, the interaction should make a complex structure in the plume.

The aim of this thesis is to investigate the interaction process between a laser ablation plasma and an axial magnetic field with R_m around 1 and thereby to elucidate the guiding mechanism for controlling the ablation plasma. For this purpose, we investigated the behavior of the ablation plasma through an axial magnetic field and response of the field to the plume injection experimentally. The correlation of the behaviors and the guiding mechanism were discussed. Then, based on the found mechanism, we proposed and demonstrated two ways to guide the plasma more effectively from the viewpoint of ion source.

By this study, the guiding mechanism was clarified, and the basic concept of plasma guiding was proposed. Those are important to develop a novel ion source and thereby an intense ion accelerator.