Effect of applying solenoidal magnetic field on laser ion source

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A laser ion source is an ion source that extracts ions from an ablation plasma generated by irradiating a solid target with a pulsed laser. It can generate plasmas at high-density from various elements in solid state at room temperature. The first laser ion source was proposed within ten years of the invention of lasers in 1960 [1], and it was one of the earliest applications of lasers. Laser ablation plasmas have the characteristic of having a large drift velocity in the direction perpendicular to the target surface. Due to the generation of high-density plasmas compared to conventional ion sources, laser ion sources can easily generate high-current ion beams. In addition, a laser ion source with the direct plasma injection scheme [2], which is a technique that extracts ions from a plasma and injects them into a linear accelerator without low energy beam transport, demonstrated to accelerate heavy ion beams with much higher current compared to those extracted from conventional ion sources [2, 3].

Owing to its capability of supplying ion beams with high current for various ion species, a laser ion source has been in operation at Brookhaven National Laboratory (BNL) in NY since 2014 [4]. The employed laser is a Nd:YAG laser with nano-second pulse duration and the energy is on the order of 100 mJ. It is the first laser ion source in the world to supply stable ion beams for users at a large accelerator facility. It is located at the upstream end of the heavy-ion accelerator complex at BNL. Recently, laser ion sources are expected to be used as ion sources that supply ion beams for medical applications, neutron sources, and drivers for heavy-ion inertial fusion [5-9].

The maximum beam current that can be transported in an accelerator is limited by the space charge limiting current and focusing force by magnetic or electric lens.

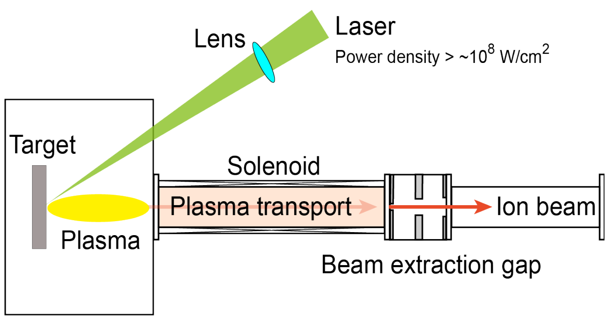

Figure 1. Schematic setup of a laser ion source with a solenoidal magnetic field.

Therefore, in order to increase the number of ions per laser pulse, it is necessary to maintain the current below the upper limit and extend the pulse duration.

In a laser ion source, the pulse duration of the plasma can be easily extended by increasing the plasma drifting distance. However, as the plasma expands three-dimensionally, the plasma density decreases drastically, leading to a decrease in ion current density with the increase in the drift distance. To suppress the decrease in the current, a method was proposed that guiding the laser ablation plasma with a solenoidal magnetic field while transporting the plasma. In addition, the effect of magnetic field has been investigated on other characteristics of ion beams such as emittance [11] and the distribution of ion charge-state [12].

In order to design an appropriate solenoid magnetic field for guiding ablation plasma, considering the differences in required ion species and charge-states, further understanding in the behavior of plasma inside the solenoid is necessary. This study discusses the results of investigating the behavior of plasma and the extracted ion beam when applying a solenoidal magnetic field as shown in Fig. 1 with the aim of developing high-current laser ion sources.

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