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Investigation of plasma transport through a neutral gas layer in a high-repetition-rate laser ion source.

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In the laser ion source, it is known that the amount of plasma supplied to the ion extraction gap decreases with increasing laser repetition frequency due to the interference of neutral gas released by laser ablation and remaining in the surrounding space. In particular, charge exchange reactions with neutral gas molecules have a significant impact on the amount of highly charged ions, so suppressing the effects of neutral gas is a critical issue for high-repetition-rate laser ion sources.

To investigate the plasma transport through the neutral gas layer near the laser target, plasma ion fluxes were measured under various laser repetition rates up to 10 Hz using a laser ion source with a rotating cylindrical target. Highly charged ions are produced from a solid target or a solidified gas target formed on a liquid-nitrogen-cooled cold head. The pressure increase during repetitive operation was compared between these two targets. The ion charge state distributions in the supplied plasma were also measured and the dependence of the amount of highly charged ions on the repetition rate was examined.

In addition to the experimental investigation, numerical investigations were performed using a 2D PIC-MCC simulation and a fluid simulation using a rarefied gas model. The former was used for plasma ion tracking in background neutral gas, the latter for neutral gas dynamics after each laser ablation.

The effectiveness of introducing a differential pumping system in high-repetition-rate laser ion sources is discussed on the basis of the experimental and numerical results.

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