EXAMINATION OF FIXING METHOD OF PLASMA POTENTIAL FOR ION EXTRACTION BY USING BACKGROUND PLASMA

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Abstract

In the ion extraction in laser isotope separation using atomic vapor, the conditions to fix the potential of the photo-ionized plasma by using the background plasma was investigated experimentally. Whether or not the potential of the photo-ionized plasma could be fixed was judged by measuring its potential with a Langmuir probe when the center density of the background plasma was changed from 0.1×10^{14} m^{-3} to 1.3×10^{15} m^{-3}. The threshold density of the background plasma needed for fixing the potential of the photo-ionized plasma increased when the density of the photo-ionized plasma increased.

1. Introduction

In laser isotope separation using atomic vapor, the atomic vapor of a metal evaporated by electron beam heating is irradiated by pulse laser light and then the specified isotope is selectively ionized. The ions are extracted from the photo-ionized plasma and collected at the cathodes by a static electric field formed between the photo-ionized plasma and the cathodes.

So far, the photo-ionized plasma has been fixed at a higher electric potential than that of the cathode by being in contact with the anode. Simplification of the ion extraction electrode system demands that the anode should be as small as possible. This requirement has been satisfied from the previous experimental result that the potential of the photo-ionized plasma is fixed at the anode potential when the ratio of the anode area to the cathode one is larger than 0.5 % [1]. However, further simplification of the ion extraction electrode system may be achieved by omitting the anode if the background plasma can be used as a potential reference.

The background plasma is generated on the crucible by interaction between the vapor and the electron beam. The potential of the background plasma is zero because the background plasma is connected with the crucible. Therefore, the photo-ionized plasma may be fixed at the earth potential due to the effect of a short circuit to the crucible if the background plasma is connected with the photo-ionized plasma. However, the physical picture describing the method for fixing the plasma potential by using the background plasma is not known clearly. Then, we experimentally investigated the conditions to fix the plasma potential using the background plasma.

2. Experimental setup and method

Figure 1 shows a schematic diagram of the experimental setup. The laser lights composed of the XeCl excimer laser light (308nm) and the dye laser light (447.7nm) were irradiated onto the gadolinium vapor evaporated by the electron beam in the vacuum chamber and the photo- ionized Gd^+ plasma was generated with a two step photo-ionization. Typical plasma density and electron temperature of the photo-ionized Gd^+ plasma were about 10^{16} m^{-3} and 0.43 eV, respectively. The cross section of the photo-ionized plasma was 90mm x 90mm, which was defined by the rectangular stop shown in Fig. 1. The electrodes for

Fig.1. Schematic diagram of experimental setup (top view)

removing the background plasma were positioned below the bottom of the photo-ionized Gd^+ plasma. The density distributions of the photo-ionized and background plasmas were measured by two Langmuir probes that can be moved either in the X or Z direction.
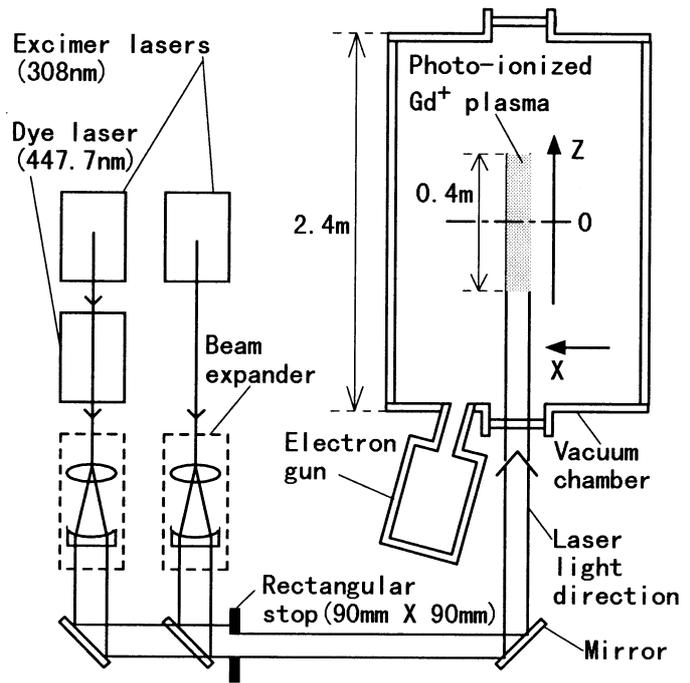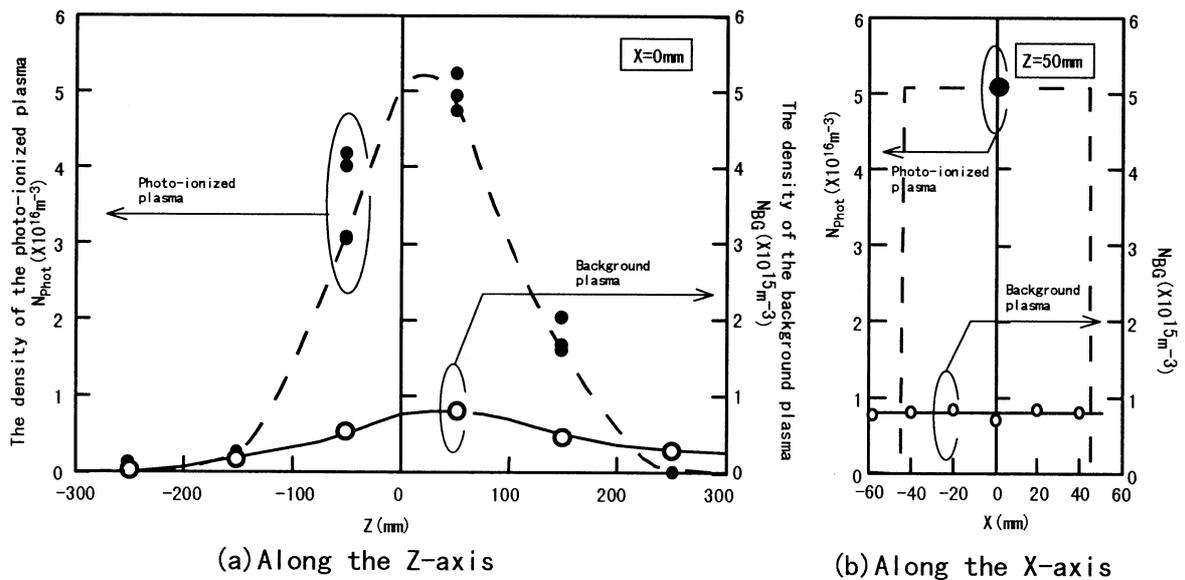

(a) Along the Z-axis

(b) Along the X-axis

Fig. 2. Typical density distributions of the photo-ionized and background plasmas

Figure 2 shows typical density distributions of the photo-ionized and background plasmas. The density distribution of the background plasma was measured for VBG (the voltage applied to the electrodes for removing the background plasma) set to zero volts. The density distributions of both the photo-ionized plasma and the background one had a maximum peak at the center along the Z-axis, as shown in Fig. 2(a). On the other hand, the distributions along the X-axis were flat within the measurement range, as shown in Fig. 2(b).

The density of the photo-ionized plasma was controlled by tuning the wavelength of the dye laser from a resonant wavelength without changing the vapor generation conditions to maintain the conditions of the background plasma. The density of the background plasma in the generation region of the photo-ionized plasma was controlled by changing the V_{BG}. Whether or not the photo-ionized plasma could be fixed was examined by monitoring the probe characteristics in the photo-ionized plasma.

Figure 3 shows typical time evolution of the plasma potential that was fixed or floating. When N_{BG} (the density of the background plasma) was 8.2 x $10^{14}m^{-3}$, the plasma potential was fixed on nearly zero volts at 30 μs after the laser irradiation. On the other hand, when N_{BG} was 0.4 x $10^{14}m^{-3}$, the plasma potential was floating at 30 μs and rose gradually to zero volts with an 80 μs delay.
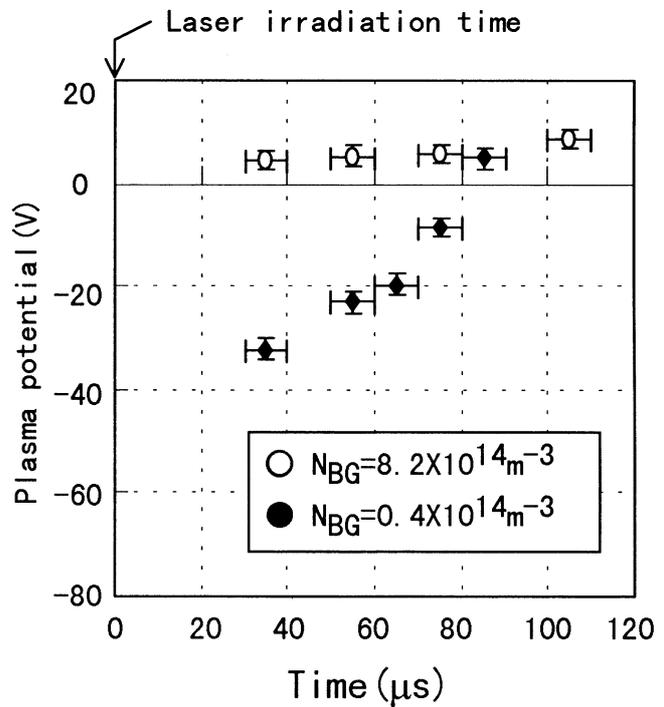

Fig. 3. Time evolution of plasma potential of the photo-ionized plasma density of 4.5 x $10^{15}m^{-3}$

Therefore, a judgement could be made as to whether or not the plasma potential was fixed at the earth potential by monitoring the probe characteristics in the time range of 30 - 40μs. The probe potential was swept from -20 V to +20 V and this sweep was kept the same range to simplify the measurement procedure. We judged the plasma potential was fixed at the earth potential when typical probe characteristics where the electron current increased exponentially against the probe potential were obtained. When the electron current was noticeably large, it was judged to be floating.

3. Results

Figure 4 shows the dependence of the potential of the photo-ionized plasma on N_{BG}. The N_{phot} (the density of the photo-ionized plasma) was set to 4.5 x $10^{15}m^{-3}$ and 1.5 x $10^{16}m^{-3}$. The N_{BG} was changed from 0.1 x 10^{14} m^{-3} to 1.3 x 10^{15} m^{-3}. In both cases, the plasma potential became zero when N_{BG} exceeded a certain value, shown by the vertical line. This means that a certain threshold density of the background plasma exists for fixing the potential of the photo-ionized plasma.
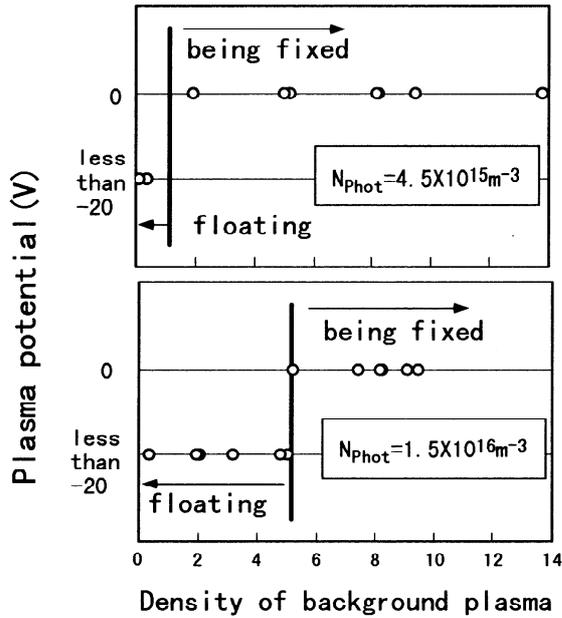
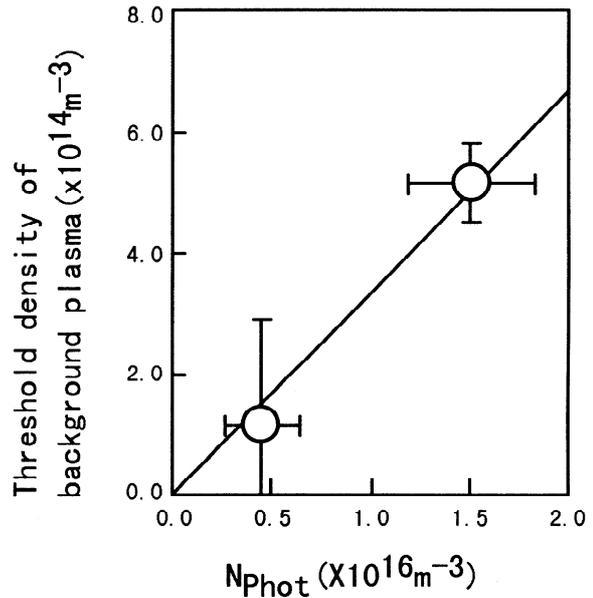**Fig. 4.** Judgement of possibility of fixing plasma potential

Fig. 5. Dependence of threshold density on photo-ionized plasma density

Figure 5 shows the dependence of the threshold density of the photo-ionized plasma on N_{phot}. The threshold of N_{BG} increased when N_{phot} increased.

4. Conclusions

For ion extraction of laser isotope separation using atomic vapor, the density of the background plasma needed for fixing the potential of the photo-ionized plasma was estimated. When the center density of the background plasma was larger than a certain threshold density, the potential of the photo-ionized plasma was fixed at the earth potential. The threshold density increased when the density of the photo-ionized plasma increased.

These results suggest that it is possible to simplify the ion extraction electrode system by using the background plasma.

References

[1] S. Tsuda et al.: *Proc. Int. Conf. on Plasma Physics,* Nagoya, Japan, 1996 Vol. **2**, pp. 1846-1849