21PB-092

High-Energy-Density Plasma Generation by a Plasma Merging Technique in the Double Plasma Gun Device

ダブルプラズマガン装置におけるプラズマ合体技術を用いた高エネルギー密度プラズマ生成

Yusuke Kikuchi, Ikko Sakuma, Yasuhiro Asai, Koji Onishi, Wataru Isono, Takumi Nakazono, Masato Nakane, Naoyuki Fukumoto, Masayoshi Nagata
菊池 祐介, 佐久間 一行, 浅井 康博, 大西 晃司, 礒野 航, 中園 拓実, 中根 優人, 福本 直之, 永田 正義

Graduate School of Engineering, University of Hyogo
2167 Shosha, Himeji, Hyogo 671-2280, Japan
兵庫県立大学 工学研究科 〒671-2280 兵庫県姫路市書写2167

A plasma merging experiment for high-energy-density plasma generation was performed using the double plasma gun device. Two magnetized coaxial plasma guns were connected to a target chamber in order to achieve a plasma merging with an oblique angle of 90 deg. The line-averaged electron density of the single plasmoid was ~1.5x10^{21} m^{-3}, whereas the merging plasmoid had ~2.5x10^{21} m^{-3}. The ion temperature of the merging plasmoid was ~35 eV, corresponding to twice of that of the single plasmoid. The high-energy-density plasma generation due to the plasma merging was successfully demonstrated in this study.

1. Introduction

The plasma merging is of interest for both understanding of magnetic reconnection mechanism and high-energy-density-physics studies. The merging experiments in spherical torus (ST) devices revealed significant ion heating during magnetic reconnection due to shock formation and viscous damping [1]. On the other hand, plasma jet merging experiments were also conducted to produce high-energy-density plasmas for applications such as magetoinertial fusion driver [2]. The stagnation layer between two obliquely merging super-sonic plasma jets was experimentally characterized, and it was explained by hydrodynamic oblique shock theory.

Recently, plasma gun devices have been used in order to simulate pulsed plasma heat load such as type-I ELM and disruption predicted in future magnetically confined fusion devices [3, 4]. The heat load onto the divertor plate during type-I ELM in ITER is predicted to be 0.2-2 MJ m^{-2} with the pulse duration of 0.1-1 ms [5]. A magnetized coaxial plasma gun (MCPG) can produce a high-speed plasmoid with spheromak magnetic configuration [6], so that both plasma kinetic and thermal energy transfers to a target material. A plasma merging technique is one of the potential tools to enhance the plasma energy density for thee simulation experiment of transient heat loads. In this work, we constructed a new experimental device using two MCPGs of so-called “double plasma gun” to generate a high-energy-density plasma by a plasma merging technique. In this paper, the preliminary experimental results are shown.

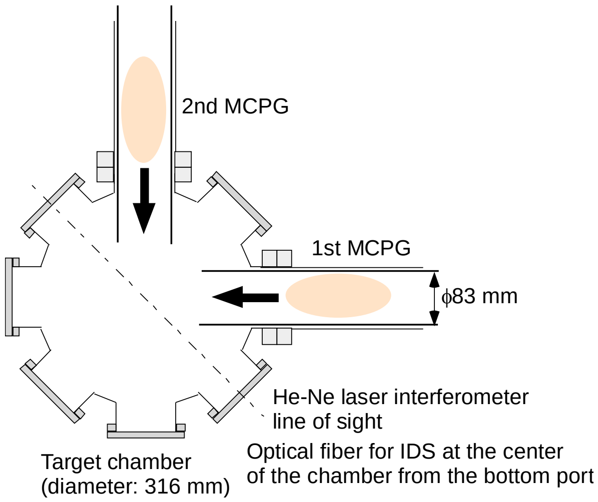

Fig. 1. Schematic view of the double plasma gun device

2. Experimental Setup

Figure 1 shows the schematic view of the double plasma gun device. The two MCPGs were connected to a target chamber in order to realize a plasma merging with an oblique angle of 90 deg. The distance from the inner electrode of the MCPG to the center of the target chamber is 461.5 mm. Two sets of capacitor banks (1 mF, 7 kV, 25 kJ) were used as the power supply of the 1st MCPG and the 2nd MCPG in order to produce two plasmoids at the same time. In addition, a bias magnetic field was applied to magnetize the plasmoid. Helium gas was injected just before applying the gun voltage between the two electrodes by fast gas puff valves in this study. The gun current in the MCPGs was ~100 kA, where the gun voltage was 6 kV. The plasma duration was ~150 μs. The magnetic field of the plasmoid was ~0.1 T at the target chamber.

The line-averaged electron density with and without the plasma merging was measured with a He-Ne laser interferometer. The interferometer chord intersects the plasma merging region, as shown in Fig. 1. The optical emission of He ion (He II, 468.58 nm) was also measured with the ion Doppler spectrometer (IDS). The optical fiber for the IDS was installed at the center of the target chamber from the bottom port. The wavelength resolution was 0.018 nm, and the data was recorded at the sampling time of 1 μs, respectively. The ion temperature was evaluated from the Doppler broadening of He II emission line.

3. Experimental Results

Figure 2 shows time evolutions of the line-averaged electron density of the 1st plasmoid, the 2nd plasmoid, and the merging plasmoid, respectively. Here, the laser path length for evaluation of electron density was 117 mm that corresponds to the diagonal length of the plasma merging area. The line-averaged electron density of the single plasmoid was ~1.5×10^{21} m^{-3}. On the other hand, the merging plasmoid had ~2.5×10^{21} m^{-3} which was almost two times larger than that of the single plasmoid. Figure 3 shows time evolutions of the ion temperature measured with the Doppler broadening of He II emission. As the result, the ion temperature of the single plasmoid was ~18 eV, whereas that of the merging case was ~35 eV. It could be considered that the ion heating originated from converting the kinetic energy of the plasmoids into the ion thermal energy. The electron temperature was not measured in the present experiment. However, the increase of the electron temperature during the magnetic reconnection due to the current sheet Ohmic heating has been reported in the plasma merging experiment [1]. Thus, measurements of the electron temperature is one of the future studies.

4. Summary

We have performed the high-energy-density plasma generation using the plasma merging technique in the double plasma gun device. The increase of the electron density and the ion heating due to the plasma merging were successfully demonstrated in this study.

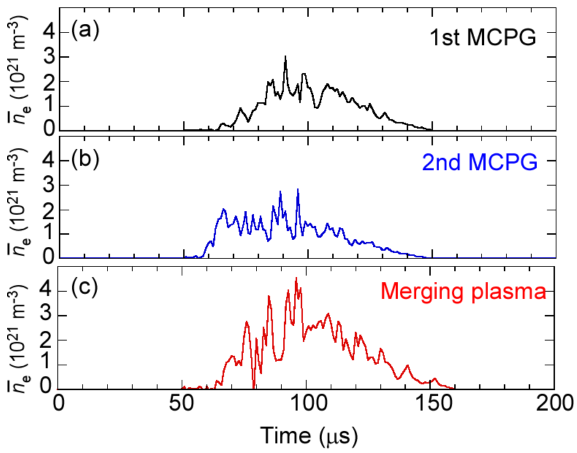

Fig. 2. Time evolutions of the line-averated electron density of (a) 1st plasmoid, (b) 2nd plasmoid, and (c) merging plasmoid.

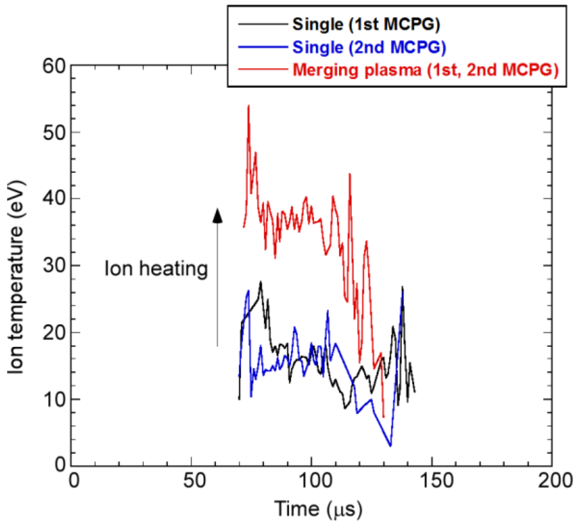

Fig. 3. Time evolutions of the ion temperature of the single and the merging plasmoids.

Acknowledgments

This work was supported by Grant-in-Aid for Scientific Research (C) 26400535.

References

[1] Y. Ono, H. Tanabe, T. Yamada, et al.: Plasma Phys. Control. Fusion **54** (2012) 124039.

[2] E.C. Merritt, A.L. Moser, S.C. Hsu, et al.: Phys. Rev. Lett. **111** (2013) 085003.

[3] Y. Kikuchi, I. Sakuma, D. Iwamoto, et al.: J. Nucl. Mater. **438** (2013) S715.

[4] I.E. Garkusha et al.: J. Nucl. Mater. **390–391** (2009) 814.

[5] G. Federici et al.:Plasma Phys. Control. Fusion **45** (2003) 1523.

[6] Y. Kikuchi, R. Nakanishi, M. Nakatsuka, et al.: IEEE Trans. on Plasma Science **38** (2010) 232.