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Formation and confinement properties of repetitively generated magnetized plasmoids by an IGBT inverter control

IGBTインバータによる連続生成磁化プラズマの生成・保持特性

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A power inverter with IGBTs was developed and has been applied in a mini-magnetized plasma gun experiment. A magnetized plasmoid was generated by M2PG with 10 kHz of discharge frequency. Then repetitively generated plasmoid are ejected into metal chamber as a flux conserver. In the repetitive discharge case, an electron temperature up to 140 eV and an electron density up to 2×10^{19} m^{-3} were measured. In contrast with repetitive discharge case, an electron temperature and density is up to 50 eV and 1×10^{19} m^{-3}, respectively. These results indicate that the formation and confinement of plasmoid by repetitive discharge are improved compared to single discharge case.

1. Introduction

In this work, we have developed a power inverter to control electrode discharge current, and it has been applied in a small sized magnetized coaxial plasma gun (MCPG) device. A generated plasmoid by a MCPG can easily be accelerated to the range of the Alfven speed and has significant amounts of thermal and kinetic energy, particles and magnetic helicity [1]. Therefore a MCPG has been utilized in nuclear fusion research.

Repetitive operation of a MCPG is required to inject significant amounts of helicity, particles and energy into the fusion core of plasma. Also, the repetitive operation produces a continuous plasma source, for a UV light source for example [2]. However, conventional high-power fast switches (e.g., ignitron and spark gap) are not adequate for repetitive operation. Therefore, we have developed a power inverter with IGBTs to control the discharge current on a MCPG and have evaluated formation and confinement characteristics of generated plasmoid by MCPG with repetitively generation.

2. Experimental device

An experimental device has been consisted a power inverter with IGBTs, a MCPG, and a metal chamber as a flux conserver. Figure 1 shows a typical diagram of the experimental device.

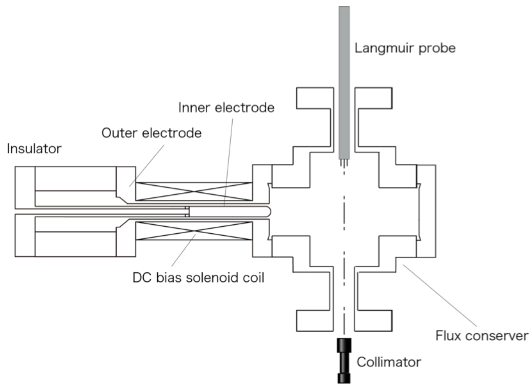

Fig.1. A Schematic view of M2PG-device.

2.1. Mini-magnetized plasma gun (M2PG)

In this work, magnetized plasmoid has been generated on a small size MCPG named Mini-magnetized plasma gun (M2PG). The M2PG has a simple configuration consisting of inner and outer electrodes and a magnetized coil as shown in Fig.1. The outer electrode has an 8 mm of I.D., and the inner electrode has a 3 mm of O.D. These electrodes are insulated by a spacer flange made of acetal copolymer (Duracon).

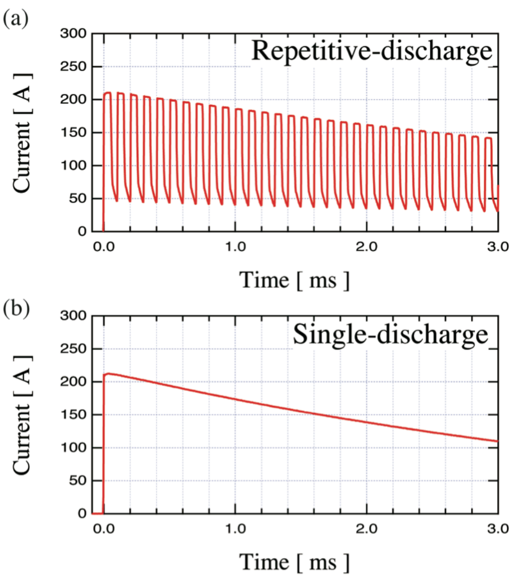

Fig.2. Typical discharge current waveforms of (a) repetitive discharge case and (b) single discharge case.

2.2. Power inverter with IGBTs

A power inverter using IGBTs consists of a power supply, IGBTs (Nihon Inter Electronics Corporation, PHMB600BS12), snubber circuit, and a current limited resister. In this work, the power inverter was connected to a capacitor of 640 μF which is charged by DC power supply.

3. Experimental Result

3.1. Typical discharge waveforms

Typical waveforms of discharge current are shown in Fig. 2. A discharge current was measured by a Rogowski-coil. A series of repetitive discharge was operated with 10kHz of discharge frequency and 50% of duty-cycle. Duty-cycle indicates a ratio of pulse width to a cycle of the discharge frequency.

3.2. Properties of repetitively generated plasmoid

In this study, we have measured a line spectrum emission of HeI (471.3 nm), electron temperature and density as shown in Fig. 3. A thin (red) line indicates the case of repetitive discharge (Case 1) and a bold (blue) line indicates the case of single discharge (Case 2). The emission of HeI was measured by optical measurement system consisting of a collimator and a photo multi plier tube with interference-filter (470±5 nm). Figure 3 (a) shows a time evolution of emissions of HeI. In the Case-1, intensity of HeI emission is decreased compared to the Case-2.

Figure 3 (b) and (c) show an electron temperature and an electron density, respectively. The electron temperature and density were measured by triple

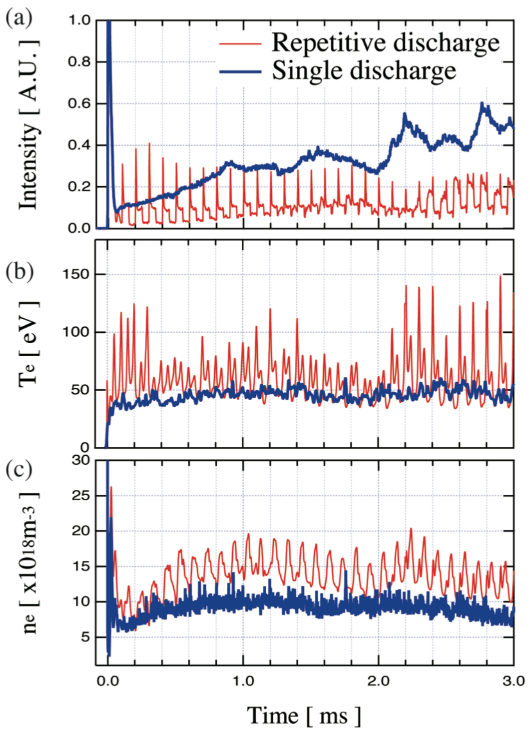

Fig.3. Time evolutions of (a) emission of HeI, (b) electron temperature and (c) electron density.

Langmuir probe. The triple probe measured at 18 mm from a center of flux conserver. In the Case-1, an increasing of electron temperature and density have been observed as shown in Fig. 3 (b) and (c), and at the pulse-peak of an electron temperature and density in the Case-1 are increased as compared to Case-2.

These results are considered an effect of repetitive discharge. In the case of repetitive discharge, collision between two ejected magnetized plasmoid is occurred. Additionally, increasing of an electron temperature has been measured at the pulse peaks of repetitive discharge. Therefore it seems that there is possibility of plasma heating via magnetic reconnection event.

4. Summary

In the repetitive discharge case, we have observed an increasing of an electron temperature and density and a decreasing of line spectrum emission of HeI compared to single discharge case. This is considered that plasma confinement property is improved with repetitive discharge.

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