23P065-P

Magnetic helicity injection into a field-reversed configuration by a magnetized coaxial plasma gun.

磁化同軸ガンを用いたFRCプラズマへの磁気ヘリシティ注入

Hiroyuki Matsunaga[1], Atsushi Takase[1], Hirotomo Itagaki[2], Tsutomu Takahashi[1], L.C.Steinhauer[3], Tomohiko Asai[1]

松永宏幸[1], 高瀬敦司[1], 板垣宏知[2], 高橋努[1], L.C.Steinhauer[3], 浅井朋彦[1]

1) College of Science & Technology, Nihon University
1-8-14, Kandasurugadai, Chiyoda-ku, Tokyo 101-8308, Japan.
2) Department of Complexity Science and Engineering, Graduate school of Frontier Sciences The University of Tokyo
5-1-5,Kashiwanoha, Kashiwa-shi, Chiba 277-8561, Japan.
3) Department of Aeronautics & Astronautics, University of Washington
211 Guggenheim Hall, Seattle, WA 98195-2400. USA.
1)日本大学大学院 理工学研究科 〒101-8308 東京都千代田区神田駿河台1-8-14
2)東京大学大学院 新領域創成科学研究科複雑理工学専攻 〒277- 8561 千葉県柏市柏の葉5-1-5
3)ワシントン大学 航空宇宙工学科 98195 シアトル.

A coaxial helicity injection (CHI) onto a field-reversed configuration (FRC) has been applied. As one of the effect of CHI, delayed onset time of toroidal deformation with a mode number n = 2. Based on the theoretical prediction that the modest amount of toroidal magnetic field could stabilize the rotational instability [Milroy, R.D and L.C. Steinhauer: Phys. Plasma **15**, 056101, (2008)] , the injected helicity and its stabilization effect have been experimentally investigated on a theta-pinch type of FRC device, NUCTE-III. Magnetic helicity is injected into a FRC through a spheromak generated by a magnetized coaxial plasma gun coaxially mounted at the end of cylindrical chamber. The experimental results have indicated advantage of CHI for suppression of the rotational instability while it keeps confinement property.

1. Introduction

A field-reversed configuration (FRC) plasma has a self-generated toroidal rotation. It causes rotational instability with toroidal mode number n = 2 which it could destroy the configuration, In order to control this destructive instability, several methods had been proposed and demonstrated. The application of static multipole fields demonstrated suppression of the instability [1,2]. However, it has been shown that non-axisymmetric multipole fields have adverse effect on confinement [3]. The other report that the onset time of rotational instability is delayed by presence of a low toroidal field in FRC had been came out [4].

In this work, use of a magnetized coaxial plasma gun (MCPG) has been proposed as an effective method to control FRC. Indeed, these initial results of coaxial spheromak injection demonstrated suppression of the most prominent FRC instability. This observation has been made on the Nihon University Compact Torus Experiment (NUCTE) which is a flexible theta-pinch-based FRC facility [5].

2. Experimental device

This experiment has been performed on the theta-pinch based FRC device that named NUCTE – III [6].

NUCTE-III has a set of theta pinch coil consist of 25 coil elements. The discharge tube made of transparent fused silica is 0.256 m in diameter and 2 m in length. The central part of the theta pinch coil is 0.9 m in length and 0.34 m in inner diameter, and a passive mirror coil of axial length 0.275 m is arranged at each end. These coils connected to 1920μF of capacitor bank (charged up to 2 kV) that produces magnetic bias field of 0.032 T. Two set of fast capacitor banks of a 32 kV, 67.5μF and 25 kV, 18.75μF are employed for main compression and theta pre ionization respectively.

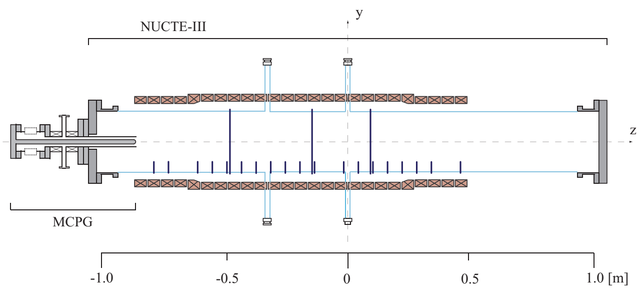

Fig.1 Schematic view of NUCTE-III with a magnetized coaxial plasma gun.

As basic diagnostic system, magnetic probes, flux loops, He-Ne laser interferometer, an ion Doppler spectroscopy (IDS), and 60 channels collimators are arranged on the NUCTE-III device. The collimators measure radiation profile from plasma using the interference band-pass filter with wavelength range of 550±5 nm which does not have any line spectrum from impurity and deuterium ions [7]. In this experiment, two set of 7 channels collimator array with the interval of 24 degrees are arranged at z = -16.5 and -49.5 cm. Other 28 collimators are arranged along the x and y axis at z = -22 cm. Two chords of He-Ne laser passing through discharge tube at z = -16.5, -55 cm and measure averaged electron density. The IDS system is placed at z = -22cm, measuring the ion temperature and toroidal ion flow with a line spectrum of CV 227.2 nm.

The MCPG consists of the inner and outer electrodes, insulator between both electrodes and an acceleration region. The dimension of MCPG is 46.5 cm in length and diameters of inner and outer electrodes are 1.6 cm and 2.9 cm, respectively. It operated with a 6kV, 250μF capacitor. A fast solenoid valve is employed for gas puffing. A bias coil is directly wound on middle of outer electrode to magnetize the generated plasmoid. The coil is connected to a 200V, 800μF capacitor bank. The MCPG is mounted on the end of theta-pinch chamber as shown in Fig.1.

3. Experimental Result

A magnetized plasmoid generated by the MCPG is ejected into the vacuum chamber and get to the edge of FRC in approximately 30 microseconds. Fig.2 shows typical time sequence of FRC formation and MCPG discharge.

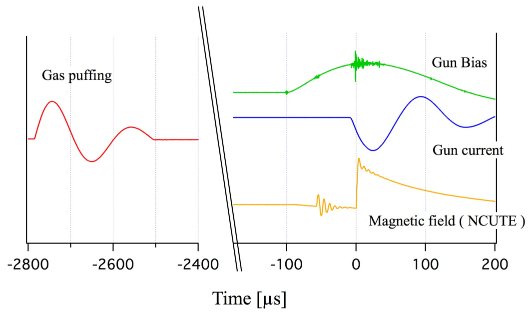

Fig.2 Typical time sequence of FRC formation and MCPG discharge

The trigger timing for plasmoid injection has set at -25 ~ -30μs before the initiation of main compression.

Figure 3 shows a time evolution of separatrix radius and bremsstrahlung at midplane. Because of less reproducibility, these shot are selected by the similarity of the condition in the pre-ionization process.

At a FRC with helicity injection, lifetime of separatrix radius has slightly been prolonged.

Observed time evolution of Bremsstrahlung indicates that helicity injection also makes delayed onset time of rotational instability. However, this effect is strongly depends on the injection timing. Especially, plasmoid injection after the formation process brought a destruction of confinement. In the series of experiments, injection timing of -20 ~ -30μs before the main compression shows better effect of CHI. It is consistent with the traveling time of 20 ~ 30μs of plasmoid from gun muzzle to the end of FRC.

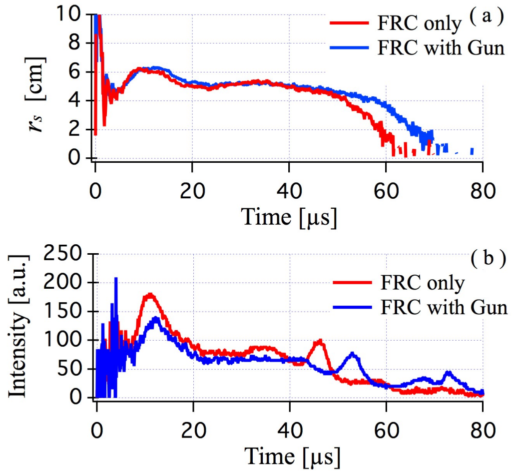

Fig.3 Time evolutions of (a) separatix radius r_s and (b) bremsstrahlung at midplane.

Acknowledgements

This work was partially supported by Grant-in-Aid for Scientific Research (KAKENHI) 21740403, Nihon University Symbolic project and Nihon University Strategic Projects for Academic Research.

References

[1] S. Ohi, T. Minato, Y. Kawakami et al.: Phys. Rev. Lett., **51**, 12, pp.1042-1045, (1983)
[2] S. Shimamura and Y. Nogi: Fusion Technol.**9**, 1, pp.69-74, (1986)
[3] Y. Ohkuma, Ts. Takahashi, K. Suzuki, and Y. Nogi: J. Phys. Soc. Japan, **63**, 8, pp.2845-2848, (1994)
[4] L.C. Steinhauer, H. Guo, A. Hoffman, et al.: Phys. Plasmas **13**, 052514, (2006)
[5] Y. Matsuzawa, T. Asai, Ts. Takahashi, et al.: Phys. Plasmas **15**, 082504, (2008)
[6] Y. Ohkuma, M. Urano, M. Nakamura, et al.: Nucl. Fusion **38**, 1501, (1998)
[7] T. Asai, Ts. Takahashi, T. Kiguchi, Y. Matsuzawa and Y. Nogi: Phys. Plasma **13**, 072508, (2006)