19PB-065

Structure of Two Component Magnetic Reconnection and the Generation of High Frequency Magnetic Fluctuations by the Counter-helicity Merging
異極性合体における二成分磁気リコネクション構造と高周波磁場揺動の発生

Ryoma Yanai, Akihiro Kuwahata, Michiaki Inomoto and Yasushi Ono
矢内亮馬, 桑波田晃弘，井通暁，小野靖

Graduate School of Engineering, The University of Tokyo
2-11-16, Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan
東京大学大学院工学系研究科電気系工学専攻 〒113-0032 東京都文京区弥生2-11-16

Two different types of magnetic fluctuations were observed during counter-helicity merging experiment in TS-4. One type of fluctuations had characteristic power spectral density (PSD) lower than 5 MHz. The other type of fluctuations had distinctive PSD about 7-20 MHz. The fluctuation power of lower frequency mode was concentrated in the outboard-side downstream region of the reconnection point while the fluctuation power of higher frequency mode was localized near the X-point. These results suggest that each of these two modes might relate to energy conversion and reconnection enhancement, respectively.

1. Introduction

Magnetic reconnection is an important phenomenon in magnetized plasmas because it leads to plasma heating by released magnetic energy and global changes of magnetic field structure. For this reason, magnetic reconnection is studied not only in space plasmas but also in fusion plasmas. Intensive numerical and experimental studies have revealed that the classical 2-D picture of steady reconnection cannot interpret true reconnection dynamics in collisionless regime. There are two unsolved problems regarding magnetic reconnection; what mechanism account for fast energy release, i.e. fast reconnection and what mechanism account for conversion to kinetic and thermal energy. It is considered that fluctuations or waves play important roles in both processes of energy release and conversion. There are some experimental studies of fluctuations during magnetic reconnection. For example, electrostatic fluctuations were measured on the edge of current sheet and magnetic fluctuations were measured in the center of current sheet during null-helicity reconnection [1,2]. Monochromatic magnetic fluctuations were also observed inside of current sheet during magnetic reconnection with a guide field [3]. Nevertheless, the roles and behaviors of fluctuations during magnetic reconnection have not been well understood yet. In this paper, detailed results from electromagnetic fluctuation measurement performed in TS-4 counter-helicity merging experiment will be presented.

2. Experimental setup

Plasma merging device TS-4 was used in this experiment. TS-4 is a cylindrical vacuum vessel made of stainless steel and has a diameter of 1600 mm and a total length of 1600 mm (Fig. 1). We can merge two spheromaks generated by two flux cores in TS-4 and cause well-controlled magnetic reconnection. If the polarities of toroidal magnetic field of spheromaks are the same, reconnection of only poloidal magnetic field is occurred (co-helicity merging). If the polarities of toroidal magnetic field of spheromaks are the opposite, reconnection of both poloidal and toroidal magnetic field is occurred without guide field component (counter-helicity merging). Global 2-D structures of poloidal magnetic flux, toroidal current density, and toroidal electric field are derived by achieved data from 2-D magnetic probe array which measures axial and toroidal magnetic fields in r-z plane of TS-4. L-shaped magnetic fluctuation probe was employed in this experiment (Fig. 1). This probe can measure axial distribution of radial and toroidal

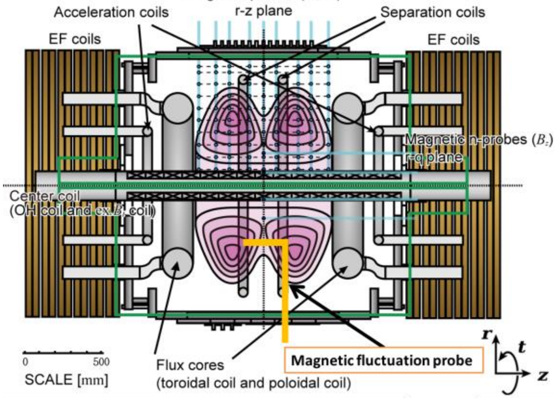

Fig. 1. An overview of plasma merging device TS-4 and experimental setup of magnetic fluctuation probe.

magnetic fluctuations with spatial interval of 10 mm. In this experiment, L-shaped probe was inserted at z = 130 mm to measure the reconnection event during counter-helicity merging which takes place on the midplane (z = 0 mm).

3. Experimental results

Magnetic fluctuations were measured during counter-helicity merging. Fig. 2(a) and (b) indicate typical magnetic fluctuations measured by L-shaped probe during magnetic reconnection. Both are toroidal components. The fluctuation in Fig. 2(a) was measured at r = 450 mm and the fluctuation in Fig. 2(b) was measured at r = 550 mm. PSD of each fluctuation is shown in Fig. 2(c). The fluctuation in Fig. 2(a) had distinctive PSD lower than 5 MHz whereas the fluctuation in Fig. 2(b) had distinctive PSD about 7-20 MHz. Spatial distribution of magnetic fluctuations was measured by scanning the L-shaped probe. Left panel of Fig. 3 shows fluctuation power profile with frequency 0.5-5 MHz and right panel shows that with frequency 7-20 MHz. It was found that the high frequency fluctuation was localized near the X-point, suggesting that this mode is directly excited by micro scale reconnection physics. On the other hand, the low frequency fluctuation was significant in the outboard-side downstream region, which might be responsible for the plasma heating at the outflow region.

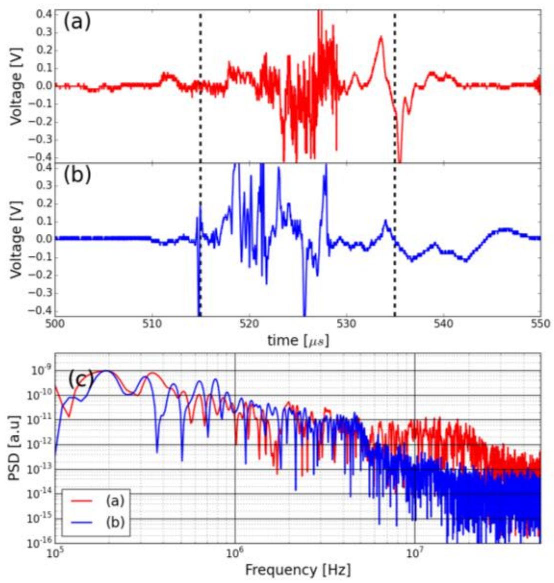

Fig. 2. (a), (b) Magnetic fluctuation signals measured by L-shaped magnetic fluctuation probe in counter-helicity merging experiment and (c) power spectral density (PSD) of fluctuation signals in (a) (red) and (b) (blue). The fluctuation signals between dotted lines in (a) and (b) were used to calculate PSD (515-535 μs)

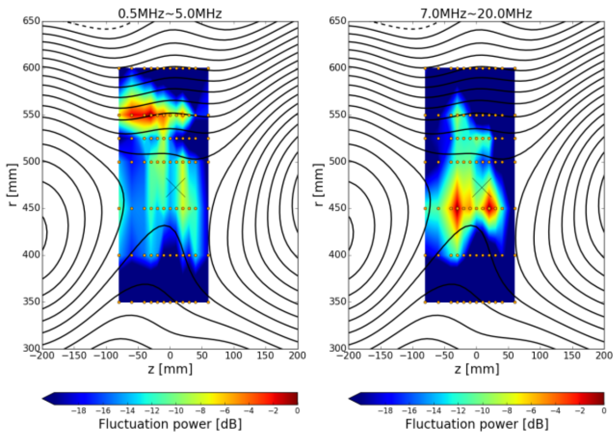

Fig. 3. The fluctuation power distribution of (left) 0.5-5 MHz and (right) 7-20 MHz frequency range measured by L-shaped magnetic fluctuation probe and poloidal magnetic flux contour (black line) measured by 2-D magnetic probe. Orange dots indicate measurement points and black x-mark denotes the X-point.

4. Summary

We carried out high-frequency probe measurement to observe magnetic fluctuations during counter-helicity merging. Two distinct frequency components were observed during reconnection. The lower frequency component was concentrated in the outboard-side downstream region of reconnection site, while the higher frequency component was localized in near the X-point. These modes might be related to the mechanisms of conversion to thermal energy and fast energy release, respectively.

Acknowledgments

This work was supported by JSPS A3 Foresight Program “Innovative Tokamak Plasma Startup and Current Drive in Spherical Torus”, JSPS Core-to-Core Program 22001, Grant-in-Aid for Scientific Research (KAKENHI) 26287143, 25820434, 22686085, 22246119, and the NIFS Collaboration Research program (NIFS14KNWP004).

References

[1] T. A. Carter, H. Ji, F. Trintchchouk, M. Yamada, and R. M. Kulsrud: Phys. Rev. Lett. **88** (2002) 015001
[2] H. Ji, S. Terry, M. Yamada, and R. Kulsrud, A. Kuritsyn and Y. Ren: Phys. Rev. Lett. **92** (2004) 115001
[3] M. Inomoto, A. Kuwahata, H. Tanabe, and Y. Ono: Phys. Plasmas. 20 (2013) 061209