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Generation of Magnetic Fluctuations with Ion Cyclotron Frequency Range during Magnetic Reconnection

磁気リコネクションによるイオンサイクロトロン周波数帯の磁場揺動の発生

Akihiro Kuwahata, Gao Boxin, Taichi Ito, Hiroshi Tanabe, Shingo Ito, Michiaki Inomoto, Yasushi Ono

桑波田晃弘, 高博シン, 伊藤大智, 田辺博士, 伊藤慎悟, 井通暁, 小野靖

Graduated school of Engineering, The University of Tokyo
260, The 10th Engineering building, 2-11-16, Yayoi, Bunkyo-ku, Tokyo 113-8656, Japan
東京大学大学院 〒113-8656 東京都文京区弥生2−11−16 東京大学工学部10号館 260号室

Large amplitude magnetic fluctuation with the ion cyclotron frequency range was observed inside the current sheet region during magnetic reconnection in the plasma merging experiment with a guide field. The fluctuation exhibited the amplitude of 10-20% of the reconnecting field and the propagating to the downstream region. The fluctuation strongly damped at current sheet edge and the reconnection electric field increased. These results indicate that the enhancement of reconnection rate and prospect of ion heating due to the fluctuation.

1. Introduction

Magnetic reconnection has the deep relationship to a variety of magnetized plasmas, such as solar flares[1,2], the earth's magnetosphere[3] and laboratory plasmas[4,5]. One of the major questions on magnetic reconnection is "How does fast magnetic reconnection happened?". In the resistive magnetohydrodynamics (MHD) regime, the reconnection rate remains very small as compared that of real reconnection events observed in the universe.

The TS-3 device has been investigated the physical properties of magnetic reconnection by using a torus plasma merging method. Previous experiment results reported that fast magnetic reconnection is achieved when the current sheet half width is compressed shorter than ion gyroradius in conjunction with the anomalous resistivity and significant ion heating[4]. However, the direct mechanism that enhances the reconnection speed still remains unclear.

2. Experimental setup

In the TS-3 device, two torus plasmas, with both poloidal and toroidal magnetic fields, are produced and their poloidal magnetic fields reconnect during the plasma merging process under a guide field. Two torus plasmas approach to the center of TS-3 and collide. During the plasma merging, magnetic field lines reconnect, and the magnetic energy is converted to plasma kinetic and thermal energy.

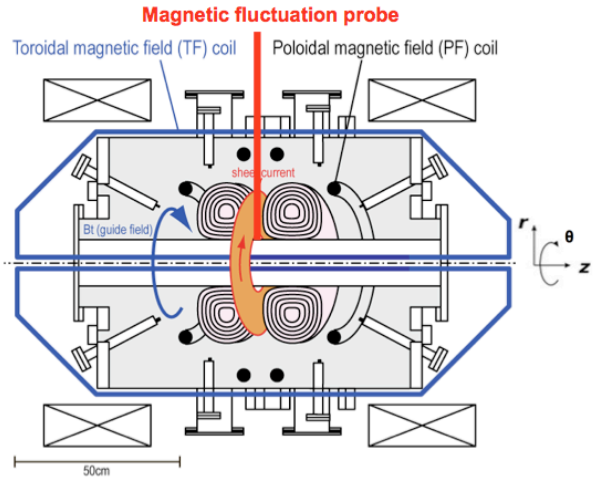

Fig. 1 Schematic of TS-3 plasma merging device with a magnetic fluctuation probe. The reconnecting field component is in the R direction and current sheet flows in the θ direction. Inflow and outflow are in the Z (axial) and R (radial) directions, respectively.

The toroidal (out-of-plane) magnetic field B_θ, which serves as a guide field in the reconnection framework, is applied in this experiment by a center conductor current. The guide field at the X-point B_x of 40 mT is comparable to the reconnecting magnetic field $B_{//} = B_r$, that is approximately 50 mT. Typical ion and electron temperatures T_i and T_e are approximately 10 eV, and electron density n_e is 1×10^{20} m^{-3}.

The magnetic fluctuation measurement was carried out by using a magnetic probe array. The probe has 16 pickup coils and is located the mid-plane

(z=0 mm) to measure reconnected magnetic fluctuations B_z at the various radial positions. (Fig. 1)

3. Experimental results

Figure 2 shows time evolution of reconnected magnetic fluctuation signals at 16 radial positions. Magnetic reconnection period is 187-197 μ s. Large magnetic fluctuations are observed during the magnetic reconnection inside the current sheet region (r=130-240 mm). The frequency spectrum of the fluctuation signal has clear peak at 2 MHz, which is slightly larger than ion cyclotron frequency (1 MHz). The amplitude of the fluctuation is about 10-20 % of the reconnecting field. The fluctuation propagates to the downstream region with about 50 km/s.

Figure 3 shows time evolution of reconnection electric field E_θ at the X-point, which is calculated by using equations (1,2) and assuming axial symmetry. In the large fluctuation case, the reconnection electric field increases and is a several times large as compared with small fluctuation case.

$$E_\theta = -\frac{1}{2\pi r}\frac{\partial \Psi}{\partial t} \tag{1}$$

$$\Psi = \int_{r_{\min}}^{r} 2\pi r' B_Z(r', z)\, dr' \tag{2}$$

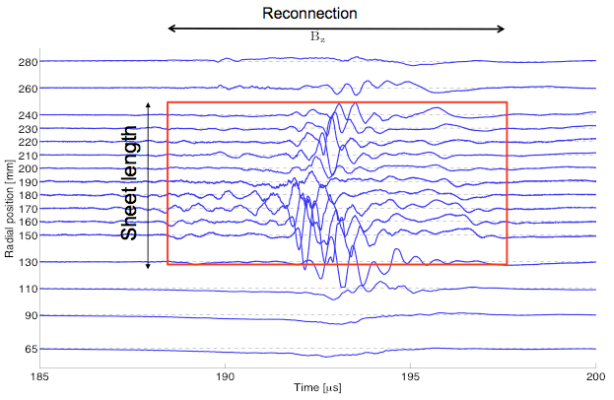

Fig. 2 Time evolution of reconnected magnetic fluctuation signals at various radial positions. Reconnection period and sheet length are 187-197 μ s and 100 mm, respectively.

Fig. 3 Time evolution of reconnection electric field E_θ at the X-point: the large and small fluctuation cases.

4. Conclusion

We have detected magnetic fluctuations during magnetic reconnection under a guide field. The amplitude of fluctuations is about 10-20 % of the reconnecting magnetic field. The fluctuation propagates to the downstream region and strongly dumps at the current sheet edge. The reconnection electric field at the X-point increases when fluctuations appear. These results indicate that the prospect of ion heating and enhancement reconnection rate due to the fluctuations.

Acknowledgments

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