19pB-4

Impurity line spectroscopy during spherical tokamak merging in UTST

UTSTにおける球状トカマク合体時不純物発光の分光計測

Hiroki Ishikawa, Takenori G Watanabe, Naoto Kawakami, Michiaki Inomoto

石川裕貴, 渡辺岳典, 川上直人, 井通暁

The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa,Chiba 277-8561, Japan

東大新領域 〒277-8561 千葉県柏市柏の葉5-1-5

Formation of disk-shaped emission region was found in high guide field reconnection in UTST merging experiment. This emission burst is possibly caused by toroidally accelerated electrons and suggests that electron kinetic effect could be significant in the experimental condition. Small scale charge separation is expected to generate extremely large axial electric field near the edge of the electron diffusion region. Local spectroscopic measurement was carried out during the emission burst event and the experimental results showed largely deformed spectra, suggesting the existence of micro structure of ion temperature, flow, or large electric field.

1. Introduction

Magnetic reconnection plays important roles in ubiquitous magnetized plasma such as energy release, magnetic topology change, particle acceleration, and so on. Recent theoretical and numerical studies have shown that kinetic behaviors of not only ions but also electrons are important for the dynamics of collisionless magnetic reconnection. The role of a guide field, which is a magnetic field perpendicular to the reconnecting/reconnected fields, has also become important in the situation of collisionless reconnection. One of significant change provided by a guide field is particle acceleration mechanism. Since the reconnection electric field is in parallel with the guide field, direct parallel acceleration of particles near the X-point region is expected [1]. The accelerated electrons and ions in guide field reconnection are exhausted along different pair of separatrices because of the distorted Hall current pattern. Since the electrons have shorter inertia length than ions, the electrons penetrate deep into the reconnection region while the ions have larger scale flow pattern. Thus, charge separation between separatrices of electron-rich branches and ion-rich branches occurs. The in-plane electrostatic field is then expected to cause secondary modification on particle motion.

Electric field measurements [3] of the local reconnection region were carried out by using Langmuir probes, however, their resolution is not fine enough to detect electron scale potential change, or microscopic electric field structure. If the potential structure has electron scale length, extremely high electric field of ~kV/cm is expected, which is large enough to exhibit Stark effect on hydrogenic atomic line [4]. In this paper, preliminary experimental results from local spectroscopic measurement in UTST reconnection experiment will be presented.

2. Experimental Setup

Well-controlled magnetic reconnection situation with very high guide field more than 10 times of reconnecting field is achieved in UTST plasma merging experiment (fig.1). Two spherical tokamak plasmas are generated at once and are pushed by magnetic pressure to merge through magnetic reconnection on the mid-plane of the device. Here,

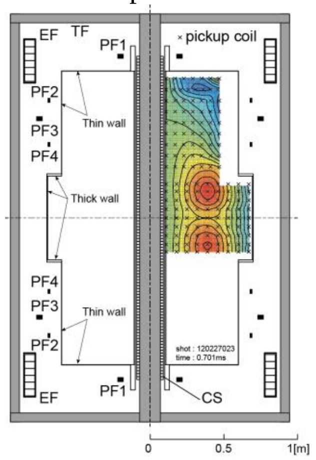

Fig. 1 Cross-sectional view of UTST device.

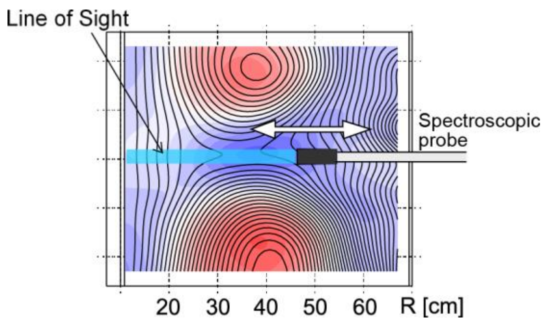

Fig. 2 Schematic view of the spectroscopic probe superposed on the observed magnetic field structure.

the toroidal magnetic field act as the guide field and the poloidal field is the reconnecting magnetic field. Large axial electric field is expected to arise during fast reconnection phase on the mid-plane.

A small probe for spectroscopy is installed on the mid-plane as shown in fig.2 superposed on the observed magnetic field lines. The probe consists of a collimator lens and optical fiber bundle coupled with monochromator and photomultiplier linear array to achieve the temporal evolution of the line spectrum. Local emission burst from the X-point region was confirmed by fast camera imaging observation in UTST. A sharp disk-shaped emission region of carbon impurity and neutral particles was formed possibly due to the toroidally accelerated electrons. In this measurement, emission during the burst timing is investigated.

3. Experimental Results

Fig. 3 (a) shows the time evolutions of reconnection electric field at the X point and (b) the Hβ emission intensity observed by the spectroscopic probe located at various radial positions. It was found that the line-integrated light intensity during the burst showed almost linear increasing trend with the probe radius, indicating that the disk-shaped emission region has nearly uniform emissivity.Fig.4 shows the spectral profile of (a) radially integrated Hβ line observed from R=40cm, 35cm, 30cm, and 25cm. Note that the reconnection X-point located around R=35cm. All these spectra look Gaussian function, however, (b) radial difference of these spectra, in other words, local Hβ emission from X-point region revealed significant deformation as well as blue shift, which is consistent with the fact that the reconnection outflow in the inboard region (R<25cm) will have velocity away from the probe (red shift)..

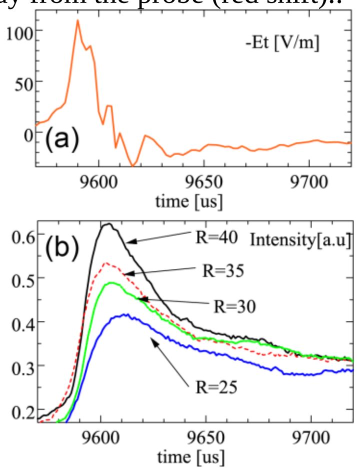

Fig. 3 Time evolutions of reconnection electric field and Hβ intensity observed from different radial positions.

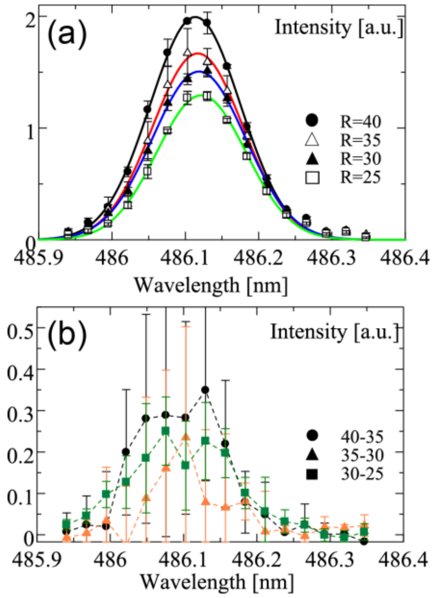

Fig. 4 Spectral profiles of (a) radially-integrated Hβ line and (b) their radial difference.

4. Summary

Spectroscopic measurement of the disk-shaped emission burst region during high guide field reconnection was conducted. The local emission showed clear non-Gaussian profiles, suggesting the existence of micro structure of ion temperature or ion flow, or extremely strong electric field. Further investigation will be conducted using various line spectra in order to distinguish the cause of the spectral deformation.

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).

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