19PB-101

Verification of heating mechanism during spherical tokamak merging using Doppler spectroscopy

ドップラー分光計測を用いた球状トカマク合体加熱機構の検証

[1]T.G.Watanabe, [1]H.Tanabe, [1]H.Ishikawa, [1]N.Kawakami, [1]K.Yamasaki, [1]A. Wang, [1]T. Ushiki, [1]X. Guo, [1]H. Nakamata, [2]S. Kamio, [3]T. Yamada, [1]M. Inomoto, [1]Y. Ono
渡辺岳典, 田辺博士, 石川裕貴, 川上直人, 山崎広太郎, 王安斉, 牛木知彦, 郭学瀚, 中俣浩樹, 神尾修治, 山田琢磨, 井通暁, 小野靖

[1]*The University of Tokyo, Graduate school of engineering, Depart of Electrical Engineering 5-1-5, Kashiwanoha, Kashiwa, Chiba, 277-8561, Japan*
東京大学大学院 〒277-8561 千葉県柏市柏の葉5-1-5
[2]*National Institute for Fusion Science 322-6 Oroshi-cho Toki-city, Gifu*
自然科学研究機構 核融合科学研究所 〒509-5292 岐阜県土岐市下石町322-6
[3] *Faculty of Arts and Science, Kyushu University, Fukuoka 819-0395, Japan*
九州大学 〒819-0395 福岡市西区元岡744

A plasma merging induces a magnetic reconnection, which heats plasma quite quickly. Fast time resolution is needed to observe the reconnection heating. Thus, a Doppler spectroscopy system with 8 × 8 PMT assembly was introduced. It enabled high-speed measurement of the ion temperature using Doppler broadening of impurity lines. The rapid increase of the ion temperature was measured near the X-point and in the outflow. Ion was intermittently heated during merging.

1. Introduction

The plasma startup without use of a central solenoid (CS) coil is an important technical subject for a low aspect ratio configuration of a spherical tokamak (ST). The plasma merging scheme is one of those CS-coil-free startup techniques, and is investigated in START/MAST (UKAEA) [1], TS-3/4 [2] and UTST [3] (The University of Tokyo) devices. The magnetic reconnection induced by the plasma merging converts the magnetic field energy to the thermal and kinetic energy of plasma, therefore it increases the plasma beta in a quite short time.

High-power reconnection ion heating was observed in TS-3 [4]. They showed the ions were heated quite quickly.

A Doppler spectroscopy system with 8 × 8 PMT assembly enables high-speed and multi-point measurement of the ion temperature, which provides spatial (8 channels) and wavelength (8 channels) resolution[5]. This system was introduced in MAST to measure the reconnection ion heating under the high magnetic field.

2. Experimental Results

Figure 1 shows time evolutions of the current of ST plasma and P3 coil, which is a pair of poloidal field coils located inside the vessel and utilized to plasma breakdown and current ramp-up in MAST merging startup experiments. The initial plasmas were initiated near the two P3 coil and then moved towards the mid-plane and merged together. The plasma merged current upped at once. The current depended on the magnitude of P3 coil current and upped 190 kA in the case that P3 coil current upped 150 kA.

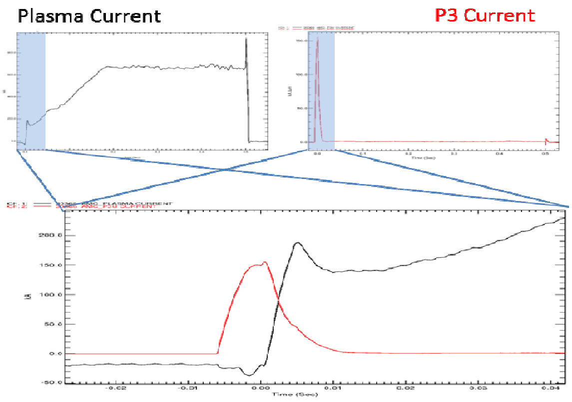

Fig.1 Time evolutions of the current of plasma and P3 coil.

In this discharge, the Doppler spectroscopy system was arranged to have tangential lines of sights at mid-plane (Z = 0). The eight chords were located at 0.26 m, 0.34 m, 0.423 m, 0.506 m, 0.588 m, 0.670 m, 0.750 m, 0.830 m, and CⅣ impurity line was measured.

Figure 2 shows (a) fast camera images with Dα filter and (b) differential images at 4.4 ms, 4.5ms and 4.6ms. The difference images were produced by subtracting the brightness values between temporally successive images to enhance the change and enable us to estimate the reconnection location.

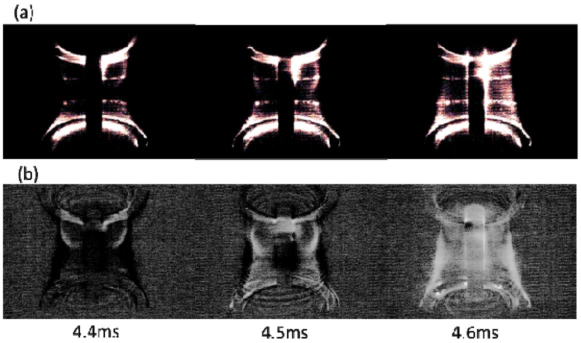

Fig. 2 Time evolution of (a) fast camera images with Dα filter (b) differential images of (a) at 4.4ms, 4.5ms, 4.6ms.

The position of the merging varied with time and from discharge to discharge. It is estimated that the X-point located around Z = 0 m and R= 5.7 m in this discharge. Figures 3 show the radial profiles of averaged ion temperature measured by the Doppler spectroscopy system. The peak temperature in the outflow region was measured after that was measured near the X-point. The ion heating near the X-point and in the outflow was observed intermittently. This indicated that the magnetic reconnection was non-steady.

4. Summary

The high-speed measurement system of the ion temperature was introduced in MAST. The rapid increase of the ion temperature was measured during the plasma merging. The magnetic reconnection was non-steady induced by the plasma merging. The non-steady caused the ion heating at the X-point and in the outflow region to be intermittent.

In MAST, the utilizable measurements which have a fast time resolution for the plasma merging are scant. UTST device has internal magnetic probes and high-speed measurements, which must enable us to absorb the details of the merging.

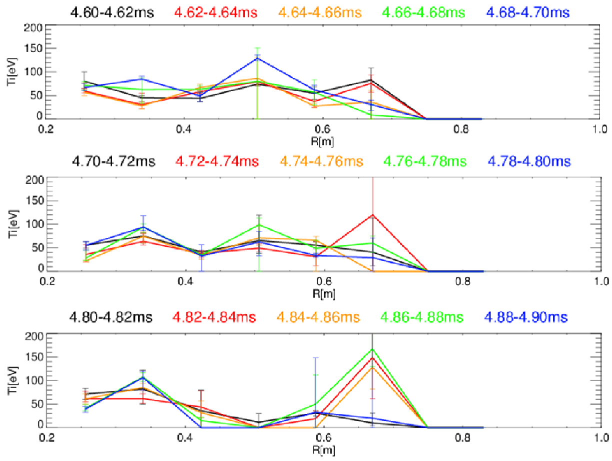

Fig. 3 Radial profiles of averaged ion temperature measured by the Doppler spectroscopy system

Acknowledgement

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] A. Sykes *et al.*, Nucl. Fusion **41**, 1423 (2001)
[2] Y. Ono and M. Inomoto, Phys. Plasmas **7**, 1863 (2000).
[3] T. Yamada *et al.*, Plasma Fusion Res. **5**, S2100 (2010).
[4] Y. Ono *et al.*, Phys. Rev. Lett. **107**, 185001 (2011).
[5] S. Kamio et al, Rev. Sci. Instruments., **83**, 083103 (2012).