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FAST POTENTIAL CHANGES AT H-MODE TRANSITION IN THE JFT-2M TOKAMAK

Y.HAMADA, T.IDO[*] , K.KAMIYA[**] , A.NISHIZAWA, Y.KAWASUMI
National Institute for Fusion Science , Toki, 509-5292, Japan

Y. MIURA, and JFT-2M GROUP
Japan Atomic Energy Research Institute, Ibaraki, 319-1195, Japan

Abstract

The fast potential change at H-mode transition was measured for the first time by a 500 keV heavy ion beam probe installed on the JFT-2M tokamak. It is found that in an ordinary sawtooth-triggered L/H-transition, the fast positive potential change is observed near the separatrix in coincidence with the fast D_α rise and the fast density change. The potential goes down at the fall of D_α. The structure of the radial electric field about 30 msec after L/H transition agrees with the previous results determined by the poloidal, toroidal rotation speed and the pressure gradient.

1. INTRODUCTION

H-mode transition has been so effective in improving the confinement of hot plasmas. Therefore, it has been the targets of intensive experimental and theoretical research in plasma physics. Up to now, it has been claimed experimentally and theoretically that the radial electric field plays key roles for causing the transition. So far the highly time-resolved and direct measurement of the potential or electric field has not been performed, and it was difficult to establish the causality between the potential change and H-mode transition.

The heavy ion beam probe (HIBP) is particularly suited for fast and the local measurement of the plasma potential. The local plasma potential can be obtained by the measurement of the change of the secondary beam energy generated at the sample volume. The intensity of the secondary beam is the indicator of the local density although the attenuation along the trajectory must be taken into account. In order to study the physics of H-mode transition, we installed a 500 keV heavy ion beam probe on the JFT-2M tokamak under collaboration program between NIFS and JAERI.

At H-mode transition we observed clear and unambiguous change of potential and density near the separatrix. The radial profiles of plasma potential at stationary L and H-mode is in general agreement with the results obtained with the spectroscopic measurements. In addition, we obtained new results because of local and direct potential/density measurement with high time resolution.

2. APPARATUS

Figure 1 is the schematic view of the HIBP system on JFT-2M. It injects singly ionized thallium ions (primary beam) and detects the doubly charged ions (secondary beam) that are ionized in a plasma. They are accelerated up to 500kV with the low ripple of 2V or less by the electrostatic accelerator which was previously used in the JIPPT-IIU HIBP. The accelerator is set on the iron

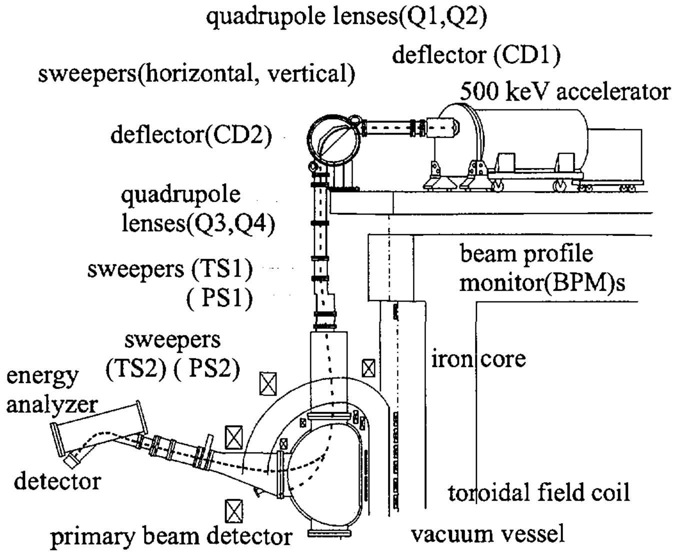

FIG. 1. Schematic View of the HIBP system on JFT-2M

[*] Department of energy engineering and science, Nagoya University, Nagoya, 464-8603, Japan
[**] Department of Fusion Science, The Graduate University for Advanced Studies, Toki, 509-5292, Japan

core in order not to interfere with various kind of heating and diagnostics apparatuses. There are two electrostatic cylindrical deflectors and two pairs of double electrostatic quadrupole lens (doublet) to transport beam to the vertical entrance port as shown in Fig.1. The main task of the first doublet is to compensate the strong focusing power of cylindrical deflectors. The second doublet may be able to change the shape of the sample volume freely. The diameter of the beam is adjusted to about 5 mm at the observation point in a plasma.

The energy of the secondary beam is measured by a parallel plate electrostatic energy analyzer[1]. In the energy analyzer we installed as we did at JIPPT-IIU HIBP, seven sets of slits, which is just in front of the energy analyzer, and seven sets of upper and lower detector plates at the focusing point of the analyzer[2]. The potential is measured by the ratio of the upper and lower detector currents. The density is related to the intensity of the secondary beam (the sum of upper and lower detector currents). We can measure simultaneously at seven points, which extend over a few cm across the magnetic surface. The error due to the toroidal deflection of the beam by the plasma current can be suppressed with two toroidal sweepers (TS1 and TS2 shown in Fig.1).

The radial sweep frequency with the sweeper (PS1 shown in Fig.1) is up to 2kHz, so the time resolution of an entire potential profile measurement is up to 250μsec. We fix the sweep voltage to observe fast phenomena. Then the time resolution is a few μsec, which depends on beam intensity. The frequency response of the detector extends to about 100kHz at 3dB down and the sampling time of the analog-digital-converter is 5μsec in the present condition.

3. EXPERIMENTAL RESULTS

Figure 2 (b)-(c) show the time history of an H-mode that is triggered by a sawtooth. The H-mode without ELM is a typical JFT-2M H-mode and is the target of the present study. Figure 2 (a) shows radial potential profiles near the plasma boundary in various time points (see arrows on the D_α trace) by sweeping the primary beam poloidally at the entrance of the tokamak. In the L-mode phase, the potential profile drops smoothly from 200V to -150V from the separatrix. During the decay phase of D_α intensity by the L/H transition, the potential only where the position close to the separatrix shows the drop. After about 2 msec from the transition, the potential structure is almost fixed as shown by closed triangles in Fig.2(a). General characteristics (deepening of the potential and the large gradient of the potential near the separatrix at H-mode) and the amount of decrease of the plasma potential at far inside is about -300 V, are in agreement with the previous observation determined by the poloidal, toroidal rotation speed and the pressure gradient[3].

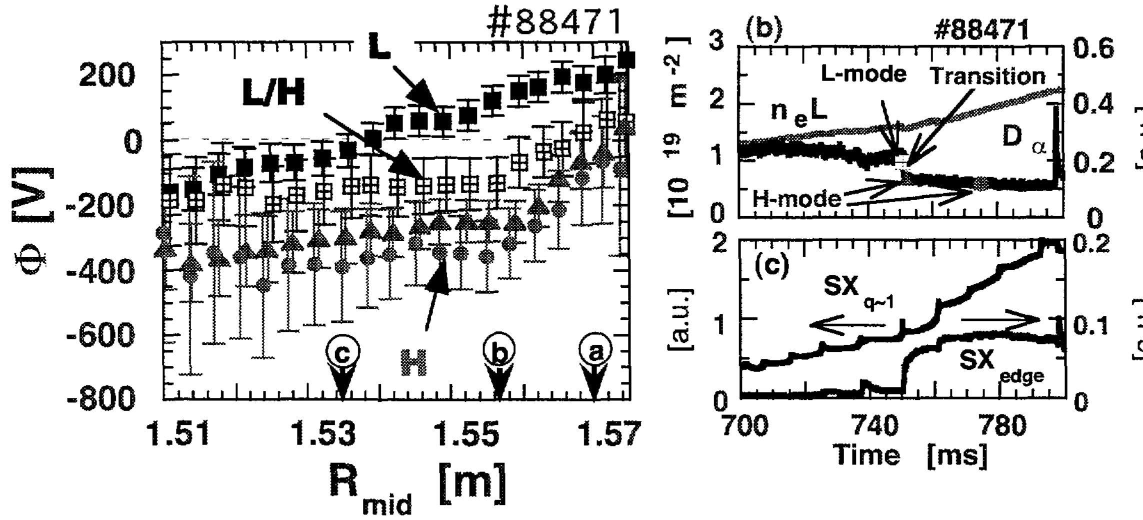

FIG.2. (a)The potential profiles near the plasma boundary. Time History of H-mode, (b)Line integrated density and D_α intensity, (c)Soft X-ray intensity of around q~1 and edge sight lines. Arrows in (b) on the D_α trace show the time of the potential profile shown in (a). The separatrix position is estimated to be around R~1.56m.

Figure 3 shows time behaviors of a local plasma potential, the secondary beam intensity and the D_{α} intensity when the sample volumes are placed outside the separatrix about (a)-1.2cm, and inside the separatrix (b)0.5 cm and (c)2.4 cm (see also in Fig.2 shown by arrows). After a few sawtooth crashes during neutral beam injection (NBI) heating, the sawtooth crash induces the H-mode transition. A sharp potential rise as well as the rise of D_{α} intensity are observed in most cases at the time between the sawtooth heat pulse propagation and the formation of the transport barrier. Then the fall of both D_{α} and that of the local potentials occur simultaneously although the potential drop is faster. The intensity of the secondary beam shows the increase at the onset of a small rise of D_{α} and potential in the case of (b). In the case of (a) and (c), it shows the decrease of the intensity. In case (c), the sample volume is rather far inside the separatrix that the local density at this position does not change at this time scale. Accordingly we only observe the decay of the intensity through the increase of the attenuation on the trajectory from the plasma boundary to the sample volume. It is caused by the increase of plasma density/temperature due to the formation of transport barrier or the effect of the sawtooth heat pulse propagation, although the effect of the previous crash (~735msec) is much smaller than that shown in Fig.3(c). Case (b) shows the increase of the intensity due to the increase of the density/temperature at the sample volume due to the formation of the transport barrier. The decrease of the intensity observed in case (a) can be interpreted by the decay of density/temperature at the sample volume outside the transport barrier.

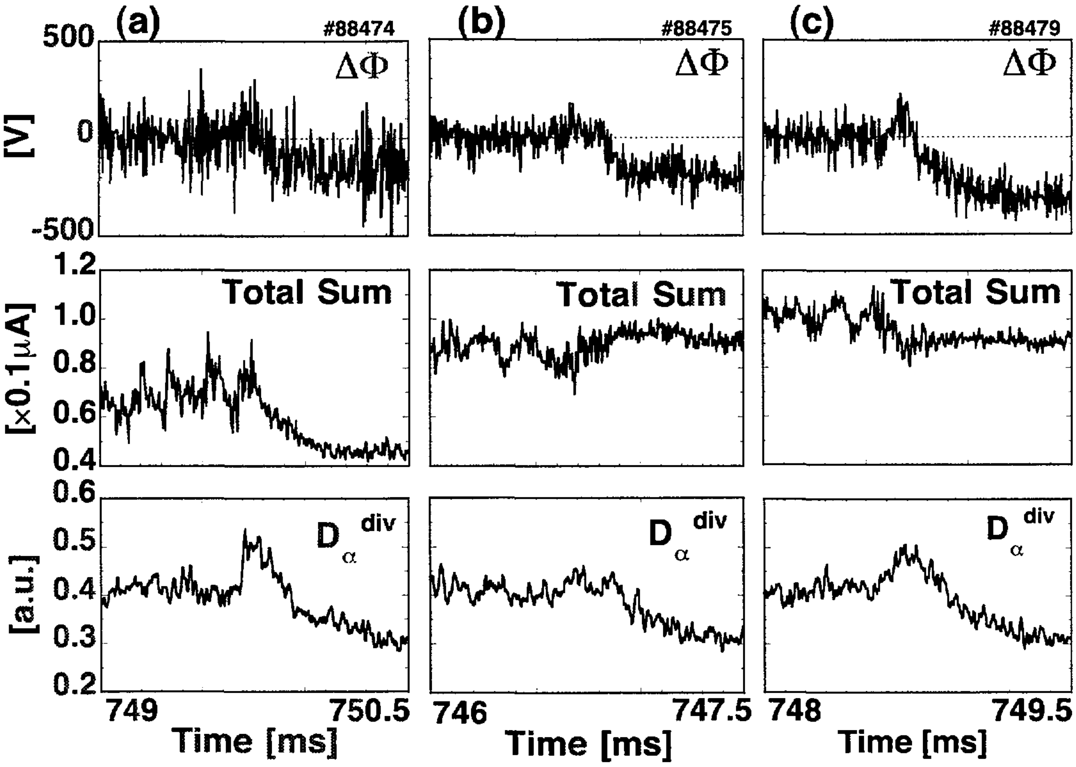

FIG.3. Fast time behaviors at the H-mode transition. The plasma potential(ΔΦ), the secondary beam intensity(Total Sum) and D_{α} intensity. The sample volume is placed about (a)1.2 cm outside the separatrix and (b)0.5 cm and (c)2.4 cm inside the separatrix. These positions are also shown in Fig.2 (a).

4. DISCUSSION

In the previous section, it is shown that L/H transition occurs within a few hundreds microsecond after a sawtooth heat pulse reaching the plasma edge. The potential changes positively at first and decrease gradually to about -300V at a few centimeter inside the separatrix. It takes about 200 microsecond to reach the saturated value of -300V. However, the fluctuation observed in the secondary beam intensity decreases more earlier than the drop of the saturated potential. Therefore, we think that the formation of the transport barrier may not be directly connected to the large negative potential change. Figure 4 shows a very interesting behavior of the potential and the fluctuation. In this case, the sample volume is very close to the separatrix, but about 0.5cm inside to the plasma core compared with that shown in Fig.3(a) (shot is the same). The interesting point is the time of 749.8msec that the change of the very rapid drop of the potential is observed together with the drop of the fluctuation in the secondary beam intensity and the magnetic probe data of dB_θ/dt. The power of the fluctuation integrated from 10 to 50kHz drops about one order. It is difficult to discuss the causality between them, they seem to occur simultaneously. Since the number of the observation with fixing the sample volume to this position is very limited, we need further study to find the relation between the rapid drop of the potential and the fluctuation. It is left for the future work.

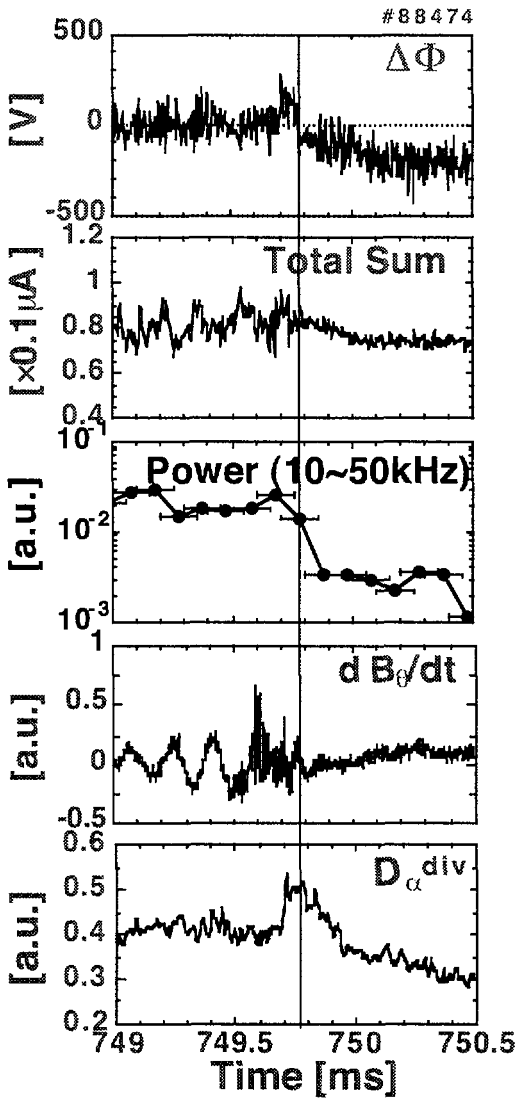

FIG.4. Fast time behaviors at the H-mode transition. The plasma potential(ΔΦ), the secondary beam intensity (Total Sum), the power of the fluctuation in the beam intensity integrated from 10 to 50kHz, the magnetic probe signal of dB_θ/dt and D_α intensity when the sample volume is placed about 0.5cm inside to the plasma core compared with that shown in Fig.3(a) (shot is the same)

5. SUMMARY

The fast potential change at H-mode transition was measured for the first time by HIBP on the JFT-2M tokamak. It is found that in an ordinary sawtooth-triggered L/H-transition, the fast positive potential change is observed near the separatrix in coincidence with the fast D_α rise and the fast density change. The potential goes down gradually (~200μsec) to large negative value of about -300V together with the fall of D_α. Therefore, we think that the formation of transport barrier may not be directly connected with the formation of the large negative potential change measured by the spectroscopic method previously. The rapid change of the potential and the drop of the fluctuation, however, is observed simultaneously only when the sample volume is very close to the separatrix. To clarify the relation between them, further study is needed.

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