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H-Modes of JIPP T-IIU**

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ABSTRACT

In limiter H-modes of JIPP T-IIU, a new type of L-H transition preceded by an ELM is observed. The preceding ELM (pre-ELM) appears *just prior to* the L-H transition. This type of transition is usually observed in H-modes of JIPP T-IIU. The L-H transition without the pre-ELM is triggered only in the case when a sufficiently large rapid current ramp down is employed. In H-modes with constant $q(a) \sim 3.5-4.5$, coherent magnetic oscillations with $m=3/n=1$ destabilized during L-phase are further enhanced at the pre-ELM, and suppressed suddenly at the transition. This mode is situated in the region of the transport barrier. Propagation frequency of the $m=3/n=1$ mode, which may be affected by plasma mass rotation, rises appreciably (by $\sim 10\%$) during H-phase with frequent ELMs, but remains unchanged for at least $200 \mu\text{s}$ after the transition. Behaviours of the $m=3/n=1$ and $m=2/n=1$ modes are well explained by quasi-linear resistive tearing mode analysis for modelled toroidal current density profiles slightly detached from the limiter. These experimental results suggest that the transition is controlled by the change of a magnetic field structure relating to the modification of a toroidal current density profile near the edge. The possibility for the development of edge radial electric field as a *consequence* of the transition is discussed.

Keywords: L-H Transition, Edge Localized Modes, Preceding ELM,
 $m=3/n=1$ Magnetic Fluctuations, Edge Radial Electric Field,
Poloidal Rotation, Resistive Tearing Mode, Detached Toroidal
Current Density Profile

1. INTRODUCTION

The influence of edge radial electric field or poloidal rotation on the L-H transition, turbulence suppression and confinement improvement is widely discussed[1]. The experimental data from DIII-D[2] where edge radial electric field E_r becomes more negative at the transition and edge turbulence is suppressed dramatically appeared to be explained with the theory[1]. However, recent numerical simulations have not confirmed the stabilizing effect related to E_r [3]. We also note that edge poloidal rotation obtained with fairly good time resolution ($\Delta t \sim 1$ ms) does not precede the transition[2]. Therefore, the cause and consequence relationship between E_r or E_r' and the L-H transition is still obscure. Observed dramatic change in edge radial electric field may be explained as a consequence of the transition, because transport analyses on ASDEX, DIII-D and JET data have confirmed that electron transport is dominantly reduced after the transition[4]. Coherent magnetic oscillations such as $m=4/n=1$ or $m=3/n=1$ [5,6] whose rational surface locates near the edge provide useful information on the edge magnetic structure which may intimately affect electron edge confinement. From the characteristic behaviours of the coherent modes, we constructed an alternative model of the L-H transition[6,7] which is governed by the slight detachment of the current channel from the limiter or magnetic separatrix. The L-H transition in limiter H-modes of JIPP T-IIU is classified into two types of the transition: (1) transition without preceding ELM, and (2) new type of the transition preceded by an ELM (termed as "pre-ELM"). In this paper, we mainly study the latter transition along our transition model[6,7].

2. CHARACTERISTICS OF L/H TRANSITION

Figure 1(a) shows a typical L-H transition without the pre-ELM, of which transition is triggered only in the case with a sufficiently large rapid current ramp-down. This type of the transition seems to be triggered when a toroidal current channel is sufficiently detached from the limiter with CRD. Figure 1(b) shows a new type of the transition preceded by the pre-ELM. The transition is usually observed in H-modes of JIPP T-IIU. The pre-ELM (at $t=231$ ms in Fig.1(b)) has the same characters with ELMs observed in H-phase: the spike in H_{α}/D_{α} -emission I_{α} or ion saturation current I_{S} , and sudden drop in edge electron temperature T_{eb} . The signal I_{S} as a measure of the outward loss flux is depressed down to the level in H-phase just after the pre-ELM. The amplitude of $m=3/n=1$ mode is further increased at the pre-ELM. The $m=3/n=1$ mode is stable during OH-phase, destabilized in L-phase and is stabilized in H-phase. This feature seems not to be explained by the

process of quasi-linear drift stabilization arisen from the considerable rise in T_{eb} [8]. The amplitudes of $m=2/n=1$ mode and incoherent components ($f > 30$ kHz) decreases more slowly.

As discussed in JET[9], we indirectly estimate the poloidal rotation velocity v_θ from the frequency of the above-mentioned coherent modes which rotate in the electron diamagnetic drift direction, using the profile of toroidal rotation velocity V_ϕ obtained from a charge exchange recombination (CXR-) spectroscopy[10]. Figure 2 shows temporal evolution of the propagation frequencies of $m=3/n=1$ and $m=2/n=1$ modes and poloidal rotation velocity estimated at each rational surface, where $V_\phi \sim 20$ km/s (counter direction to I_p) at the rational surface of $m=3/n=1$ mode ($r_S/a \sim 0.85$, which approximately coincides with the location of the transport barrier determined experimentally [6]) and ~ 25 km/s for $m=2/n=1$ mode ($r_S/a \sim 0.65$), and electron diamagnetic drift frequency is taken into account. The $m=3/n=1$ mode frequency is slightly (by $\sim 10\%$) but obviously raised during H-phase. However, the poloidal rotation velocity is almost unchanged. The reason why the poloidal rotation estimated above is unchanged across the transition is that the mode frequencies in H-phase are detected only around ELMs and the velocity may be close to the level of L-phase as observed in DIII-D[2]. The most significant point is that the mode frequency of $m/n=3/1$ remains unchanged for at least 200 μ s after the L-H transition defined as the start of I_α -depression. This fact suggests that enhanced poloidal rotation in the transport barrier may be generated not as the cause of the L-H transition, but as the consequence.

3. COMPARISON WITH TEARING MODE ANALYSIS

We analyze the magnetic fluctuation data shown in Fig.1(b) or Fig.2, by the quasi-linear analysis of resistive tearing mode ($\Delta'(w)$ -analysis). As strong electron heating or generation of appreciable amount of bootstrap current tends to increase a plasma current and to induce reversed toroidal electric field through conservation of the poloidal magnetic flux, a toroidal current channel may be detached from the limiter or magnetic separatrix. Moreover, the increase in edge current density with rapid current ramp-up easily quenches the H-mode even in very high heating power[6,7]. From these experimental evidences, we introduce a set of j_ϕ -profiles detached from the limiter with fixed $q(a)$ for the $\Delta'(w)$ -analysis(Fig.3(a)). The

calculated relative amplitude $\frac{\tilde{B}_a}{B_0}$ for $m=3/n=1$ and $m=2/n=1$ is shown in Fig.3(b) as a function of the position of the detached edge of j_ϕ -profile. The amplitude of $m=3/n=1$ mode is rapidly increased and stabilized suddenly when the current

channel is detached to $r/a \sim 0.80-0.85$, which approximately coincides with the location of the transport barrier[6]. On the hand, the amplitude of $m=2/n=1$ mode decreases gradually with respect to the degree of the detachment. The amplitudes

of $m=3/n=1$ and $m=2/n=1$ modes estimated from Mirnov probe are $\frac{\tilde{B}_0}{B_0} \sim 0.4\%$ and 0.2% , respectively, for the shot in Fig.1(b) or Fig.2. The characters in Fig.3(b) have a fairly good agreement with the experimental observations (Fig.1(b) and Fig.2(i)).

4. SUMMARY

The analysis of $m=3/n=1$ mode around the L-H transition with the pre-ELM suggests that the j_{ϕ} -profile near the edge is modified first at the transition and then the transition occurs. As pointed out in ref.[8], we speculate that significant change in E_r or v_{θ} profile may be caused through the preferential improvement of electron edge confinement as a consequence of the transition.

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Figure Captions

Fig.1 (a) Time behaviour of the transition without the pre-ELM observed in the H-mode with CRD. (b) Time behaviour of the new type of the transition with the pre-ELM, where "S.T." on T_{eb} -trace denotes the rise due to a sawtooth event.

Fig.2 (a) Temporal evolution of the frequencies for $m=3/n=1$ (solid circles) and $m=2/n=1$ (solid squares) modes and poloidal rotation velocities at each rational surface indirectly estimated from the MHD modes (open circles and open squares respectively). (b) Expanded time behaviour of the transition.

Fig.3 (a) Examples of j_{ϕ} -profiles detached from the limiter introduced for the $\Delta'(w)$ -analysis. (b) Dependence of calculated relative amplitudes of $m=3/n=1$ (open symbol) and $m=2/n=1$ (solid symbol) modes on the degree of the current detachment.

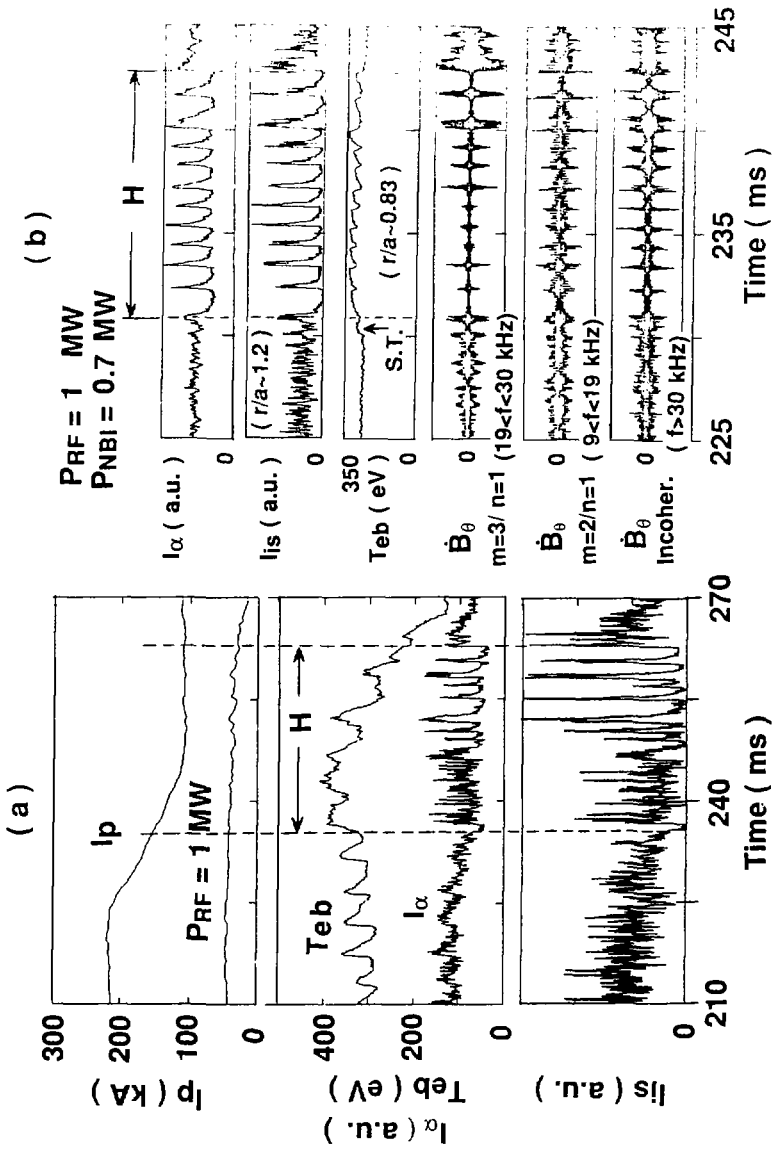


Fig.1

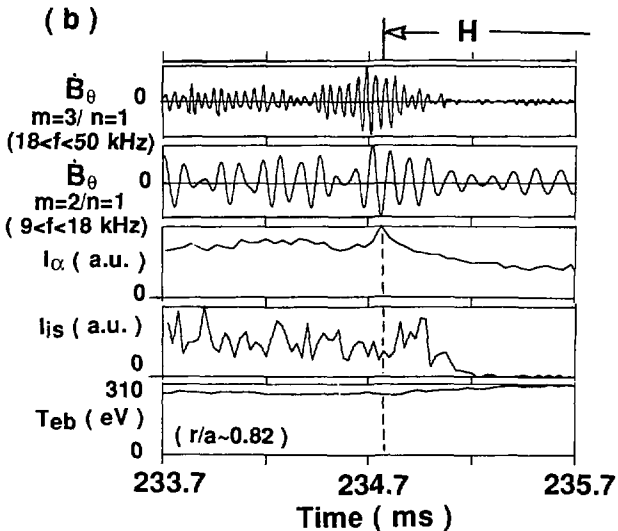
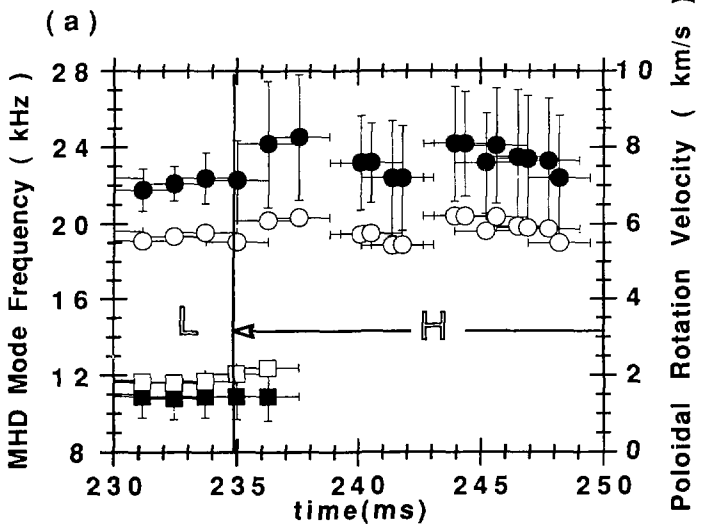


Fig.2

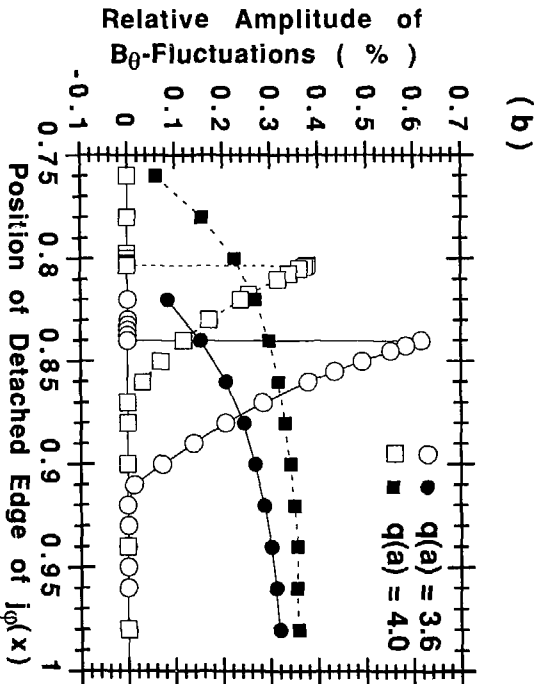
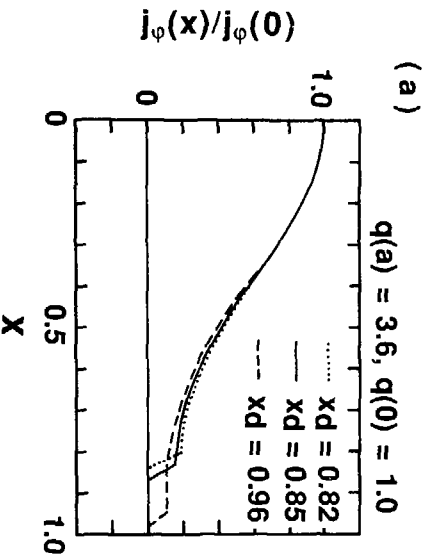


Fig.3

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