ISSN 0915-633X

INTERNATIONAL ATOMIC ENERGY AGENCY

FOURTEENTH INTERNATIONAL CONFERENCE ON PLASMA PHYSICS AND CONTROLLED NUCLEAR FUSION RESEARCH

Würzburg, Germany, 30 September – 7 October 1992

IAEA-CN-56/A-7-14

NATIONAL INSTITUTE FOR FUSION SCIENCE

New Features of L-H Transition in Limiter H-Modes of JIPP T-IIU

K. Toi, S. Morita, K. Kawahata, K. Ida, T. Watari, R. Kumazawa, A. Ando, Y. Oka, K. Ohkubo, Y. Hamada, K. Adati, R. Akiyama, S. Hidekuma, S. Hirokura, O. Kaneko, T. Kawamoto, Y. Kawasumi, M. Kojima, T. Kuroda, K. Masai, K. Narihara, Y. Ogawa, S. Okajima, M. Sakamoto, M. Sasao, K. Sato, K.N. Sato, T. Seki, F. Shimpo, S. Tanahashi, Y. Taniguchi and T. Tsuzuki

(Received – Aug. 31, 1992)

NIFS-179 Sep. 1992

RESEARCH REPORT
NIFS Series

INTERNATIONAL ATOMIC ENERGY AGENCY

FOURTEENTH INTERNATIONAL CONFERENCE ON PLASMA PHYSICS AND CONTROLLED NUCLEAR FUSION RESEARCH

Würzburg, Germany, 30 September – 7 October 1992

IAEA-CN-56/A-7-14

NEW FEATURES OF L-H TRANSITION IN LIMITER H-MODES OF JIPP T-IIU

K. TOI, S. MORITA, K. KAWAHATA, K.IDA, T. WATARI, R. KUMAZAWA, A. ANDO, Y. OKA, K. OHKUBO, Y. HAMADA, K. ADATI, R. AKIYAMA, S. HIDEKUMA, S. HIROKURA, O. KANEKO, T.KAWAMOTO, Y. KAWASUMI, M. KOJIMA, T. KURODA, K.MASAI, K. NARIHARA, Y. OGAWA[1)], S. OKAJIMA[2)], M. SAKAMOTO, M. SASAO, K. SATO, K.N. SATO, T. SEKI, F. SHIMPO, S. TANAHASHI, Y. TANIGUCHI, T. TSUZUKI

National Institute for Fusion Science, Nagoya 464-01,Japan

1)Department of Engineering, University of Tokyo, Tokyo 113, Japan
2)Department of Applied Physics, Chubu University, Kasugai 487, Japan

14th International Conference on Plasma Physics and
Controlled Nuclear Fusion Research, Würzburg,
Germany, 30 September - 7 October 1992

IAEA-CN-56/A-7-14

NEW FEATURES OF L-H TRANSITION IN LIMITER H-MODES OF JIPP T-IIU

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 emploied. In H-modes with constant q(a)~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 ~ 10 %) during H-phase with frequent ELMs, but remains unchanged for at least 200 μs *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 Er or Er' 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_{is}, and sudden drop in edge electron temperature T_{eb}. The signal I_{is} 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_φ ~ 20 km/s (counter direction to I_p) at the rational surface of m=3/n=1 mode (r_s/a ~ 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 ~ 0.65), and electron diamagnetic drift frequency is taken into account. The m=3/n=1 mode frequency is slightly (by ~ 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 μs 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 $\frac{\tilde{B}_\theta}{B_\theta}$ 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~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 $\frac{\tilde{B}_\theta}{B_\theta}$~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(b)).

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.

ACKNOWLEDGEMENTS

Authors thank Professor M. Fujiwara and Professor A. Iiyoshi for their continual encouragement.

REFERENCES

[1] BIGLARI, H., et al., in Plasma Phys. and Contr. Nucl. Fus. Res. (Proc. 13th Int. Conf., Washington D.C., 1990) **2** (1991) 191.

[2] DOYLE, E.J. et al., Phys. Fluids **B3** (1991) 2300.

[3] WAKATANI, M. et al., Phys. Fluids **B4** (1992) 1754.

[4] GRUBER, O. et al., 18th EPS (Berlin, 1991) Vol. I, p381 and Max-Planck-Institut für Plasmaphysik (1991) Annual Report , p.31

[5] TOI, K.et al., Phys. Rev. Lett. **62** (1989) 430.

[6] TOI, K.et al., Phys. Rev. Lett. **64** (1990) 1895.

[7] TOI, K.et al., in Plasma Phys. and Contr. Nucl. Fus. Res. (Proc.13th Int. Conf. Washington D.C., 1990), Vol.1, IAEA, Vienna (1991) 301.

[8] STRAUSS, H.R., Phys. Fluids **B4** (1992) 934.

[9] NARDONE, C., et al., 18th EPS (Berlin, 1991) Vol. I, p377

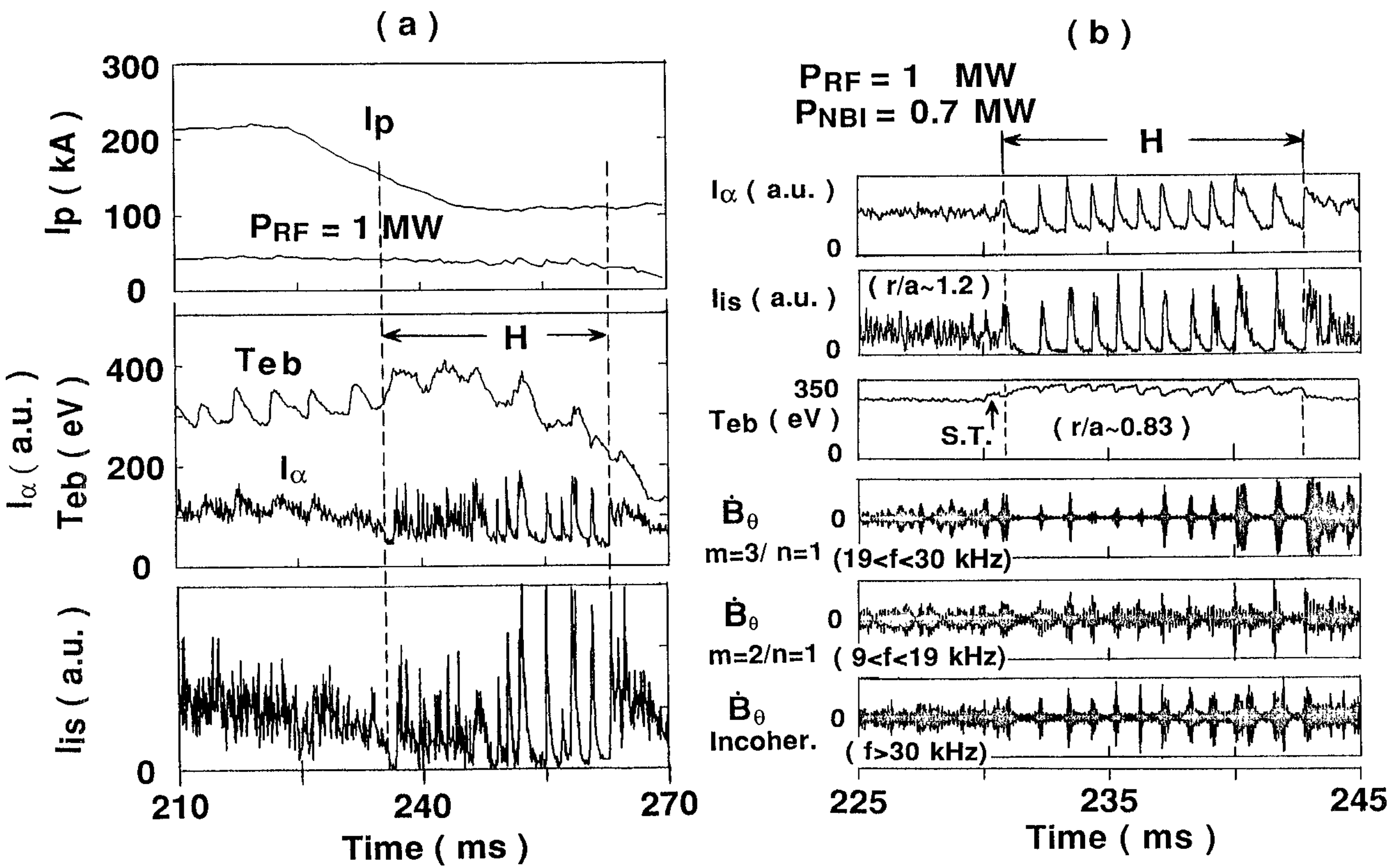
[10] IDA, K., HIDEKUMA, S., Rev. Sci. Instrum. **60** (1989) 876.

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.

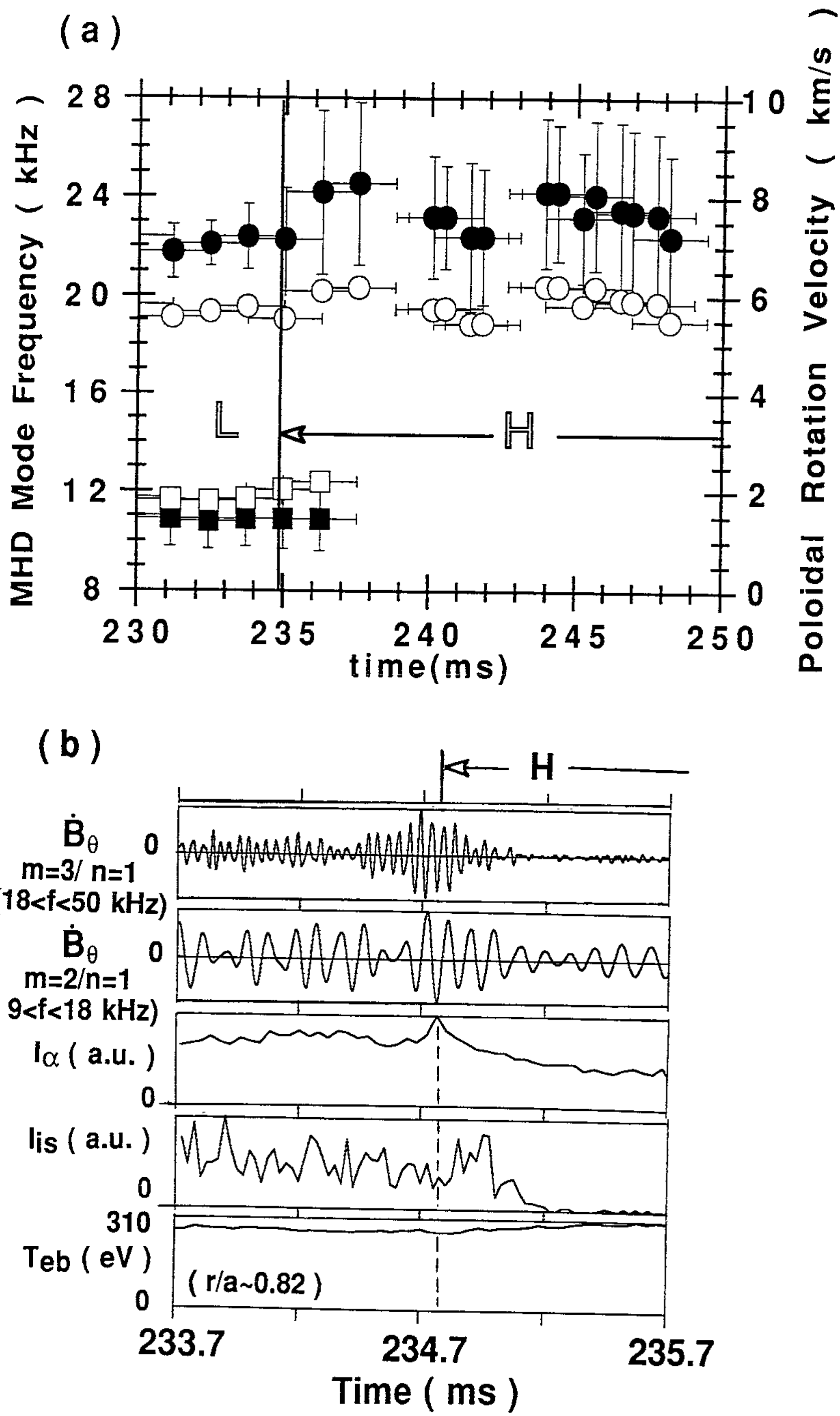
Fig.2 (a) Temporal evolution of the frequencies for m=3/n=1 (solid circles) and m=2/n=1 (solid squares) modes and poloidal rotation velocities at each rational surface indirectly estimated from the MHD modes (open circles and open squares respectively). (b) Expanded time behaviour of the transition.

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.



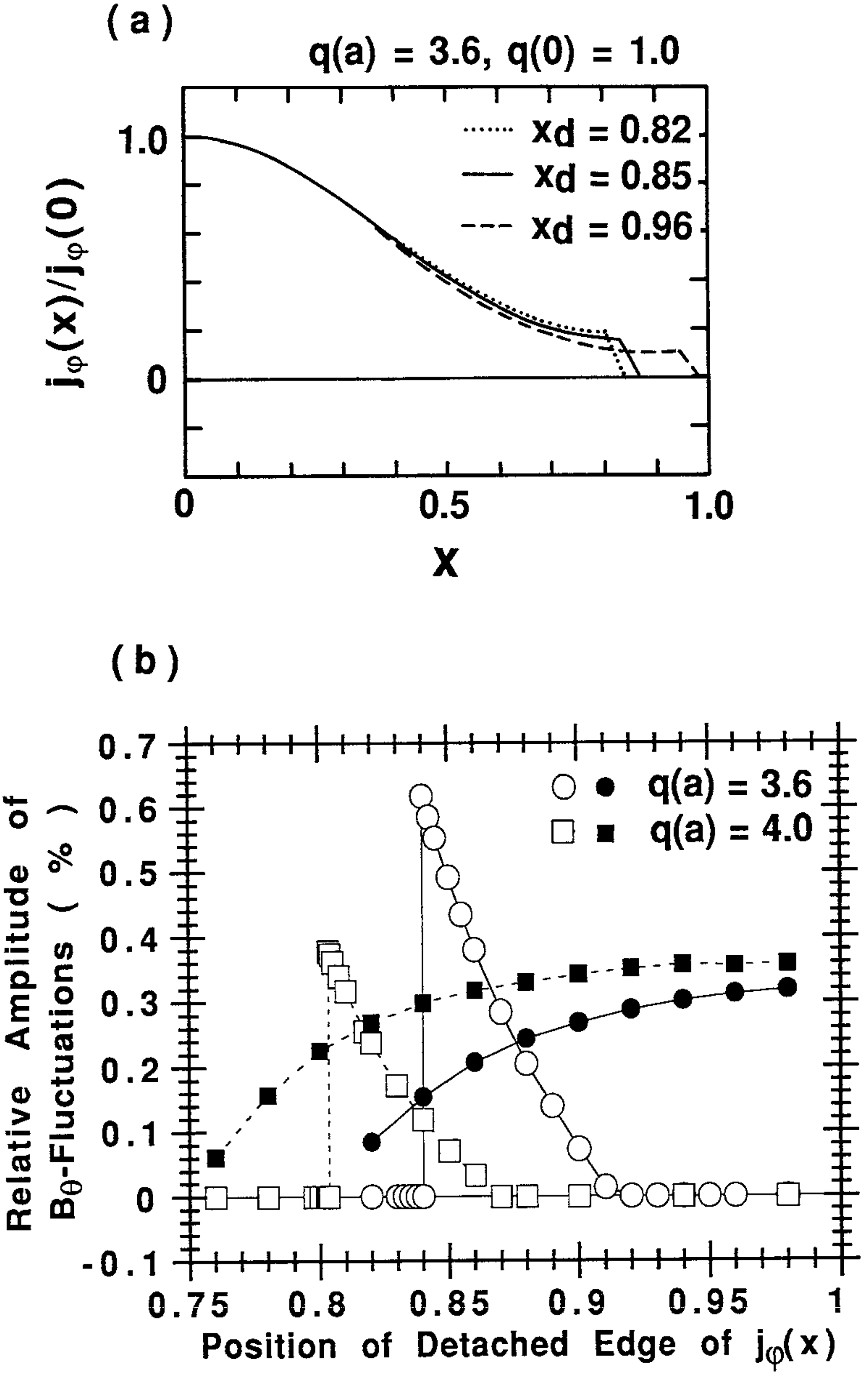
(a)
(b)
Ip (kA)
Ip
PRF = 1 MW
PNBI = 0.7 MW
H
Iα (a.u.)
Teb (eV)
Teb
Iα
Iis (a.u.)
(r/a~1.2)
S.T.
(r/a~0.83)
Ḃθ
m=3/ n=1
(19<f<30 kHz)
m=2/n=1
(9<f<19 kHz)
Incoher.
(f>30 kHz)
Time (ms)

Fig.1



(a)
MHD Mode Frequency (kHz)
Poloidal Rotation Velocity (km/s)
28
24
20
16
12
8
10
8
6
4
2
0
L
H
230
235
240
245
250
time(ms)
(b)
H
$\dot{B}_\theta$ 0
m=3/ n=1
(18<f<50 kHz)
$\dot{B}_\theta$ 0
m=2/n=1
(9<f<18 kHz)
Iα (a.u.)
0
Iis (a.u.)
0
310
Teb (eV)
(r/a~0.82)
0
233.7
234.7
235.7
Time (ms)

Fig.2



(a)
q(a) = 3.6, q(0) = 1.0
xd = 0.82
xd = 0.85
xd = 0.96
jφ(x)/jφ(0)
1.0
0
0
0.5
1.0
x
(b)
q(a) = 3.6
q(a) = 4.0
Relative Amplitude of Bθ-Fluctuations (%)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0.75
0.8
0.85
0.9
0.95
1
Position of Detached Edge of jφ(x)

Fig.3

Recent Issues of NIFS Series

NIFS-129 K. Ida and T. Kato, *Line-Emission Cross Sections for the Charge-exchange Reaction between Fully Stripped Carbon and Atomic Hydrogen in Tokamak Plasma*; Jan. 1992

NIFS-130 T. Hayashi, A. Takei and T. Sato, *Magnetic Surface Breaking in 3D MHD Equilibria of l=2 Heliotron* ; Jan. 1992

NIFS-131 K. Itoh, K. Ichiguchi and S. -I. Itoh, *Beta Limit of Resistive Plasma in Torsatron/Heliotron* ; Feb. 1992

NIFS-132 K. Sato and F. Miyawaki, *Formation of Presheath and Current-Free Double Layer in a Two-Electron-Temperature Plasma* ; Feb. 1992

NIFS-133 T. Maruyama and S. Kawata, *Superposed-Laser Electron Acceleration* Feb. 1992

NIFS-134 Y. Miura, F. Okano, N. Suzuki, M. Mori, K. Hoshino, H. Maeda, T. Takizuka, JFT-2M Group, S.-I. Itoh and K. Itoh, *Rapid Change of Hydrogen Neutral Energy Distribution at L/H-Transition in JFT-2M H-mode ;* Feb. 1992

NIFS-135 H. Ji, H. Toyama, A. Fujisawa, S. Shinohara and K. Miyamoto *Fluctuation and Edge Current Sustainment in a Reversed-Field-Pinch;* Feb. 1992

NIFS-136 K. Sato and F. Miyawaki, *Heat Flow of a Two-Electron-Temperature Plasma through the Sheath in the Presence of Electron Emission;* Mar. 1992

NIFS-137 T. Hayashi, U. Schwenn and E. Strumberger, *Field Line Diversion Properties of Finite β Helias Equilibria;* Mar. 1992

NIFS-138 T. Yamagishi, *Kinetic Approach to Long Wave Length Modes in Rotating Plasmas*; Mar. 1992

NIFS-139 K. Watanabe, N. Nakajima, M. Okamoto, Y. Nakamura and M. Wakatani, *Three-dimensional MHD Equilibrium in the Presence of Bootstrap Current for Large Helical Device (LHD)*; Mar. 1992

NIFS-140 K. Itoh, S. -I. Itoh and A. Fukuyama, *Theory of Anomalous Transport in Toroidal Helical Plasmas;* Mar. 1992

NIFS-141 Y. Kondoh, *Internal Structures of Self-Organized Relaxed States and Self-Similar Decay Phase;* Mar. 1992

NIFS-142 U. Furukane, K. Sato, K. Takiyama and T. Oda, *Recombining Processes in a Cooling Plasma by Mixing of Initially Heated Gas*; Mar. 1992

NIFS-143 Y. Hamada, K. Masai, Y. Kawasumi, H. Iguchi, A. Fijisawa and JIPP T-IIU Group, *New Method of Error Elimination in Potential Profile Measurement of Tokamak Plasmas by High Voltage Heavy Ion Beam Probes;* Apr. 1992

NIFS-144 N. Ohyabu, N. Noda, Hantao Ji, H. Akao, K. Akaishi, T. Ono, H. Kaneko, T. Kawamura, Y. Kubota, S. Morimoto. A. Sagara, T. Watanabe, K. Yamazaki and O. Motojima, *Helical Divertor in the Large Helical Device;* May 1992

NIFS-145 K. Ohkubo and K. Matsumoto, *Coupling to the Lower Hybrid Waves with the Multijunction Grill*; May 1992

NIFS-146 K. Itoh, S. -I.Itoh, A. Fukuyama, S. Tsuji and Allan J. Lichtenberg, *A Model of Major Disruption in Tokamaks*; May 1992

NIFS-147 S. Sasaki, S. Takamura, M. Ueda, H. Iguchi, J. Fujita and K. Kadota, *Edge Plasma Density Reconstruction for Fast Monoenergetic Lithium Beam Probing*; May 1992

NIFS-148 N. Nakajima, C. Z. Cheng and M. Okamoto, *High-n Helicity-induced Shear Alfvén Eigenmodes*; May 1992

NIFS-149 A. Ando, Y. Takeiri, O. Kaneko, Y. Oka, M. Wada, and T. Kuroda, *Production of Negative Hydrogen Ions in a Large Multicusp Ion Source with Double-Magnetic Filter Configuration*; May 1992

NIFS-150 N. Nakajima and M. Okamoto, *Effects of Fast Ions and an External Inductive Electric Field on the Neoclassical Parallel Flow, Current, and Rotation in General Toroidal Systems*; May 1992

NIFS-151 Y. Takeiri, A. Ando, O. Kaneko, Y. Oka and T. Kuroda, *Negative Ion Extraction Characteristics of a Large Negative Ion Source with Double-Magnetic Filter Configuration*; May 1992

NIFS-152 T. Tanabe, N. Noda and H. Nakamura, *Review of High Z Materials for PSI Applications* ; Jun. 1992

NIFS-153 Sergey V. Bazdenkov and T. Sato, *On a Ballistic Method for Double Layer Regeneration in a Vlasov-Poisson Plasma*; Jun. 1992

NIFS-154 J. Todoroki, *On the Lagrangian of the Linearized MHD Equations*; Jun. 1992

NIFS-155 K. Sato, H. Katayama and F. Miyawaki, *Electrostatic Potential in a Collisionless Plasma Flow Along Open Magnetic Field Lines;* Jun. 1992

NIFS-156 O.J.W.F.Kardaun, J.W.P.F.Kardaun, S.-I. Itoh and K. Itoh, *Discriminant Analysis of Plasma Fusion Data*; Jun. 1992

NIFS-157 K. Itoh, S.-I. Itoh, A. Fukuyama and S. Tsuji, *Critical Issues and Experimental Examination on Sawtooth and Disruption Physics*; Jun. 1992

NIFS-158 K. Itoh and S.-I. Itoh, *Transition to H-Mode by Energetic Electrons*; July 1992

NIFS-159 K. Itoh, S.-I. Itoh and A. Fukuyama, *Steady State Tokamak Sustained by Bootstrap Current Without Seed Current*; July 1992

NIFS-160 H. Sanuki, K. Itoh and S.-I. Itoh, *Effects of Nonclassical Ion Losses on Radial Electric Field in CHS Torsatron/Heliotron*; July 1992

NIFS-161 O. Motojima, K. Akaishi, K. Fujii, S. Fujiwaka, S. Imagawa, H. Ji, H. Kaneko, S. Kitagawa, Y. Kubota, K. Matsuoka, T. Mito, S. Morimoto, A. Nishimura, K. Nishimura, N. Noda, I. Ohtake, N. Ohyabu, S. Okamura, A. Sagara, M. Sakamoto, S. Satoh, T. Satow, K. Takahata, H. Tamura, S. Tanahashi, T. Tsuzuki, S. Yamada, H. Yamada, K. Yamazaki, N. Yanagi, H. Yonezu, J. Yamamoto, M. Fujiwara and A. Iiyoshi, *Physics and Engineering Design Studies on Large Helical Device*; Aug. 1992

NIFS-162 V. D. Pustovitov, *Refined Theory of Diamagnetic Effect in Stellarators;* Aug. 1992

NIFS-163 K. Itoh, *A Review on Application of MHD Theory to Plasma Boundary Problems in Tokamaks*; Aug. 1992

NIFS-164 Y.Kondoh and T.Sato, *Thought Analysis on Self-Organization Theories of MHD Plasma*; Aug. 1992

NIFS-165 T. Seki, R. Kumazawa, T. Watari, M. Ono, Y. Yasaka, F. Shimpo, A. Ando, O. Kaneko, Y. Oka, K. Adati, R. Akiyama, Y. Hamada, S. Hidekuma, S. Hirokura, K. Ida, A. Karita, K. Kawahata, Y. Kawasumi, Y. Kitoh, T. Kohmoto, M. Kojima, K. Masai, S. Morita, K. Narihara, Y. Ogawa, K. Ohkubo, S. Okajima, T. Ozaki, M. Sakamoto, M. Sasao, K. Sato, K. N. Sato, H. Takahashi, Y. Taniguchi, K. Toi and T. Tsuzuki, *High Frequency Ion Bernstein Wave Heating Experiment on JIPP T-IIU Tokamak*; Aug. 1992

NIFS-166 Vo Hong Anh and Nguyen Tien Dung, *A Synergetic Treatment of the Vortices Behaviour of a Plasma with Viscosity*; Sep. 1992

NIFS-167 K. Watanabe and T. Sato, *A Triggering Mechanism of Fast Crash in Sawtooth Oscillation*; Sep. 1992

NIFS-168 T. Hayashi, T. Sato, W. Lotz, P. Merkel, J. Nührenberg, U. Schwenn and E. Strumberger, *3D MHD Study of Helias and Heliotron;* Sep. 1992

NIFS-169 N. Nakajima, K. Ichiguchi, K. Watanabe, H. Sugama, M. Okamoto, M. Wakatani, Y. Nakamura and C. Z. Cheng, *Neoclassical Current and Related MHD Stability, Gap Modes, and Radial Electric Field Effects in Heliotron and Torsatron Plasmas;* Sep. 1992

NIFS-170 H. Sugama, M. Okamoto and M. Wakatani, *K- ε Model of Anomalous Transport in Resistive Interchange Turbulence* ; Sep, 1992

NIFS-171 H. Sugama, M. Okamoto and M. Wakatani, *Vlasov Equation in the Stochastic Magnetic Field* ; Sep. 1992

NIFS-172 N. Nakajima, M. Okamoto and M. Fujiwara, *Physical Mechanism of E_{ϕ}-Driven Current in Asymmetric Toroidal Systems* ; Sep.1992

NIFS-173 N. Nakajima, J. Todoroki and M. Okamoto, *On Relation between Hamada and Boozer Magnetic Coordinate System* ; Sep. 1992

NIFS-174 K. Ichiguchi, N. Nakajima, M. Okamoto, Y. Nakamura and M. Wakatani, *Effects of Net Toroidal Current on Mercier Criterion in the Large Helical Device* ; Sep. 1992

NIFS-175 S. -I. Itoh, K. Itoh and A. Fukuyama, *Modelling of ELMs and Dynamic Responses of the H-Mode* ; Sep. 1992

NIFS-176 K. Itoh, S.-I. Itoh, A. Fukuyama, H. Sanuki, K. Ichiguchi and J. Todoroki, *Improved Models of β-Limit, Anomalous Transport and Radial Electric Field with Loss Cone Loss in Heliotron / Torsatron* ; Sep. 1992

NIFS-177 N. Ohyabu, K. Yamazaki, I. Katanuma, H. Ji, T. Watanabe, K. Watanabe, H. Akao, K. Akaishi, T. Ono, H. Kaneko, T. Kawamura, Y. Kubota, N. Noda, A. Sagara, O. Motojima, M. Fujiwara and A. Iiyoshi, *Design Study of LHD Helical Divertor and High Temperature Divertor Plasma Operation* ; Sep. 1992

NIFS-178 H. Sanuki, K. Itoh and S.-I. Itoh, *Selfconsistent Analysis of Radial Electric Field and Fast Ion Losses in CHS Torsatron / Heliotron* ; Sep. 1992