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Impact of Rotational-Transform Profile Control on Plasma Confinement and Stability in CHS

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IMPACT OF ROTATIONAL-TRANSFORM PROFILE CONTROL ON PLASMA CONFINEMENT AND STABILITY IN CHS

Abstract

In neutral beam heated plasmas of CHS, which is a low aspect-ratio heliotron/torsatron device, the effect of rotational transform (ι) profile shape on plasma confinement and stability is studied by inducing a net plasma current (Ip). In the case that the external ι is increased by Ip, very rapid H-mode transition (within ~0.2 ms) is observed at the thresholds of Ip and heating power, having all characteristics found in the tokamak H-mode. There is no obvious difference in the H-mode characteristics between deuterium and hydrogen plasmas. In the opposite case that the external ι is decreased by reversing Ip, the H-mode transition is not observed.

Keywords: L-H Transition, Heliotron/Torsatron, Transport Barrier, Threshold Power, Rotational Transform, Density Fluctuations

1. Introduction

In a stellarator and heliotron/torsatron, the rotational transform (ι) profile plays an important role on plasma confinement and stability[1, 2, 3]. The magnetic field structure of a helical plasma is mostly composed of a set of external coil currents, in contrast to the tokamak configuration. However, finite plasma pressure can appreciably deform the magnetic configuration even in helical plasmas. This requires active control of ι-profile and/or pressure profile during the discharge. It is significant to investigate the plasma response to modification of ι-profile. In the CHS heliotron/torsatron, we have studied two cases where ι-profile is controlled by small ohmic heating(OH-) current (I_p), that is, to increase the external ι by I_p, and to decrease it. Figure 1 shows typical ι-profiles of CHS plasmas studied in this experiment, that is, those in the vacuum field, and with increased and decreased ι.

2. Experimental Results

In previous campaign of H-mode study in CHS[4, 5], the observed depression of Hα/Dα-light at the L-H transition was relatively slow and the back transition was usually unclear, although the discharge exhibited many characteristics found in the tokamak H-mode.

In the present experiment, we have observed the H-mode with very rapid transition in deuterium plasmas, as shown in Fig.2(a). The rotational transform at the center is estimated to be increased up to ~0.8, which is slightly higher than the previous campaign. The depression time of Hα/Dα -light at the L-H transition is typically 0.2 ms, and the back (H-L) transition is also very clear. Line integral electron density of the central chord shows a small drop at the transition and rises continuously till the gas puffing is switched off. The line integral density near the plasma edge ($\langle r\rangle/\langle a\rangle$~0.8) rises faster than the central chord. Electron density near LCFS ($\langle r\rangle/\langle a\rangle >$ 0.9) obtained by thermal lithium beam probe(LIBP) evolves very rapidly (0.05-0.1 ms) at the transition. Figure 2(b) shows the time evolution of Li I light obtained with LIBP in the H-mode discharge similar to that in Fig.2(a). The Li5-signal views just inside LCFS indicates a rapid increase in electron density, and Li8-signal just outside LCFS indicates the sudden decrease there. This figure shows rapid formation of edge transport barrier near LCFS. In Fig.3 we compare radial profiles of electron and ion temperatures, electron density and poloidal rotation velocity of C^{6+} ion in L-phase(~10 ms before the L-H transition) and H-phase(~20 ms after the transition). Poloidal rotation velocity is enhanced in the electron diamagnetic drift direction in the H-phase, indicating the increase in radial electric field shear near the edge.

Figure 4 shows the time evolution of electron density fluctuations near LCFS measured with LIBP, where the data are averaged every 0.4 ms time interval. High frequency fluctuations more than 50 kHz are clearly suppressed at the L-H transition, but are gradually increased during the H-phase. Fluctuation signals more than 50 kHz from microwave reflectometer(MWR) are also suppressed at the transition, although the MWR signal obtained with homodyne detection is not necessarily proportional to density fluctuations. Moreover, incoherent magnetic

fluctuations more than 50 kHz are also decreased at the transition. Internal disruption related to m/n=3/2 mode, which is excited near the plasma center, is sometimes observed before the L-H transition. In previously studied H-modes, the internal disruption is initiated by m/n=2/1 mode excited near the center[5].

In H-mode of CHS, the transition sensitively depends on Ip for fixed toroidal field(Bt). The threshold heating power is determined by changing NBI power at the same plasma current and density. The threshold NBI (absorbed) power is about 320 kW at Bt=1.2 T, Ip=30 kA (at the transition) and target density n_e=2.3 x 10^{13} cm^{-3}. The threshold is about factor of two higher than the scaling law[6]. No obvious difference in threshold condition and plasma quality is found in deuterium and hydrogen H-mode plasmas of CHS, in contrast to the tokamak H-mode.

When the external ι is decreased by reversing Ip as shown in Fig.1, density profile measured with 2-channel FIR interferometer and with Thomson scattering is broad and even hollow throughout the discharge, and electron temperature is low and its profile is peaked(open squares in Fig.3). The reduced temperature may be caused by very small ι in the central region. In this case, edge density fluctuations measured with LIBP are appreciably enhanced. In this case the H-mode transition is not observed.

3. Conclusion

Rapid transition from L to H-phase or H to L phase is observed by controlling ι-profile in deuterium and hydrogen plasmas, without an obvious isotope effect of a main plasma ion on the threshold condition and confinement quality. The above ι-profile control experiments in CHS suggest that the presence of ι=1 surface just inside LCFS (<r>/<a>~0.9 - 1.0) and internal disruption induced by interchange modes near the plasma center seem to be important for the transition.

Acknowledgments

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Figure Captions

Fig.1 Rotational transform (ι-) profiles of CHS in this experiment. Dotted curve denotes the ι-profile in the vacuum field. Thick solid curve shows the profile in low beta plasma where the external ι is increased by Ip(=30 kA) at the toroidal magnetic field Bt=1.2 T, and the thin solid curve the profile where the external ι is decreased by reversing Ip(=-15 kA).

Fig.2(a) Time behaviour of the H-mode achieved in deuterium plasma, where Bt=1.2 T, and line averaged density of the target plasma is about 2.2×10^{13} cm^{-3}. The first H-phase initiated at "A" lasts for only a few milliseconds, and the second H-phase from "B" lasts till "C". Line integral densities at the center and near the edge($\langle r \rangle / \langle a \rangle \sim 0.8$) are shown, together with Hα/Dα-lights at two toroidal locations.
(b) Time evolution of Li I line intensities just inside(Li5) and outside(Li8) LCFS in the H-mode discharge similar to Fig.2(a).

Fig.3 Radial profiles of electron and ion temperatures, electron density and poloidal rotation velocity of C^{6+} ion ~10 ms before(open circles) and ~20 ms after(solid circles) the L-H transition. Negative v_θ means the direction of electron diamagnetic drift. Open squares in T_e and n_e-profiles show the data in the decreased ι-case.

Fig.4 Time evolution of edge density fluctuations in the range from 50 kHz to 200 kHz measured with LIBP in the H-mode discharge.

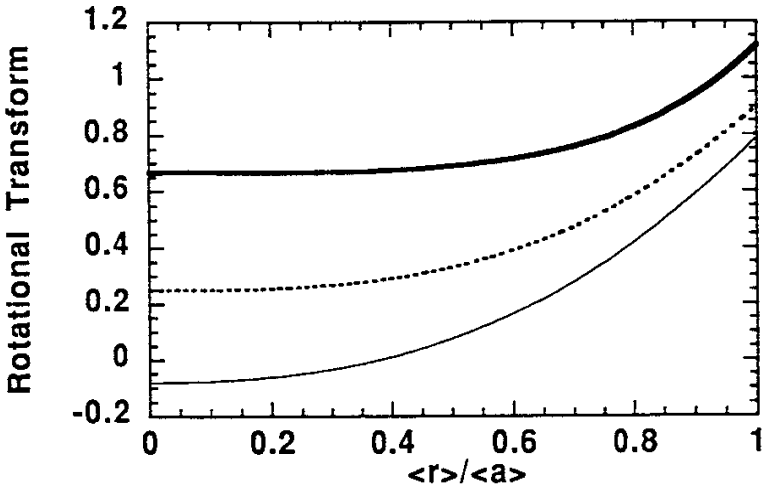

Fig.1 K. Toi et al.

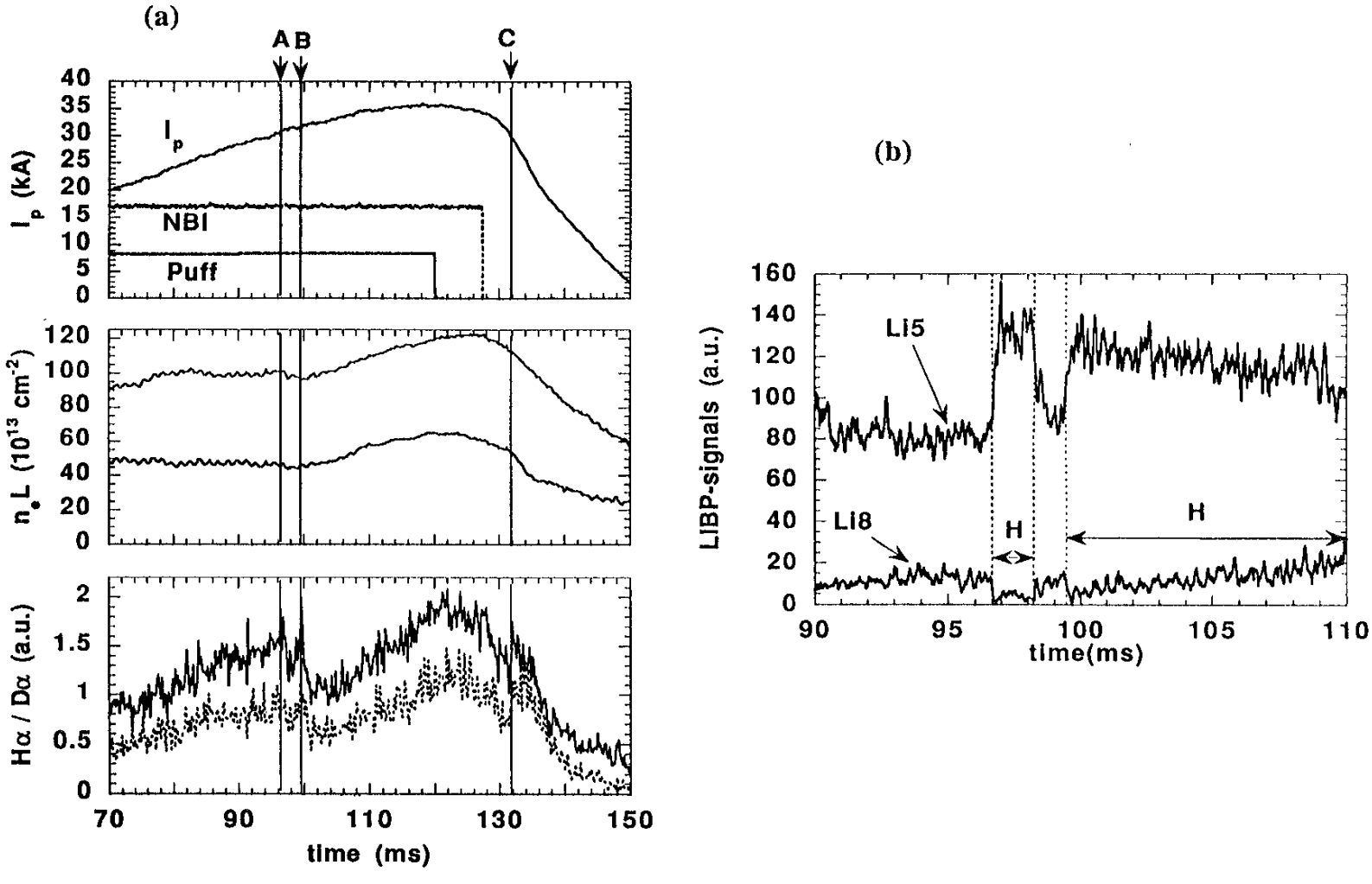

Fig.2 K. Toi et al.

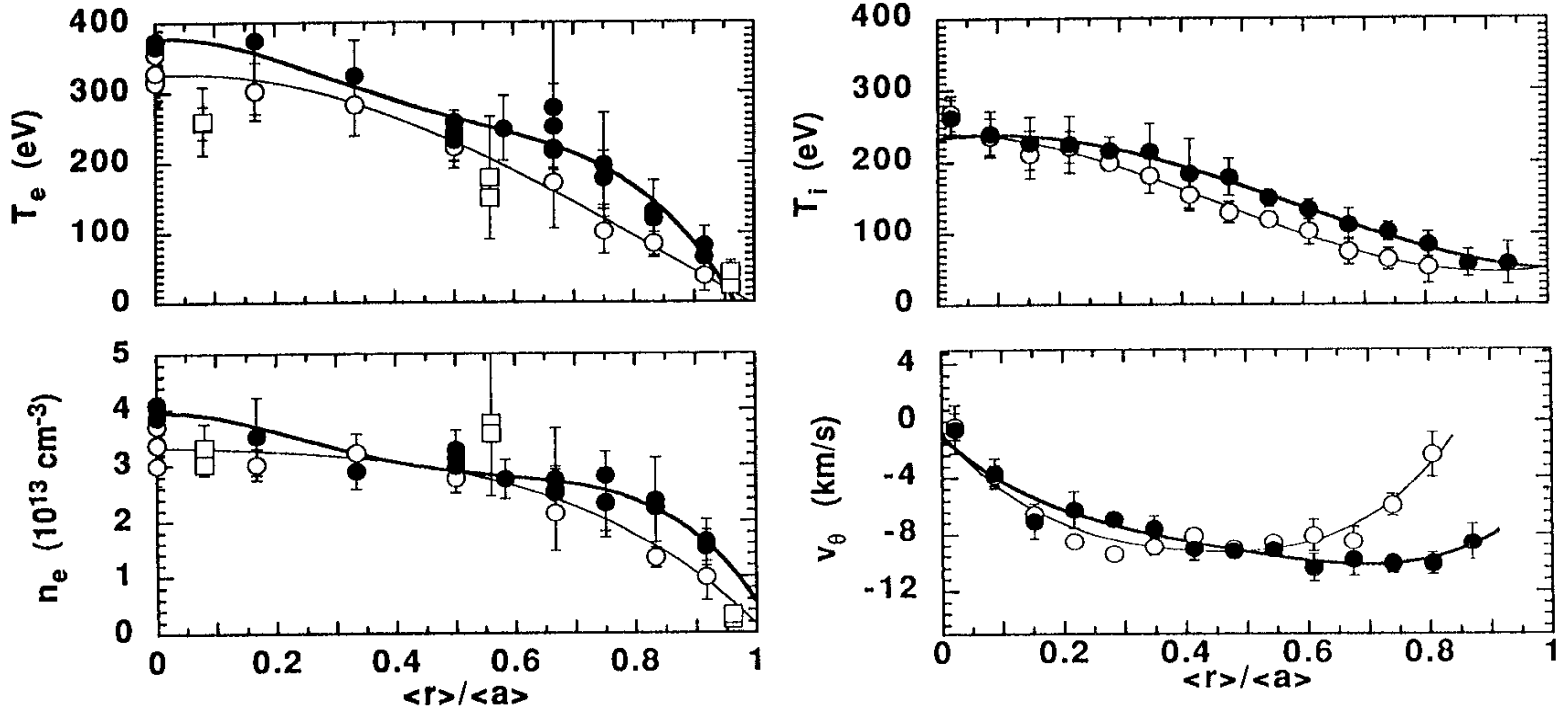

Fig.3 K. Toi et al.

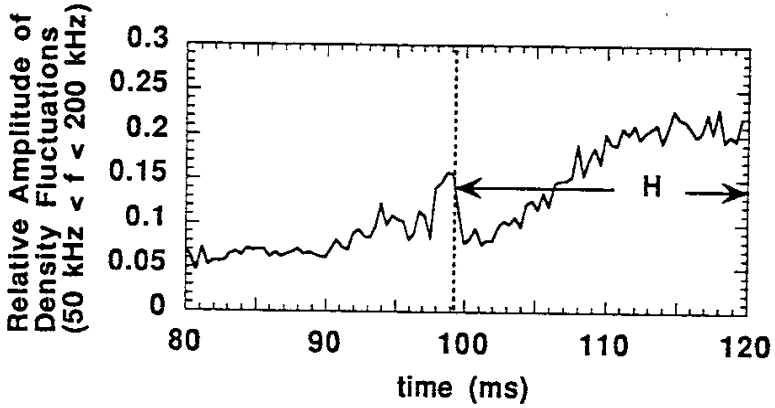

Fig.4 K. Toi et al.

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