Transition of Edge Particle Transport in CHS

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A clear transition of edge particle transport was observed for the neutral beam heated plasmas in CHS. The heating power threshold for the transition is about 1 MW for a plasma with 2×10^{19} m^{-3} average density. The H_α emission drops within 1 msec and the increase of the local edge density at the transition was confirmed by means of YAG Thomson scattering and beam emission spectroscopy. When the heating power is well above the threshold, the transport barrier is maintained for the full duration of NBI heating (100 msec). A clear back transition appears when the heating power is decreased during the discharge.

Keywords:

edge transport barrier, transition, power threshold, H-mode, H_α emission

Various types of transport barrier have been observed in helical experiments. In CHS, the H-mode was found first for the plasma with co-direction ohmic current [1]. In these discharges, a considerable level of plasma current (~ 20 kA) was necessary for making the transition. Recently in LHD, H-mode discharge was also found in the low magnetic field operation [2]. In addition to the transport barrier at the edge, the internal transport barrier has also been found in CHS for the electron transport [3] and it has grown to a more general transport barrier with the improvement of ion confinement [4]. This paper reports a new type of edge transport barrier (ETB) observed in the neutral beam heated plasma in CHS. This ETB is characterized by the clear drop of H_α emissions and the appearance of the back transition when the heating power decreases below the power threshold. No ohmic current drive is necessary. New arrangement of two neutral beams in both co-directions and effective wall conditioning are necessary for ETB formation.

Figure 1 shows the time traces of a discharge which demonstrate the transition of the edge particle transport. Two (co-direction) neutral beams are injected to the ECH heated plasma followed by hydrogen gas puffing. The boundary of the plasma is limited by the inboard side of the vacuum chamber wall and no helical separatrix structure exists. The H_α detector monitors the line-integrated emission from the plasma. The plasma contacting point is not within the detector's viewing area on the wall. The plasma size parameters are as follows: the major radius R = 92 cm and the minor radius a = 19 cm, and the magnetic field strength is 0.95 T. The port-through heating power of two neutral beams are 0.8 MW and 0.6 MW respectively. Beam driven current is roughly 5 kA. About 30 msec after the injection of the neutral beam, the H_α emission drops

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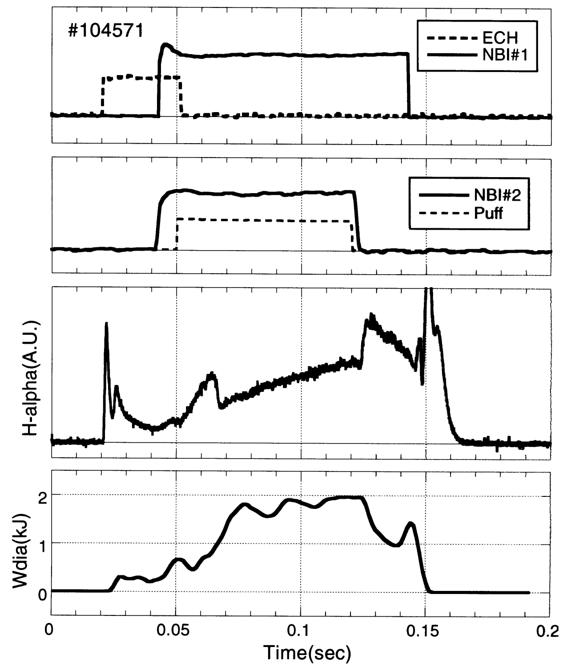

Fig. 1 Time traces of NBI heated discharge with a transition of edge particle transport.

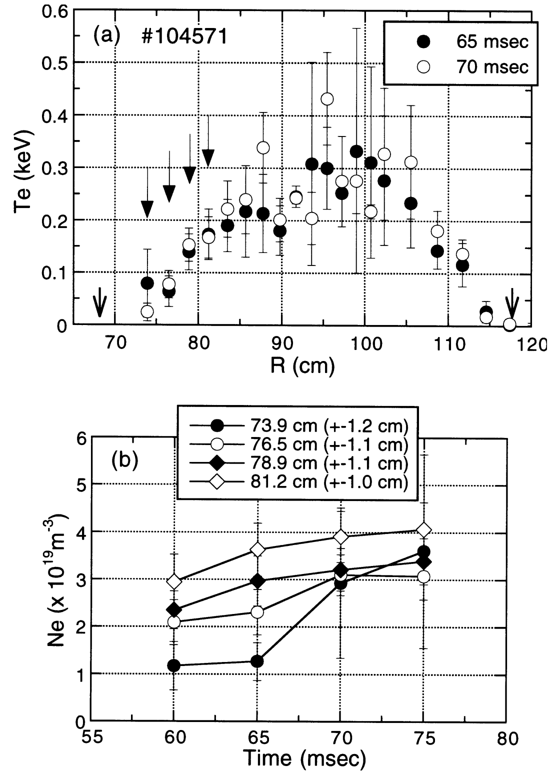

Fig. 2 Electron temperature profiles and the variation of local density at the ETB formation.

showing the formation of the ETB. The back transition occurs about 3 msec after the NBI#2 termination which is comparable to the energy decay time of the beam particles. When two NBIs are applied to the end of the discharge, the transition phase continues for more than 100 msec without a large increase of radiation. The average electron density at the transition is in the range of $2–3 \times 10^{19}$ m^{-3}.

Figure 2(a) shows the electron temperature profiles at two different time points before and after the transition. There is no noticeable increase of edge electron temperature with the ETB formation. On the other hand, the increase of the edge electron density is very clear as shown in Fig. 2(b). The time variation of the local densities measured by YAG Thomson scattering are plotted for four measuring points at the plasma edge region (shown in Fig. 2(a) by arrows). The normalized minor radii for outer two measuring points are: r/a = 0.87 for R = 73.9 cm and r/a = 0.79 for R = 76.5 cm (positions of the outermost magnetic surface are shown by short arrows). The quick increase of the local edge density is also confirmed by beam emission spectroscopy as reported in a separate paper [5].

The heating power of two NBIs are necessary for the transition to ETB formation. When the second NBI is injected to the plasma sustained by the first NBI, the transition appears just after the second beam starts. Figure 3 shows the transition and the back transition triggered by the heating power control of the second NBI. The transition occurs at the flat top of the density and it is clearly observed that the density starts to increase at the time of the transition. The line-averaged electron density is measured using a 2 mm microwave interferometer which provides information limited to the range shown in the figure. The bottom frame of Fig. 3 shows the time relation between the signals. It also shows the speed of the H_α emission drop which is shorter than 1 msec.

The heating power threshold is examined by controlling the second NBI power for different plasma densities The power threshold for the transition is roughly proportional to the density. For a 2×10^{19} m^{-3} density, the power threshold is about 1 MW in the port-through power. The estimation of the heating efficiency for this density is 60 to 70%. For lower heating power, the time delay for the appearance of the transition after the increase of the heating power becomes longer and the speed of the H_α emission drop becomes slower. When the heating power is close to the threshold,

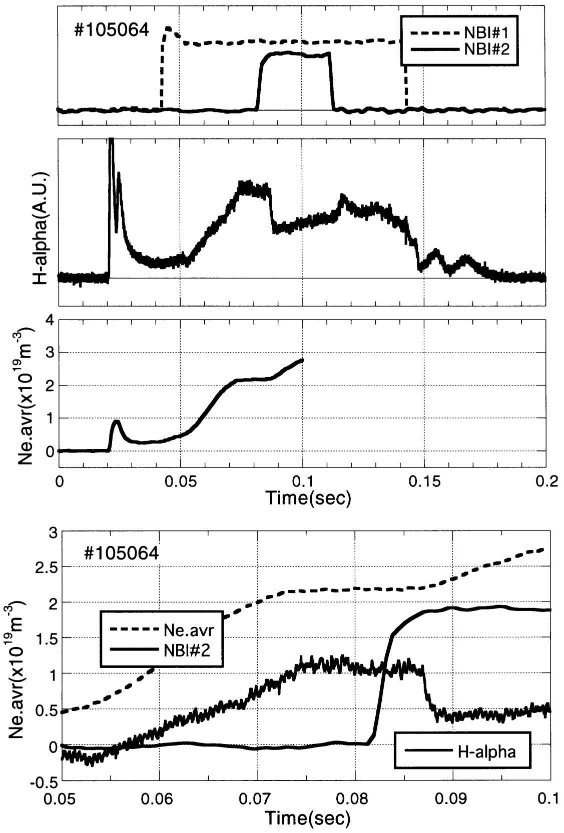

Fig. 3 Time traces of the discharge with heating power control and the expansion of the transition phase.

transition dithering appears in the H_α emission signal which is very similar to the H-mode discharges in tokamaks.

Even though the formation of the ETB is very clear, the increase of the global confinement is not significant up to this point. For the discharge shown in Fig. 3, the estimation of the increase of the total energy due to the ETB formation is 20 to 30%. One possible reason for the small improvement of the global confinement is the change of the density profile after the transition. The Thomson scattering measurement shows the flattening of the density profile after the transition with the decrease of the central density. The electric field measurement using HIBP is planned for the future experiments to clarify the mechanism of ETB formation.

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