The Measurements of the Plasma Electric Potential Profile by Heavy Ion Beam Probe on T-10 tokamak

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Abstract

The Heavy Ion Beam Probe (HIBP) diagnostics on T-10 tokamak was modified to measure the local values of the plasma potential in ECRH plasma. The Tl^+ ion beam with the energy up to 250 keV and intensity about a few dozens μA was used in experiments. The clear fall of potential in the range of -200 ÷ -600 V was observed during the phase of the improvement plasma confinement in the outer region with respect to EC resonance. The fall down of potential accompanies the fall of D_α. The time evolution of spatial profile was also observed.

1. Introduction

The importance of the radial electric field for the plasma confinement and equilibrium in the fusion devices with magnetic confinement is well recognised now [1,2]. It is expected that the electric field can help us to understand the underlying mechanisms that forms transport processes in the plasma. The study of the electric field in the L-H transition and H-mode is the most desirable target for the experimental research now. The Heavy Ion Beam Probe (HIBP) is the only diagnostics allowing us to investigate directly the plasma potential in the bulk and edge plasma. The local value of the plasma potential can be obtained by the measurements of the change of the beam energy in the sample volume. The intensity of the secondary beam indicates the local density. The exact density measurement has to take into account the beam attenuation along the trajectories.

The first experimental step in this way was done in JFT-2M [3] by the HIBP potential measurements near the separatrix during the sawtooth-triggered L-H transition. In the circular tokamak T-10 the features of the improvement in confinement were observed. The measurements performed during these process shows the strong fall down of the potential. The features of the process are discussed in the paper.

2. HIBP Diagnostic set-up

To study the ECRH-ECCD plasmas on T-10, the HIBP diagnostic system [4,5] was improved. The energy range increased up to 240 keV for routine measurements. The conventionally used Cs+ beam was replaced to heavier Tl+. The specific feature of this system is the presence of the toroidal steering electrostatic plates in the diagnostic port before the entrance of energy analyzer. These plates correct the toroidal displacement of the secondary ions with the voltage pulse up to 5 kV. The power supply provides the measurements during the 7 ms of the correcting pulse flat top every 20ms. The analyzer was inclined toroidally in accordance with the 3D-trajectory calculation in order to reduce the amplitude of the correcting voltage and to avoid the arcs effect to the secondary beam signal. These modifications allow us to make the measurements in OH and ECRH plasmas within almost the whole operational range of the T-10 (B = 1.5 T - 2.5 T, I_p = 75-280 kA, n_e =1-4×10^{13} cm^{-3}). The observed range of radii is 18-30 cm for 2.5 T and 7-30 cm for 1.5 T.

The HIBP on T-10 has made the measurements of the plasma electric potential with a good time and spatial resolution in two main operating regimes:
Shot by shot measurements allow us to obtain the time evolution of the plasma parameters in every desired point of the detector grid. Used bandwidth of the system allows us to see the slow oscillations.
Scanning along the detector line in the single shot allows us to get a set of plasma parameters profiles. The scanning was realised by variation of the injection angle during the pulse of the correcting voltage. The scanning time was about 4 ms. The spatial resolution of measurements is L = 5-10 mm, the temporal resolution was limited by the data acquisition system (for now the bandwidth is 20 kHz)

3. Experimental Results

The search of the internal transport barrier (ITB) on T-10 (R=150 cm, a=30 cm) [6] leads to the observation of the well-known phenomenon of the improved confinement. The clear effect was observed during off axis ECRH with B_0=2.28 T, I_p=150 kA, $n_e=1.2\times10^{13}$ cm^{-3}, P_{EC}=0.5 MW, a_{lim}=25 cm. The time history of the typical shot with the improved confinement in comparison with the reference one is presented in Fig. 1. The simultaneous rump up of the averaged density and D_α decrease allow us to detect the typical feature of the H-mode. The total stored energy increases correspondingly. The difference of the two shots is defined by the small variation of q_{min}. The plasma electric potential φ observed at r=18.3 cm (ρ=r/a=0.73), rapidly decrease during the density increase (t=800 - 850 ms). The absolute change of the potential is –600 V. Later on (t=850 - 900 ms) the rise of the density becomes much smaller and the decrease of the potential has the similar effect. After the end of the gyrotron pulse (900 ms) the potential returns back to the initial Ohmic value.

The radial structure of the potential during the transition was studied by the scanning of the injection angle. The outer area of the EC-resonance r = 14 cm (ρ=0.56) is of the most interest. Fig 2 shows the radial distribution of the extra potential over the initial steady-state values. One can clearly see that the potential falls down to the Ohmic level almost simultaneously over the observed region during the transition phase.

4. Discussion

The observed phenomenon of the fast potential drop during the improvement of the plasma confinement is similar to the fast potential change at the H-mode transition, observed first by Y. Hamada et al near the separatrix of JFT-2M tokamak [3]. In both cases the rise of negative potential indicates the improvement of the electron confinement. The range of the effect is very similar, but features of the transport barrier formation in divertor (JFT-2M) and limiter (T-10) plasmas may cause the difference in the values and the time scale of the rise

Along with the plasma potential, HIBP is also sensitive to the plasma density. The total secondary ion current is proportional to the local plasma density $I_{tot} \sim n\, f(T_e)$. The time evolution of the I_{tot} presented in Fig. 3 indicates the fast formation of the density gradient region after the transition. This data is also in accordance with the JFT-2M measurement and can be interpreted as formation of the transport barrier in T-10.

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References

[1] K.Ida, Y.Muira, S-I Itoh et al., NIFS-313, Nagoya, Japan, 1994.
[2] S-I Itoh, ~. Itoh., Phys. Rev. Lett., v. 60, p. 2276, 1998.
[3] Y. Hamada et al. In: 17^{th} IAEA Fusion Energy Conference, Yokohama, Oct. 1998.
[4] A.V. Melnikov et al., IEEE Trans. on Plasma Sci., v. 22, p. 363, 1994.
[5] A.V. Melnikov et al., 23 EPS Conf. Plasma Phys. and Control. Fusion, Kiev, 1996, p. 321.
[6] K.A. Razumova et al. This conference, Or20.

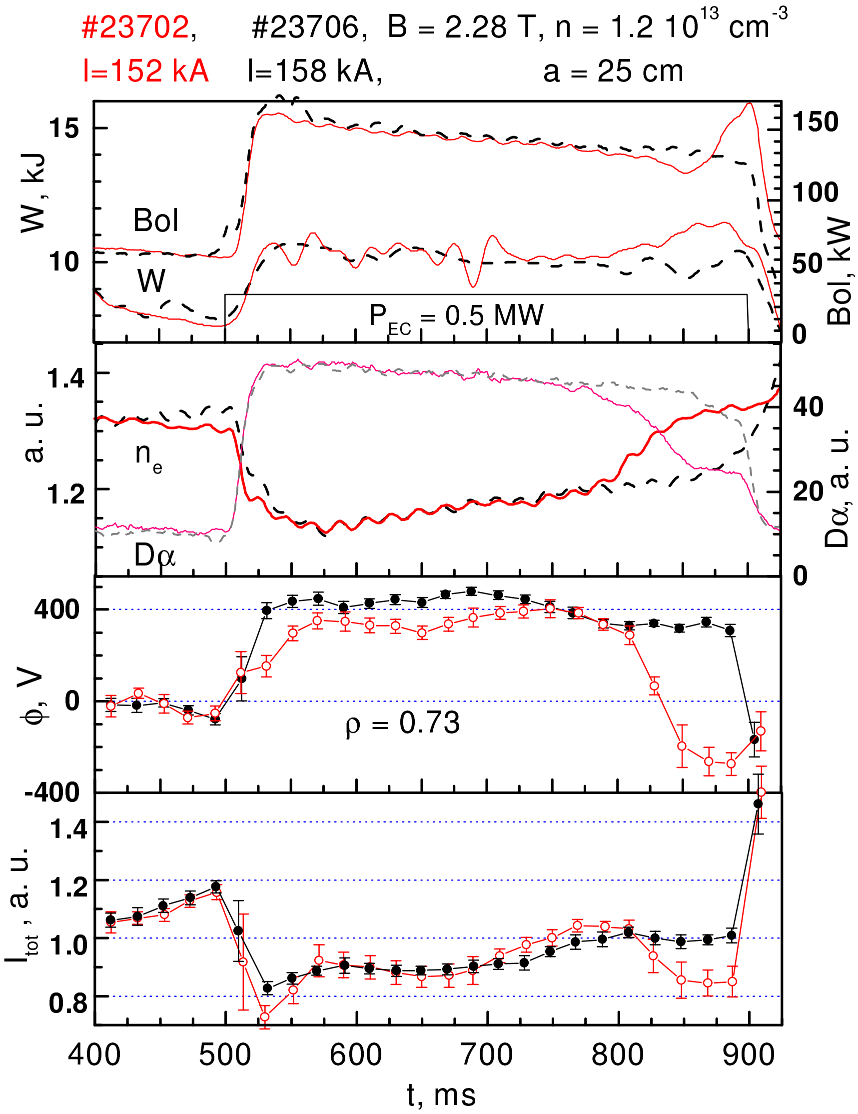

Fig.1. Time history of the typical shot with improved confinement #23702 (solid lines) with respect to the reference one #23706 (dashed lines)

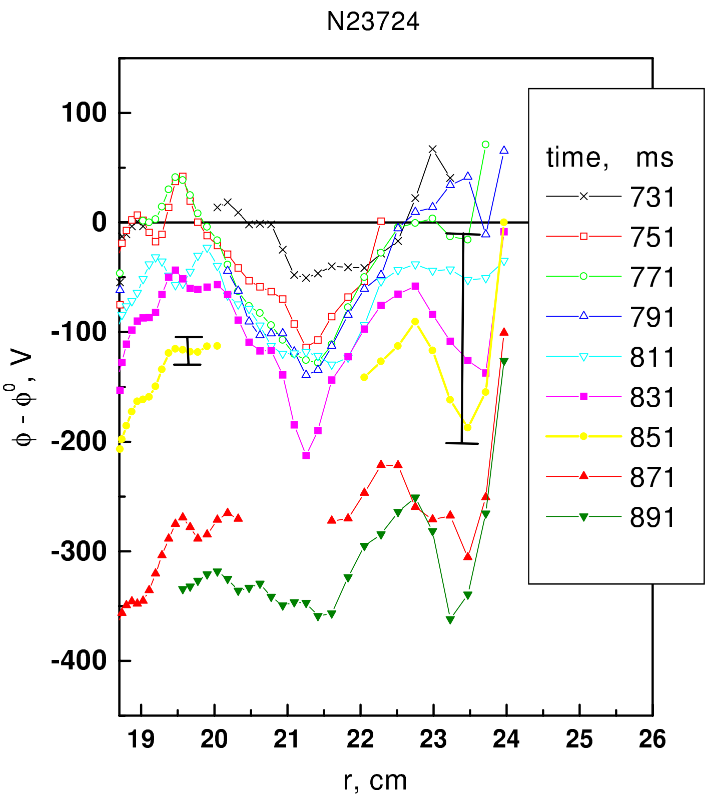

Fig 2. Time evolution of the potential profile with respect to steady state phase
$\phi^0 = \phi$ (711 *ms*)

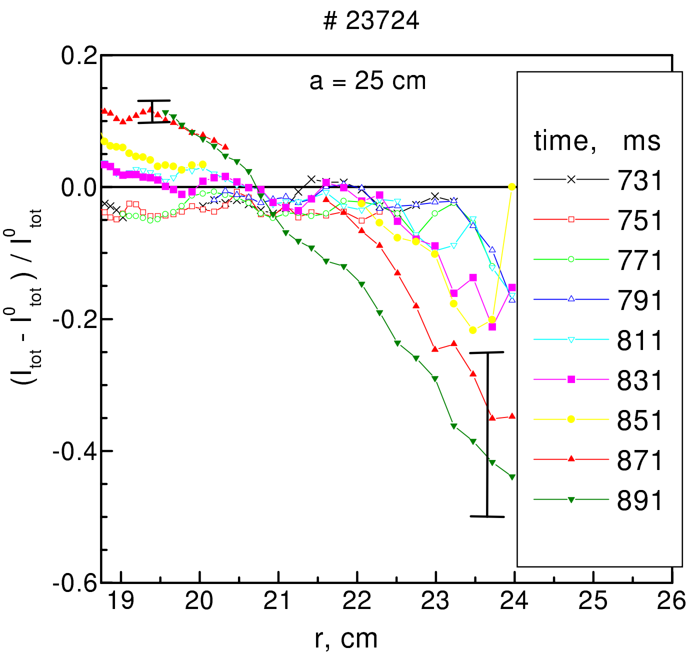

Fig. 3. Time evolution of the secondary beam intensity I_{tot} profile with respect to steady state phase $I^0_{tot} = I_{tot}$ (711 ms). Indication of the formation of density barrier.