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Investigation of the plasma potential behaviour at the edge of the T-10 tokamak by HIBP

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Unless almost the quarter of the century passed since the discovery of the state of High plasma confinement (H-mode) [1], the physical mechanism underlying the phenomenon is still unclear in thermonuclear researches. It was stated in the many theoretical works and found experimentally [2] that electric field has a leading role in the process of the confinement improvement of the hot plasma. The detailed knowledge of the electric field structure is important in the plasma periphery for both H and L-mode plasmas. Heavy Ion Beam Probing (HIBP) is the only diagnostics, which is able to provide the plasma electric potential measurements in the bulk plasma. An overlapping of the HIBP bulk potential profile and Langmuir probe edge potential profile is an important issue in the studies of the periphery plasma. The changes of the edge plasma potential during L-H transition have been measured by HIBP in tokamaks [3, 4]. The steady state edge profiles have not been reported so far.

The edge plasma potential profile was investigated by HIBP at the low field side of the T-10 tokamak (R = 1.5 m, a = 0.3 m, B_0 = 2.4 T) within the radial interval of 25-30 cm ($0.85 < r/a < 1$). The plasma was limited by the movable rail limiter at a_{lim} = 27 – 30 cm, and the circular limiter at $a_{\mathrm{c\ lim}}$ = 33 cm. The plasma potential profile was measured along with the probing beam current, representing the density profile.

In the Ohmic phase of the deuterium discharge (I_p = 180 kA, $n_e = 1.5\times10^{19}$ m^{-3}) the negative plasma potential was observed (Fig. 1). The gradient part of the profile takes place inside the LCMS (25 cm < r < 30 cm). The HIBP potential profile has zero reference value at the rail limiter position $a_{\mathrm{r\ lim}}$ = 30 cm. The slope of the potential profile gives the estimation of the mean radial electric field in a range of E_r = - 50 – - 100 V/cm.

In the ECRH phase with on- and off- axis power deposition (P_{EC} = 1- 1.2 MW, r_{ECRH} = 0, -13 cm) the potential well becomes significantly swallower. The estimated mean radial electric field was in a range of E_r = -10 – - 30 V/cm.

In the Ohmic phase of the He discharge (Ip = 240 kA, $n_e = 2.5\times10^{13}$ cm^{-3}) the negative plasma potential was also observed with the similar range of E_r.

The insertion of the rail limiter into a_{lim} = 27 cm leads to the modification of the plasma profiles (Fig. 2). The HIBP potential profiles have the absolute reference at the plasma potential value of Langmuir probe, located at rail limiter. The potential profile was shifted together with the rail limiter position, while its shape remains similar to the initial one. In the rail limiter shadow, 27 cm < r < 30 cm, the potential variation is small within the experimental accuracy.

The angle point in the potential profile was found to be an empirical marker of the limiter. The existence of such empirical marker helps to verify the radial reference and decrease the ***Er*** uncertainties.

The density profiles (by secondary beam current) show the increase of the gradient when limiter is inserted at a_{lim}=27 cm. The interferometer measurements show the same changes. There is no marker of the limiter position on secondary beam current.

To verify the link between the position of LCMS and the edge potential profile the experiment with shift of the plasma column during one shot was done (Fig. 3). The gradient part of the potential moves with LCMS position (Fig. 4). Secondary beam current profile is also shifted accordingly. The rms errors in potential have reasonable peak-to peak values of 50 V (±25V) inside the LCMS (Fig. 5). The changes in the profiles are above the experimental accuracy inside the LCMS. The movement of the edge potential profile is pronounced. Outside the LCMS, in the SOL, the density/temperature is quite low, the efficiency of the plasma target for the probing beam secondary ionisation became smaller. Due to the low secondary beam current outside the LCMS we have significant rms errors in the potential, higher than ±100V. Averaging the 3÷4 scans in the steady state phase of the discharge helps to increase the reliability of the profiles (Fig. 6). It is clear the small potential variation in the SOL.

The plasma potential evolution shows the link of the potential value with density. During the C-pellet injection in OH plasma (I_p = 180 kA, n_e = 1.5×10 ^{19} m^{-3}), the edge potential falls down up to –100 V (Fig. 6) with the density rise (Fig. 7). The mean value of the negative electric field becomes stronger up to E_r = –120 V/cm

Conclusions

The edge plasma potential was studied by Heavy Ion Beam Probing (HIBP) and Langmuir probes at the low field side of the T-10 tokamak within the radial interval of 25-30 cm (0.85<r/a<1).

In the Ohmic phase of the deuterium discharge (I_{pl} = 180 kA, $n_e = 1.5 \cdot 10^{19}$ m-3) the negative plasma potential was observed. The estimation of the mean radial electric field gives a range of E_r = -50 –100 V/cm. The ECRH heating leads to decrease of the edge electric field up to E_r = -10 – - 30 V/cm.

The gradient region of the potential profile moves with the position of LCMS. In the shadow of the limiter potential variation is small.

The C-pellet injection leads to the increase of the n_e and the edge negative electric field.

Acknowledgements

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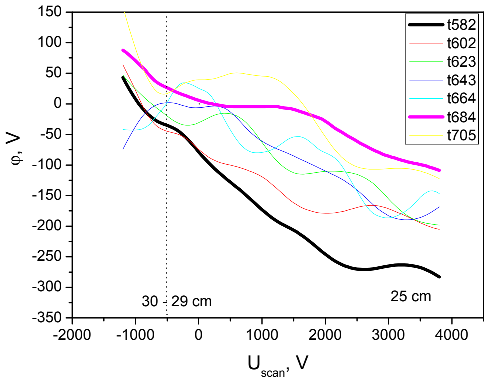

Fig. 1. Plasma potential profiles in OH (black) and ECRH (others) heating. In ECRH phase of discharge plasma potential is increased up to + 200 V at r = 25 cm.

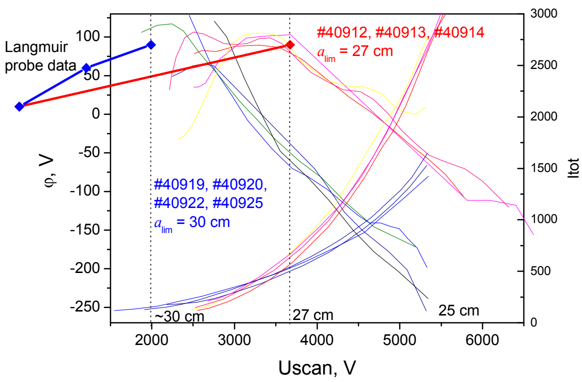

Fig. 2. Profiles of the plasma potential and secondary beam current for a_{lim} = 27 (cold colours) and a_{lim} = 30 cm (warm colours). Absolute values of the plasma potential are referenced to the Langmuir probe measurements. The gradient region of the potential profile moves with limiter position.

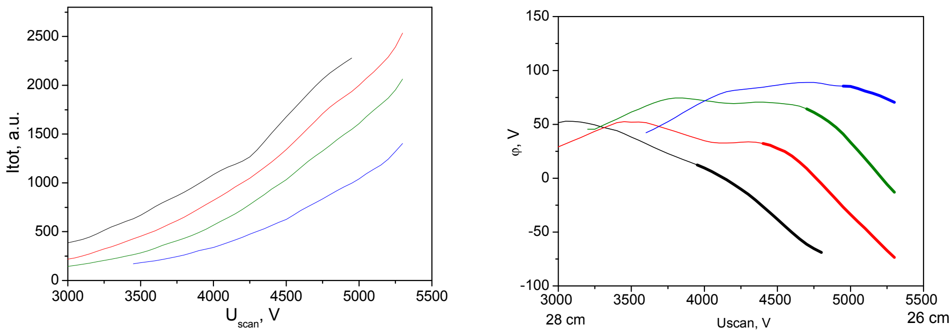

Fig. 4. Plasma potential and secondary beam current profiles evolution during shift of the plasma column. Gradient region of the potential profile moves with shifting of the plasma column. Secondary beam current profile are also shifted accordingly.

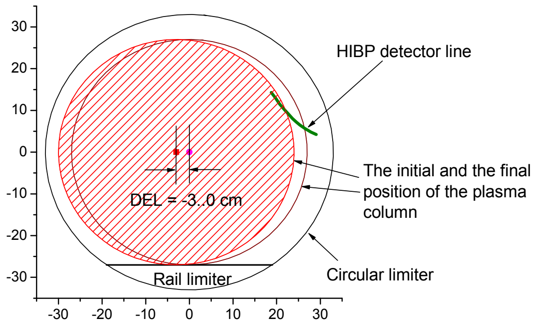

Fig. 3. Plasma shift experiment layout. Initially almost whole the detector line was outside the LCMS.

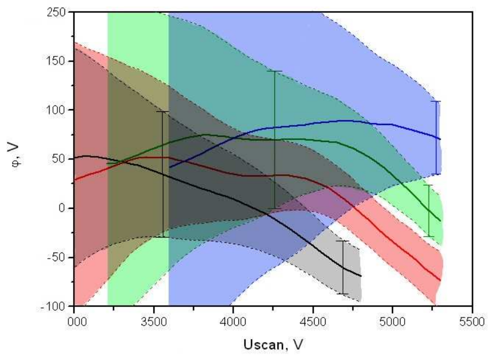

Fig. 5. Average potential profiles and standard deviation in the experiment with shift of the plasma column. Each profile is averaged over several scans. The standard deviation depends inversely on the secondary beam intensity.

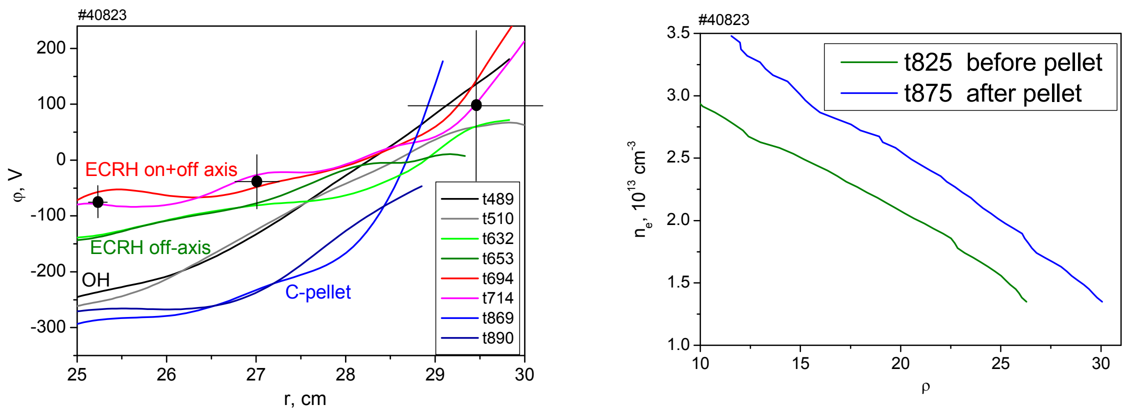

Fig. 6. The plasma potential and electron density profiles before and after C-pellet injection. C-pellet injection causes significant rise of the electron density and decrease of the plasma potential approximately on 100 V.