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Study of the core plasma potential and turbulence evolution during ECRH in the T-10 tokamak

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The best performance of existing fusion plasma devices has been obtained in plasma conditions where ExB shear stabilization mechanisms are likely playing a key role; both edge and core transport barriers are related to a large increase in the ExB sheared flow. The direct experimental study of plasma radial electric field is the key issue to clarify ExB shear stabilization mechanisms. The plasma turbulence rotation velocity measurements, compared with E_rxB_{tor} drift rotation velocity may explain whether turbulence moves altogether with plasma or independently.

The plasma potential was studied by Heavy Ion Beam Probing (HIBP), the plasma turbulence was studied by the correlation reflectometry in the core of T-10 tokamak (R = 1.5 m, a = 0.3 m). There was observed the set of plasma regimes with B_T = 2.12 - 2.5 T, I_{pl} = 180 - 260 kA, $\langle n_e \rangle \approx (1.5 - 2.5) \times 10^{19}$ m^{-3}. The Ohmic and ECR heated plasmas with on- and off-axis power deposition, using two frequencies were studied, $P_{ECRH} \leq$ 1.2 MW, f_{ECRH} = 129 GHz + 144 GHz. To probe the plasma core, Tl^+ ions were accelerated up to 250 kV. The recent modification of the beamlines and the entrance ports expands the HIBP observation area. This allows us to observe the radial range 20-25 cm for the toroidal field B_T= 2.33 T. The observed radial interval moves towards the plasma center with B_T decrease. For B_T = 2.12 T, the observed radial range was approximately 13 - 20 cm.

The sample volume passes from the peripheral area towards the more central one and back during the single scan of the entrance angle. So, the radial intervals were observed two times with different poloidal position. Plasma potential radial profiles, obtained in two paths are in an agreement (Fig 1).

Correlation reflectometer was able to observe routinely the whole plasma radius with frequency adjustment.

In the Ohmic phase of the discharge the plasma potential in the observed region was negative. The slope of the potential profile gives us the estimation of the mean radial electric field in a range of E_r = -80 – -150 V/cm. In the ECR heated plasmas with on- and off-axis power deposition (P_{EC} = 0.4 – 1.2 MW) the depth of the potential well becomes significantly smaller. The estimation of the mean radial electric field gives a range of E_r=-20 – -50 V/cm.

The potential follows by the electron temperature, getting the additional value up to + 400 V, still remaining negative. Potential follows the local Te with lower increment. (Fig 3.) The characteristic time of the potential evolution is ~ 50 ms, higher than energy confinement time τ_E .

Nearly edge potential is sensitive to both on- and off-axis ECRH in deuterium plasma. The mean radial electric field averaged over outermost 5 cm (25 cm < r < 30 cm) has a range of - 50- - 60 V/cm in OH phase. It decreases op to -20 - -30V/cm in ECR phase.

The clear link between the core plasma potential and ECRH power was observed: the stronger power leads to the higher (more positive) absolute potential. (Fig. 5). This is right either for the core plasma or for the edge. This tendency was also found in TJ-II stellarator during experiments with the ECRH power modulation [1].

The turbulence rotation velocities were measured by the correlation reflectometry at the same discharges. The values of the angular rotation velocity $\mathbf{\Omega_{TURB}}$ are close to the plasma drift rotation velocity $\mathbf{\Omega_{E\times B}}$. In core deuterium plasma both turbulence and E×B drift rotation velocities decrease in ECRH. Fig 7. The uncertainties of calculated velocities are determined by the uncertainties in estimations of Er. In spite of the data scattering the $\mathbf{\Omega_{TURB}}$ rotation velocity seems fit better to $\mathbf{\Omega_{E\times B}}$.

The similar comparative measurements were done at the plasma periphery of Helium plasma [2]. Radial electric field was estimated at the edge (25 cm < r < 30 cm). Similar to the observations in deuterium plasma at the edge and deeper areas, the Er decreases at the periphery after ECRH. The clear disagreement between turbulent and E×B drift rotation was observed: $\mathbf{\Omega_{TURB}}$ increases, while $\mathbf{\Omega_{E\times B}}$ decreases in ECRH.

To clarify the link between the plasma drift rotation and turbulence rotation more work should be done, especially at different B_T

Conclusions

The plasma potential was studied by Heavy Ion Beam Probing (HIBP), the plasma turbulence was studied by the correlation reflectometry in the core of T-10 tokamak.

In the Ohmic plasmas (B_T = 2.12 - 2.5 T, I_{pl} = 180 - 260 kA, $\langle n_e \rangle \approx (1.5 - 2.5) \times 10^{19}$ m^{-3}) the plasma potential in the observed gradient region was negative. The estimation of the mean radial electric field gives a range of $\mathbf{E_r}$ = -80 – -150 V/cm.

In the ECR heated plasmas with on- and off-axis power deposition (P_{EC} = 0.4 – 1.2 MW) the depth of the potential well becomes significantly smaller. The potential follows the electron temperature, getting the additional value up to + 400 V, still remaining negative. The estimation of the mean radial electric field gives a range of **Er** = -20 – -50 V/cm.

The link between the plasma potential and ECRH power was observed: the stronger power leads to the higher absolute potential.

The drift rotation velocity $\mathbf{\Omega}_{\mathbf{E\times B}}$ derived from HIBP potential profile and the turbulence rotation velocity $\mathbf{\Omega}_{\mathbf{TURB}}$ obtained by the correlation reflectometry were compared. Both velocities are close each other in deuterium plasmas, but the data scattering and uncertainty in $\mathbf{E_r}$ measurements do not allow to make definite conclusions so far.

[1]. L.I.Krupnik et al. EPS-04. London.
[2]. L.G. Eliseev et.al. **(P 2.018)** This conference.

Acknowledgements

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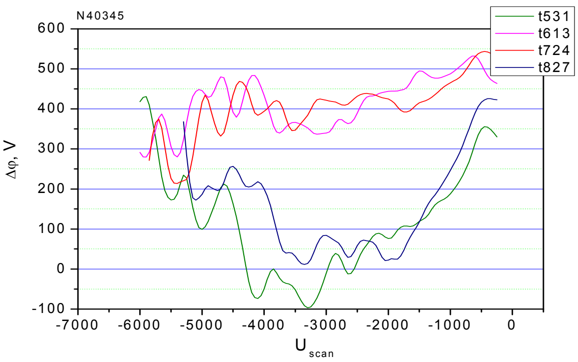

Fig 1. Double pass and potential profiles on OH phase (black and green) versus evolution during ECRH.

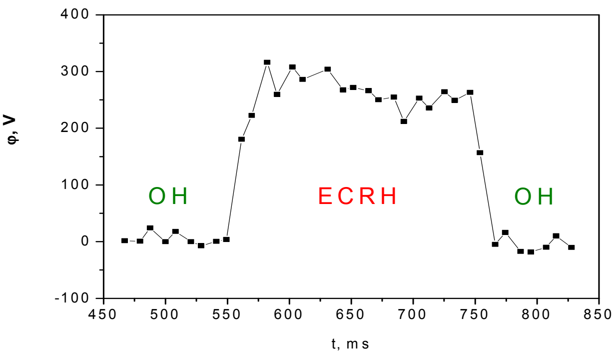

Fig 2. #40345 E = 250 keV. Potential evolution at the deepest penetration point r_{min} = 13 cm.

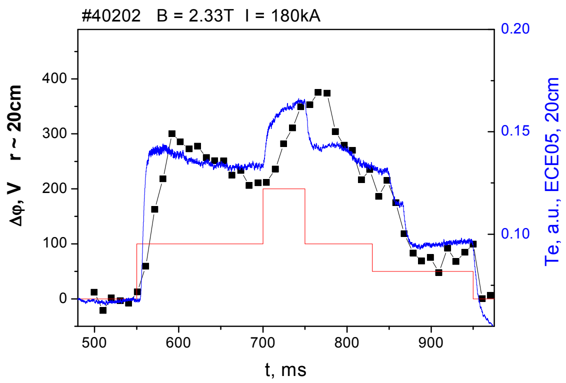

Fig 3. Core potential evolution (black squares) with Te (blue) variations under ECRH (red).

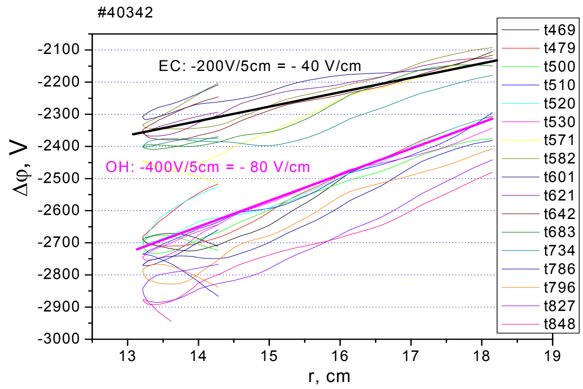

Fig 4. Upper set of the profiles - ECRH phase. Lower set of the profiles - OH phase Straight lines - mean E_r estimation.

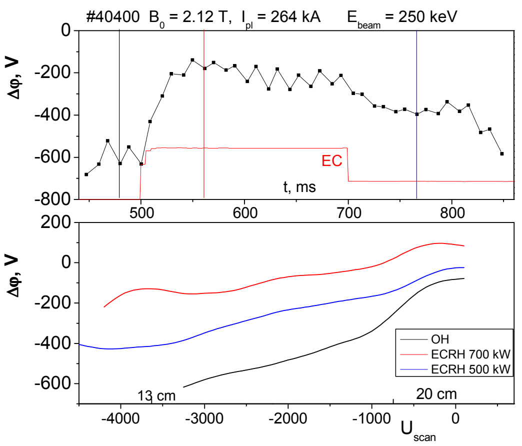

Fig. 5. Plasma potential versus T_e / P_{EC}
Top – time traces of potential (black) and P_{EC} (red), bottom – potential profile evolution.

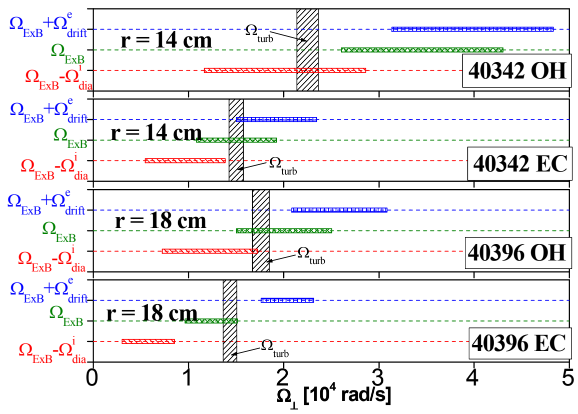

Fig. 6. Comparison of rotation velocities of density perturbations with core plasma rotation in OH and ECRH deuterium plasma.

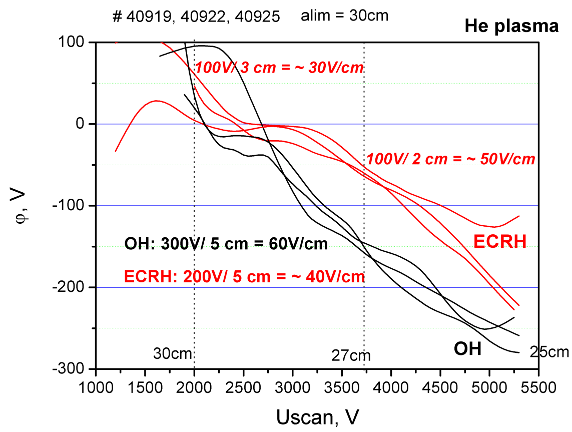

Fig 7 Radial electric field estimations at the edge of He plasma.

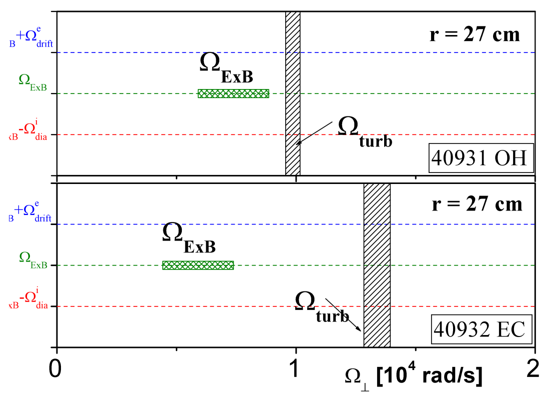

Fig 8. Comparison of the turbulence rotation Ω_{TURB} with Ω_{ExB} in OH and ECRH helium edge plasma.