Effect of Edge Polarization on Plasma Turbulence in TCABR Tokamak

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In the TCABR tokamak (R = 0.61m, a = 0.18 m, B_t = 1.1 T) H-mode confinement has been obtained using a biased electrode inserted into the edge plasma [1], similarly to the results obtained in many other tokamaks. In the present work, we report data of the effect of plasma biasing on the edge turbulence at the initial line averaged plasma density $n_e = 10^{19}$ m^{-3} and plasma current I_p = 85- 95 kA. The electrode is a 20 mm diameter and 8 mm thick disk made of hard graphite fixed at the tip of a shaft insulated with an alumina tube. The front face of the electrode was positioned at radius r = 16.5 cm in the equatorial plane at the low field side. The electrode is biased positively with respect to the vacuum vessel with voltages of 300-320 V and providing an electrode current of about 100 A. Local plasma parameters are measured using a set of three Langmuir probes positioned at the low field side. The probe was built using a boron-nitride bar in which 3 sets of 7 pins, linearly displaced, were installed. The pins are of tungsten wire of 0.8 mm diameter and 5 mm length, and the separation between them is 5 mm. Two sets of pins, poloidally separated by 5 mm, are used for measuring the floating potential and the third set, separated by 5 mm in the toroidal direction, is used to measure the ion saturation current. The signals are digitized with 1 MHz sampling rate. The rake probe was used to study plasma turbulence in the SOL. Radial profiles can be obtained on shot-to-shot basis.

The measured effects of plasma biasing on the intermittence of turbulence are shown in the figure 1. The local plasma density (ion saturation current) increases at the edge and decreases at the SOL indicating edge transport barrier (ETB) formation. We calculated the skewness and kurtosis of the ion saturation current fluctuating data to quantify the non-Gaussianity due to intermittency. Before biasing, turbulent fluctuations deviate definitely from the Gaussian PDF ($S = K = 0$) at the edge. With biasing, the intermittency at the edge decreases drastically. At the same time, the opposite dependency is observed in the SOL, i.e. both S and K increase somewhat with biasing. The floating potential fluctuations have less intermittency (not shown here), typically $S \sim 0$, $K < 1$.

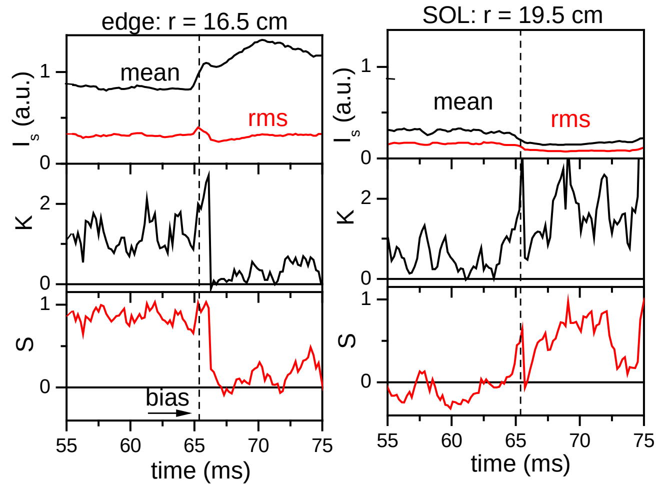

Figure 1. Effect of plasma biasing on turbulence intermittency at the edge and SOL.

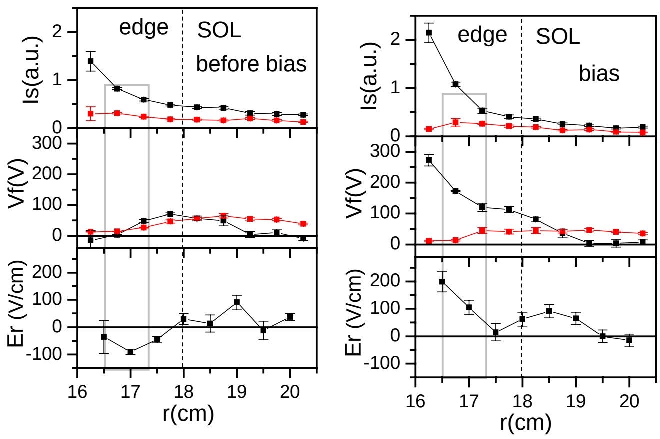

Figure 2. Radial profiles of E_r, I_s, and V_f. The electrode position is indicated by grey vertical bars.

Without biasing electric field is usually negative at the edge and positive at the SOL. With biasing, the E_r changes to positive, and it is strongest and highly sheared at the edge. The current saturation current increases at the edge and decreases at the SOL indicating steepening of plasma density due to the edge transport barrier formation. An interesting point is an effect of biasing on propagation of turbulence structures. With our probes, the poloidal phase velocity of the turbulence could be calculated from the maximum of cross-correlation function of two poloidally spaced pins as $v_{\tau au} = d/\Delta\tau$, where d is the distance and $\Delta\tau$ is the time-shift of maximum. The $E \times B$ drift velocity caused by radial electric field is $v_E = E_r/B_t$. The measured radial profiles of $\Delta\tau$ and calculated poloidal velocities $v_{\tau au}$ and v_E are presented in figure 3. Shot-to-shot data are well reproducible and give velocities of ~ 10 km/s. Change in the $\Delta\tau$ sign at the edge occurs concomitantly with change in E_r direction due to biasing. However, values of these two velocities disagree completely at small electric field and time-shift. We do not observe an expected increase of $\Delta\tau$ for small E_r and an increase of E_r for small $\Delta\tau$.

The rake probe provides more accurate determination of the radial profiles, radial and poloidal phase velocities, and correlation length. It was used to measure radial profiles in the SOL. Figures 4-6 present data of three similar discharges with different position of the rake probe.

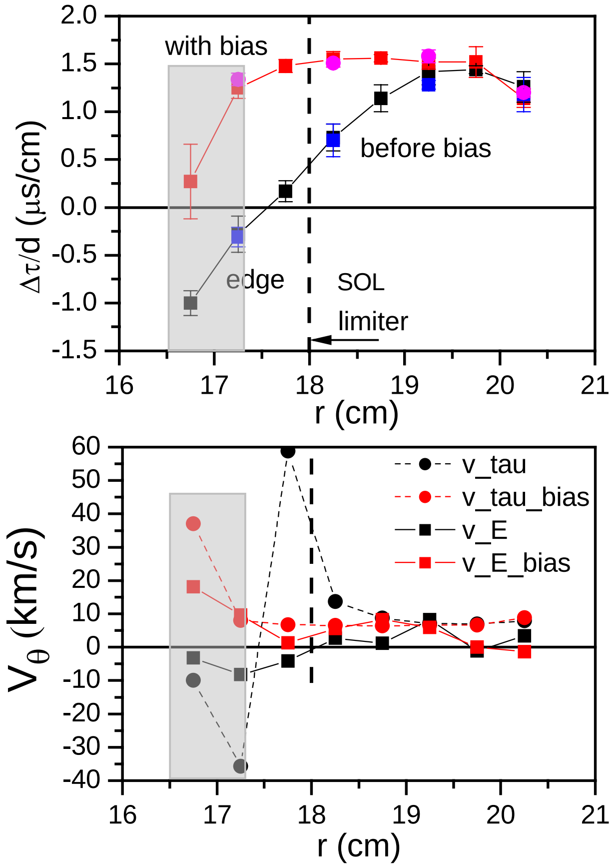

Figure 3. Shot-to-shot determination of the poloidal phase velocity at the edge and SOL by Langmuir probes.

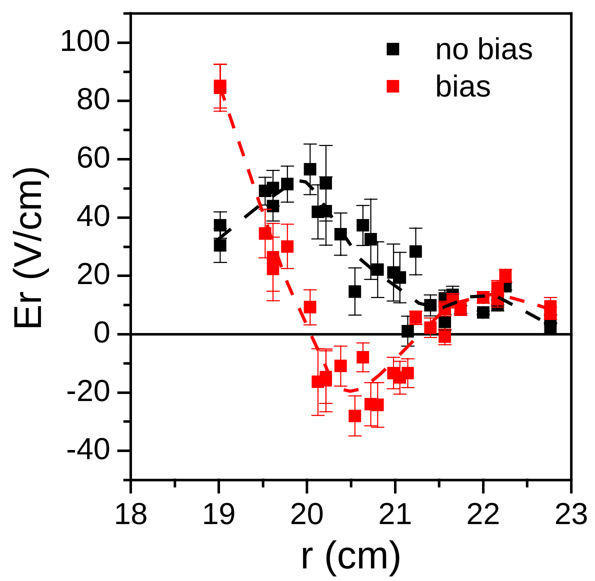

Figure 4. Radial electric field in the SOL measured by the rake probe

Edge biasing affects strongly the radial electric field (Fig. 4) in the SOL. The radial velocities obtained from floating potential and ion saturation current are quite different (Fig. 5). The poloidal velocity of ~ 5 km/s obtained from floating potential is in agreement with value of $E\times B$ velocity calculated for maximum value of the measured radial electric field of ~50 V/cm.

The correlation length of turbulence in the SOL is of ~2 cm for ion saturation current and ~ 4 cm for floating potential (fig. 6). The edge plasma biasing decreases somewhat the correlation.

In conclusion, experimental data show that edge plasma biasing leads to strong changes of the plasma turbulence in the edge and SOL. In general, results on turbulence intermittency, toroidal correlation length, poloidal and radial phase velocities agree with data of other tokamaks [2]. The intermittency without biasing is more strong in the edge. In this point our results differ from TEXTOR [3] and other tokamaks. There is large disagreement between poloidal phase velocity and $E\times B$ drift velocity especially at low values of the radial electric field and high values of the phase velocity.

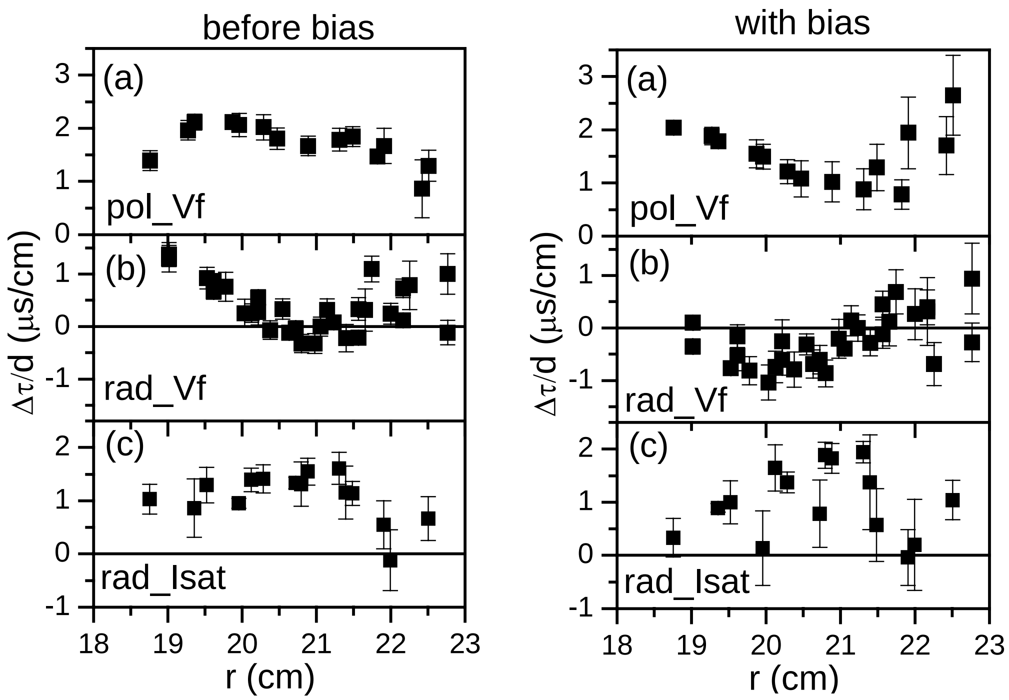

Fig. 5. Poloidal and radial propagation of turbulence measured by the rake probe in the SOL.

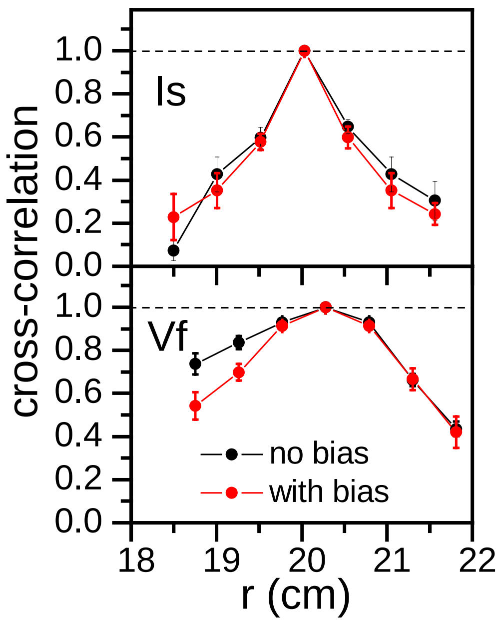

Fig. 6. Determination of the correlation length in the SOL

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