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Transport and fluctuations during electrode biasing on TJ-II

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1. Introduction

The influence of limiter biasing on plasma confinement, turbulence and plasma flows have been previously investigated in detail on the TJ-II stellarator [1]. Experimental results showed that it is possible to modify global confinement and edge plasma parameters with both positive and negative biasing and showed evidence of electric field induced improved confinement via multiple mechanisms. Electrode biasing is expected to introduce more substantial changes in energy and particle confinement than limiter biasing as it has the advantage of forcing an electric field in the edge plasma.

In this contribution we report on the results of edge polarization experiments carried out in TJ-II using an electrode. The effect of bias at different densities is studied, particularly in what concerns their effects on the edge plasma parameters and particle confinement.

2. Experimental set-up

Experiments were carried out in ECRH plasmas (P_{ECRH}=200-400 kW, B_T=1 T, R=1.5 m, $\langle a \rangle$=0.22 m) created in the TJ-II stellarator. The edge plasma was characterized mainly by a multi-Langmuir probe system, installed in a fast reciprocating probe drive, measuring simultaneously different edge plasma parameters. A graphite electrode has been developed and also installed in a fast reciprocating probe drive. The electrode head is mushroom shaped and made of 2-D Carbon composite, having a height (radial extension) of 12 mm and a diameter of 25 mm, screwed to a stainless steel shaft, which is protected by boron nitride as insulating material to be exposed to the plasma. The electrode was inserted typically 2 cm inside the LCFS and biased with respect to one of the two TJ-II limiters.

3. Experimental results

The modifications in the plasma properties induced by electrode biasing depend on several parameters as the biasing voltage, the electrode location and plasma density. The latter is very important on TJ-II as the edge parameters depend strongly on it [2]. Previous experiments on TJ-II showed that the development of the naturally occurring velocity shear layer requires a minimum plasma density [2]. In the region just inside the last-closed flux surface, LCFS, the radial electric field increases significantly when the plasma density reaches the threshold value and the perpendicular phase velocity of fluctuations reverses sign. The plasma response to bias is therefore different at densities below and above the threshold value to trigger the spontaneous development of ExB sheared flows.

3.1 Density below the threshold value

The effect of positive electrode bias for low values of plasma density is shown in figure 1. The bias voltage was applied at t=135 ms for 70 ms, and the electrode was located approximately 20 mm inside the LCFS. Figure 1 shows the temporal traces of bias current and voltage, line-average density, $\bar{n}$, average H_α emission and ratio $\bar{n}/H_\alpha$. Also shown are edge parameters derived from the Langmuir probes located at r/a=0.8: floating potential, phase velocity of fluctuations, fluctuations induced particle flux, I_{sat} fluctuation level and root mean square, RMS, of the poloidal electric field, E_θ.

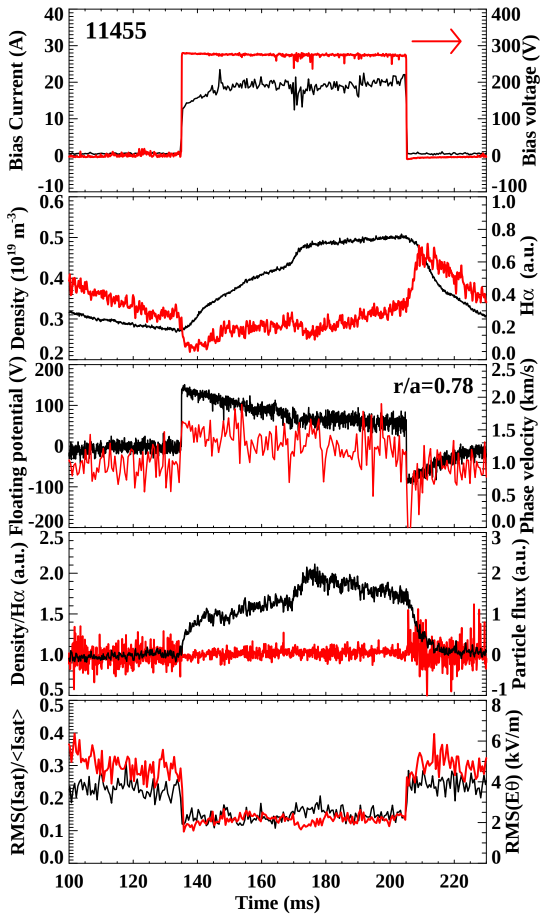

Figure 1: Time evolution of the main plasma parameters for a discharge with positive electrode bias at low density.

We note that the density increases and the H_α emission decreases during the polarization, so that the ratio $\bar{n}/H_\alpha$ (which is roughly proportional to the particle confinement time τ_p) increases substantially (~100%). The floating potential increases by more than 100 V, confirming that both the plasma potential and the edge radial electric field can be strongly modified for positive applied voltages. As shown in figure 1, both the turbulent transport and the fluctuation level of the edge quantities are strongly reduced after the bias is applied. Observations are therefore consistent with a local reduction of the anomalous particle flux, as a result of a reduced electrostatic turbulence. Spectral analysis of the probe signals shows that the reduction in turbulent transport results mainly from a decrease in the poloidal electric field fluctuations, being that reduction stronger for frequencies between 10 and 100 kHz.

The emission from several impurities lines (e.g. B, C and O) is recorded simultaneously on TJ-II. It has been observed that the emission intensity increase is generally proportional to the variation in the line-averaged density, so that the density rise can be unequivocally attributed to better particle confinement, as opposed to increased ionization by impurity penetration. Furthermore, a larger increase is observed for impurities lines located near the plasma centre (e.g. Fe XVI, C VI) when compared those located near the edge plasma (e.g. C III, B III). This different behaviour may be attributed to a distinct density increase in the plasma periphery and centre.

To better characterize the modifications introduced by the electrostatic polarization at the plasma edge, the radial profiles of V_f and I_{sat} have been measured and are presented in figure 2. The V_f profile is strongly modified by electrode bias in the region ρ<0.9, leading to the formation of a strong radial electric field (up to 10 kV/m). These results are consistent with the time evolution of the phase velocity (shown in figure 1), which increases during biasing. Also shown in figure 2 is the I_{sat} radial profile, which becomes stepper during biasing in the region where the electric field is modified. In summary, figure 1 and 2 shows that for low densities, the edge plasma potential is fully controlled by external biasing.

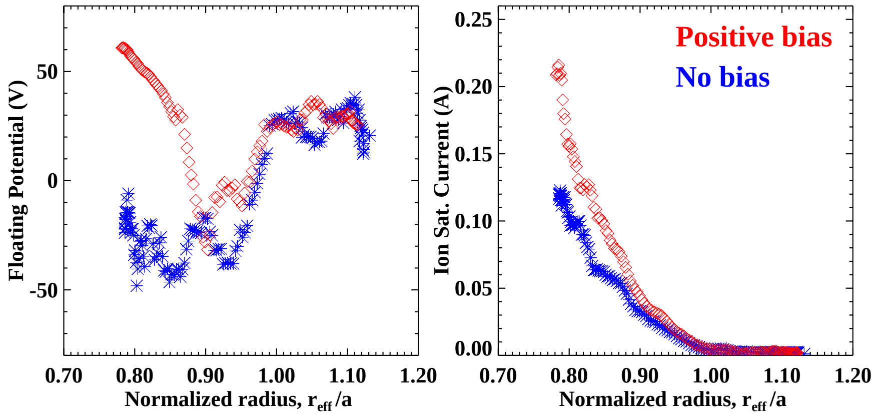

Figure 2: Edge radial profiles with and without electrode bias for a low density discharge.

3.2 Density above the threshold value

As explained before, above the threshold density (~0.6×10^{19} m^{-3} for the configuration used), the floating potential inside the LCFS becomes strongly negative and the plasma rotates in the electron drift direction. Positive bias will tend to increase the edge floating potential at the electrode location and therefore reverse the plasma rotation direction. As a consequence, when the bias is applied to plasmas with a density around the threshold value for shear formation, the effects are clearly distinct from those previously presented (see figure 3). As the bias is applied, the density increases and the H_α emission decreases, leading to a clear improvement in particle confinement (~40%). The floating potential is also strongly modified indicating that the edge electric field is modified in this case too. However, as the density increases above the critical value it will also influence the edge profiles. The H_α

emission tends to follow the density time evolution; the floating potential decreases and the phase velocity reverses again. In summary, at higher densities edge plasma potential profiles are determined not only by external biasing but also by the electric fields spontaneous developed. For positive bias, the floating potential at ρ<0.9 increases strongly to a value similar to that observed in the low density case, resulting in a large electric field shear. Furthermore, the I_{sat} is also observed to increase in the edge plasma and to reduce in the SOL.

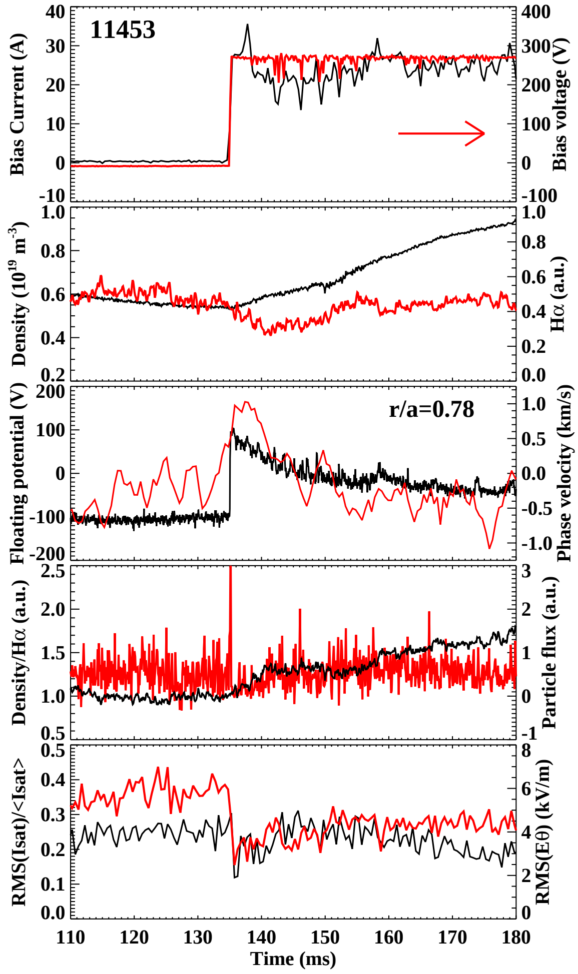

Figure 3: Time evolution of the main plasma parameters for a discharge with positive electrode bias at medium density.

4. Summary

Electrode biasing experiments on TJ-II have shown that it is possible to modify the edge radial electric field and particle confinement for positive bias. Furthermore, it has been found that the plasma response is different at densities below and above the threshold value to trigger the spontaneous development of ExB sheared flows. At low densities, the edge plasma potential is fully controlled by external biasing. In this case, strong increase in plasma density and reduction in edge fluctuation level and H_{α} signals is observed during biasing. At higher densities edge plasma potential profiles are determined not only by external biasing but also by the electric fields spontaneous developed.

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