

## Investigation of the turbulence intermittency in the scrape-off layer during the static DED operation in TEXTOR

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### 1. Introduction

It has long been observed that the plasma transport in the scrape-off layer (SOL) is characterized by turbulent intermittency [1-4], which unfavorably increases wall erosion and reduces the divertor efficiency. In recent years, experiments in several machines [5-7] have shown the importance of an ergodized magnetic boundary in optimizing the plasma-wall interaction. In the static DED (dynamic ergodic divertor) operation on TEXTOR, a reversal of turbulent flux from radially outwards to inwards has been observed in the ergodic zone along with other changes of turbulence properties [8]. In this paper, we report the results about the impact of the static DED on the intermittent transport in the SOL of TEXTOR.

### 2. Experimental setup

The experiments were performed in TEXTOR tokamak under the static  $m/n=6/2$  DED configuration [7] with following ohmic discharge conditions:  $R/a=1.73/0.46$  [m/m],  $B_T=1.9$  T,  $I_p=200-360$  kA,  $\langle n_e \rangle = (1.6-3.5) \times 10^{19} \text{ m}^{-3}$ . The *dc* DED current ( $I_{DED}=6$  kA) was applied during the stationary phase of the discharge, which induced a perturbation field  $B_T/B_T \sim 10^{-4}$  in the edge and thus stochastization of magnetic field lines in the plasma boundary [9, 10]. The measurements were mainly made by a fast reciprocating Langmuir probe array installed at the outer midplane. Two pins of the array were DC-biased to record the ion saturation current,  $I_s$ , while the other two were poloidally separated to detect the poloidal electric field  $E_\theta$  from their floating potential difference. The radial speed of the blobs is hence estimated by  $V_r =$

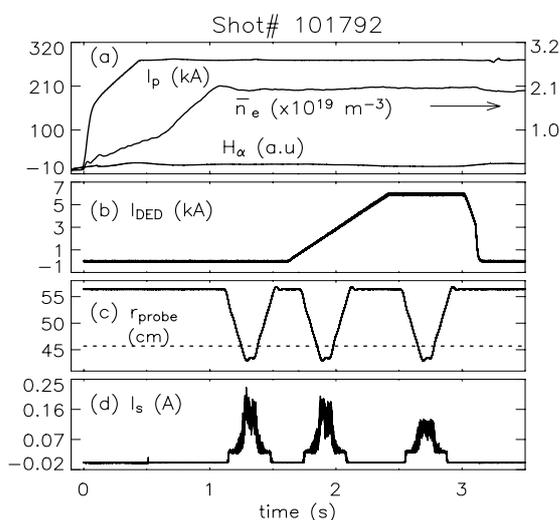


Fig. 1 Discharge waveforms in a static 6/2 DED experiment on TEXTOR. (a) plasma current ( $I_p$ ), line-averaged density and  $H_\alpha$  emission; (b) *dc* DED current; (c) radial position of fast probes (dotted line denotes limiter location); (d) ion saturation current.

$E_{\theta} \times B/B^2$ . The turbulence-driven particle flux,  $\Gamma_r$ , is calculated by  $\Gamma_r = \langle \tilde{n} \tilde{E}_{\theta} \rangle / B$ , where  $\tilde{n}$  (density fluctuations) is taken from  $I_s$  fluctuations. The fluctuation data were digitized at a rate of 500 kHz.

### 3. Results and discussion

Figure 1 plots some typical waveforms in a static 6/2 DED discharge. Figs. 1(a) and (b) show that the  $I_{DED}$  is applied in the stationary discharge duration. Fig. 1(c) shows that the fast probes are plunged three times during one shot: the first one before DED, the second in ramp phase and the third in the plateau of  $I_{DED}$ . For each plunge, the probe position reaches the plasma edge (the dotted line denotes limiter locus). The corresponding  $I_s$  signal is plotted in (d). Here, we simply assume that the fluctuating  $I_s$  reflects density fluctuations. In order to have an insight into the basic features of the blob transport, we look first on the  $I_s$  data in the ohmic phase before the DED. The raw signal is depicted in Fig. 2(a) for a radial range of  $1.1 \geq r/a \geq 0.98$ . One can see a lot of “bursts” in  $I_s$  data, extending 4-5 cm deep into the SOL. To have a close view, we plot a zoom of  $I_s$  for 5 ms in Fig. 2(b), together with corresponding  $V_r$  and  $\Gamma_r$  signals in (c) and (d), respectively. From Figs. 2(b)-(d), we can see that at almost each intermittent “peak” (marked by circles), there exists a burst of radial speed,  $V_r \sim 1$  km/s, which

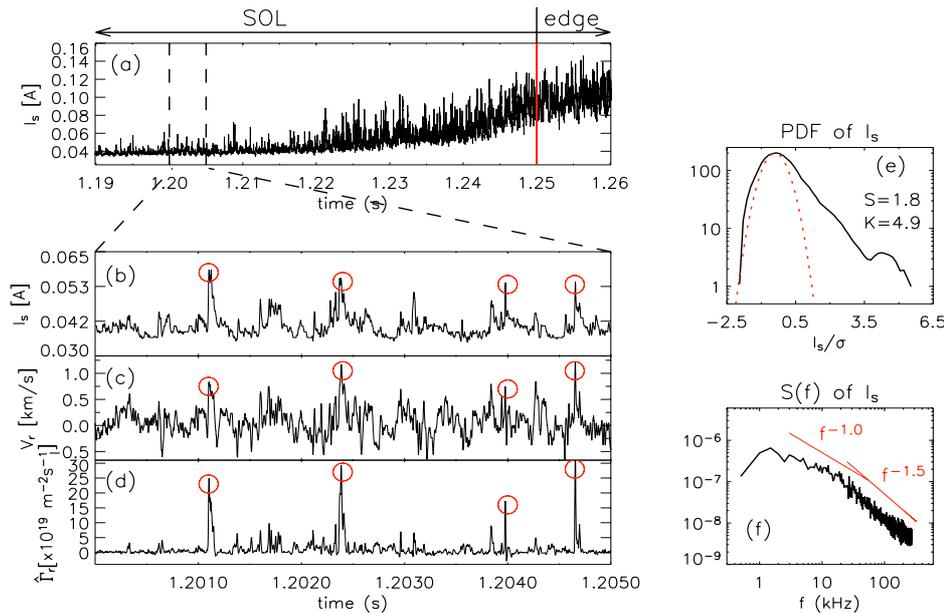


Fig. 2 (a) Time series of  $I_s$  signal detected in the plasma boundary ( $1.1 \geq r/a \geq 0.98$ ) before the DED. Shown in (b)-(d) are zoom of  $I_s$ ,  $V_r$  and  $\Gamma_r$  signals for a 5ms time window. The large bursts are marked by red circles. (e) PDF of  $I_s$  shown in 2(b), the dotted curve denotes a Gaussian-fit. (d) frequency spectrum  $S(f)$  of  $I_s$  measured in the SOL.

eventually induces a large ejection of radial flux  $\Gamma_r$ . Because of the positive bursts, the PDF (probability distribution function) of  $I_s$  exhibits a strong non-Gaussianity with high values of skewness ( $S$ ) and kurtosis ( $K$ ) ( $S=K=0$  for Gaussian) [4], as seen in Fig. 2(e). The power-law shape of frequency spectrum of  $I_s$ , drawn in (f), further indicates that the intermittency doesn’t happen periodically, but is well embedded in the “sea of

turbulence”. The time-asymmetry of the burst, i. e., quick jump and slow decaying, suggests that the blob ejection is unlikely caused by a pure coherent vortex [3, 4]. In this experiment, we also made a density scan and a safety factor scan. Comparison of the results before the DED explicitly reveals a dependence of the SOL intermittency on  $\langle n_e \rangle$  and  $q(a)$ . As an example, Fig. 3 plots the  $I_s$  signal and their  $S(K)$  values in the insets for two different density discharges. One can see that at the same  $q(a)$ , the intermittency is enhanced with increasing  $\langle n_e \rangle$ . This has also been seen in the reversed  $B_T$  and  $I_P$  discharges. Similarly, for the same  $\langle n_e \rangle$  plasmas, the intermittency is enhanced with increasing  $q(a)$ .

The influence of static DED on the SOL blob transport is illustrated in Fig. 4, where the left and right column displays data before and during the DED, respectively. As shown in Fig. 1, the probe data are taken from the first and the third plunge before and during the plateau of  $I_{DED}$ , respectively. The time duration in both column covers the same radial range of  $1.1 \geq r/a \geq 1.0$ . In Figs. 4(a) and (e), we can see that with DED the amplitudes of blob bursts in  $I_s$  are decreased. The corresponding  $V_r$  is also reduced slightly [see (b) and (f)]. The intermittency degree in turbulent flux and the averaged level of  $\Gamma_r$  are largely depressed by the DED, as seen in (c)-(h). To understand the mechanism, we

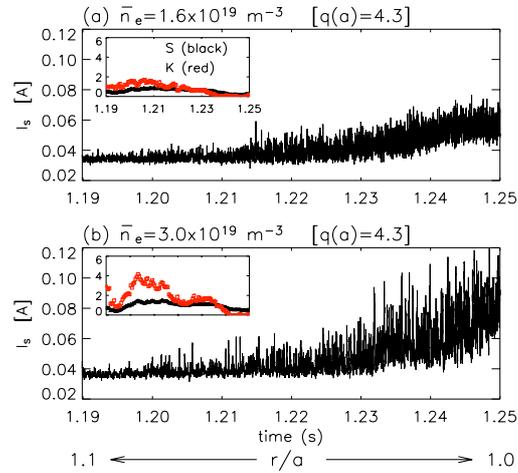


Fig. 3 Comparison of  $I_s$  signals in the SOL for two different density discharges in the ohmic phase before DED. Shown in insets are the corresponding skewness (black) and kurtosis (red) of the  $I_s$  signal.

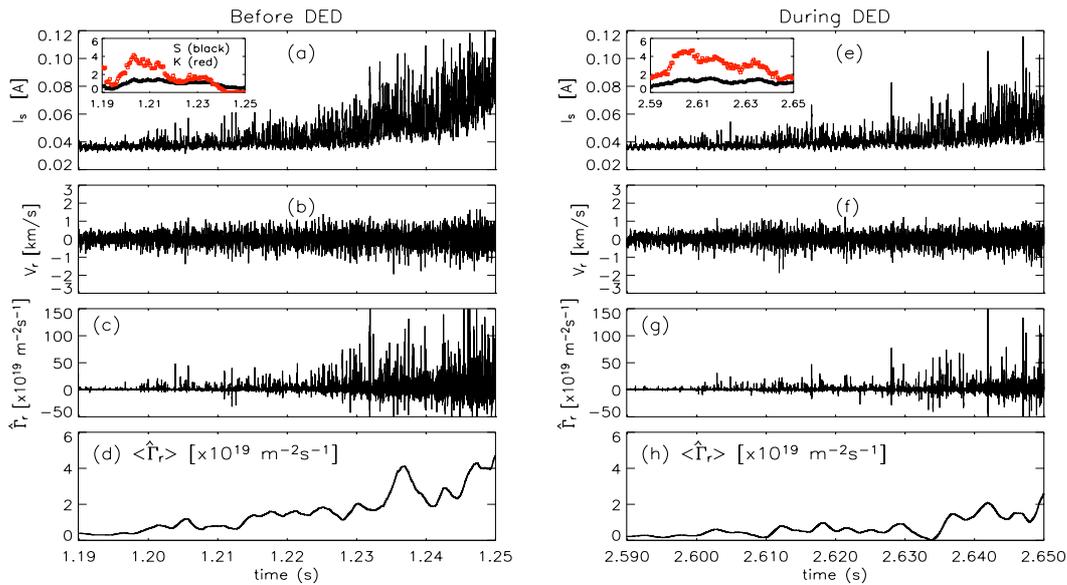


Fig. 4 Comparison of the  $I_s$ ,  $V_r$  and  $\Gamma_r$  signals measured in the SOL ( $1.1 \geq r/a \geq 1.0$ ) before (left column) and during (right column) the 6/2 DED (No. 101795). (a)-(e)  $I_s$  signal; (b)-(f) radial speed  $V_r$ ; (c)-(g) turbulent flux  $\Gamma_r$ ; (d)-(h) time-averaged flux  $\langle \Gamma_r \rangle$ . Plotted in the insets of (a) and (e) are the corresponding skewness (black) and kurtosis (red) of  $I_s$  signals.

first compare the  $S$  and  $K$  values of  $I_s$ , plotted in the insets of (a) and (e). It is seen that during DED both the skewness and kurtosis are slightly enhanced, suggesting that the bursty feature of  $I_s$  remains during the DED. However, despite of the similar shape, the amplitude of each blob is substantially reduced by the DED, and consequently, the number of large blobs is decreased during the DED phase. The results are consistent with recent simulations [11]. The apparent destructive role of the DED on the blob amplitude might be related to an associated theoretical paradigm based on the interchange instability [11-14]. This theory proposes that the blob structure is created on a base of a turbulent eddy and then driven radially outwards by the curvature drift. The role of the curvature drift has been confirmed in our reversed  $B_T$  experiment (not shown here). With DED, we generally observe that the large-scale (small wave-number) turbulence structures are suppressed in the stochastic region [8, 15]. The large-amplitude blobs appear thus to be depressed as their sources, large-size eddies, are destroyed by the DED.

#### 4. Conclusion

Intermittent transport has been investigated in the SOL of TEXTOR during the static 6/2 DED operation. In the ohmic phase before the DED, the intermittent blobs exhibit high non-Gaussian positive skewness and kurtosis in the  $I_s$  signal, extend 4-5cm deep into the SOL with a radially outward speed  $\sim 1$  km/s and thus eject large turbulent flux. Moreover, the degree of intermittency is enhanced with increasing plasma density and edge safety factor within the parametric ranges studied. With the application of the static DED, the burst amplitude, the number of large blobs and the velocity of their radial motion are all generally reduced, thus leading to a reduction of the intermittent turbulent flux in the SOL. The possible physical mechanisms are discussed. The present results suggest that controlling SOL blob transport by an ergodized magnetic boundary might be a possible means for optimizing plasma-wall interaction.

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