Possible Use of Dynamic Ergodic Divertor as a Contactless Biasing in Tokamaks

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Intermittent positive bursts of plasma density are detected by Langmuir probe at the edge of the TEXTOR tokamak. Radial dependence of burst statistical properties and temporal characteristics is studied in two different regimes – with electrode biasing and dynamic ergodic divertor (DED). Similar modification of burst characteristics is observed. Namely, average burst rate increases and average burst duration decreases compared to Ohmic conditions. Statistical properties are also modified in the same way in both regimes. The reason is that biasing and certain regimes of DED modify the radial electric field which affects similarly the dynamics of coherent turbulent structures through $E_r \times B_t$ induced sheared poloidal rotation. Thus, after detailed investigations and refinement, certain regimes of DED can be used as "contactless biasing" for the external control of plasma turbulent transport in fusion devices.

Investigation of tokamak plasma turbulent transport is one of the most important tasks of modern fusion research. The transport is bursty and intermittent. Large turbulent events – density bursts are responsible for such transport. They are formed intermittently and propagate radially outwards. This causes degradation of confinement, high heat load on first wall and unwanted retention of tritium. It is very important to understand the physical nature of bursty transport, especially in the context of developing the methods for its external control.

Investigation of temporal characteristics of intermittent density bursts such as burst rate, inter-burst time and burst duration together with their statistical properties is an efficient method for better understanding of turbulent transport in tokamak edge plasma [1-4]. In the present paper we report the results of such investigation of intermittent density bursts measured at the edge of the TEXTOR tokamak [5,6] by means of reciprocating Langmuir probe in two different regimes – with electrode biasing and dynamic ergodic divertor (DED).

On the TEXTOR tokamak two methods are used for external control of plasma turbulent transport, namely electrode biasing [5] and the DED [6]. Both have strong influence on edge transport and biasing can even trigger the L-H transition [5].

During analyzed biasing discharge of TEXTOR (*R=1.75 m*, *a=0.475 m*) I_p = *200 kA*, B_t*=1.9 T*, line average density 1×10^{19} m^{-3}, and the biasing voltage V_{bias}*=150 V*. First radial scan with the probe is made during Ohmic phase, and second one during biasing phase. Ion saturation current I_{sat}, floating potential V_{fl} and electron temperature T_e were measured. Sampling frequency is 500 kHz. Same measurements were performed during discharge with DED for which I_p*=250 kA*, B_t*=2.25 T*, line average density 1.5×10^{19} m^{-3}, DED current I_{DED}*=3 kA*. First radial scan is made during Ohmic phase, and second one during DED.

In Ohmic phase of biasing discharge we observe intermittent positive bursts of I_{sat} in all radial positions. As the radial distance increases they are more dominant. This is confirmed by statistical analysis – probability density function (PDF) of I_{sat} is positively skewed and skewness increases radially (see Fig.1). Similar radial dependence of I_{sat} skewness was reported in the papers [1-4]. Fig.1 shows that during biasing skewness rises in 1.5 cm wide radial region starting at 44 cm. At larger radii I_{sat} skewness decreases compared to Ohmic phase. Radial dependence of temporal characteristics of intermittent bursts during biasing discharge is also presented in the Fig.1. During biasing average burst rate increases and average burst duration decreases compared to Ohmic phase. It must be mentioned that similar modification of burst temporal characteristics has been observed in CASTOR tokamak too [1].

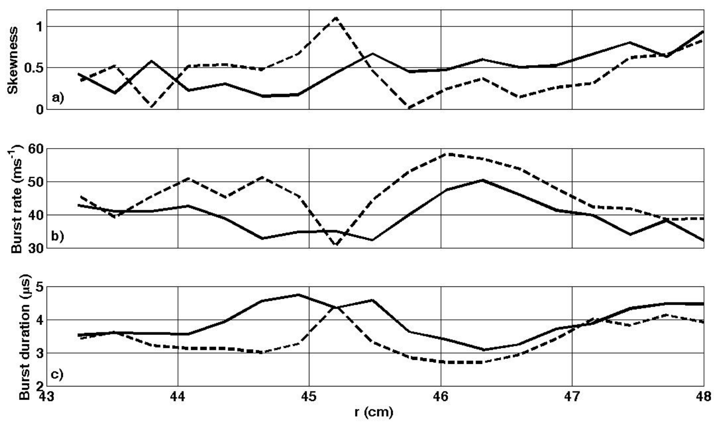

Fig.1 *Radial dependence of* I_{sat} *(a) skewness, (b) average burst rate, and (c) average burst duration before (solid lines) and during (dashed lines) biasing (shot #112172)*

The reason of such modification is that biasing generates strongly nonuniform radial electric field, changes the radial electric field which already existed in Ohmic phase (see Fig.2) and imposes stronger sheared poloidal rotation on plasma.

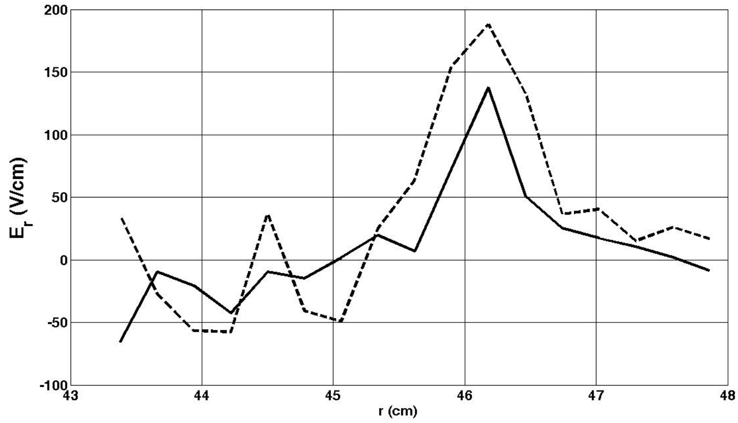

Fig.2 *Profile of the radial electric field before (solid line) and during (dashed line) biasing (shot #112172)*

Sheared poloidal rotation splits coherent structures, which are responsible for appearance of intermittent bursts, into smaller ones and moves them faster poloidally [1]. As a result Langmuir probe detects more bursts in biasing phase and their average duration decreases [1].

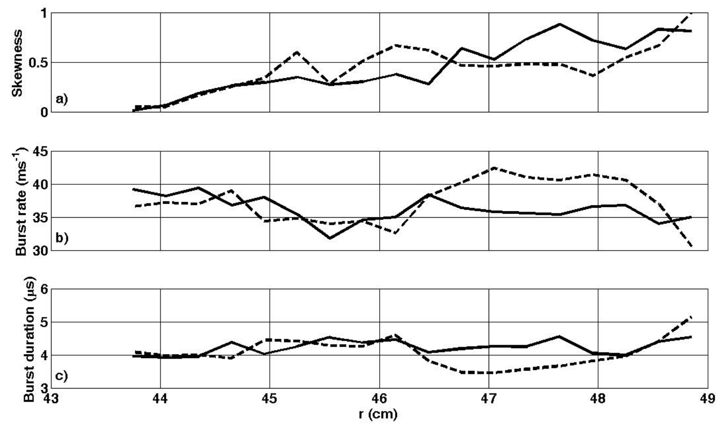

Fig.3 *Radial dependence of I_{sat} (a) skewness, (b) average burst rate and (c) average burst duration before (solid lines) and during (dashed lines) DED (shot #111626)*

During DED operation open stochastic magnetic field lines appear in plasma boundary and radial magnetic connection between edge plasma and wall is created. Electrons move faster than ions along radial field lines. As a result the radial electric field is modified in the plasma. Since radial electric field is modified during DED operation and different DED regimes have different influence on plasma, one can presume that in a certain DED regime we may get similar modification of intermittent bursts as in case of biasing. We found such DED regime among many different ones used on TEXTOR. During DED I_{sat} skewness rises in 1.5 cm wide radial region and at larger radii it drops compared to Ohmic phase (see Fig.3). Average burst rate increases and average burst duration decreases compared to Ohmic phase (see Fig.3). These modifications are quite similar to those observed during biasing. The reason should be the modification of radial electric field by DED (see Fig.4).

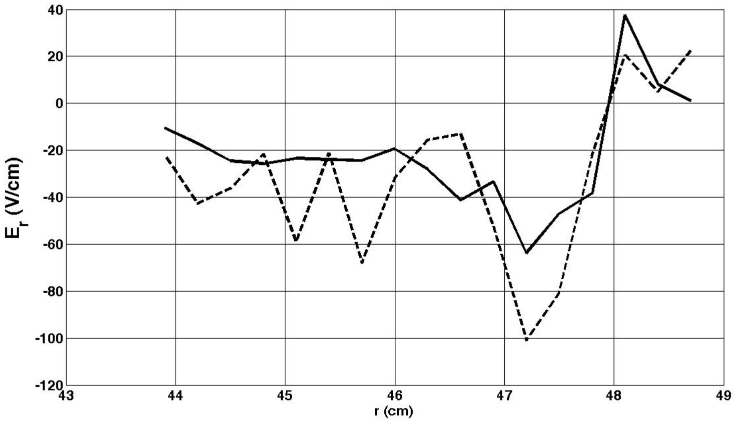

Fig.4 *Profile of the radial electric field before (solid line) and during (dashed line) DED (shot #111626)*

Radial position of shear layer practically does not change in DED regime, but radial electric field is stronger (more negative) inside this layer compared to Ohmic conditions. Electric field slightly decreases outside the shear layer, but the difference between the peaks of the field around the shear layer increases during DED. Thus, sheared poloidal rotation is stronger during DED. As a result coherent structures are splitted into smaller ones which move faster poloidally and burst characteristics are modified in the same way as during biasing.

In conclusion, we report the study of intermittent burst characteristics at the edge of the TEXTOR tokamak and their modification during electrode biasing and DED operation. Similar modifications are observed in two regimes. The reason is that these regimes modify the radial electric field which affects similarly the dynamics of coherent turbulent structures through $E_r \times B_t$ induced sheared poloidal rotation. Thus, after detailed investigations and refinement, certain regimes of DED can be used as “contactless biasing” which should be beneficial for external control of plasma turbulent transport in next generation fusion devices.

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