

# Investigation of the intermittent burst events in the edge region of the J-TEXT tokamak

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## 1. Introduction

The experimental studies of electrostatic fluctuations, especially the intermittent burst events (IBEs) imbedded in fluctuations and their influence on radial transport, have been carrying on in the plasma edge region of the J-TEXT tokamak [1]. The J-TEXT, formerly TEXT-U (Texas Experimental Tokamak Upgrade), which has a major radius of 1.05m and a minor one of 0.27m, has been reconstructed and obtained its first plasma in 2007.

## 2. Experimental setup

The scenarios on this topic has been undertaking by manipulating a movable probe system mounted on the top of J-TEXT at 45 degree toroidally from the limiter, as diagrammed in Fig. 1. The flexible design of the system enables itself to equip with different types of electrostatic probes, e.g. four-tip probe, 1-D (radial or poloidal) comb probe, and 2-D probe array, as shown in Fig. 2. The four-tip probe, which consists of four graphite tips and each having a 2mm long, 1mm in diameter and 3.5mm spacing, is essentially used to detect the plasma density ( $n_e$ ), electron temperature ( $T_e$ ), floating potential ( $\phi_f$ ), and their fluctuations around the boundary region [2]. The 1-D comb probe has 6 tungsten tips, each having a 3.5mm long, 0.5mm in diameter, and 5mm spacing. In practical, the comb probe is applied to measure the ion saturation current ( $I_s$ ), which is proportional to the plasma density under the assumption that the electron temperature fluctuations would be ignored. The 2-D probe array has 5×6 tungsten tips, each having a 3mm long, 0.5mm in diameter, and 5mm spacing. It directly provides the two dimension profile of the plasma floating potential ( $\phi_f$ ).

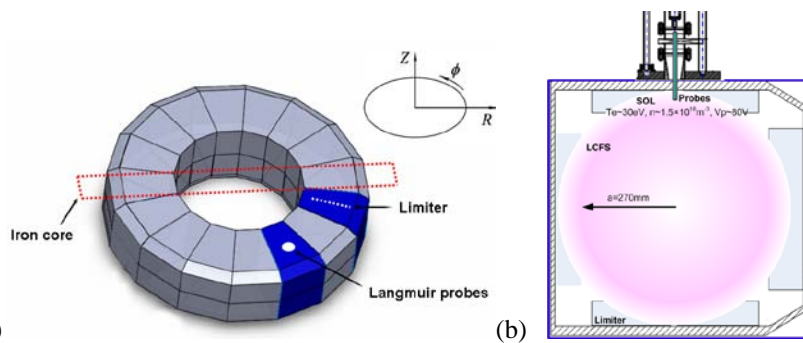


Figure 1. Schematic of the movable probe system and its location: (a) location of the system on the J-TEXT; (b) structure of system in the poloidal cross section.

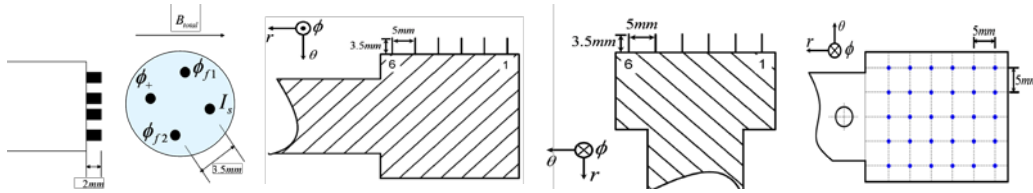


Figure 2. Diagrams of different electrostatic probes (from left to right): Four-tip probe; Radial comb probe; Poloidal comb probe; and 2-D probe array.

All the measurements have been done in the typical Ohmic pure hydrogen discharges with a limiter configuration and some key operation parameters listed as follows: plasma current  $I_p = 160kA$ , toroidal magnetic field  $B_T = 1.8T$  and central line-averaged plasma density  $n_{e0} = 1.0 \sim 1.5 \times 10^{19} m^{-3}$ . The survey are undertaken in the boundary region near the last closed flux surface (LCFS), where the plasma temperature, density and potential are 30eV,  $1.5 \times 10^{18} m^{-3}$ , and 80V, respectively. Measured signals with the time length of 200ms at a sampling rate of 500ksps used for analysis are acquired in the current flattop of the discharge and digitized and stored into the database.

### 3. Experimental results

#### 3.1 Relative electron temperature and density fluctuations

Fig. 3(a) gives an example of fluctuations with the imbedded IBEs in the time traces of  $\phi_f$  and  $I_s$  measured by a four-tip probe, respectively. The IBEs can be easily discriminated from the signals in the figure. These measured data can also be statistically evaluated to study the radial dependence of relative electron temperature fluctuations ( $T_{erf} = \tilde{T}_e/T_e$ ) and density fluctuations ( $n_{erf} = \tilde{n}_e/n_e$ ) as plotted in Fig. 3(b) and (c), respectively, where the error-bar gives the standard deviation of those reproducible discharges. The results reveal that  $T_{erf}$  and  $n_{erf}$  would increase along with the expanding radius in the boundary region and furthermore, the lowest value of  $T_{erf}$  and  $n_{erf}$  near the LCFS would attribute to the influence of poloidal shearing flow where turbulence can be suppressed to a low level.

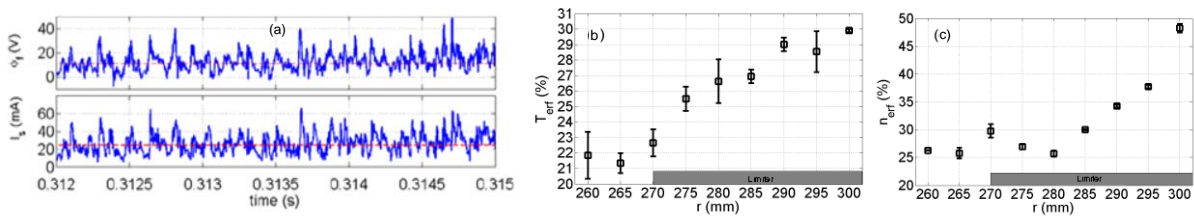


Figure 3. Results obtained by a four-tip probe: (a) fluctuations and IBEs in the time traces of  $\phi_f$  and  $I_s$ , respectively; (b) radial distribution of relative electron temperature fluctuations; and (c) for the density

#### 3.2 Power spectrum of the ion saturation current fluctuation

The power spectrum of the density fluctuations (similarly,  $I_s$  fluctuations) is obtained by the conventional Fourier analysis [2]. Fig. 4 shows an example of power spectrum at  $r =$

290mm. It is obvious that the linearity of the logarithmic spectrum tends to vary at about 7 kHz and 25 kHz. Accordingly, the spectrum can be essentially divided into three regions and thereby, can be governed by a power-law dependence ( $S(f) \propto f^{-m}$ ), where a rather flat region at frequency lower than 7 kHz could be catalogued into  $m = 0$ , the intermediate region between 7 kHz and 25 kHz into  $m = 1$ , and the steep one at frequency higher than 25 kHz into  $m \cong 2$ . Similar power spectrum is also obtained by using the measured data of density fluctuations in the J-TEXT boundary region.

### 3.3 Quiet time analysis of the intermittent burst events

Quiet-time statistics [3] is an approach to investigate the dynamics between the successive IBEs. It can extract information of the long-range correlation by mainly taking into account the quiet times  $\tau_q$  between two subsequent events. Here, a reference level equaled to 2.5 times deviation of the  $I_s$  fluctuations is used to dig the quiet times out of the measured signals. The probability distribution function (PDF) of the quiet times  $\tau_q$  can be catalogued into two distinct regions described by the power law ( $P(\tau_q) \propto \tau_q^{-\gamma}$ ) with  $\gamma = 1.05 \pm 0.06$  and  $\gamma = 2.29 \pm 0.18$  as shown in Fig. 5, respectively. The result implies the existence of correlation between the successive burst events.

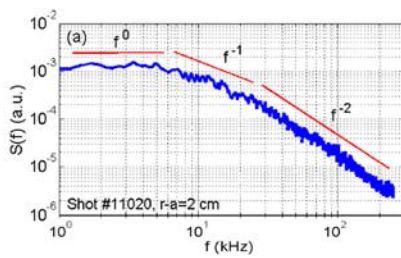


Figure 4. Power spectrum of the ion saturation current fluctuations at  $r = 290mm$ .

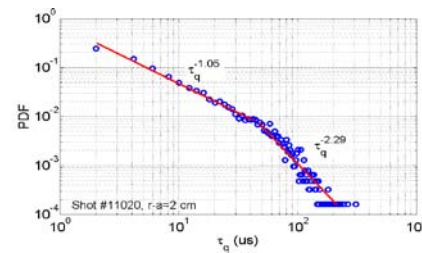


Figure 5. PDF of the quiet times  $\tau_q$  between the successive IBEs in the  $I_s$  fluctuations.

### 3.4 Characters of the intermittent burst events

Time evolution of radial (or poloidal) profile of the IBEs in the  $I_s$  fluctuations is deduced by applying the conditional average (CA) [2] on the signals provided by the corresponding radial (or poloidal) comb probe, where the reference tip in the radial (or poloidal) comb probe is at  $r = 280mm$  (or  $d_\theta = 15mm$ ). Both radial and poloidal evolution profiles can be inferred from the comb probes' data, as contoured in Fig. 6. From the time evolution profile shown in figure 6, the size and velocity of the IBEs can be deduced. The time evolution of 2-D ( $r$ - $\theta$ ) profile of the IBEs in the plasma floating potential fluctuations is also calculated by adopting the CA to analyze the signals recorded by the  $5 \times 6$  tips probe array, where the reference tip is at  $r = 295mm$  and  $d_\theta = 15mm$ . And the computing process results in Fig. 7. Fig. 6

(and/or 7) shows that the size of an observed IBE structure is approximately 15~30mm in poloidal length and 10~25mm in radial width. The size would be varied when the time and position is changed.

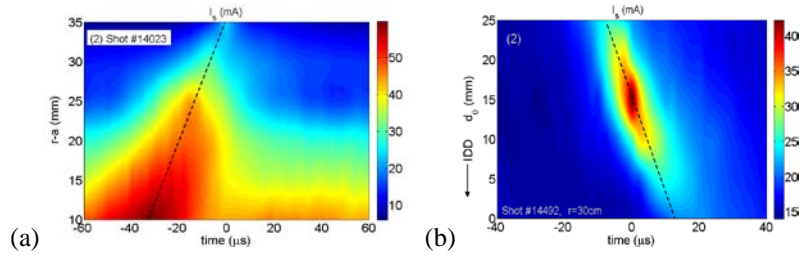


Figure 6. Time evolution profiles of IBEs in the ion saturation current with respect to the radial direction (a) and the poloidal direction (b). Measurements are done at  $r = 300\text{mm}$ . Here IDD means the direction of the ion diamagnetic direction.

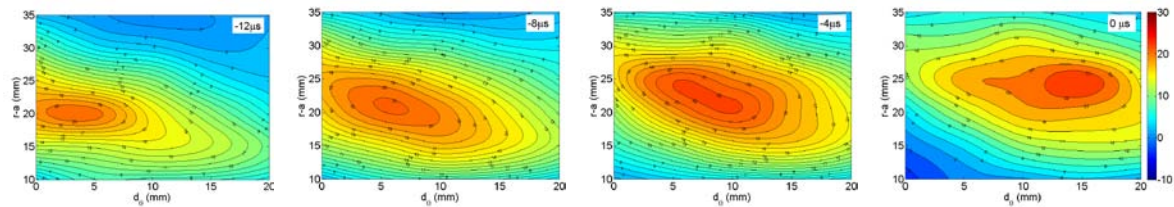


Figure 7 2-D time evolution profile of the IBEs in the plasma floating potential at -12, -8, -4 and  $0\text{ }\mu\text{s}$ . Here IDD means the direction of the ion diamagnetic direction.

Apart from the size of the IBEs, the velocity could also be traced out from the figures. Figure 8 shows that the radial and poloidal velocities of the IBEs vary with radius. It is clearly indicated in the figure that the IBEs are characterized by a radial velocity of 0.8~1.1 km/s and a poloidal velocity of 1~1.6 km/s in the SOL region. Both values are gradually decreased outwards along the radius.

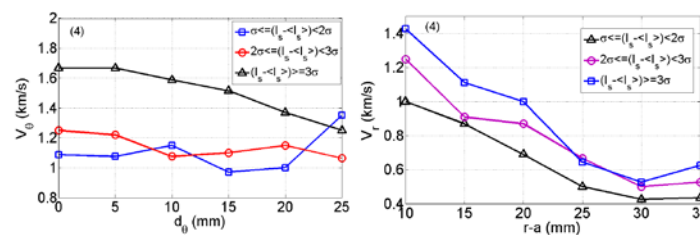


Figure 8. Radial (left) and poloidal (right) velocities of the IBEs vary along with the radius. Where  $\sigma$  is the standard deviation of the  $I_s$  fluctuation of and  $(I_s - \langle I_s \rangle)$  is the amplitude of IBEs

## References

- [1] G. Zhuang, et al, Plasma Science and Technology 11 (2009) 439
- [2] Zweben S J, Boedo J A, Grulke O, Hidalgo C, LaBombard B, Maqueda R J, Scarin P and Terry J L, Plasma Phys. Control Fusion 49 S1(2007)
- [3] Lynch V. E, Carreras B. A., Sanchez R., LaBombard B., van Milligen B. Ph. and Newman D. E., Phys. Plasmas 12 052304(2005)