Electrostatic turbulence in the edge region of RFX-mod

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The reversed field pinch (RFP) experiment RFX (R=2 m, a=0.5 m)[1] has undergone major modifications of the load assembly and is now equipped with a large number of active external coils for MHD mode control and is now called[2]. An integrated system of internal magnetic, electrostatic and calorimetric sensors (ISIS) has been realised to investigate the properties of the edge region of the plasma even at high plasma current. The electrostatic sensors are arranged[3] in one toroidal array (72 single probes) and one poloidal array (8 triple probes), providing spatially and temporally resolved measurements of the floating potential and of the electric field. Aim of the present paper is to describe the first results of the system of electrostatic probes concerning the features of floating potential fluctuations in the edge of the plasma of RFX-mod.

The data presented herein refer to a plasma campaign with plasma current I_p= 400-600kA, reversal parameter F (ratio of toroidal magnetic field at the edge and average toroidal field) from –0.2 to –0.15, I_p/N ~$4\cdot10^{-14}$ Am ($N = \pi a^2\langle n_e\rangle$ and $\langle n_e\rangle$ is the volume-averaged electron density). An example of global parameters can be seen in Fig. 1. In the present campaign only part of the system was in operation; specifically, only the signals coming from 20 sensors of the toroidal array and from a few electrodes belonging to the poloidal array of triple probes were measured, for a total of about 30 sensors. The signals were optically transmitted (1MHz bandwidth) to a stand-alone data

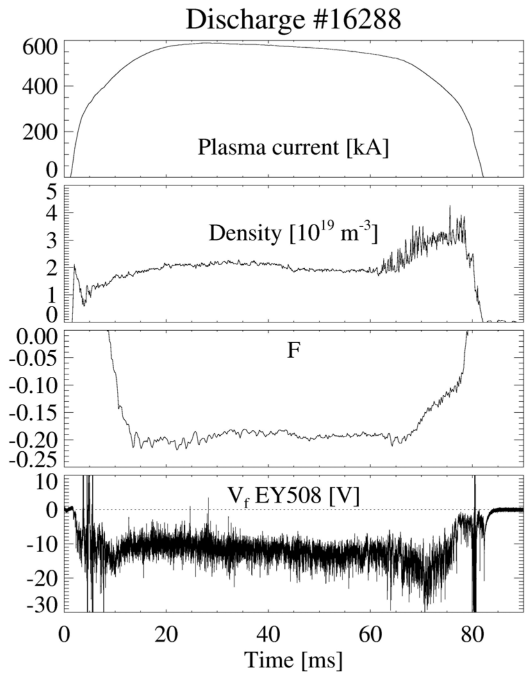

Fig. 1: Plot of plasma current, reversal parameter (F), electron density, instance of electrostatic signals.

acquisition system having DC-8 MHz bandwidth, 5MSamples/s sampling frequency, 12-bit resolution and 4 MWord memory depth per channel[4]. In all cases discussed herein the locking position of magnetic modes was at least 40° away from the sensors.

The floating potential measurements at the outboard equatorial plane of RFX-mod are consistent with the results obtained in RFX[5]: the average values are slightly negative with respect to the vacuum vessel (about –10V) and the RMS values are of a few Volts.

As can be seen from Fig. 1, the floating potential signals present a rich dynamics. This is confirmed by the inspection of the power spectra and, in particular, by the slope of the spectra in the range 100-600kHz, where it decays as a power-law of the frequency (with an exponent of –3), suggesting the existence of an energy exchange process between different time scales. To assess more precisely the characteristics of the signals, a thorough statistical analysis has been carried out, according to the procedure described in ref. 6: for each signal at a certain time scale a wavelet transform is evaluated; the probability distribution function (PDF) of the resulting coefficients is computed and is approximated by a stretched exponential of the form $A \cdot exp(-b|X|^{\zeta})$. In the absence of intermittency, the PDFs of normalised fluctuations should collapse to a single shape, so that the parameter ζ would exhibit no dependence on the time scale. Also in RFX-mod, as can be seen from fig. 2, conversely, the results show intermittency, namely a higher probability of occurrence of large bursts in the signals at shorter scales.

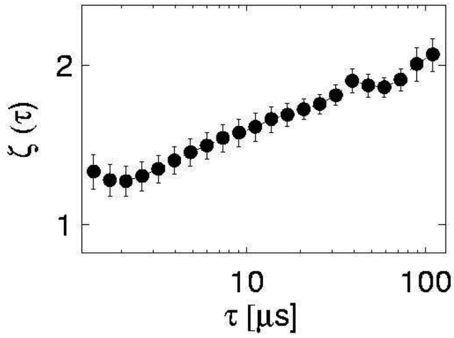

Fig. 2: ζ versus time scale.

The bursts responsible for intermittency can be identified, according to the method described in [7], as the events that render non-Gaussian the PDF at a particular scale. In fig. 3, the occurrence of intermittent events in the floating potential (vertical dotted lines) is compared to the behaviour of *F*, which oscillates during the discharge due to the cyclical process of magnetic diffusion and flux generation occurring

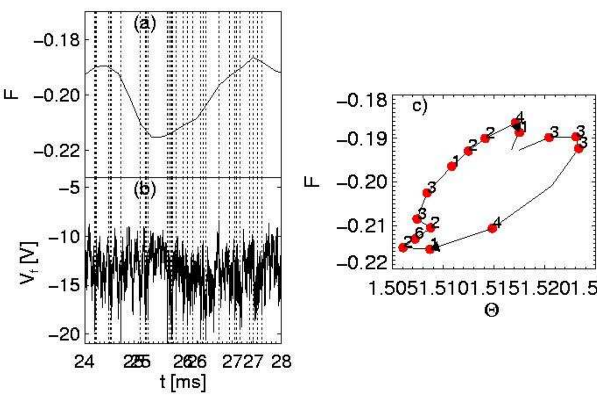

Fig. 3: Clustering of intermittent events.

in the core region of an RFP. Indicating the number of occurrences beside the red dots in the F-Θ plot (Θ is the ratio between the poloidal magnetic field at the edge and the average toroidal field) confirms that intermittent events tend to concentrate during the returning phase of the oscillation, when magnetic energy is released, as already found in RFX[7] and in EXTRAP-T2R[8]. It is worth noting that intermittent events are found to be correlated with global relaxation phenomena although the sensors are located at the very edge of the plasma, where a lower correlation is usually detected with *F* [9].

Thanks to the toroidal array, the intermittent events can be followed as they move. In fact, after identifying an event in the signal of a sensor, the cross-correlation can be computed with the surrounding sensors at different time lags, within a time window twice as large as the selected event. Very high values of the correlation are detected, indicating that indeed single events are being followed, as shown in Fig. 4 for events on a scale of 10μs and a window twice as large. Thus the propagation velocity of the event can be roughly estimated; the event highlighted in Fig. 4 propagates with a toroidal velocity of approximately 40 km/s. Moreover, inspection of Fig. 4 suggests a balance between the amounts of positive and negative events; this is confirmed by direct estimation of the amount of events per unit time and can be justified since the measurements are collected at the plasma edge, where the velocity shear is small and where the phenomena ruling the selection between positive and negative bursts are feebler[10].

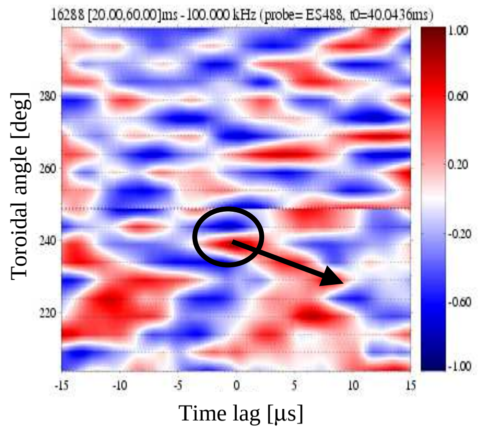

Fig. 4: Intermittent event propagation.

A similar analysis can be applied to the poloidal array of sensors, giving a velocity almost one order of magnitude larger. This evidence may be interpreted either as the poloidal propagation of fluctuations or as the toroidal rigid-body motion of a structure elongated along the total magnetic field at the edge of the plasma (it is reminded that in RFPs the edge magnetic field is essentially poloidal, the pitch being about 5-7° at the edge of RFX).

Cross-correlation analysis between the signals allows the determination of a propagation velocity of fluctuations. In particular, the use of the signals from the triple probe located on the outboard equatorial plane gives a toroidal velocity of 20-30 km/s opposite to the plasma current; this velocity is generally consistent with the slope of the wavenumber-frequency spectrum. It is found that the distance from the locking affects such velocity. Similar results are obtained in the plasma edge by other diagnostic systems, like the Gas Puffing Imaging[11].

The portion of the toroidal array presently in operation makes it possible to investigate the presence of a modal structure in the electrostatic signals. Indeed, on assuming that the measured pattern is periodically mirrored in the rest of the plasma, the results shown in Fig. 5 are found: toroidal mode numbers *n*=12 and 24 are simultaneously present during most of the discharge, as well as a low-*n* component (the present configuration does not allow a resolution better than Δn=3). In the same figure, at the time indicated by the dashed-dotted line, the instantaneous mode decomposition and a comparison between the original data and the corresponding reconstruction are also shown. Analysis of the phase reveals that when the amplitude is low (30-40ms) the modes rotate at ~20km/s in this discharge.

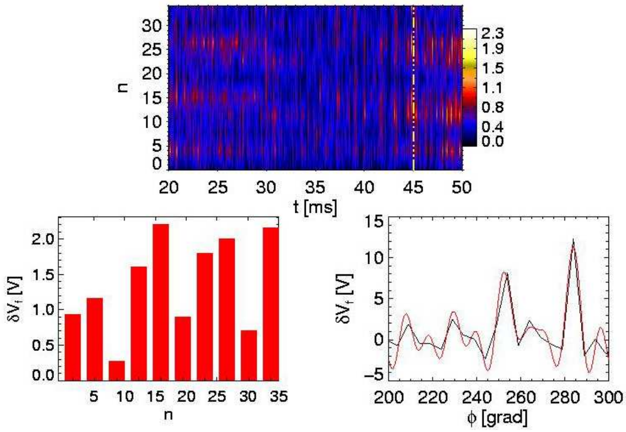

Fig. 5: Mode decomposition.

The present paper describes the first results concerning the floating potential measurements carried out in the RFX-mod machine; at the same time, these are the first measurements with the new system of internal sensors, ISIS. The results suggest a similarity with the structure of the plasma edge of RFX, including the presence of intermittency. It is also shown that the new diagnostic system allows investigation of the spatial structure of turbulence and modal analysis of the toroidal pattern of the floating potential.

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[1] G. Rostagni, Fusion Eng. Des. **25**, 301 (1995).
[2] P. Sonato *et al.*, 2003, Fusion Eng. Des. **66-68**, 161; W. Baker *et al.*, 2002, Fusion Eng. Des. **63-64**, 461.
[3] Serianni G. *et al.*, 2003, Rev. Scient. Instrum. **74**, 1558.
[4] Serianni G. *et al.*, 2004, Rev. Scient. Instrum. **75**, 4338.
[5] Antoni V. *et al.*, 1996, Nucl. Fusion **36**, 435.
[6] Antoni V *et al.*, 2001, Phys. Rev. Lett. **87**, 045001-1.
[7] Antoni V *et al.*, 2001, Europhys. Lett. **54**, 51.
[8] Vianello N. *et al.*, 2002, Plasma Phys. Control. Fusion **44**, 2513.
[9] Martines E. *et al.*, 2001, Czech. J. Phys. **51**, 983.
[10] Spolaore M. *et al.*, 2002, Phys. Plasmas **9**, 4110.
[11] Cavazzana R. *et al.*, P1.073, this conference.