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Optical Investigation of Edge Turbulence on RFX-mod

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The new Gas Puffing Imaging Diagnostic (GPID) system [1] has been installed on RFX-mod [2] to investigate the dynamical structure of plasma edge turbulence in the Reversed Field Pinch (RFP) configuration, especially during operation at plasma currents higher than 400 kA, when the Langmuir probes cannot be inserted. The system consists of a gas-puffing nozzle and 32 optical channels to measure the local H_α emission from an area normal to the local magnetic field. The optical lines are 5 mm spaced, and are distributed over an area of about 70 mm in the toroidal direction and 40 mm in the radial one. The effective bandwidth of the electronics is 2 MHz and signals are sampled at 10 MSamples/s.
In the proper operating condition, the brightness of the local Hydrogen cloud in front of the GPID is at least one order of magnitude more intense than the background emission from the H_α due to the influx from the first wall. However when any region of the intense plasma wall interaction caused by an m=1 localised kink perturbation enters in the view field of the GPID, the background brightness becomes comparable to the local cloud emission.
In this paper we report some results obtained during experiments with an externally driven mode rotation on discharges at 500 kA current. In these experiments a rotating m=0 toroidal magnetic field (B_t) perturbation, approximately saw-tooth shaped, has been applied, in order to drag the m=1 kink perturbation and avoid wall locking [3]. Even when the rotation of the m=1 kink fails, the m=0 perturbation modifies the structure of the edge turbulence, without the trouble of excessive plasma wall interaction. These effects were already observed in the old RFX configuration [4] and the supplemental piece of information added by the GPID are a good example to display the capability of this diagnostic system.
As pointed out in ref. [4] the most remarkable feature associated with the rotating m=0 perturbation is the reversal of the edge toroidal velocity (we remind that in the RFP edge the magnetic field is mainly poloidal). The propagation velocity of the fluctuation has been measured by cross-correlating different chords of the GPI [5] and has the same order of magnitude of the E×B velocity measured in the past using Langmuir probe arrays.
An example of this phenomenon is shown in Fig. 1, where a series of sudden velocity inversions synchronised with the variation of B_t can be observed. During unperturbed

plasma pulses the velocity of fluctuations is counter-directed with respect to the plasma current (negative velocity). In the discherges with m=0 external perturbation the velocity changes its direction from negative to positive when the local B_t intensity decreases. The

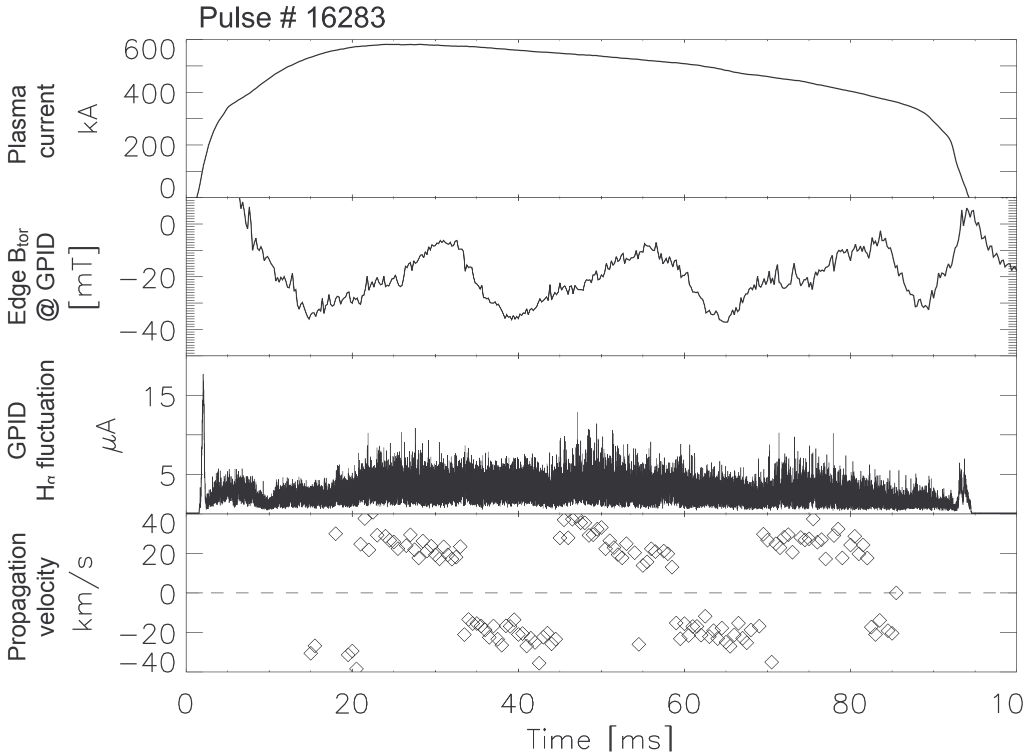

Fig 1: time evolution of the plasma current, toroidal magnetic field at GPID location, H_α emission intensity and propagation velocity of fluctuations from GPID measurements

precise magnetic structure associated to this inversion of velocity is difficult to identify, because of the delay of the plasma response with respect to the external perturbation and the screening effect of the vacuum vessel on the magnetic measurements. It is worth to mention that passive GPID measurements obtained without gas puffing confirm that Hydrogen influx from the wall during m=0 rotation does not change significantly and thus

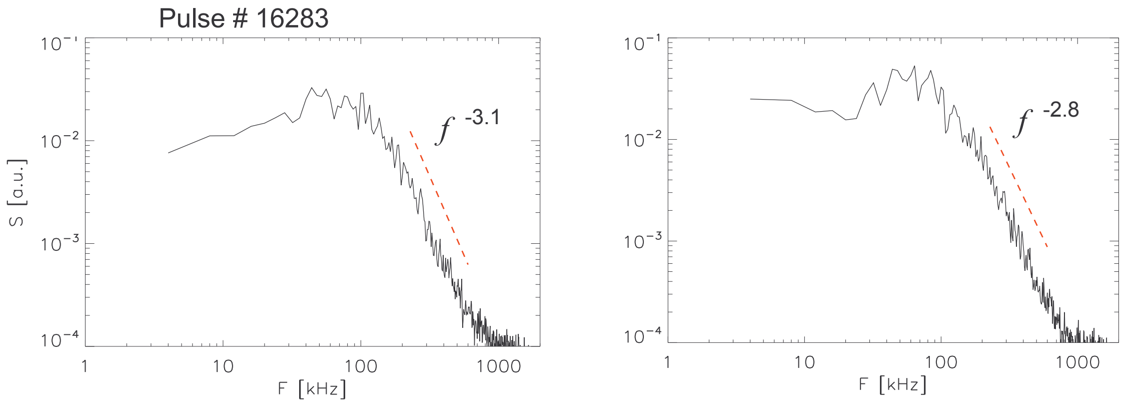

Fig. 2: Power spectra of central GPID chord:

left with negative velociy ("standard") and rigth with positive velocity ("perturbed").

no effect on the measurements obtained with gas puffing is expected.

In order to characterise the structure of the turbulence in the two conditions (positive and negative velocity), the measurements have been analysed by means of several methods. The most trivial is to compute the power spectra of the signals corresponding to the central line of sight (Fig. 2). This method does not point out any significant modifications: in both cases the cut-off frequency remains at about 100 kHz and the decay exponent close to -3.

The *S(k,f)* spectra confirm the change of the rotation and highlights a different structure of the fluctuations. The different broadening in the *k* wavenumber suggests a turbulent situation during the negative velocity phase, while a more ordered structure appears during

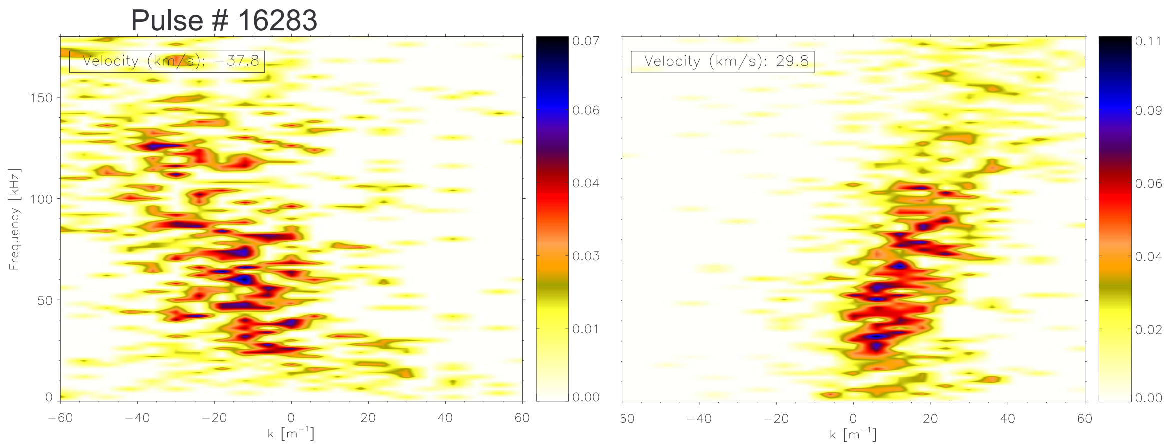

Fig. 3: S(k,f) spectra from two chord correlation.

Left at 36 ms (negative velocity, "standard") and rigth at 50 ms (positive velocity).

the positive phase. Furthermore, the probability distribution functions (pdf) of the fluctuation at different scales have been computed by means of the continuous wavelet decomposition. The analyzed data are taken during quiescent periods of MHD activity, avoiding larger reconnection events, which are known to raise the intermittency [6]. This effect can be quantified by the flatness parameter (Kurtosis), which gives the amount of the deviation of the pdf tails from a gaussian one. The result (see Fig. 4) shows a remarkable increase of intermittency when the velocity is positive. This feature becomes clearly visible when looking directly at the signal in Fig. 5, where "intermittent" events associated

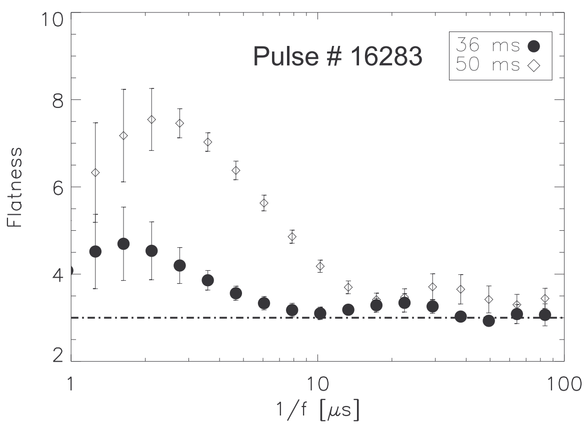

Fig. 4: flatness of pdfs at different timescales (black dot negative velocity, diamonds positive velocity)

with fluctuation amplitude beyond the level expected for a gaussian distribution are indicated.

It should be noted that the signal has in both cases roughly the same average density of

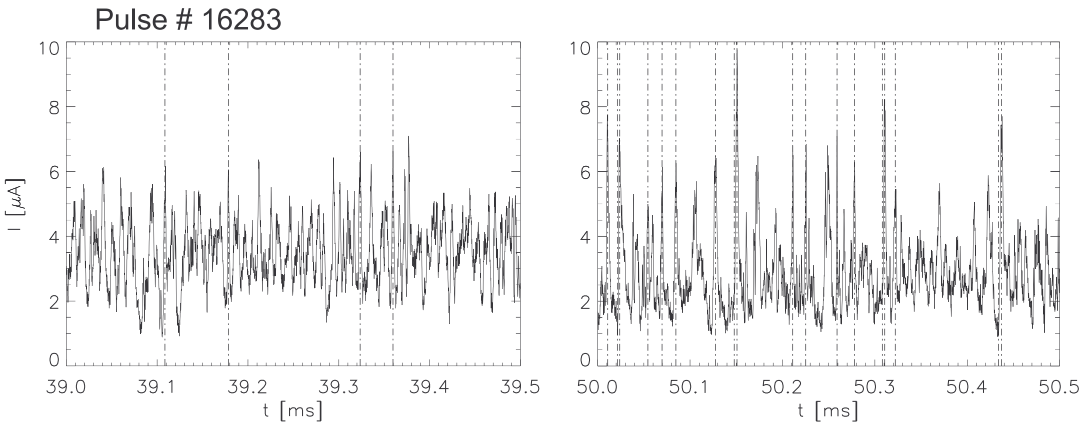

Fig. 5: signal samples of H_α emission, with "intermittent" events identified at 2 μs scale.

spikes regardless of their shape, corresponding to the 100 kHz knee present on both power spectra. Instead the increase of intermittency is due to the higher amplitude of the spikes, compared to the "background" signal. However this kind of analysis tells us little about the time ordering of these structures. On looking at the signals themselves the case with positive velocity appears to have a more defined repetition frequency of the structures, which is confirmed by the better defined shape of the *S(k,f)* spectrum. This would indicate that the basic mechanism driving the increase of intermittency may be ascribed to the non-linear behaviour of some kind of instability.

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