2-D filament dynamics in high and low shear flows in the edge of the RFX-mod tokamak

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Filaments or blobs are coherent density structures aligned to the magnetic field and generated by the nonlinear saturation of turbulence. Their cross-field motion is believed to be responsible for setting the SOL width [1], which is understood to be the net result of the competition between cross-field and parallel transport in first order. Different background environments can affect their dynamics, as well as being affected by them [2]. Strong $\vec{E} \times \vec{B}$ shear flows, usually observed in H-mode plasmas in tokamaks, are responsible for suppressing the local turbulence and inhibiting its growth. Blobs or streamers (radially elongated turbulence structures) in certain conditions can be torn apart by $\vec{E} \times \vec{B}$ shear flow depending on its strength [3].

H-mode was recently achieved in the RFX-mod operated as tokamak in single null configuration with the aid of an external biasing electrode [4]. A remarkable improvement on the plasma confinement has been observed when the electrode was polarized negatively with respect to the wall (in ground connection). In the present work, we address further effects of the biasing on the plasma in the RFX-mod tokamak, in particular, the dynamics of filaments, comparing it with the ohmic L-mode scenario. For this purpose, we use an insertable Langmuir probe with two towers spaced 88 mm poloidally [4]. 40 pins arranged as an array of 5 poloidal x 8 radial are installed in each tower.

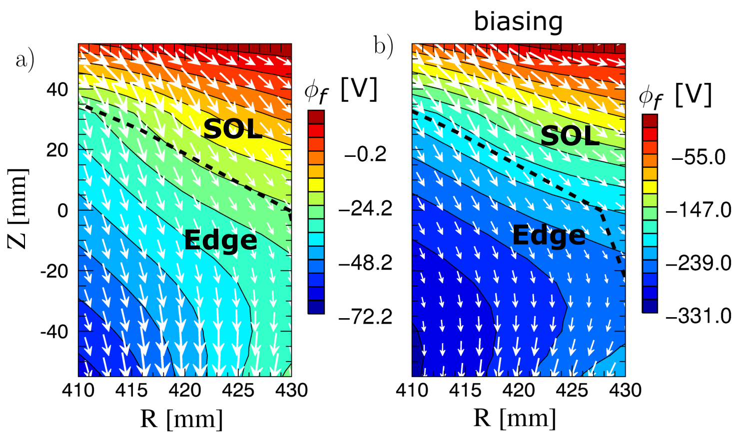

Figure 1: *Two-dimension floating potential map measured with Langmuir probe for a) L-mode, and b) plasma external biased, H-mode phase. The black dashed line represents the separatrix (#39136). The white arrows represent the $\vec{E} \times \vec{B}$ flow.*

The probe was inserted from the equatorial plane low field side and the data were acquired at 2 MHz sampling frequency. The experiment was carried out in single null configuration with plasma current $I_p \approx 50\ kA$, central line density average $\bar{n}_e \approx 2 \times 10^{18} m^3$, and magnetic field on axis $B_0 \leq 0.55$ T.

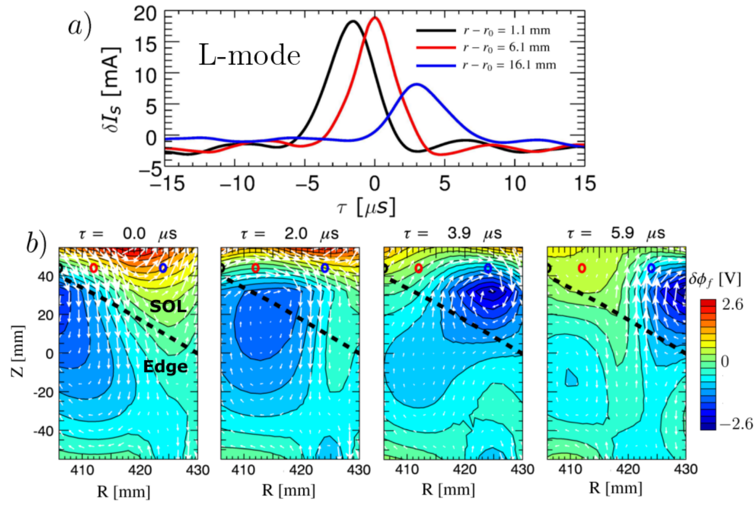

Figure 2: *The conditional average of filaments detected with the threshold criterion seen by a) the ion saturation signals (the red line is the reference one) and b) 2D floating potential map in four frames (#39136). The white arrows represent the $\vec{E} \times \vec{B}$ flow.*

The two-dimension floating potential map for L and H-mode is shown in Fig. 1. Quadratic interpolation was applied to better visualize the 2D image. The dashed black line represents the separatrix between the edge and the Scrape-Off Layer (SOL - upper right region). The white arrows displayed in Fig. 1 represent the $\vec{E} \times \vec{B}$ flow: $\vec{v}^{E\times B} = \vec{E} \times \vec{B}/B^2 \cong -\vec{\nabla}\phi_f \times \vec{B}/B^2$. One can see that the flow is mainly poloidal and stronger near the separatrix. During biasing, the negative potential well intensifies and, thus, the $\vec{E} \times \vec{B}$ flow. As result, a shear layer around the separatrix is established.

Filaments were identified from the ion saturation current fluctuation ($\tilde{I}_s$), considered as a proxy for density fluctuation. They were defined as the extreme events in I_s: 2.5σ higher than the mean for a given time sampling, where σ is the corresponding standard deviation. Fluctuations were taken in the range 2-500 kHz. From the cross-conditional average, the dynamics of the detected filaments are seen from the neighbouring I_s and ϕ_f signals. Fig. 2 a) shows the I_s blob amplitude for three radial positions (the red line represents the reference signal) and b) the correspondent potential structure for four time frames. The black, red, and blue small circles in b) are the positions of the three δI_s signals in a). Both graphs show outward propagation. Fig. 2 b) captures the dipolar behaviour of the potential structure related to the blob. Particularly, at $\tau = 0\ \mu s$, the reference δI_s is maximum, and the $\delta\phi_f$ dipole middle distance roughly lies at the same position, which is in agreement with the classical view of the dipole potential related to the peak of density. The vorticity ($\vec{\nabla} \times \vec{v}^{E\times B}$) becomes clearer as the filament moves into the SOL, which can be seen from the flow around the negative potential. The spatial resolution does not allow to visualize the positive potential completely.

The filament motion during H-mode induced by biasing is shown in Fig. 3. Analogously to Fig. 2, the reference is the red signal. One can see in Fig. 3 a) that the structure detected in I_s moves initially very fast, the velocity between the two innermost signal (black and red Fig. 3 a) is about ≈ 5 km/s. The amplitude of the third pin, the outermost (blue line), reduces sharply. This result is supported by the negative potential structure related to the I_s in Fig. 3 b). In the first frame ($\tau = 0$), a dipole structure more aligned poloidally than radially is observed. In the subsequent frames, the structures seems to get trapped roughly at the same position displayed in the second frame ($\tau = 2$ μs). Its amplitude gradually reduces to zero, which suggests that the structure is both trapped and suppressed.

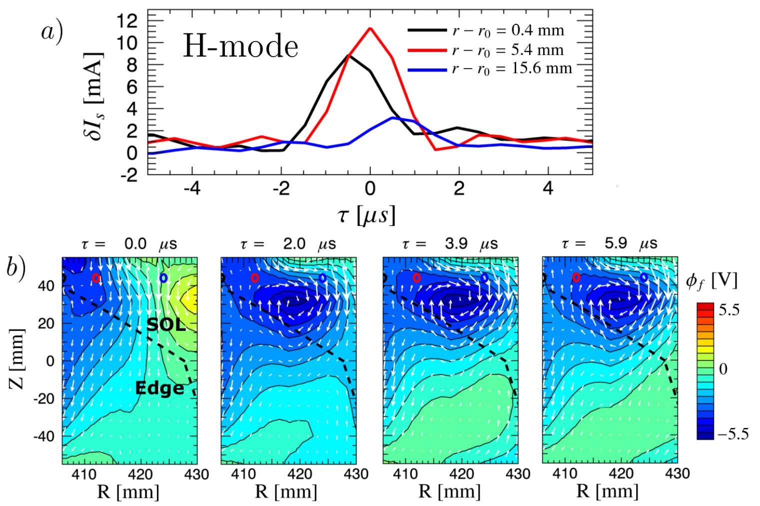

Figure 3: *The conditional average of filaments detected with the threshold criterion during high biasing seen by a) the ion saturation signals (the red line is the reference one) and b) 2D floating potential map in four frames (#39136). The white arrows represent the $\vec{E} \times \vec{B}$ flow.*

Blob parameters evaluated from the 2D potential map are shown in Fig. 4. Its motion was computed by using the two dimension cross-correlation technique (2D-CC). The displacement between frames is estimated by the maximum of 2D-CC and the blob extension was defined as the points that satisfies 2D-CC > 0.8. Those points define an area in the Cartesian system of coordinate (R, Z), which was later changed to the proper plasma coordinate. In addition, the blob area was approximated by an ellipse through the eigendecomposition of its covariance matrix. The eigenvalues give the major and minor axes of the ellipse and the eigenvectors the direction of its axes in the space or, alternatively, the tilt angle with respect to the coordinate axes. The filament dynamics and its interaction with the background is shown in: (a)-(b) radial velocity, (c)-(d) potential amplitude, (e)-(f) ratio between the poloidal and radial size, (g)-(h) tilt angle (clockwise), and (i),(j) vorticity for L and H-mode. In L-mode, the blob is more elongated in the poloidal direction than in the radial one inside the plasma (Fig. 4 (e), (g)), due to the high flow in this region (Fig. 1 a)). The transition to the SOL is characterized by an increase of the radial velocity and a reduction of both poloidal and radial size. In the SOL, the radial velocity decreases gradually and the potential amplitude reaches its maximum. The vorticity (g) is lower in the edge and becomes higher in the SOL. In H-mode, close to the edge, the structure has high radial (b) and poloidal velocity (see poster P2.1101), but both almost vanish further outside, suggesting a trap effect. The structure is mainly poloidally elongated throughout the range (f), (h), coherently with the high poloidal flow in this region (Fig. 1 b). Lastly, the fast reduction of the structure amplitude and vorticity (Fig. 4 (d), (j) suggests its suppression.

According to [3], the L-mode filament is expected to endure the background, since $L_r^2/(v_r L_\theta)$ is higher than the local $\vec{E}\times\vec{B}$ shearing rate. Whereas in H-mode, it is smaller in the trap region (see poster P2.1101). Therefore, the $\vec{E}\times\vec{B}$ shear flow acts to limit the filament dynamics in the SOL of the RFX-mod device operated as tokamak. In H-mode, only smaller and/or faster blob, compared to the L-mode, are likely to survive to the shear. The technique presented in this paper might be of interest to study ELM filaments observed in the RFX-mod tokamak [4].

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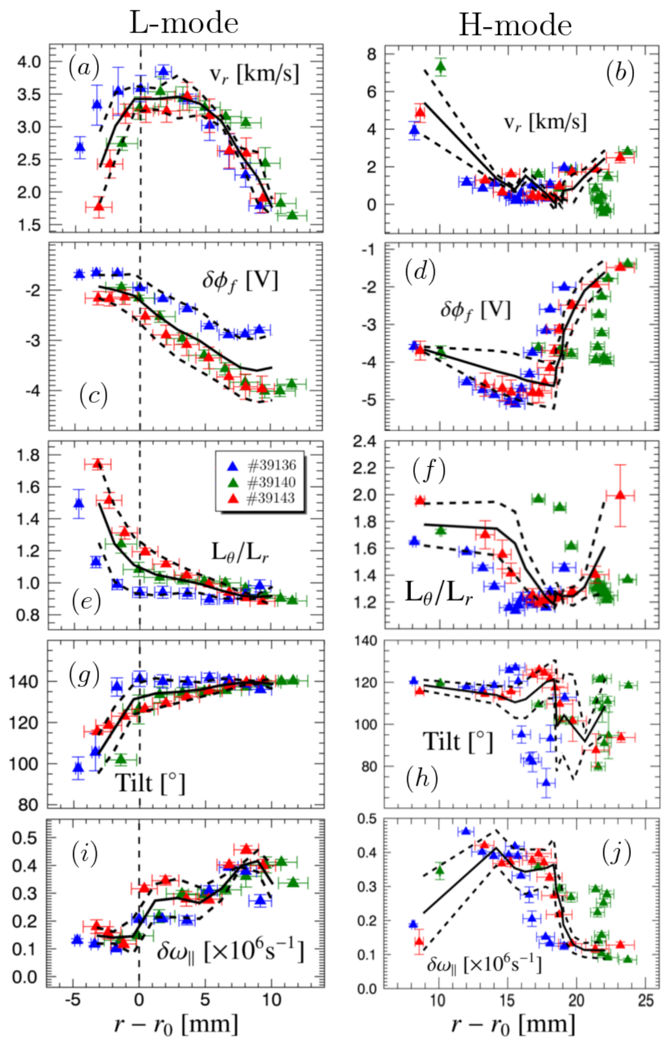

Figure 4: *Blob parameters: (a)-(b) radial velocity, (c)-(d) potential amplitude, (e)-(f) ratio between the poloidal and radial size, (g)-(h) tilt angle (clockwise), and (i), (j) vorticity for L and H-mode. The full black line indicates the average of the parameter over the three shots and the dashed lines are the standard deviation.*

References

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