Fluctuation measurements with 2D matrix of Langmuir probes on the CASTOR tokamak

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The control of the parallel and perpendicular fluxes in the Scrape Off Layer (SOL) is an important issue for the fusion reactor. An extensive experimental activity is being carried out on the CASTOR tokamak, aimed at gaining a better understanding of the SOL properties and at finding ways to control it. Among the attempts, which have been made, we can cite the creation of convective cells by means of a biasing electrode, exploiting the periodic structure of the SOL due to the local safety factor [1]. In this paper we report some results about the use of electrodes and probe arrays for mapping the magnetic field lines periodicity in the SOL, and properties of edge fluctuations.

The experiment is performed on the CASTOR tokamak (R=40 cm, a=8.5 cm, B_T=1.3 T). Two kinds of Langmuir probe arrays were used for measurement of the edge plasma parameters. The 2D probe is a two-dimensional matrix of 64 graphite tips with a spacing of 6 mm in the poloidal direction and 4.5 mm in the radial direction [2]. The rake probe is a radial array of 16 Langmuir tips made of molybdenum spaced by 2.5 mm. The individual tips of both the arrays measure either the floating potential or the ion saturation current with a temporal resolution of 1 μs. It should be mentioned, however, that the majority of the results obtained in this experiment is related to the floating potential mode of operation. Both these probe arrays were inserted into the tokamak from the top and their radial positions can be adjusted on the shot-to shot basis. Typically, the range of radii from 60 to 90 mm is investigated. Since the plasma is shifted downwards, the probe arrays measure three regions of the edge plasma: behind the limiter (r>85 mm), and the SOL region (60 mm < r < 85 mm) with a long connection length ($L \gg 2\pi R$) [1].

The set-up of the experiment is shown in scale in the fig. 1, which displays the toroidal and poloidal position of all key element of the experiment on the unfolded magnetic surface associated with the biasing electrode. It has to be noted that the orientation of the 2D

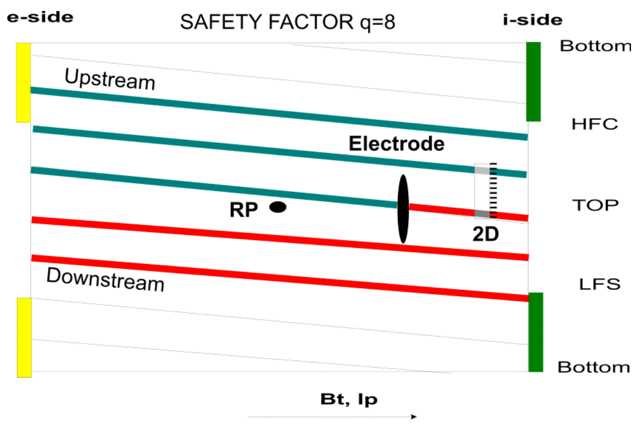

Fig 1. *Unfolded magnetic surface: The surface is cut at the limiter and the bottom. Toroidal and poloidal position of the probe arrays and of the electrode is marked. The flux tube emanating from the electrode either upstream or downstream along the magnetic field line is emphasized by different color.*

probe could be either parallel, or antiparallel to the magnetic field lines. Thus, in the antiparallel case the tips of the 2D probe are oriented towards the biasing electrode, while in the parallel case they are oriented to the opposite direction. For antiparallel orientation, the 2D probe is in the middle of the chamber (in the poloidal direction), while for the parallel orientation it is shifted of about 4 cm to the low field side of the torus.

Mapping of magnetic field lines in the SOL. At first, we have applied a harmonic voltage (±80 V) at different frequencies (1, 5 or 10 kHz) on the biasing electrode. The floating potential of the individual tips of the 2D probe is measured and the power spectra are evaluated for all the tips. The value of the spectrum at the driving frequency for the anti-parallel orientation of the 2D probe is plotted in fig. 2.

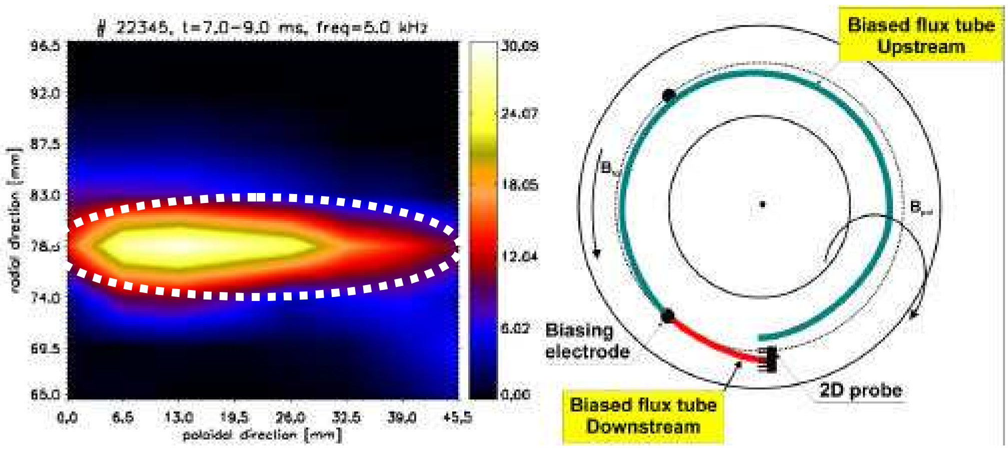

Fig. 2 *Left: Power spectra from the 2D probe with antiparallel orientation. Right: Trace of the flux tube associated with the electrode.*

The clear pattern which can be observed in fig. 2 corresponds to the projection of the biasing electrode to the 2D probe over the distance ~30 cm. From this pattern, the poloidal (~50 mm) and radial (~5 mm) extent of the biased flux tube can be determined. This roughly corresponds to the dimensions of the biasing electrode as expected.

Another kind of pattern can be observed in figure 3 for the 2D probe turned to the opposite side and shifted poloidally. On the right-hand side, we see just a part of the upstream flux tube. The second pattern (on the left) is a shadow of the downstream flux tube coming from back of the probe (see fig. 1). The shift in the radial direction is caused by the shift of the probe in the poloidal direction. The length of the upstream flux tube is ~ 30cm

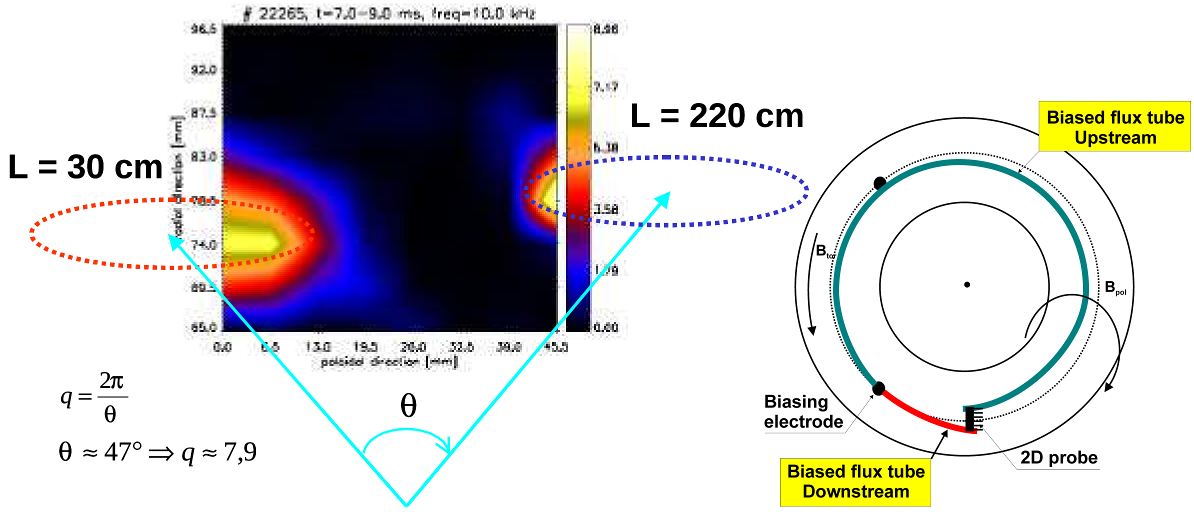

Fig. 3 *Left: Power spectra from the 2D probe with parallel set-up. Right: Trace of the flux tube associated with the electrode.*

and of the downstream flux tube is ~220 cm. If we consider the size of the structure as obtained in the previous case (fig. 2) and calculate the angle between them, we find that it is equal to about 47 degrees. From this angle we can calculate an edge safety factor q = 7.9. This value is in a good agreement with the value expected from magnetic measurements (around 8).

<u>Fluctuations measurements by 2D matrix and by the rake probe.</u> Now, we describe measurements obtained using the rake probe and the 2D probe, with the biasing electrode retracted from the plasma. The toroidal distance between the rake probe and the 2D probe is about 1 meter. One reference tip on the rake probe was selected and its signal was confronted with all the 2D probe tips by computing the cross-correlation functions with the time lag = 0 ms. The result is shown in fig. 4.

A clear pattern of a structure with a high cross-correlation is observed in the fig. 4 in the left panel. Its poloidal extent can be estimated as 1.5 cm, while the radial extent is 0.6 cm. The

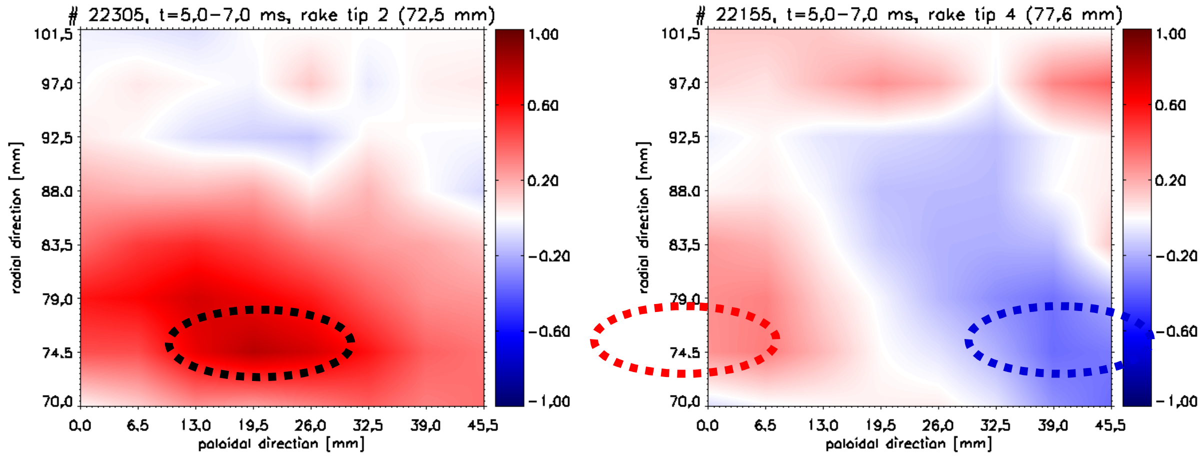

Fig. 4 *Cross-correlation functions of a rake probe tip with the 2D probe matrix. Left: Rake probe tip 2 (72.5 mm radially from the centum of plasma), antiparallel orientation. Right: Cross-correlation functions of the rake probe tip 4 (77.6 mm) with 2D probe matrix, parallel orientation.*

toroidal length of this structure is longer than 1 m, as follows from the experimental arrangement. A similar pattern of a structure can be observed also in the right panel of fig.4.

A maximum of cross-correlation can be recognized in the left bottom corner of the picture. The other side of the structure is out of the range of the 2D probe, however we can see an anti-correlation pattern on the right. Such bi-polar character of the edge turbulence has been identified on CASTOR in [3]. If we mark the correlated and anti-correlated pattern as is shown in the figure 4 and compute the edge safety factor, we obtain q=8, which is in good agreement with previous results.

In conclusion, the magnetic field configuration in the edge region was diagnosed by biasing the flux tubes by a harmonic voltage. Furthermore, the turbulent structures can be characterized by the cross-correlation analysis between two toroidally spaced probe arrays. This allows to establish the radial and poloidal extent of turbulent structures in the SOL. The results of this experiment are linked up with the previous ones [2, 3].

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References

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