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Simultaneous measurements of fluctuations with cold and emissive probes in ISTTOK

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Abstract: An array of four heatable floating probes and one cylindrical probe staggered on the same poloidal meridian was used for fluctuation measurements in the ISTTOK edge plasma. The array permits the simultaneous measurement of density and poloidal electric field, and thereby of the radial turbulent flux. We have found that emissive probes deliver more reliable results than the cold probes.

The edge region of magnetically confined plasmas shows high fluctuation levels of density and potential that lead to a large anomalous particle transport [1,2,3,4]. Of particular interest are the dynamics of edge and scrape off layer (SOL) transport of heat, particles and momentum for the understanding and control of edge properties in fusion machines.

ISTTOK (Instituto Superior Técnico TOKamak) is a large aspect ratio circular cross-section tokamak (major radius R = 46 cm, minor radius a = 85 mm, toroidal magnetic field B_T = 0,5 T) with a fully poloidal graphite limiter at r = 85 mm. Typical values of the ISTTOK discharge parameters were: plasma current $I_{pl} \cong$ 4,5 kA, discharge duration up to $\tau_d \cong$ 100 ms, central electron density $n_e(0) \cong 3{,}5\cdot10^{18}\ \mathrm{m}^{-3}$, central electron temperature $T_e(0) \cong$ 150 – 200 eV and edge safety factor $q(a) \cong 5$.

The probe array consisted of four heatable probes and one cylindrical probe staggered on the same poloidal meridian above each other (see Fig. 1) with a distance of 2 mm between two adjacent probes. Each heatable probe consisted of a 8 mm long loop of 0,2 mm diameter tungsten wires. By "cold probe" we mean an unheated loop probe, while in case of an "emissive probe" the loop is heated to electron emission. The cylindrical probe was biased to ion saturation. The probe manipulator is mounted at the low field side mid-plane and allows moving the probe radially through the plasma from r = 61 – 93 mm. In case of Fig. 1 two loop

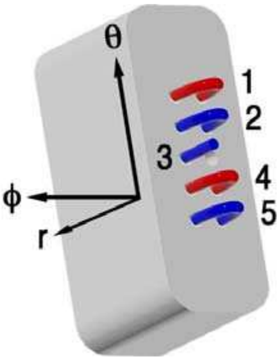

Fig. 1: Schematic of the probe array. Four heatable wire loop probes and one cold probe are mounted in a case of boron nitride.

probes (#1 and #4) are shown in red as emissive whereas the other two (#2 and #5) are cold (blue) .

The floating potentials of the emissive probes were taken as reliable measures of the plasma potential Φ_{pl}, whereas those of the cold probes were the conventional ones: $V_{fl} = \Phi_{pl} - \alpha T_e$, with $\alpha = \ln(I_{es}/I_{is}) \cong 2{,}5$ in a magnetized hydrogen plasma [5]. $I_{es,is}$ is the cold probe electron/ion saturation current. This array permits the simultaneous measurement of density and poloidal electric field needed for deriving the radial turbulent flux. The poloidal electric field was determined, on one side, from the difference between the floating potentials of two cold probes and, on the other side, of two emissive probes, divided by the respective distances between the probes. As shown previously, emissive probes deliver more reliable measures than cold probes for the plasma potential Φ_{pl} and thus also for the electric field [5].

First the floating potentials of all four heatable probes were compared with each other when two probes were heated and two not. The cross correlation between the signals of two emissive and two cold probes show qualitatively the same behaviour although the time lag is nearly double for the latter. Fig. 2 shows the correlation in case of two emissive probes (#1 and #4). The poloidal correlation is very high ($\gamma \cong 0{,}9$) at the innermost probe position ($r \cong$ 65 mm) and has a minimum at $r \cong 74$ mm ($\gamma \cong 0{,}7$). Outside the limiter, the signal-to-noise ratio becomes very poor.

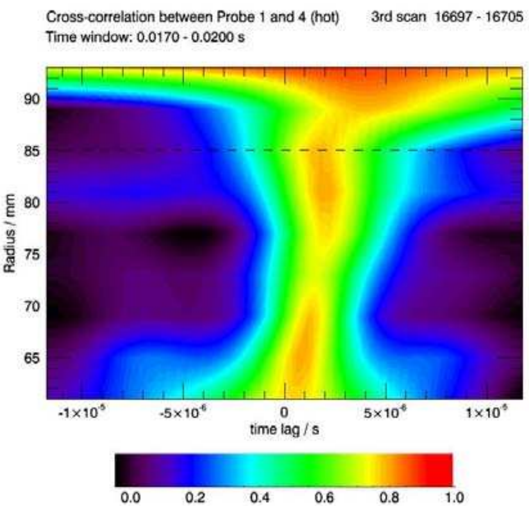

Fig. 2: Cross correlation between the two emissive probes shown in red in Fig. 1 as function of the minor radius.

The minimum in the correlation at $r \cong$ 74 mm can be explained by a de-correlating shear layer. Further indications for this assumption is the change of the radial electric field direction for $r \cong$ 74 mm, seen from the radial plasma potential profile (Fig. 3, red line). Fig. 3 shows also the profile of the cold floating potential (blue line). The difference between the two profiles is proportional to the electron temperature [5]. Fig. 4 shows the radial profile of the averaged radial turbulent flux with a maximum at $r \cong 74$ mm. From this figure is also obvious that the averaged flux is un-

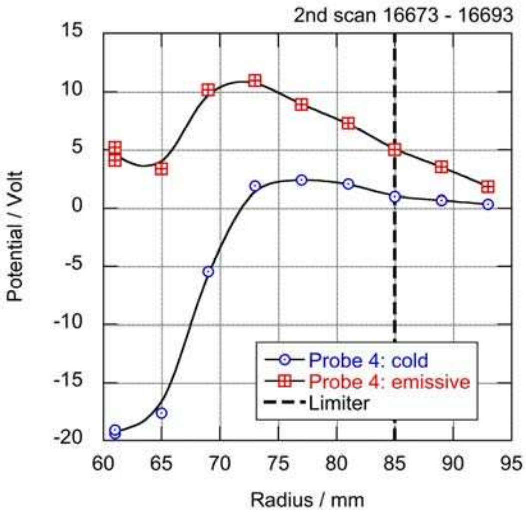

Fig. 3: Radial profile of the plasma potential (red squares), measured by probe #4 as emissive one, and of the cold floating potential (blue circles), measured by probe #4, when cold.

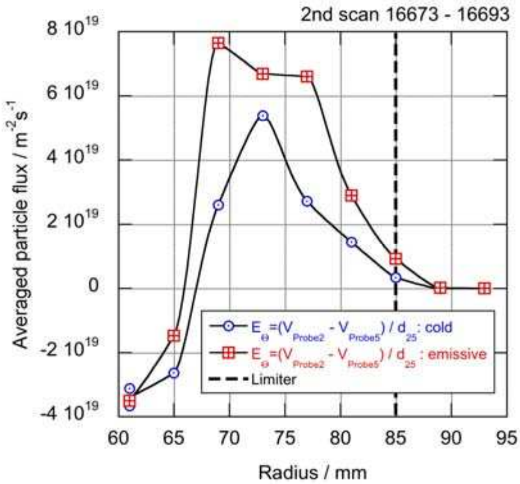

Fig. 4: Radial profiles of the averaged radial turbulent flux, once measured with probes #2 and #5 as emissive probes (red squares), once with the same probes as cold probes (blue circles).

derestimated when measured by cold Langmuir probes. Furthermore both types of probes see an inward flux for $r \cong 64$ mm. The change of the sign and the non-vanishing divergence of the fluxes seem to indicate that ion sources play an important role in this region. This will be subject of a forthcoming publication.

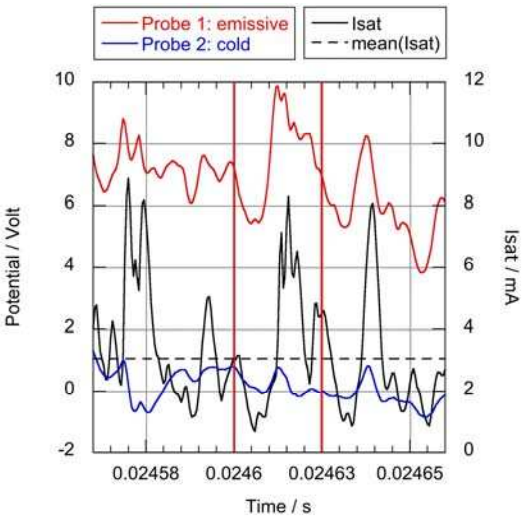

Fig. 5: Temporal evolution of Φ_{pl} measured by probe #1 (red), of V_{fl} measured by probe #2 (blue) and of the ion saturation current to probe #3 (black) at r = 85 mm. The two red vertical bars indicate the time interval shown in Fig. 6.

Investigations on intermittent events exhibit clear differences in the floating potentials measured by emissive and cold probes. Fig. 5 presents the temporal evolutions of the floating potentials of emissive probe #1 and cold probe #2, and of the ion saturation current for r = 85 mm. Thus probe #1 was measuring $\Phi_{pl}(t)$ while #2 was measuring $V_{fl}(t)$. Blob-like transport events are better visible and finer structured in the emissive probe signals, suggesting that temperature perturbations associated with blobs cannot be neglected [5]. Obviously emissive probes reveal more details of fluctuations in fusion plasmas than cold probes. This is also visible in Fig. 6 which shows a close-up of one blob event, marked in Fig. 5 by two red vertical

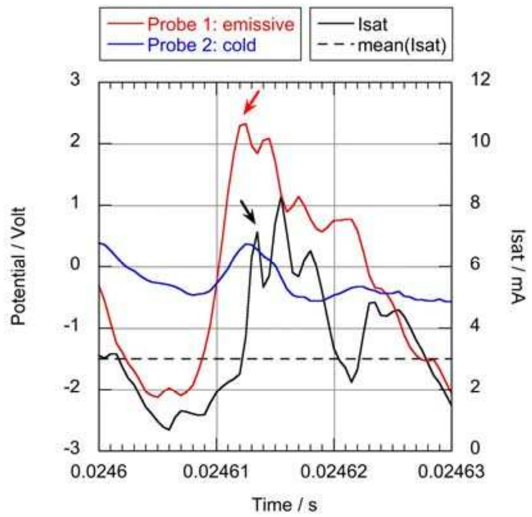

Fig. 6: Close-up of signals of emissive probe #1 (red), cold probe #2 (blue) and of the cylindrical probe #3 (black), indicated in Fig. 5 by two red bars. The arrows show a blob event first appearing in $\Phi_{pl}(t)$ and then in $I_{is}(t)$.

bars. We point out the three peaks in the ion saturation current (black line) which obviously stem from the same event visible in the emissive probe signal (red line), however, smeared out in the signal of the cold probe (blue line). The temporal shift between the red peaks and the black ones is also an indication of the poloidal propagation of the blob from top to down. The time delay is about 1,5 μs and the distance between probe #1 and #3 is 4 mm, so that the poloidal velocity is approximately $4 \cdot 10^3$ m/s.

Summarizing we have investigated radial turbulent transport in ISTTOK with emissive and cold probes and found evidence for blob-like transport events. Once again we found that emissive probes are better suited than cold probes for the diagnostic of plasma potential and electric fields in fusion experiments.

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