29th EPS Conference on Plasma Phys. and Contr. Fusion Montreux, 17-21 June 2002 ECA Vol. **26B**, P-1.103 (2002)

Measurements of Plasma Potential Fluctuations in the Edge Region of the ISTTOK Plasma, Using Electron Emissive Probes

R. Schrittwieser,[1] J.A.C Cabral, P. Balan,[1] H.F.C. Figueiredo, H. Fernandes, C. Ionița,[1] C.A.F. Varandas

Centro de Fusão Nuclear – Association EURATOM/IST, Instituto Superior Técnico, Lisboa, Portugal
[1]Department of Ion Physics, University of Innsbruck, Innsbruck, Austria

1. Introduction

At the edge of a magnetically confined hot plasma, especially in the **s**crape-**o**ff layer (SOL), there are strong gradients of the charge carrier densities $n_{e,i}$, of the plasma potential Φ_{pl} and of the electron and ion temperatures, $T_{e,i}$,. These gradients can drive a number of instabilities, which are called **e**dge **l**ocalized **m**odes (ELMs). These ELMs are manifested as fluctuations mainly of Φ_{pl} and they lead to an enhanced radial loss of plasma across the SOL. To understand the actual mechanism of the turbulent transport through the SOL, a reliable and precise knowledge of Φ_{pl} and its fluctuations is vital for a comparison of the experimental observations with theoretical models and numerical simulations.

In order to measure the plasma potential as precisely and directly as possible, we have used electron emissive probes, the floating potential of which approaches the true value of the plasma potential Φ_{pl}, when the electron emission current I_{em} is increased up to a certain value by increasing the heating of the probe [1,2]. This follows from the formula for the floating potential of a heated probe (valid, however, only for a Maxwellian plasma and for probe voltages below the plasma potential, i.e., $V_p < \Phi_{pl}$)

$$V_{fl} = \Phi_{pl} - \mu T_e = \Phi_{pl} - T_e \ln\left(\frac{I_{es}}{I_{is} + I_{em}}\right), \qquad (1)$$

with I_{es} and I_{is} being the plasma electron and ion saturation currents, respectively.

Eq. (1) shows that for increasing emission current I_{em}, the floating potential of the emissive probe grows and approaches Φ_{pl}. For $I_{em} = I_{es} - I_{is}$, V_{fl} attains the plasma potential. Indeed, also in a realistic experiment, V_{fl} is observed to increase with the emission current, however, reaching a clear saturation for $I_{em} \cong I_{es}$, i.e., a further increase of I_{em} will not lead to a further growth of V_{fl}. This saturated value of V_{fl} is then considered to be a good approximation for Φ_{pl}. This result can, however, be falsified by a number of effects, among them the formation of a space charge around the emissive probe by the emitted electrons [2].

2. Experimental set-up

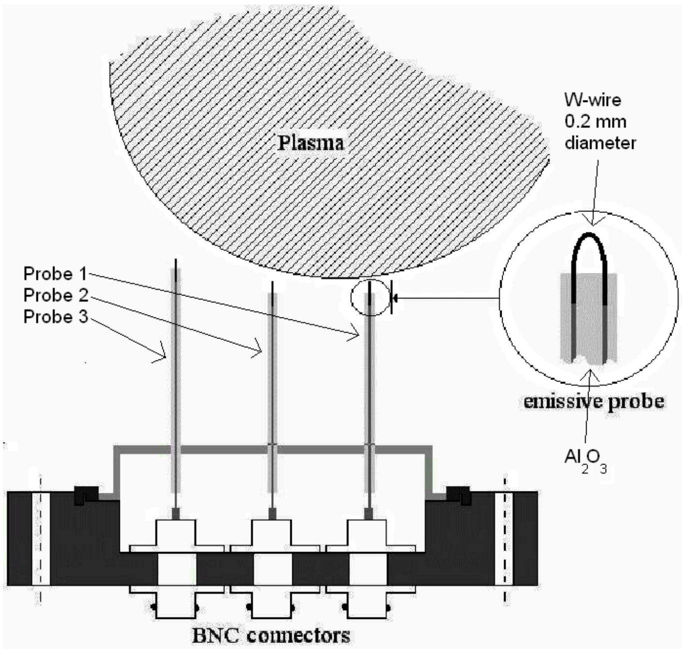

Fig. 1: Schematic of the three-emissive probe array inserted into the ISTTOK in Lisbon. The radial distances of the three probes from the plasma edge (defined by the limiter) are 1, 4 and 7 mm, respectively.

ISTTOK has a major radius of 0.46 m and a minor radius of $a = 0.085$ m, the latter being determined by a metallic limiter, which can also be biased. The background pressure is smaller than 10^{-7} mbar. Before each discharge, the chamber is filled with H_2 up to a pressure of around 10^{-4} mbar. Each shot has a duration of up to 40 ms. The strength of the toroidal magnetic field on the minor axis is usually 0.5 T, the toroidal plasma current is typically 9 kA. The maximum attainable plasma density is $(5 - 10)\times10^{18}$ m^{-3} and the electron temperature is in the range 80 - 220 eV. In the SOL the density drops to values around $(5 - 10)\times10^{16}$ m^{-3}, and T_e is on the order of 10 eV [3,4].

Into one of the radial flanges of ISTTOK, an array of three emissive probes has been inserted [1]. Each probe consists of an Al_2O_3 tube of 2.8 mm outer diameter with four bores of 0.5 mm diameter each. Through two opposite bores, a 0.2 mm diameter tungsten wire is inserted so that a loop of about 5 mm length is formed. A current up to 7.2 A is needed to heat each emissive probe sufficiently. The three probes are situated on the same poloidal meridian, but on different poloidal positions. The probe tips have different minor radii r_1 = 86 mm, r_2 = 89 mm and r_3 = 92 mm. Thus all three probes are outside the last closed flux surface. Fig. 1 shows a schematic of this probe arrangement.

3. Results and discussion

In order to make sensible measurements of the plasma potential, an electron emission current of up to about 120 mA has to be produced by each of the probes. Then the floating potentials of the emissive probes shows $\Phi_{pl}(r,t)$ on the three different radii. We have registered

$\Phi_{pl}(r_{1\text{-}3},t)$ for various conditions and have thereby obtained a rough radial profile of the plasma potential, showing also the temporal evolution during each shot. Fig. 2 shows the temporal evolution of the raw signals of the three probes versus the radius.

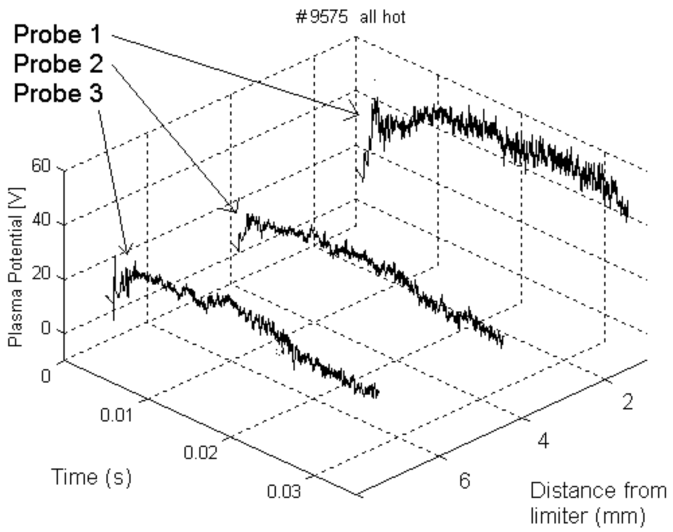

Fig. 2: Raw signal of the floating potential (which here corresponds to the plasma potential) from the three emissive probes (from IST-TOK) without limiter biasing. The probe positions are here given as the distances from the limiter.

The radial profile shows a strong drop of the plasma potential in the SOL. Between r_1 = 86 mm and r_2 = 89 mm the plasma potential decreases from $\Phi_{pl,1} \cong 48$ V to $\Phi_{pl,2} \cong 18$ V. This corresponds to an electric field of $E_r \cong 10$ kV/m even without limiter bias. This value is in keeping with similar results of the CASTOR tokamak, but has been achieved there only with a limiter bias of +100 V [2]. The amplitude of the fluctuations also decreases between these two positions. According to the assumptions, these signals show solely the fluctuations of the plasma potential so that possible temperature fluctuations are excluded.

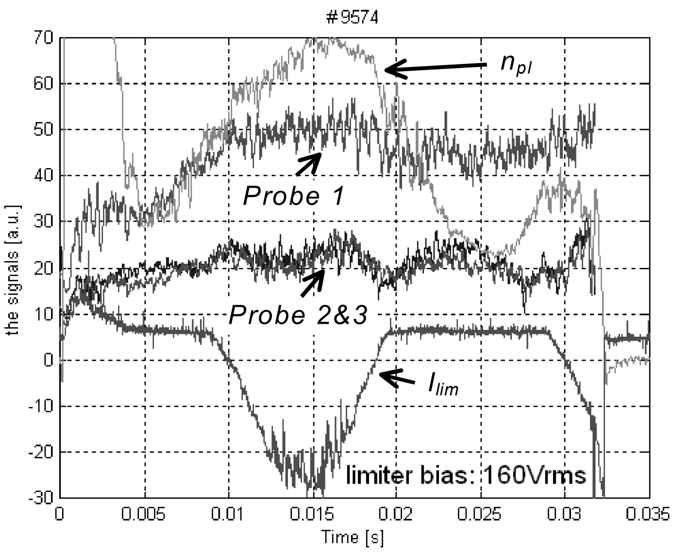

Fig. 3 In this case the limiter was biased with a 50 Hz ac-voltage of V_{lim} = 160 V_{rms}. The lowermost curve shows the current flowing to the limiter; it is positive (ions) for $V_{lim} < 0$ and becomes (much more) negative for positive values of V_{lim} when electrons are attracted to the limiter.

Fig. 3 shows the probe signals when the limiter is biased with a 50 Hz ac-voltage. As reference, the lowermost curve shows the current flowing to the limiter. For $V_{lim} > 0$, this means a strong electron current, and we observe that $\Phi_{pl,1}$ is increased only slightly during this time. Also the other two probes show a slight increase of their floating potentials $\Phi_{pl,2,3}$, respectively. The fluctuation levels, however, show no considerable change for positive or negative limiter biases. Remarkable is the strong increase of the plasma density for $V_{lim} > 0$.

We have also calculated the power spectrum of the fluctuations in a frequency range of 100 Hz $< f <$ 60 kHz. Fig. 4 shows this for the signals of Fig. 2.

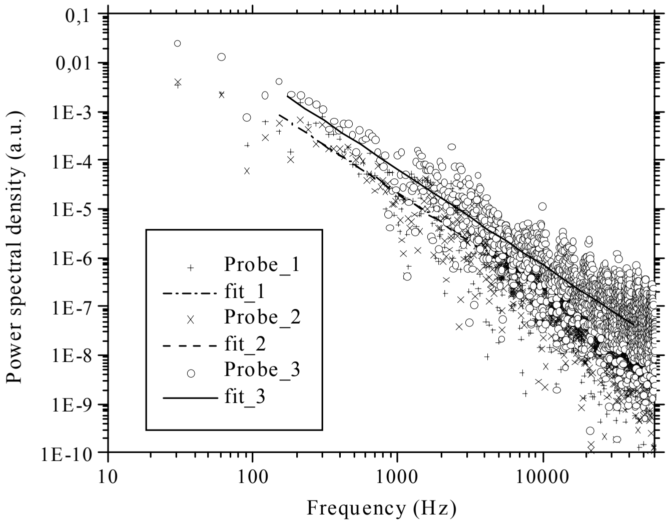

Fig. 4 Power spectra of the signals of Fig. 2 on a double logarithmic scale, where they show a linear drop proportional to $f^{-\alpha}$, with α being around 1.9.

In a certain range the spectra are proportional to $f^{-\alpha}$, and the exponent α turns out to be about 1.9. However, for the existence of flicker noise in the edge region, α should be around one. So our results are not conclusive to decide the question whether or not there is self-organised criticality in the SOL. Further measurements with a different set-up will try to shed more light into this subject.

References

[1] R. Schrittwieser, C. Ioniţa, P.C. Balan, Jose A. Cabral, F.H. Figueiredo, V. Pohoaţa, C. Varandas, *Contrib. Plasma Phys.* **41** (2001), 494.

[2] R. Schrittwieser, J. Adámek, P. Balan, M. Hron, C. Ioniţa, K. Jakubka, L. Kryška, E. Martines, J. Stöckel, M. Tichý, G. Van Oost, *Plasma Phys. Contr. Fusion* **44** (2002), 567.

[3] J.A.C. Cabral, C.A.F. Varandas, M.P. Alonso, P. Belo, R. Canário, H. Fernandes, R. Gomes, A. Malaquias, P. Malinov, F. Serra, F. Silva, A. Soares, *Plasma Phys. Contr. Fusion* **38**, (1996), 51.

[4] J.A.C. Cabral, C.A.F. Varandas, A. Malaquias, A, Praxedes, M.P. Alonso, P. Belo, R. Canário, H. Fernandes, J. Ferreira, C.J. Freitas, R. Gomes, J. Pires, C. Silva, A. Soares, J. Sousa, P.H.M. Vaessen, *Plasma Phys. Contr. Fusion* **40**, (1998), 1001.