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Measurements of the Fluctuation-Induced Flux with Emissive Probe in the CASTOR Tokamak

P. Balan,[1] J. Adámek, I. Duran, M. Hron, C. Ioniţa,[1] E. Martines,[2] R. Schrittwieser,[1]
J. Stöckel, M. Tichý[3], G. Van Oost[4]

Institute of Plasma Physics, Association EURATOM/IPP.CR, Prague, Czech Republic
[1]University of Innsbruck, Austria; [2]Consorzio RFX, Associazione Euratom-ENEA sulla Fusione, Padova, Italy; [3]Charles University in Prague, Czech Republic; [4]Ghent University, Belgium.

1. Introduction

The radial particle flux induced by fluctuations of the poloidal electric field and of the density was measured in the edge region of the CASTOR tokamak. In contrast to the standard procedure involving cold probe floating potential measurements, here for the first time a double-emissive probe was used to determine the fluctuations of the poloidal electric field.

The floating potential of a cold probe is proportional to the plasma potential Φ through the relation $V_{fl} = \Phi - \mu T_e$, where $\mu = \ln(I_{es}/I_{is})$, with $I_{es,is}$ being the electron and ion saturation currents, respectively. Assuming the temperatures being $T_e = T_i$, and the effective area for electron collection as the projection of the probe along the magnetic field lines (strongly magnetised electrons), whereas the effective area for ion collection is the total probe area, μ becomes 2.04. With an emissive probe we can, however, in principle measure the plasma potential directly, since with an emission current I_{em}, μ becomes: $\mu = \ln[I_{es}/(I_{is} + I_{em})]$. Thus the floating potential of such a probe attains the plasma potential for $I_{em} = I_{es} - I_{is}$. In addition, the floating potential of an emissive probe is independent of electron temperature fluctuations and electron drifts [1,2].

The main goal of this experiment was (i) to estimate the influence of electron temperature fluctuations on the floating potential and (ii) measurements of the fluctuation-induced flux.

We have used a radially movable arrangement consisting of two electron-emissive and two cold cylindrical probes located on the same minor radius. The former consist of loops, made from a thoriated tungsten wire of 0.2 mm diameter. Each loop has a total length of about 8 mm. By heating these probes simultaneously with currents up to 7.4 A, a sufficient electron emission could be achieved [2]. Fig. 1 shows a schematic of the experimental arrangement and the probe head used in this experiment.

2. Experimental set-up

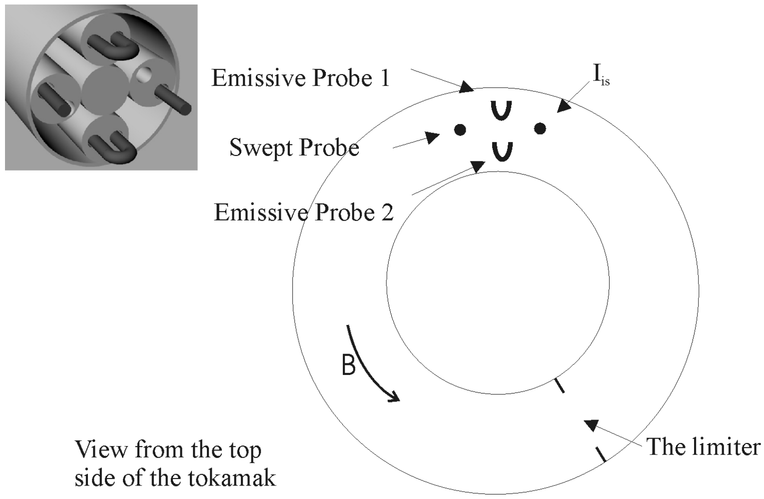

Fig. 1: Schematic of the experimental set-up.

The probe head, shown in the insert of figure 1, contains two emissive probes and two cylindrical (cold) probes. The probe head is inserted in such a way that the two emissive probes are on the same poloidal meridian, with a poloidal separation between the loop tips of 5.4 mm. The cylindrical probes are located between the emissive probes, spaced toroidally, but displaced slightly to avoid mutual shadowing in the magnetic field. One of the cold cylindrical probes was used to measure the ion saturation current and the other one was swept in order to record the *IV*-characteristics and to determine the average electron temperature.

The probe head can be shifted radially on a shot-to-shot basis. With this arrangement

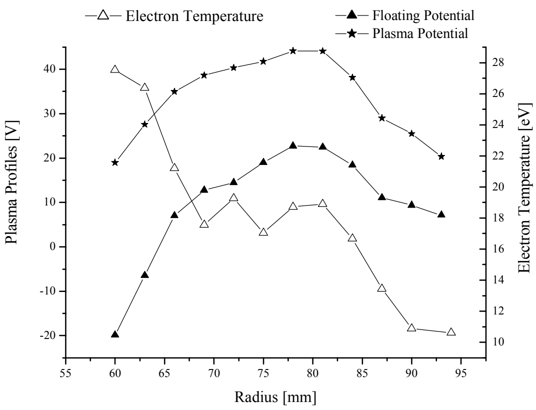

Fig. 2: The plasma and floating potential profile. The electron temperature profile was calculated choosing μ = 2.04.

we can measure the plasma potential and the fluctuation-induced flux $\tilde{\Gamma}$. We have also measured electron temperature fluctuations, which can be inferred from the above relation since $T_e = (\Phi - V_{fl})/\mu$. Thus T_e is proportional to the difference between the floating potentials of an emissive probe and of a cold probe.

3. Results

Fig. 2 shows a radial plasma potential profile, taken from the floating potential of one of the emissive probes. Also shown is a radial profile of the floating potential V_{fl}, taken by one of the cold probes. The correlation coefficient between $\tilde{\Phi}$ and $\tilde{V}_{fl}$ is 0.9, therefore we measure essentially at the same spatial position [3]. In this case, by applying the above relation, the difference between the plasma potential and the floating potential of the nearby cylindrical probe gives us an approximation of the electron temperature and its fluctuations [2].

Fig. 3a shows the radial profiles of the **r**oot-**m**ean-**s**quare(rms)-values of the floating potential of the same cylindrical probe, of the plasma potential and of the electron temperature. It is seen that the rms-values of T_e is smaller than the values of Φ and of V_{fl}.

In addition, from the formula $V_{fl} = \Phi - \mu T_e$ we can derive the variance of the floating potential, which is $\langle \delta V_{fl} \delta V_{fl} \rangle_\tau = \langle \delta\Phi\delta\Phi \rangle_\tau + \mu^2 \langle \delta T_e \delta T_e \rangle_\tau - 2\mu \langle \delta\Phi \delta T_e \rangle_\tau$. Expressed in terms of rms-values of V_{fl}, Φ and T_e and of the correlation coefficient $c_{\Phi T_e}$ between Φ and T_e, we

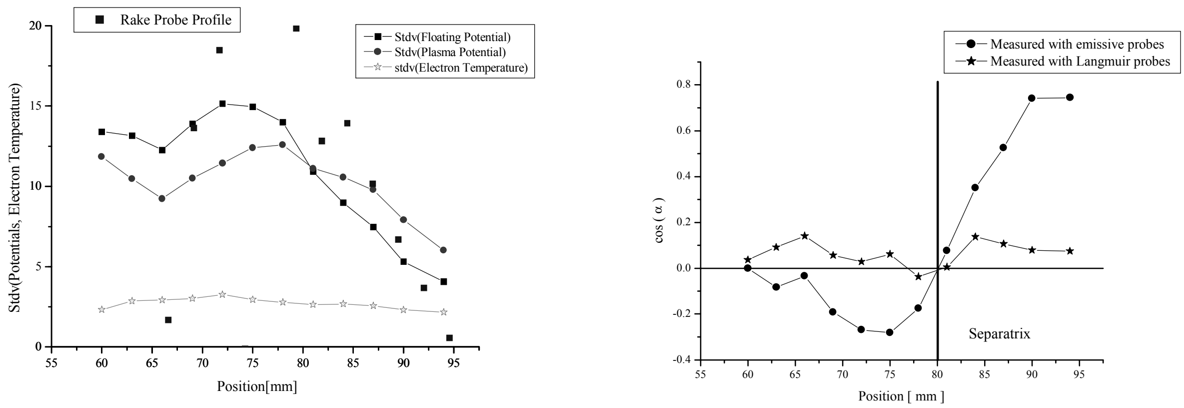

*Fig. 3: Properties of the fluctuations of the plasma potential, the cold probe floating potential and of the electron temperature; (a) rms-values of **Φ**, V_{fl} and of T_e; (b) correlation coefficient between **Φ** and of T_e.*

obtain $\tilde{V}_{fl}^2 = \tilde{\Phi}^2 + \mu^2 \tilde{T}_e^2 - 2\mu c_{\Phi T_e} \tilde{\Phi} \tilde{T}_e$. It is well seen in Fig. 3a that in the SOL $\tilde{V}_{fl} - \tilde{\Phi} < 0$, suggesting that the last term in the previous equation cannot be neglected. If we consider $c_{\Phi T_e}$ as a cosine, i.e., $c_{\Phi T_e} = \cos\alpha$, with α being a kind of phase angle, in Fig. 4b we notice that the correlation between Φ and T_e is increasing until 0.8 in the SOL. The error of $\cos\alpha$ is also shown in Fig. 3b. We see that α is almost 90° close to and inside the separatrix.

Fig. 4a,b shows the radial profiles of the particle-induced flux. In Fig. 4a the flux has been determined as the average value of $\tilde{\Gamma} = \tilde{n}\tilde{v}_{rad} = \tilde{n}\tilde{E}_p \big/ B_0$ at every radial position. Fig. 4b presents the rms-value of $\tilde{\Gamma}$ at every radial position. In both cases the poloidal electric field E_p was determined by the emissive probes, but in the case of solid square symbols the probes were not heated so that they acted as simple Langmuir probes (see Fig. 4a,b). In the case of the star symbols the probes were emissive so that the plasma potentials were measured and thus a more realistic value of E_p was determined.

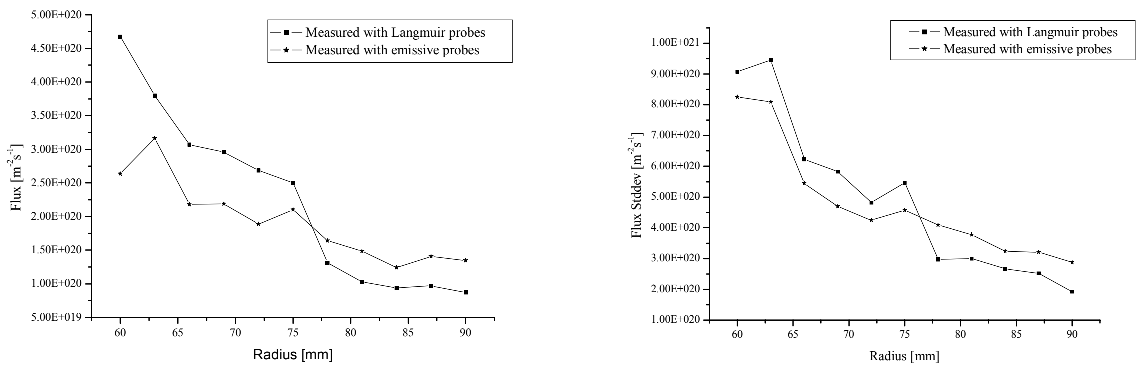

Fig. 4: Radial profile of the fluctuation-induced flux; (a) average values; (b) rms-values; in both cases the emissive probes have been once not heated ("Langmuir probes") and heated to electron emission.

Further analysis is needed to take into consideration the role of the phase relation between the plasma potential and the electron temperatures fluctuations in the SOL. This refers especially to the fact that the flux, calculated by using the emissive probes to measure $\tilde{\Gamma}$, is lower in the SOL but larger in the core compared to the same measurements done with the probes unheated ("Langmuir probes").

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