PLASMA FLUCTUATIONS AND PROBE SHEATH

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Abstract

The edge plasma parameters are monitored using electrical probes in the Castor tokamak (R = 0.4 m, a = 85 mm, B_{tor} = 1 ÷ 1.2 T, I_{pl} = 5 ÷ 20 kA, $\bar{n}_e \sim 10^{19} m^{-3}$). For this, a single Langmuir probe is modified using Stangeby's idea [1] and a so called double-pin-plate probe is designed. We have shown that the influence of the plasma potential and density fluctuations on a probe can be suppressed using signals describing the plasma parameters in front of a planar probe.

1. Introduction

The edge plasma is turbulent in tokamaks, the typical frequency spectrum of plasma fluctuations is broad ($10^3 \div 10^6\ Hz$). This might complicate the probe measurements of the electron temperature (I-V characteristics measurements), namely if a reasonable temporal resolution is necessary (e.g. for investigation of transient phenomena). In such cases, the probe voltage must be swept in a kHz-range, which is already comparable with the low-frequency band of the plasma fluctuations. [2, 3]

We have designed the double-pin-plate-probe to reduce the influence of plasma fluctuations on the form of the probe characteristics. The probe consists of a plate, oriented perpendicularly to the magnetic field lines, and from two small pins. Both pins are used to monitor either the ion saturation current or the floating potential in front of the plate. Recently, we have already described [4] the measurement of the I-V characteristics and how to avoid the influence of the plasma potential and density fluctuation on the shape of the I-V characteristic. In this contribution we are focused to more detail analysis of signals of individual electrodes: we concern on the probability distribution function of the floating potential as well as of the ion saturation current.

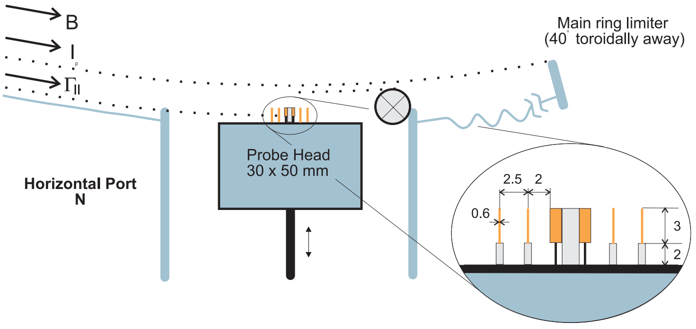

Figure 1. Arrangement of two double-pin-plate probes mounted on the same head in the SOL of the CASTOR tokamak. Construction details of the probe head are shown as an insert. The double-pin-plate probe consists of a plate and two pins. The pins are in a single row, but inclined from the axis not to shadow each other. Active areas are:

$A^{pin}_{geom} = l\pi d = 5.65\, mm^2$,
$A^{pin}_{act} = ld = 1.8\, mm^2$,
$A^{pl}_{geom} = 3mm \times 5mm = 15mm^2$,
$A^{pl}_{act} = A^{pl}_{geom} - 2 \times A^{pin}_{act} = 11.4\, mm^2$

2. Double-pin-plate probe in the edge plasma of a tokamak

The experimental arrangement of the double-pin-plate probe (DPPP) in the edge plasma of the CASTOR tokamak is shown in Fig. 1 which is a view on the diagnostic port from the top. It is apparent that, in fact, two double-pin-plate configurations are installed on the probe head. The first of them is oriented upstream, the corresponding flux tube extends to the electron side of the limiter ($\sim 2.5\ m$), while the flux tube related to the downstream probe is only a few cm long (due to the geometry of the diagnostic port). The configuration of individual electrodes is apparent from the insert of Fig. 1.

3. Experimental results

We report here results of two experiments with the DPPP configuration:

1. Both pins and plate operate either in the ion saturation current or in the floating potential regime which gives values of these quantities on the plate several millimeters in front of it.

2. The plate is biased by a harmonic voltage. One of the pins measures the floating potential, the other one the ion saturation current. The plate current is measured by fast circuits (which are designed as a bridge scheme) and the probe characteristic is constructed [4].

3.1. Probe in steady-state operation

a) Both the plate and pin operate in the ion saturation mode.
Signals of I_s from probe oriented downstream are shown in Fig. 2 together with their ratio which corresponds to the ratio of plate and pin active areas. Nevertheless, we have found the mean value $I_s^{pl}/I_s^{pin} \approx 2$ which is significantly lower than the expected active areas ratio (≈ 6.3). The fluctuations seen by the plate and pin are very well correlated: the correlation coefficient of this signals is 0.84. Consequently, the ratio of pin and plate currents shows much lower absolute amplitude of fluctuations than the raw signals do.

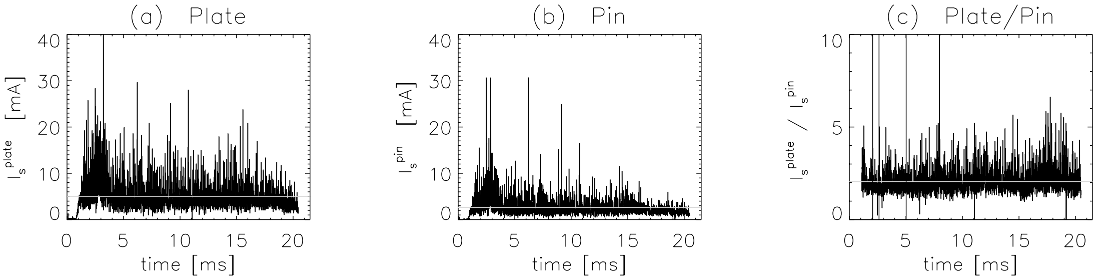

Figure 2. Temporal evolution of the ion saturation current measured by the plate (a) and by the closest pin (b) (pin – plate distance is 2 mm), and the evolution of their ratio (c). (sampling rate $5\ \mu s$, # 4245)

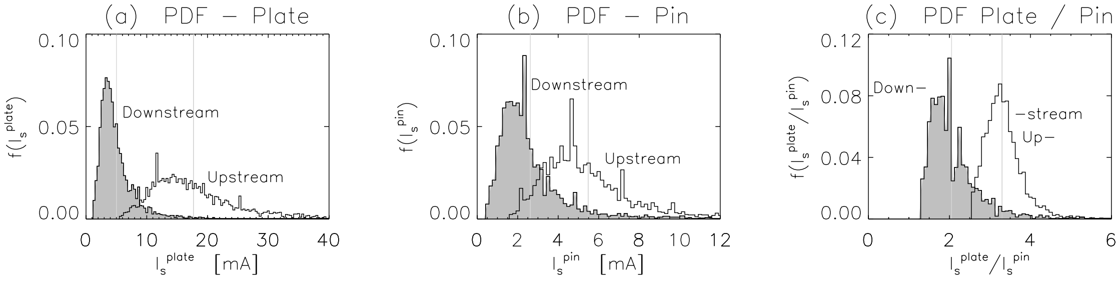

Figure 3. The probability distribution functions (PDFs) of the ion saturation current to the plate (a), to the pin (b), and PDF of their ratio (c) are shown for downstream (grey area) and upstream (non filling) configurations of the probe. The average values are marked using gray vertical lines. (# 4245 & # 4248)

The signals from the probe oriented upstream look similarly, except of higher levels of their mean values and except of a higher ratio of the plate and pin signals (≈ 3.3) which is close to the expected active areas ratio. The correlation coefficient of signals is 0.92 that is even higher than for the downstream orientation of the probe.

The probability distribution functions (PDFs) calculated for both the downstream and upstream configuration are strongly non-gaussian (see positive tails of PDFs in Fig. 3).

b) Both the plate and pin operate in the floating potential mode.
The time evolution of raw fluctuating signals V_{fl} as well as their difference ΔV_{fl} is shown in Fig. 4 for the downstream orientation of the probe. The potential drop between the pin and plate is not zero but slightly negative and its fluctuations show much lower amplitude of fluctuations than the raw signals do. The correlation coefficient 0.96 between the pin and plate potential is very high.

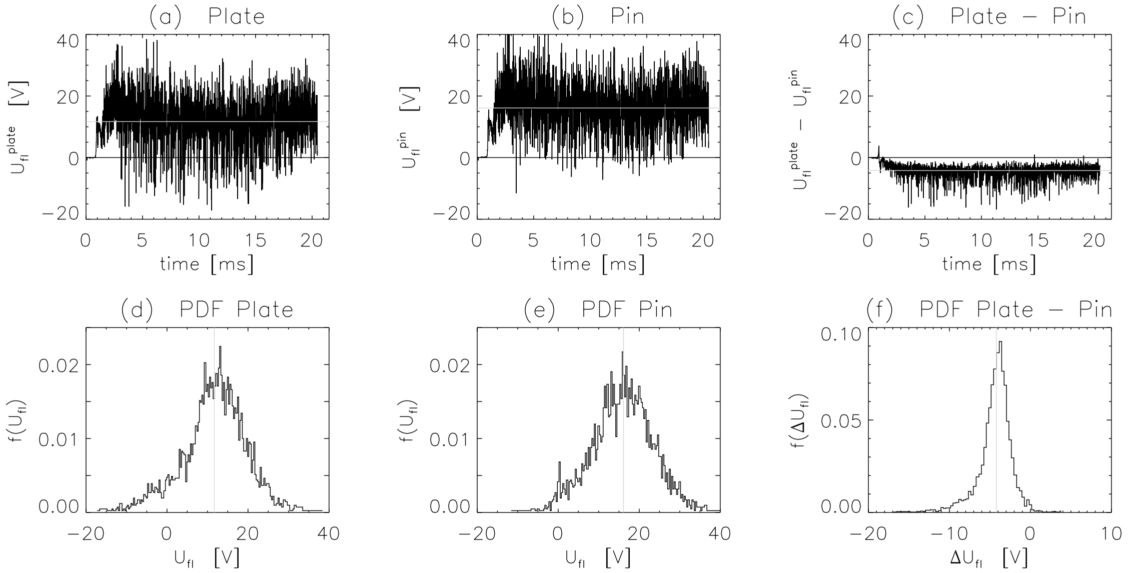

Figure 4. The temporal evolution of the raw floating potential signals measured by the plate (a) and by the pin (b) (pin - plate distance is 2 mm again), and the evolution of the potential drop $U_{fl}^{plate} - U_{fl}^{pin}$ (c). PDFs of the floating potential of the plate (d), of the pin (e), and the PDF of the potential drop between the plate and the pin (f). The average values are marked by gray lines. (sampling rate $5\ \mu s$, # 4154)

The probability distribution functions of both the signals and the potential drop are non-gaussian: all of them have a negative tail but not so pronounced as for the density (i.e. I_s) fluctuations.

3.2. Probe characteristics

A sinusoidal voltage is applied to the plate and the plate current is measured with sampling rate 0.2 μs, The resulting the I-V characteristic is strongly perturbed as seen from Fig. 5 (left panel). The non-linear data fit to a theoretical probe characteristic can not be precise in this case.

The right panel in Fig. 5. shows the I-V characteristic corrected by signals of the ion saturation current and of the floating potential measured by the pins, I_s^{pin} and U_{fl}^{pin}, according to the expression derived in [4]:

$$I_s^{plate}/I_s^{pin} = c_1(1 - \exp[-e(U_{fl}^{pin} - V^{plate}(\omega t) - c_2)/kT_e]) \quad , \tag{1}$$

where c_1 is the ratio of plate and pin active areas, c_2 is the difference of floating potentials on the pin and plate.

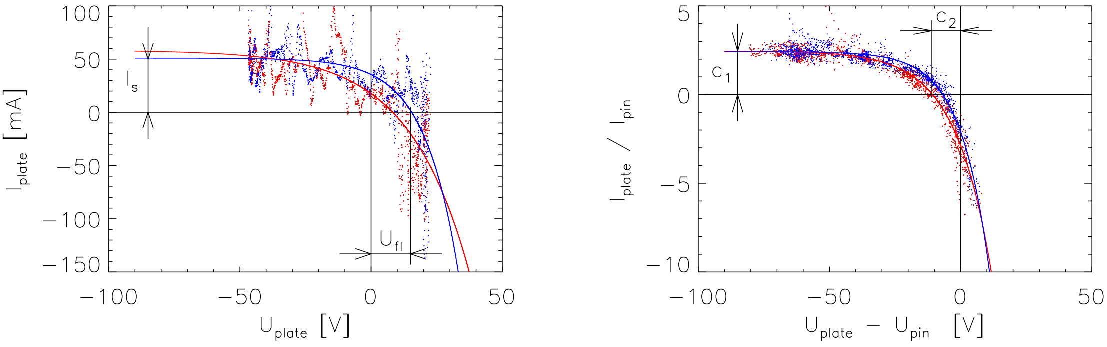

Figure 4. I-V characteristics of the upstream oriented DPPP during a ramp-up (red points) and ramp-down (blue points) phase of the sweep (phase duration $\Delta t \sim 250\ \mu s$, # 4253). Full lines represent results of non-linear fit.

(a) Plate current versus plate voltage — fit is evidently uncertain.

(b) Ratio of the plate and pin currents versus the difference of the plate and pin voltages. The derived temperature T_e is 13 eV for the plate voltage ramp-up and 10 eV for voltage ramp-down, $c_1^{up} = c_1^{down} = 2.4$, $c_2^{up} = -10$, $c_2^{down} = -7$.

This way allows to suppress the influence of fluctuations on the shape of the I-V characteristic. Nevertheless, a hysteresis is seen on the I-V characteristic. [5]

4. Summary

We have found that the fluctuations seen by the plate and pin are highly correlated. Consequently, the pins can be used to monitor the plasma in front of the plate.

We have shown that the I-V characteristics of a single Langmuir probe are significantly affected by the plasma fluctuations and determination of the electron temperature might be even impossible. We have proposed a modification of the probe which allows to avoid this effect. The two small pins located in front of the planar probe monitor there the instantaneous plasma parameters. The test measurements, performed with the double-pin-plate probe configuration on the CASTOR tokamak, have demonstrated the possibility to measure T_e with the temporal resolution up to $0.25\ ms$. Nevertheless, a hysteresis is observed on the probe characteristic.

Finally, the probability distribution functions were found to be non-gaussian that may imply an existence of coherent structures namely in the plasma density.

Acknowledgement

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References

[1] Stangeby P.C.: Report JET-P(95)21
[2] Niedermayer H., et al.: Contr. Plasma Phys. **36** (1996) S, 131-138
[3] Endler M. et al.: Nucl. Fusion **35** (1995) 1307
[4] Hron M., Stöckel J. et al.: Contrib. Plasma Phys. **38** (1998), Spec. Issue, 115 - 120
[5] Verplance Ph. et al.: Contrib. Plasma Phys. **35** (1996)
[6] Stöckel J. et al.: “Analysis of Electrostatic and Magnetic Fluctuations on the CASTOR Tokamak”, *1996 International Conference on Plasma Physics*, Nagoya 1996, Japan Society of Plasma Science and Nuclear Fusion Research 1997, Proc. I, p. 322