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ELM studies with ball-pen and Langmuir probes on ASDEX Upgrade

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Abstract

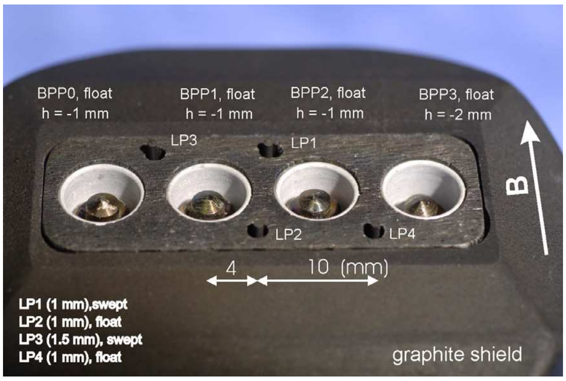
Experimental investigations of the plasma potential and electric field during ELMs were performed in the limiter shadow of ASDEX Upgrade by means of a probe head containing four ball-pen probes [1,2] and four Langmuir probes. The measurements of the gradient of both the plasma and floating potentials show the difference between these two quantities. This might be caused by the gradient of the electron temperature.

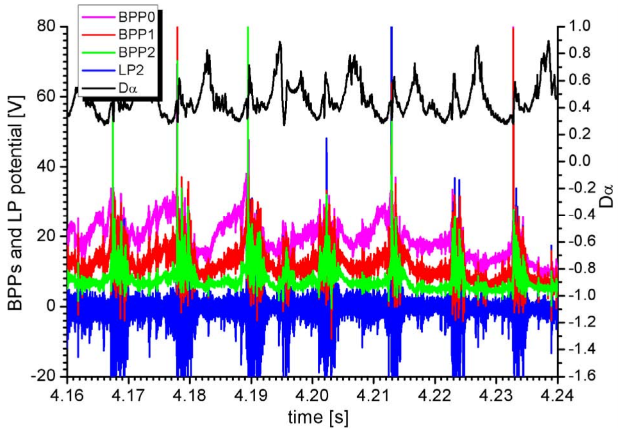
1. Introduction

The investigation of the electric field and its fluctuations remains one of the most important tasks in the context of anomalous edge plasma and momentum transport. A precise knowledge of the plasma potential and its fluctuations in the edge plasma region is vital for a better understanding of transport phenomena and is thus also relevant for ITER, in particular for the lifetime of first wall components. The ball-pen probe (BPP) [1,2,3,4] for direct measurements of the plasma potential was recently developed in the Institute of Plasma Physics in Prague. Here we compare BPP data with measurements of the floating potential by Langmuir probes located at the same probe head in ELMy H-modes of ASDEX Upgrade.

2. Probe construction and experimental set-up

The fast reciprocating probe shaft on the ASDEX Upgrade midplane manipulator was used to insert a probe head containing four BPPs with the retraction depth (h) of its collectors (h =-1 mm (BPP0), –1 mm (BPP1), –1 mm (BPP2) and –2 mm (BPP3)) and four Langmuir probes (LP1, LP2, LP3, LP4) as shown in Fig. 1a. The ball-pen probes are made of stainless steel collectors with diameters of 4 mm, which are fixed inside the ceramic shielding tubes with inner diameters of 6 mm. The two neighbouring Langmuir probes LP2 and LP4 were used in order to measure the floating potential and its gradient. The whole probe head (diameter 50mm) is protected by a graphite shield against the high heat flux of the plasma. The temporal resolution of measured potentials is given by the sampling frequency $f = 2$ MHz of the data acquisition system. The temporal evolution of experimental data of the shot #24364 is shown in Fig. 1b.





(a) **(b)**

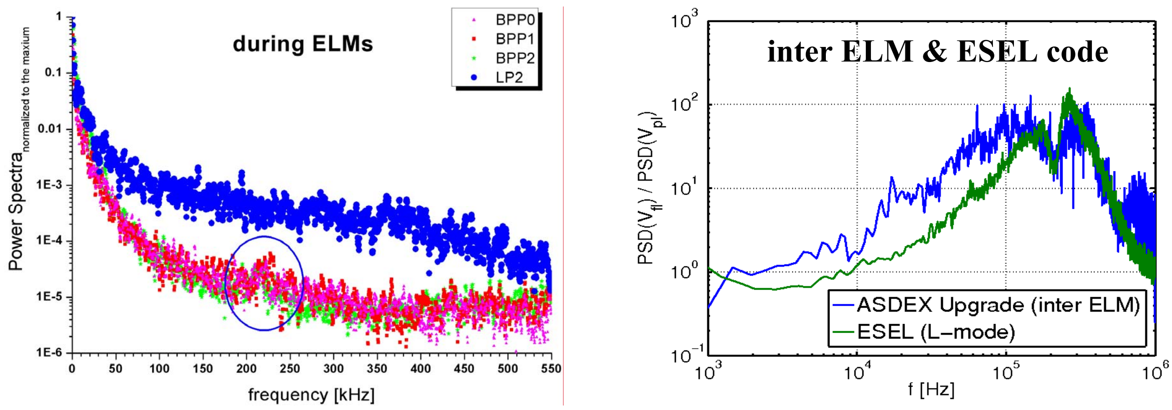
Fig. 1: (a) - Picture of the quadruple ball-pen probe used in AUG during the campaign in 2009. The probe head has four BPPs with conical tips retracted into the boron nitride screen. In addition, there are four graphite Langmuir probes. **(b)** - Temporal evolution of the plasma and floating potential measured by BPPs and LP2 in ELMy H-mode (10 MW of NBI). The probe head was located ~8 millimetres behind the limiter.

The stroke was performed in the ELMy H-mode with a neutral beam injection (NBI) power of 10 MW. The toroidal magnetic field $B_T = 2.5$ T, the plasma current $I_P = 1$ MA and the density n_e=8.5*$10^{19}$$m^{-3}$ were constant during the stroke. The temporal evolution of the plasma potentials measured by the BPPs and the floating potential of LP2 is plotted in Fig. 1b. A systematic difference between the plasma potential of the three BPPs is due to the different location of each probe with respect to the magnetic flux surfaces, with the BPP0 being the deepest inside the plasma. The angle between the probe surface and magnetic flux surfaces is about 12º. Thus, the individual probes are located at different radial and poloidal positions. It must be noted that the size of the BPP collector is much larger than the LP, which causes a certain space averaging of the measured potential. Thus, the BPP potential can be sometimes lower than the LP potential if a spatially short event is detected, which typically occurs in ELMs.

3. Power spectra and difference of Φ_{pl} and V_{fl}

Figure 2a shows the comparison of the ELM averaged power spectra of the BPPs and LP potential, normalized to its maximum value. The power spectrum of the BPP is significantly lower with respect to that measured by the Langmuir probe at higher frequencies. This might be explained by the presence of electron temperature fluctuations, because the BPP measures directly plasma potential fluctuations, Φ_{pl}, whilst the LP measures $V_{fl} = \Phi_{pl} - 2.8T_e$.

Theoretically, it is expected that potential structures of interchange turbulence (blobs) should be larger in space and smoother than both density and temperature structures. Moreover, the potential structures have different phase with respect to the temperature and density. Therefore, Φ_{pl} structures passing a probe should yield smoother signal than $\Phi_{pl} - 2.8T_e$. This is demonstrated using the ESEL turbulence model simulations (the model is described in [5]). In order to prove the influence of the electron temperature fluctuations on the power spectra, the ratio of power spectra of the floating and plasma potential obtained from ESEL model (TCV, SOL, L-mode, green line) and ASDEX Upgrade experiment (inter-ELM data, #23413, blue line) are plotted in figure 2b. The comparison shows very good agreement between modelling and experiment even on the quantitative level. Surprisingly, also the drop at ~200 kHz is reproduced.

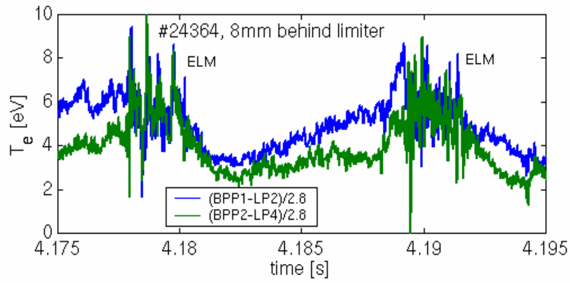


(a) **(b)**

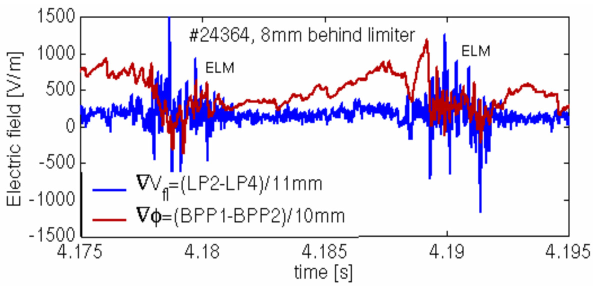
Fig. 2: (a) – The ELM averaged power spectra of the plasma potential of BPPs and floating potential of LP2 with the marked peak between 200-250 kHz. **(b)** – The ratio of power spectra of the floating and plasma potential (PS(V_{fl}) / PS(Φ_{pl})) obtained from ESEL code (L-mode, green line) and ASDEX Upgrade data measured during an inter ELM periods (blue line).

The two temporal evolutions of the difference between the plasma and floating potential, $(\Phi_{pl} - V_{fl})/2.8$, measured by neighbouring BPP and LP (BPP1, LP2 or BPP2, LP4, see Fig.1a) during ELM events are plotted in Fig. 3a. The difference can be taken as a value of the electron temperature T_e, if the energy distribution is Maxwellian. The evaluated data are averaged over 25μs (f <40 kHz) to minimize the influence of the time shifts between probe signals (different probe locations) and the space averaging (different probe dimensions). The derived T_e is strongly fluctuating during ELMs. The gradient of the floating and plasma potential calculated from V_{fl} (LP2, LP4) or Φ_{pl} (BPP1, BPP2) is plotted in Fig. 3b (data are averaged over 25μs). It is seen that the value of ∇V_{fl} is more fluctuating than the value of $\nabla \Phi_{pl}$, which can be caused by T_e fluctuations being out of phase or different in amplitude for LP2, LP4 during the

ELMs and also in between ELMs. It is interesting to see that the gradient of the plasma potential is increasing in time between ELMs whereas the gradient of the floating potential remains nearly constant.



(a)



(b)

Fig. 3: (a) Two temporal evolutions of the difference of the plasma and floating potential, $(\Phi_{pl} - V_{fl})/2.8$, measured by neighboring BPP and LP (BPP1, LP2 or BPP2, LP4). The data are processed on the frequency range $f < 40$kHz. **(b)** The gradient of the floating (blue line) and plasma potential (red line) ($f < 40$ kHz).

The investigations of ELMs by a two probe techniques (BPP, LP) show the difference between the gradient of the floating and plasma potential (∇V_{fl}, $\nabla \Phi_{pl}$) about 8 mm in the limiter shadow of ASDEX Upgrade. Here it is interpreted as a gradient of the electron temperature. The combination of these two probes offers a technique to provide the electron temperature also during ELMs, if the energy distribution remains Maxwellian. It has also been shown that the relative power spectra of the plasma and floating potential provided by ESEL code (SOL, TCV, L-mode) agrees quite well with the experimental data from ASDEX Upgrade (SOL, inter ELM). The local maximum in the plasma potential power spectra occurs during ELMs, between ELMs and also in the ESEL modelling (L-mode) around the frequency 200 kHz.

Acknowledgements

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References

[1] J. Adamek, V. Rohde, H.W. Müller, A. Herrmann, C. Ionita, R. Schrittwieser, F. Mehlmann, J. Stöckel, J. Horacek, J. Brotankova, *J. Nuc. Mat.* **390-391** (2009) 1114-1117.

[2] J. Adámek, J. Stöckel et al., *Czech. J. Phys.* **54** (2004) C95-C99.

[3] J. Adámek, J. Stöckel, I. ¸ Duran, M. Hron, R. Panek, M. Tichý, R. Schrittwieser, C. Ionita, P. Balan, E. Martines, G. Van Oost, *Czech. J. Phys.* **55** (2005) 235-242.

[4] J. Adámek, et al., 32nd EPS Plasma Phys. Conf., *Europhys. Conf. Abst.* 29C (2005) 5.081.

[5] O.E. Garcia, J. Horacek et al. *Plasma Phys. Control. Fusion* **48** (2006) L1–L10.