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Emissive Probe Measurements on ISTTOK

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1. Introduction

The edge region of magnetically confined hot plasmas shows large fluctuations of the plasma density n_{pl}, the electron temperature T_e, and the plasma potential, Φ_{pl}. Furthermore, strong poloidal and radial electric field fluctuations are observed, which induce large particle fluxes. To understand these effects it is important to measure the poloidal and the radial electric fields, E_ϑ and E_r, respectively, with high reliability and good spatial resolution. In this paper, measurements of the edge plasma potential with emissive and cold probes in ISTTOK are compared both concerning average values and fluctuations. Furthermore, the importance of temperature fluctuations on the determination of the turbulent particle flux and the effect of edge biasing is discussed.

2. Experimental set-up

ISTTOK is a large aspect ratio circular cross-section tokamak (major radius R = 46 cm, minor radius a = 7.8 cm, toroidal magnetic field B_t = 0.5 T) with a fully poloidal graphite limiter at r = 7.8 cm. Typical values of the ISTTOK discharge parameters are: plasma current $I_p \cong$ 5-6 kA, discharge duration $\tau_d \cong$ 30-40 ms, central electron density $n_e(0) \cong (5\text{-}10)\times10^{18}$ m^{-3}, central electron temperature $T_e(0) \cong$ 150-200 eV. Fig. 1 shows the experimental arrangement.

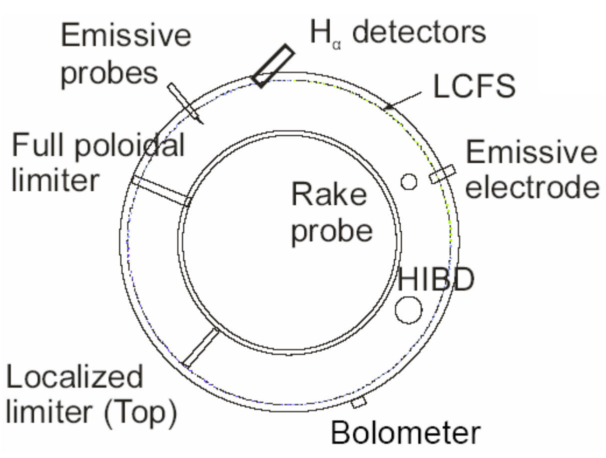


Fig. 1: Top-view of ISTTOK with the diagnostics used in the experiment.

A movable emissive electrode was used for edge biasing experiments [1,2]. The electrode is inserted 12 mm inside the last-closed flux surface (LCFS) of ISTTOK. It consists of a filament-heated, 16 mm diameter, LaB_6 disk. The electrode is inserted into a tantalum cylinder which is insulated from plasma by a boron nitride tube. For negative edge biasing experiments up to 30 A dc current can be emitted into the plasma.

A probe array consisting of emissive and cold probes was developed (see Fig. 2). This array has the advantage that from the data the ion density, the poloidal and radial electric field component can be deduced simultaneously. From these parameters the turbulent radial particle flux and the Reynolds stress can be derived. Also the electron temperature can be calculated from the difference between the cold floating potential V_{fl} and the emissive floating potential Φ_{pl}.

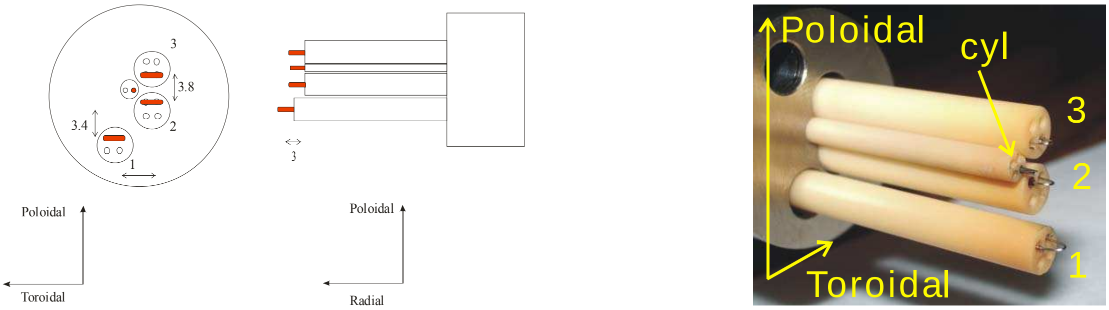


Fig. 2: Schematic drawing and photograph of the probe system used in ISTTOK, consisting of three emissive probes and one cold probe to measure the radial and poloidal electric field components and the ion saturation current simultaneously.

We have given preference to emissive probes [3,4] since cold probes deliver only an indirect measure of Φ_{pl}. Emissive probes measure the plasma potential directly and are therefore more adequate for turbulence studies. In a Maxwellian plasma, for increasing electron emission, the floating potential of the probe approaches Φ_{pl}, attaining it in principle when the emission current equals the electron saturation current. This method does not require the knowledge of the electron temperature T_e, and also works for drifting electrons or electron beams. However space charge effects might lead to deviations of the emissive floating potential from the true value of Φ_{pl} [5].

The probe array consists of three electron-emissive probes (0.2 mm diameter tungsten wire loops) and a cylindrical one (Fig. 2) [3,4]. Emissive probes #2 and #3 are 3.8 mm poloidally separated, probes #1 and #2 are 3 mm radially separated. Probe signals are simultaneously recorded at 1 MHz sampling rate for fluctuation measurements. The plasma density is determined from the ion saturation current to the 0.2 mm diameter cylindrical probe. E_ϑ can be inferred by subtracting the floating potential of probe 3 from that of probe 2, and E_r by subtracting the floating potential of probe 1 from that of probe 2. In this contribution we define as "cold probes" the unheated wire loop probes which work as Langmuir probes and as "emissive probes" the same probes heated to electron-emission.

2. Experimental results

Fig. 3 shows radial profiles of various parameters, measured on a shot-to-shot basis. We know from previous works [4] that the emissive probe does not float exactly at the plasma potential ($\Phi_{pl} = V_{fl} + 2.5\ T_e$) but at $\Phi_{pl} \cong V_{fl} + 1.3\ T_e$ due to space charge [5] effects.

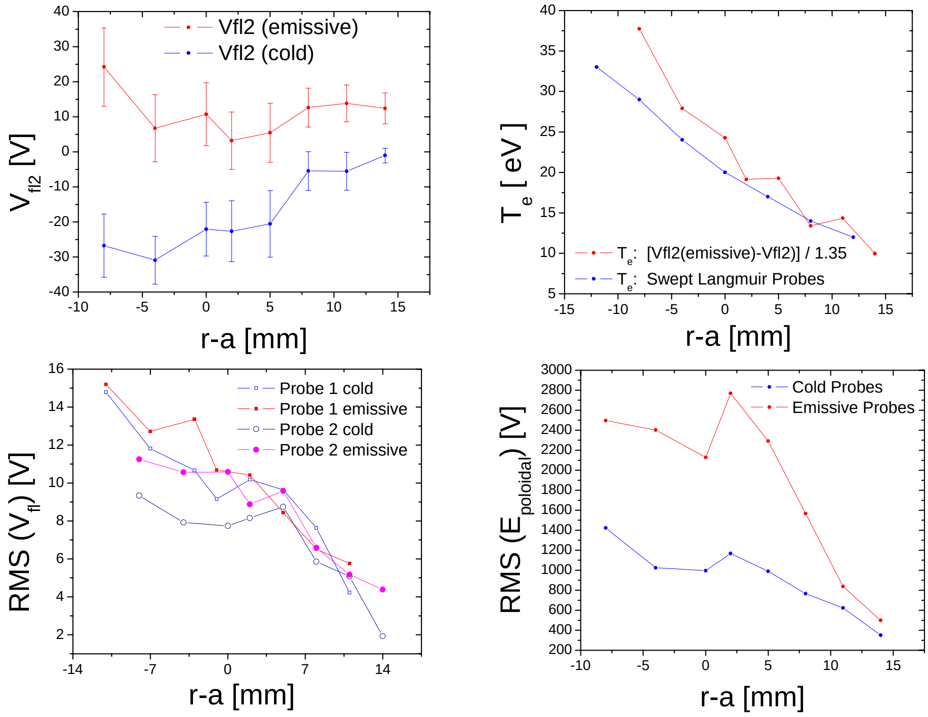
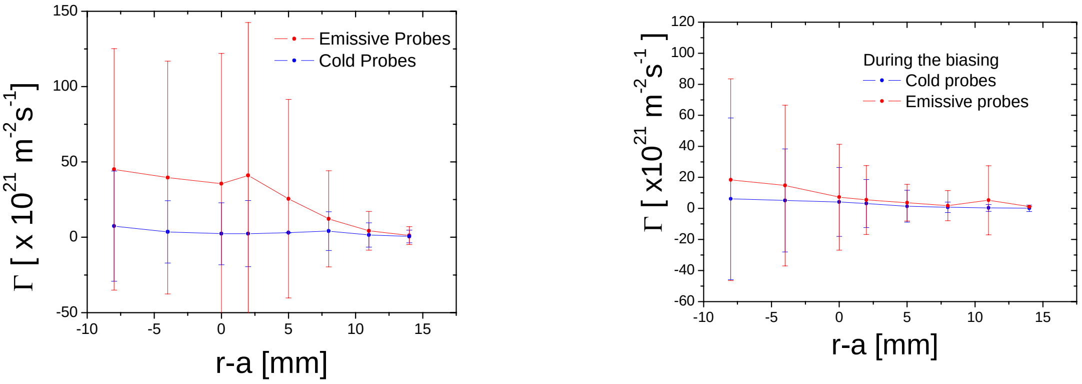


Fig. 3: Radial profiles of the V_{fl}, Φ_{pl}, T_e, and the root mean square of V_{fl} and E_ϑ (=$E_{poloidal}$) recorded with cold and emissive probes. The abscissa scale is related to the radius of the LCFS, a = 7.8 cm.

As illustrated in Fig. 3, the T_e profile measured by subtracting Φ_{pl2} from V_{fl2} and dividing by a factor of 1.3 shows a good correlation with the T_e profiles derived from a swept cylindrical probe, showing that also in the ISTTOK edge plasma the emissive probe floats below the plasma potential.

We found that the root-mean-square (rms) values of the fluctuations of Φ_{pl} are larger by about 25% than the rms values of V_{fl} fluctuations (Fig. 3). This implies that the T_e fluctuations are smaller than those of V_{fl}. On the other hand, Fig. 3 also illustrates that the rms values of E_ϑ, measured with the emissive probes, are about factor of 2 larger than those obtained with the cold probes. This large increase of the fluctuations in E_ϑ can partly be explained by the smaller poloidal correlation between the two floating potential signals for the case of emissive probes.

The turbulent particle flux is defined as $\Gamma = \langle \tilde{n}_{pl} \tilde{v}_r \rangle \cong \langle \tilde{n}_{pl} \tilde{E}_\vartheta \rangle / B_t$. Due to the higher rms values of E_ϑ and to the increase of the correlation between density and E_ϑ, the turbulent particle flux measured with the emissive probes is significantly larger than that measured with cold probes (in particular Fig. 4a). These results indicate that temperature fluctuations are correlated with the density fluctuations but not with those of the floating potential. These results also suggest that in the ISTTOK edge plasma temperature fluctuations are important for the estimation of the particle flux and therefore the standard method based on cold probe measurements may not be sufficiently accurate. Fig. 4a,b shows also a comparison of the turbulent particle flux without edge biasing and with edge biasing, where the emissive electrode was biased to –150 V, emitting a current of 20 A into the plasma. We see that during edge biasing the flux is reduced by a factor of almost two.



(a) (b)

Fig. 4: Turbulent particle flux measured with the cold and the emissive probes (blue lines and red lines, respectively): (a) without negative edge biasing; (b) during negative edge biasing.

4. Conclusion

The properties of the poloidal electric field and of the turbulent particle flux, measured with cold and emissive probes, were compared. Both the root mean square of the poloidal electric field and the fluctuation-induced particle flux were found to be significantly larger when measured with the emissive probes, indicating that temperature fluctuations are important for the particle flux determination.

5. References

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