PROBE MEASUREMENTS IN FRONT OF THE LOWER HYBRID GRILL OF THE CASTOR TOKAMAK

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A whole range of methods utilising absorption of RF waves momentum or energy is applied for electric current generation as well as for additional heating of plasma in tokamaks. Because a high RF power is often used, the wave-plasma interaction can be accompanied by a number of non-linear effects [1]. Commonly observed damages of limiter parts and divertor plates, which are connected directly with the antenna by lines of force of the confining magnetic field, can be result of such interaction. Theory explains this undesirable phenomenon by acceleration of particles due to the processes taking place just in front of the antenna. To verify this theory prediction experimentally, probe measurements of plasma parameters in CASTOR tokamak (R/a=0.4/0.085m, wall radius 0.1m) in front of the lower hybrid grill (frequency 1.25GHz, power up to 50kW) have been carried out.

For these measurements a miniaturised movable Langmuir probe has been constructed. The probe consists of two independent tips of the length 1.5mm (ϕ1mm), spaced in tokamak toroidally by 3.5mm. The outer shielding of the probes (stainless steel) are covered by corundum (Al_2O_3) using the technology of the plasma spraying to prevent the electric field short circuiting. The probe has been fixed in a spherical joint located about 500mm above the centre of the tokamak small cross section where the grill is placed. This arrangement enabled us (by a tilting of the probe) to change the radial as well as the toroidal position of the measuring tips on the shot-to-shot basis, see Fig.1. Further, vertical shift of the probe along its axis enabled to change the position of the tips also in the third dimension, denoted in figure 2 as *h* (height above the equatorial plane of the torus).

The all signals measured have been registered by the sampling frequency 1MS/s for the whole CASTOR discharge period (32ms).

Using of the probe described, the following spatial measurements of the plasma floating potential and ion saturated current have been done in front of the CASTOR lower hybrid grill:

(i) for $z=0mm$ the radial dependencies in the range $h \in <+40;+70mm>$; here *z* is the toroidal distance of the probe tips from the grill centre (grill has three waveguides with total toroidal width *46mm,* i.e. $z \in <-23;+23mm>$, see figure 2*)*, dimension of the grill mouth in poloidal direction is *160mm, i.e. h∈< -80;+80mm>);*

(ii) for *h=40mm* the radial dependencies in five toroidal positions A,B,C,D and E from the region *z∈<-5;+20mm>* (i.e. in fact toroidal dependence), see Fig. 2.

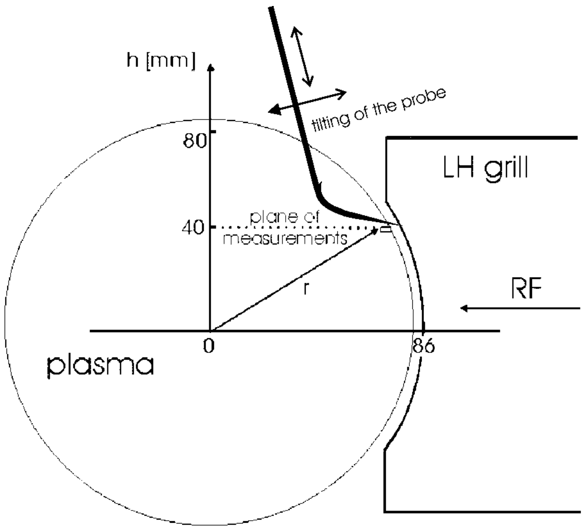


Fig.1: Schematic of CASTOR small cross-section with the lower hybrid grill (radius of the grill circular shaping is 86mm, aperture limiter radius 85mm).

Further,

(iii) to reveal a departure of electron distribution function from Maxwellian one if RF power is applied, *I-V* probe characteristics have been measured using *1kHz* sinusoidal voltage with amplitude *100V* and adjustable DC biasing;

(iv) synergetic effects of RF and positive plasma edge biasing (using a massive biasing electrode) have been investigated.

Moreover,

(v) data of several other probe diagnostics in the region far from the grill have been registered (radial rake of Langmuir probes, rotating Mach probe etc.).

The main results of these measurements may be summarised as follows:

(i) a radially very narrow layer (several mm only) of the plasma floating potential drop (negative potential „well“) has been found close to the grill mouth if RF is applied, see in Fig. 2 or further Fig. 4; such potential „well“ could indicate existence of the fast electrons generated in this layer by the launched wave;

(ii) the depth of the potential „well“ decreases in poloidal direction (i.e. along the longer wall of the waveguides) from the grill centre, in concordance with the second power of sinusoidal distribution of the electric field in the grill waveguides;

(iii) however, similar dependence of the floating potential drop has been found also in the toroidal direction (i.e. the depth of the potential „well“ decreases on the both sides from the centre of the middle waveguide, where it reaches its maximum), see a 3D picture of the situation given in Fig. 2; this fact seems to be in disagreement with the assumption of equal power distribution among the all three waveguides and it is also in contradiction with the theory, predicting just in the centre of the antenna a zero acceleration of electrons [2];

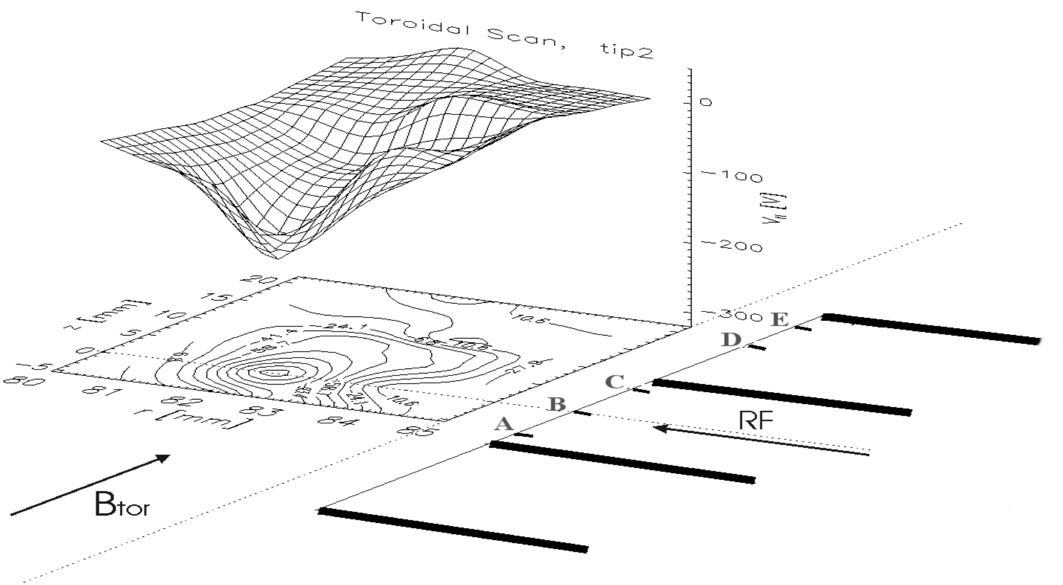
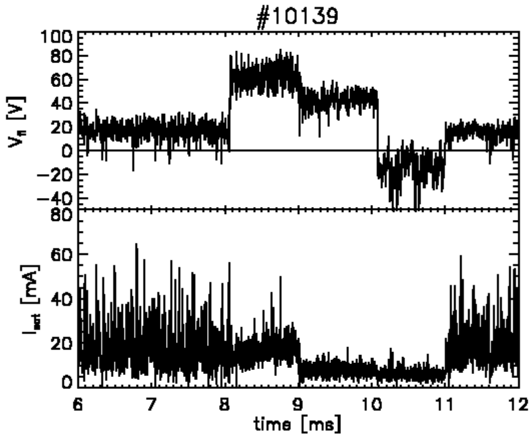


Fig. 2: Toroidal versus radial plot of the floating potential V_{fl} (averaged over 1ms period) under RF application, obtained by radial scan of the probe in five different toroidal positions denoted in the figure as A, B, C, D and E (measured at h=40mm).

(iv) biasing of the plasma can result, in certain range of experimental parameters, in some reduction of the plasma density fluctuations (see lower trace in figure 3) linked with an observed improvement of global particle confinement; however, detailed investigation of floating voltage drop during simultaneous positive biasing and RF application didn't prove that reduction of density fluctuations brings down the generation of the fast electrons by RF as it is supposed by theory and as it could be erroneously deduced from figure 3 (note that biasing is accompanied by substantial change of the plasma potential in the whole edge plasma); only a small radial shift (about 1mm inward) of the floating potential „well“ has been found, see the lower part of Fig. 4 (radius of the biasing electrode r = 63mm);

(v) an attempt to find origin of the negative „well“ formation by analysis of probe *I-V* characteristics, measured just in the place of the „well“ formation, didn't bring expected result up to now; fitting of the electron temperature to the measured characteristics indicates rather bulk electron temperature increase as an existence of a some measurable group of accelerated electrons (the contribution of the fast electrons can be quite overlap by observed effect of non-saturation of the ion current with the increasing negative voltage);

(vi) let us note that one tip of double probe used in CASTOR is measuring during the RF pulse the value of V_{fl} negative drop more than three times higher as the second one (tips are in mutual toroidal shadow), while the values of V_{fl} measured by both tips are quite identical during OH; this fact could be probably explained by launcher power spectrum asymmetry resulting in a asymmetry of electron acceleration process.



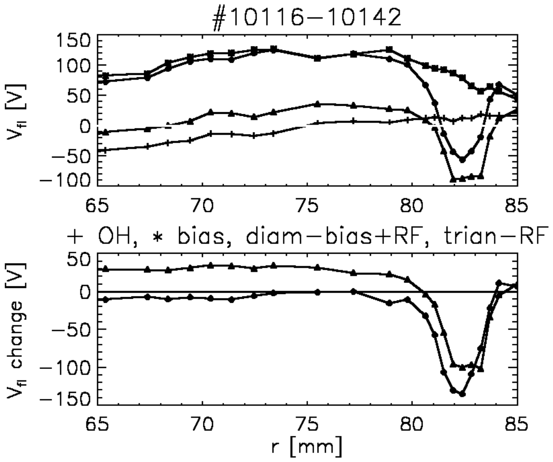


Fig.3 : Time development of probe floating potential and ion saturated current (measured simultaneously by the two tips spaced toroidally 3.5mm on the same radius) during edge plasma biasing and RF applications with a 1ms overlapping (biasing has been applied in the period 8-10ms, RF in the period 9-11ms, measuring probe radius r =83.7mm).

Fig. 4:<u>Upper part</u>: time averaged radial profiles of probe floating potential V_{fl} in pure OH (crosses), edge plasma biasing +150V (asterisk), simultaneous biasing and RF regimes (diamonds) and RF regime only (triangles);
<u>lower part</u>: triangles - drop of V_{fl} during RF (relative to OH), diamonds - drop of V_{fl} during simultaneous biasing and RF (relative to biased case only).

The experimental results given above indicate the complexity of the problem under study. Nevertheless, experimentally detected negative drop of V_{fl} may be taken surely as a certain indication of the fast electrons existence. However, to make qualitative estimates about the plasma potential from V_{fl} measurements without additional data about the particle distribution function (both electron as well as ions) is hardly possible. To obtain such data, measurements using a retarding field analyzer are under preparation.

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