Attenuation of ICRH-induced potentials in the SOL of Tore Supra

M. Kubič[1], J.P. Gunn[1], L. Colas[1], E. Faudot[2], S. Heuraux[2] and A. Ngadjeu[2]

[1] *CEA, IRFM, F-13108 Saint-Paul Lez Durance, France.*

[2] *IJL-P2M, UMR 7198 CNRS, 54506 Vandoeuvre, France.*

Abstract. When a reciprocating Langmuir probe is magnetically connected to a powered ICRH antenna, large RF-induced potentials are observed along the entire leading edge of the antenna's poloidal protection limiters. Recent experiments show that a key parameter affecting the amplitude of these potentials is plasma density. The detailed 2D map of the potentials induced in front of the ICRH antenna is presented as well as the influence of the density on these potentials and parallel flow.

The Tore Supra tokamak is equipped with three plasma heating antennas operating in the ion cyclotron range of frequencies (42-63MHz). Each antenna injects a maximum heating power of 4MW, and consists of a phased array of 2 straps extending 250mm above and below the equatorial plane. The antenna box is protected from the plasma scrape-off layer (SOL) on both sides by poloidal limiters. The vertical limiter extensions are about 550mm above and below the equatorial plane.

The interaction between a powered ICRH antenna and the SOL is investigated by a reciprocating Mach probe mounted in the top port located at φ = 160º [1]. Depending on the edge safety factor *q(a)*, the ion side of the probe can be magnetically connected to one of the antenna at various poloidal positions. The electron side of the probe is connected to the bottom toroidal limiter via the HFS. Over the series of shots, *q(a)* was changed in small steps from 4.7 - 7.8 providing a detailed mapping of the upper half of the antenna. The power level injected by the observed antenna was maintained at 2MW.

Although large potentials are observed along the entire leading edge of the antenna's poloidal protection limiters, they are most intense on field lines passing near the top and bottom of the antenna straps [2]. Radial profiles of the floating potential measured on the field lines passing the top of the antenna strap are shown on Figure1.

The potentials in this case reach up to 90V (potentials exceeding 200V have been observed in particular cases). Floating potential serves as a lower estimate of plasma potential. According to theory, to relate both it is necessary to include rectification effect [3]. Nevertheless, recent experiments held on Tore Supra with retarding field analyzer [4] show that the difference between V_{float} and V_{plasma} is in order of $\sim T_e$ in contradiction with simple probe theory (to be presented in future paper).

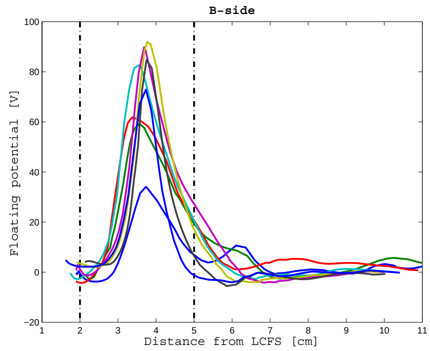

Figure 1: Probe floating potential measurement on the side connected to ICRH antenna (a). Black lines indicate the perturbed zone. Black vertical lines indicate the perturbed zone.

The perturbations do not occur only in front of the antenna strap, but can extend poloidally along the edge of the protection limiter (its extremities are not magnetically connected to the straps).

Recent experiments show that the amplitude of the V_{float} perturbation decreases with increasing density. On Figure2(a) are plotted data from three shots for which a fine poloidal scan of the top of the strap was made with different densities. Radial profiles of V_{float} for one selected magnetic connection are plotted on the right. To obtain the same ICRH power for different values of plasma density it is necessary to vary the RF voltage on antenna straps accordingly. For data presented in this paper, V_{strap} changes by ~20%, while the skin depth c/ω_{pe} (calculated using the local density measured by the probe) remains roughly constant and the floating potential changes by a factor of 2. This implies that variations of V_{strap} can not cause such strong modulations of floating potential.

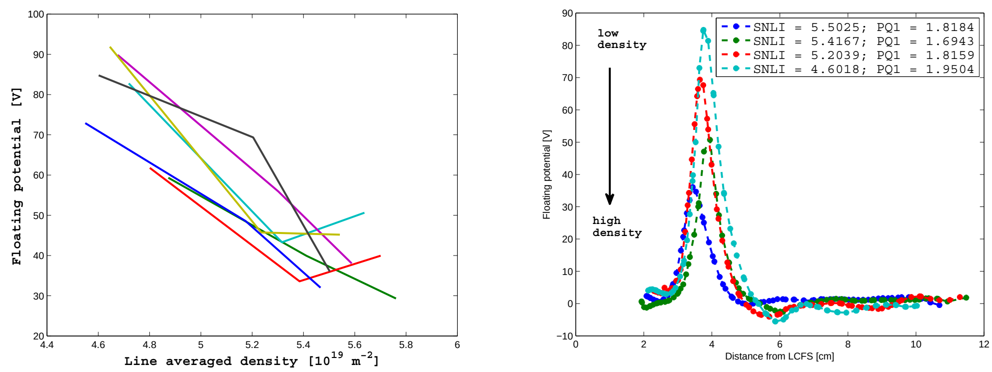

FIGURE 2. Density dependence of floating potential structures for different magnetic connections (a) and for one specific position on antenna (b).

The radial profile of parallel ion saturation current density $J_{||}$ exhibits structures in the perturbed zone (see Figure3(a)). The observed structures on $J_{||}$ are fairly different on the two sides of the probe (see Figure3(b)). Combining the measurement of $J_{||}$ from both sides provides information about local density and Mach number. To correctly unfold the influence of density and Mach number on $J_{||}$ we use following definitions [5]:

$$n_e = \frac{\sqrt{J_{||}^{ion} J_{||}^{ele}}}{0.35 e c_s} \qquad M_{||} = 0.4 \ln\left(\frac{J_{||}^{ele}}{J_{||}^{ion}}\right) \qquad 1)$$

Despite the presence of structures in $J_{||}$, the density profile is monotonic. The structures are due, rather, to a strong shear of $M_{||}$ (Figure3). For typical ohmic discharges, the flow is roughly constant on the SOL, directed from LFS to HFS [6]. The shear in the parallel flow is observed only for low densities, typically for $\bar{n}_e = 4.5 \cdot 10^{19} \mathrm{m}^{-2}$.

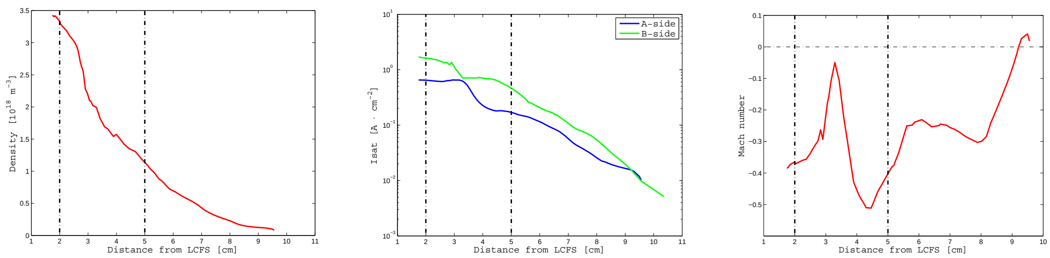

FIGURE 3. Radial profiles of n_e, $J_{||}$ (a) and $M_{||}$ (b). In the flux tube connected to a powered antenna, parallel flow is sheared. The structures vanish for higher densities. Local density is monotonic.

SUMMARY & DISCUSSION

RF-induced SOL modifications are investigated by means of Mach probes. When the probe is magnetically connected to the ICRH antenna, perturbations of the SOL plasma parameters are observed mainly in the vicinity of the antenna with a typical radial extension up to 2cm. Zones of high floating potential do not appear only in front of the extremities of the antenna box where the potential is up to 90V, but can propagate along the leading edge of the antenna protection limiter. This could imply that RF currents are induced on the limiters (which were not included in 3D antenna calculations [ ]). High potentials are unfavorable because they accelerate ions which cause enhanced sputtering as well as enhanced heat fluxes. A key parameter affecting the amplitude of plasma parameter perturbations is the plasma density. The amplitude of the potentials decreases strongly with increasing plasma density - changing by factor of ~2 for 20% change in density. These results indicate that control of edge density might provide a means to attenuate RF sheath potentials in ICRH-heated tokamaks. This operational recipe was used to reduce tungsten sputtering on ASDEX upgrade [8]. But modifying the density also increases the number of ions accelerated in the sheath. The common experience on Tore Supra and JET is that the heat loads associated to the RF sheaths do increase when the local density is high. Operational trade-offs therefore need to be found in order to accommodate the various detrimental effects of sheath rectification. Parallel flow is modified also during ICRH operation. The flow changes monotonically in radial direction in ohmic phase while during the ICRH phase is strongly sheared. In addition, the parallel flow shear diminishes as density increases. It is believed that parallel flows are driven by blobs [7]. Therefore change of the flow might imply changes in the transport in ICRH-biased flux tubes.

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