PLASMA EDGE EFFECTS WITH ICRF IN ASDEX

J.-M. Noterdaeme, G. Janeschitz, K. McCormick, J. Neuhauser, J. Roth,
F. Ryter, E. Taglauer, N. Tsois, M. Brambilla, A.W. Carlson, F.Fussmann,
G. Haas, F. Hofmeister, V. Mertens, C. Setzensack, K. Steinmetz,
F. Wagner, F. Wesner, J. Bäumler, G. Becker, W. Becker, H.S. Bosch,
F. Braun, H. Brocken, A. Eberhagen, G. Dodel[1], H.-U. Fahrbach, R.Fritsch,
O. Gehre, J. Gernhardt, G. v.Gierke, E. Glock, O. Gruber, W. Herrmann,
J. Hofman, A.Izvozchikov[2], E. Holzhauer, K. Hübner[3], F. Karger,
M. Kaufmann, O. Klüber, M. Kornherr, K. Lackner, M. Lenoci, G. Lisitano,
F. Mast, H.M. Mayer, D. Meisel, E.R. Müller, H. Murmann, H. Niedermeyer,
A. Pietrzyk[4], W. Poschenrieder, S. Puri, H. Rapp, H. Riedler[6], A.Rudyj,
F. Schneider, G. Siller, E. Speth, F. Söldner, A. Stäbler, G.Staudenmaier,
K.-H. Steuer, S. Ugniewski[5], H. Verbeek, O. Vollmer, H. Wedler, D.Zasche

Max-Planck-Institut für Plasmaphysik
EURATOM Association, D-8046 Garching
[1] University of Stuttgart, [2] Ioffe Institute, [3] University of Heidelberg,
[4] University of Washington, Seattle, USA, [5] Inst.for Nuclear Research,
Swierk, Poland, [6] Schiedel-Stiftung, Austria

Introduction: The boundary plasma plays a major role in the understanding of the multiple aspects of an RF heated plasma: the coupling of RF waves, the impurity content of the plasma, or even its overall confinement properties. The difficulty to measure the boundary plasma especially with RF is compounded by the fact that machine specific aspects have a much larger impact on the plasma boundary than at the plasma center. Systematic tendencies are however recognized. In the following we give an overview of plasma boundary data (n_e,Te electric fields in the scrape off layer) and report on Fe flux measurements in the divertor and on evidence of a local impurity production mechanism. We then propose an explanation for the enhanced impurity content of the plasma during ICRF, which is also consistent with earlier measurements /1,2,3/.

Boundary density evolution: In standard ICRH discharges the density evolution, measured with the Li beam diagnostic /4/ is as follows: As the separatrix is moved outwards, due to β_p effects, the density at a fixed radial position increases (Fig. 1a). Normalised to the position of the separatrix, however, the density there is constant (Fig. 1b) with at low plasma current a small increase of the gradient length (Fig. 1c). The density at the antenna limiter stays constant. This results in a steepening of the density gradient close to the antenna.

Edge temperature evolution: In the last experimental period the Langmuir probes in the main chamber were disturbed by the ICRF and the edge laser scattering system did not cover in the case of ICRF the separatrix region (the plasma is shifted outward for a good antenna coupling). There is, however, substantial experience (incl. numerical simulation) from ohmic and neutral injection heated discharges with an unshifted plasma where all diagnostics are working. Taking the divertor data (density, line intensities and the absolute X-ray signals can be converted into absolute Fe fluxes (Fig. 3a). In the case of NBI, the measured fluxes in the divertor, as well as the fluxes calculated by the code are in good agreement with those calculated /9,10/ from CX sputtering using data from the neutral particle diagnostics. In the case of ICRH, however, the fluxes calculated from the Fe XVI intensity are much higher than those measured by the divertor probe or calculated from CX sputtering. One has either to assume that the Fe flux measurements in the divertor were not representative of the fluxes in the main chamber or that the scrape off transport model in the code is incomplete in the case of ICRF heating.

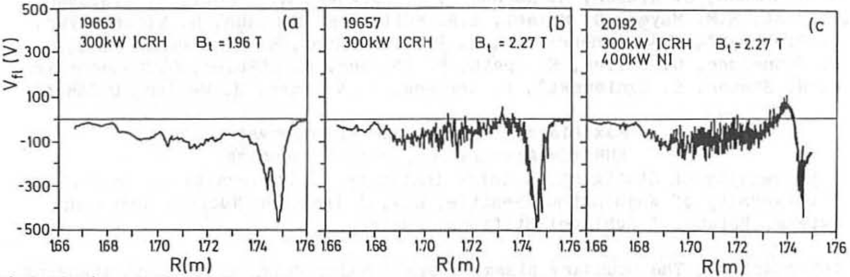

Fig.2: Floating potential in the divertor chamber
a) ICRH alone, non optimal position of resonance layer
b) ICRH alone, optimal position of the resonance layer
c) ICRH with NI

Evidence of local impurity production: There are several indications for localised impurity sources in the main chamber during ICRH. The development of the Fe XVI line intensity over a dozen of shots after wall carbonisation is shown in Fig. 4. The values for OH and ICRH were normalized at shot 18782. The faster shot to shot increase during ICRH, relative to the OH part of the pulse can only be explained by a strong local erosion due to the RF. Surface analysis of the carbon protection limiters of the antenna indicate the presence of a local Fe source /11/. A similar conclusion was reached by the JFT-2M group /12/, when they protected the antenna neighbourhood with graphite. The divertor probe could underestimate the amount of Fe originating from such local spots because much may be locally redeposited.

Discussion: In view of the now accumulated data we can propose an hypothesis for the increased impurity content in the plasma during ICRH. Earlier explanations, based mainly on the anticorrelation of wave absorption and the impurity content in the plasma /1,2,/ have emphasized increased impurity production with, however, the mechanism still to be identified. More recently, in view of the Fe measurements in the divertor, an increased penetration of neutrals through the scrape-off layer was put forward as an hypothesis/13/. Model calculations, however, show that this would require a major reduction of the boundary temperature which was not substantiated in normal discharges.
Consistent with earlier measurements and with both the measured Fe flux in the divertor, and the boundary parameters during RF, the higher impurity concentrations can be related to two effects: 1) a changed

temperature, CIII, bolometer etc.) and the main chamber edge density during ICRH, it is quite obvious that the power input into the divertor and hence the midplane temperature are substantially increased in normal ICRH discharges. This is in agreement with observations on JET and TEXTOR. RF theory /5/ also predicts that a few per cent of the power can be deposited in the boundary through collisional absorption on the electrons (the mechanism being that the electrons take up energy with their $\tilde{E}$ x B drift and thermalize it if $\nu_{ei} >> \nu_{ICRH}$, cold electrons with large ν_{ei} are preferentially heated). Close to the separatrix this is a small fraction compared to the large power outflux from the main plasma. It can, however, strongly influence the temperature and potential in the low energy scrape off layer wing.

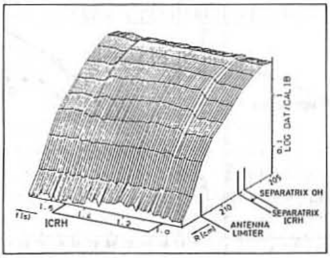

Fig. 1a: Density evolution at the boundary

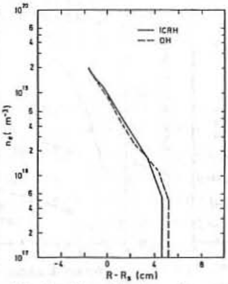

Fig. 1b: Normalized to the position of the separatrix

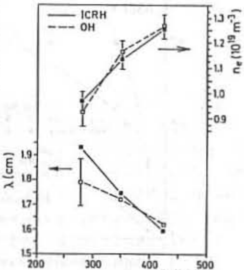

Fig. 1c: Dependence of separatrix density and decay length at the separatrix with plasma current

Floating potential measurement in the divertor: In fact, a substantial influence is observed e.g. in the floating potential in the divertor /6/. During ICRH, a strong negative peak is observed in the outer scrape-off layer wing just inside the last flux surface entering the divertor (which is also the surface directly in front of the antenna). This may be connected with the spurious edge heating mentioned above. The detailed structure of the floating potential profile depends on the heating scenario (OH, $2\omega_c$, minority, addition of NI) and on the position of the resonance layer. There are indications that there is a correlation between enhanced impurity content of the plasma and the observed radial potential pattern: Figures 2 a,b,c show how this profile changes as one goes from a case (a) resulting in a large to a case (c) resulting in a much reduced impurity content of the plasma. Note the appearance of an intermediate region with a radially inward electric field. Those radial electric fields will affect the transport in the scrape off layer, the exact mechanism, however, remains unclear.

Measurements of Fe fluxes: A divertor collector probe was used to measure the Fe fluxes in front of the divertor target plate /7/. Assuming toroidal and poloidal symmetry, those fluxes can be related to the Fe fluxes originating from the main chamber walls (Fig. 3a). Spectroscopic measurements of the Fe XVI line intensity, as a function of power, are shown in Fig. 3b. Using an impurity transport code /8/, which neglect electric fields in the scrape-off, the absolute Fe XVII transport in the SOL, because of radial electric fields at the edge, originating from a changed plasma potential, and 2) a strongly localised Fe source due to strong electric fields in the vicinity of the antenna. The anticorrelation between absorption and impurity production, seen for example in B_t scans /2/ and in the beneficial effect of NI can be explained as follows. Bad absorption would result in a strong local standing wave near the antenna /5/, which increases the impurity production directly in this region, and in larger RF fields at the plasma edge /14/, which, through acceleration of particles there, could change the plasma potential and thus the transport in the scrape off. In addition to changing the wave absorption, NI may also change the electric fields at the edge directly by the induced plasma rotation.

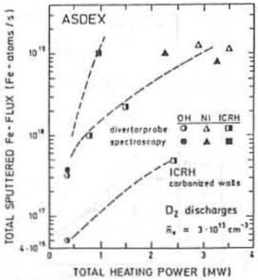

Fig.3a: Fe fluxes as calculated from the divertor probe and from the Fe intensity lines

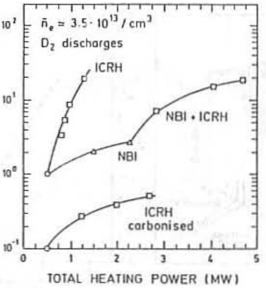

Fig.3b: Measured Fe XVI intensities

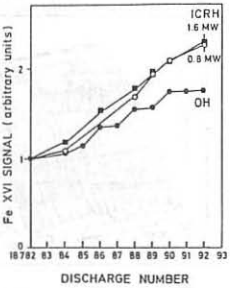

Fig.4: Normalized evolution of the Fe XVI signal

Summary: The evolution of n_e and T_e at the plasma boundary during the RF, together with measurements of the floating potential in the divertor, and the analysis of Fe collector probes in the divertor and of the antenna limiter indicate that the enhanced impurity concentration in a ICRF heated plasma is due to a combination of changed transport in the scrape-off layer because of electric fields, and an increased local production of impurities, related to large electric fields in the direct antenna neighbourhood.

References

/1/ G. Fussmann et al., Europhys.Conf.Abstr. (1985) Vol. 9F, I, 195
/2/ G. Janeschitz et al., Europhys.Conf.Abstr.(1986) Vol.10C,I, 407
/3/ C. Setzensack, IPP Report III Feb. 1987
/4/ K. McCormick, J.Nucl.Mat. 121 (1984) 48
/5/ M. Brambilla et al., this conference, and private communication
/6/ N. Tsois et al., this conference
/7/ E. Taglauer, J.Nucl.Mat. 128-129 (1984) 141
/8/ G. Fussmann, Nucl. Fus. 26 (1986) 983
/9/ H. Verbeek et al., as /1/, Vol. 9F, II, 583
/10/ G. Staudenmaier, J.Nucl.Mat. 145-147 (1987) 539
/11/ R. Behrisch et al., this conference
/12/ H. Tamai et al., JAERI-M 86-143, Tokai, Sept. 1986
/13/ J. Roth, IPP Jahresbericht 1986
/14/ R. Van Nieuwenhove et al., this conference