31st EPS Conference on Plasma Phys. London, 28 June - 2 July 2004 ECA Vol.**28G**, P-5.146 (2004)

RF Induced Impurity Transport in the Mode Conversion Regime in a H-D plasma at JET

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One of the difficulties of radiative improved mode (RI) plasmas and of some of internal transport barrier (ITB) plasmas is the impurity accumulation. We report here on a first attempt at JET to selectively heat and pump-out seeded Ar^{16+} in a H/D mode conversion regime.

1. Principle of the experiment

The principle of the TFR experiment on RF impurity pump-out [1] is adapted to JET experimental conditions with RF antennas on the low field side. With $T_e(0) \approx 3.5\,keV$ and absence of impurity accumulation, the Ar^{16+} density profile should show a maximum at x=0.8. This particular ionized state of Ar is the best candidate for testing RF induced impurity transport since the other ionized states are either too close to the edge or are uniformly

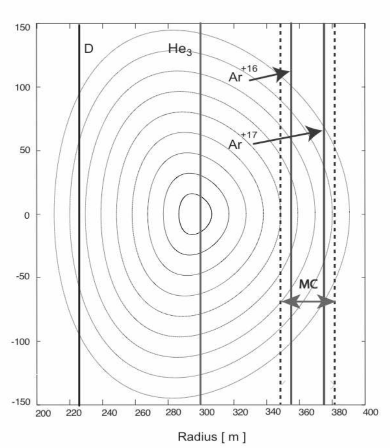

Fig. 1 : main resonance positions

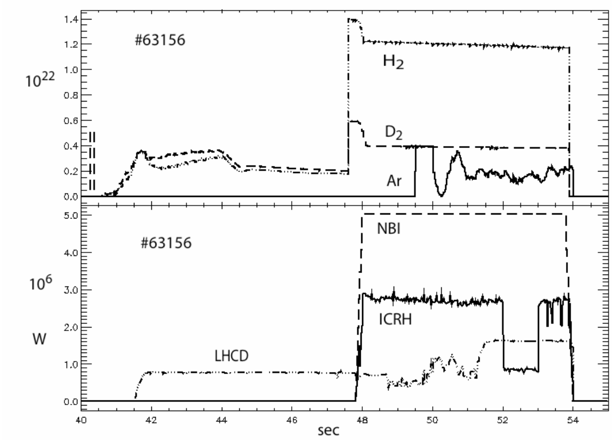

Fig. 2: The hybrid scenario is adopted for the impurity heating experiment

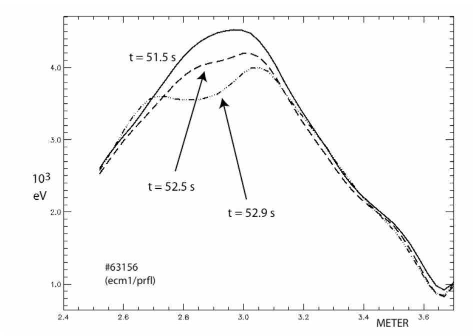

Fig. 3: Te profile for pulse #63156 before and during RF notch

distributed. In JET, heating at $\omega = \Omega\left(Ar^{+16}\right)$ is not possible, but $\omega = 2\Omega\left(Ar^{+16}\right)$ is feasible. A (possibly) efficient method to insure the direction of the RF induced pinch is use the enhanced $k_\perp E_+$ product from a mode-conversion layer (MCL) that can be superimposed to the Ar^{16+} resonance ($k_\perp$ is the perpendicular wave-vector and E_+ is the left-handed polarized component of the electric field). This scenario is realized by choosing the proper H/D ratio. In the experiment, H/D is varied from shot to shot until it is observed that the MCL is on top of the second harmonic Ar^{16+} resonance. This determines some of the JET parameters: 0.37 < H/D < 0.57, B_t = 3.3T, ICRH frequency 33.8 Mhz, so that the Ar^{16+} resonance layer is at radius 356 cm for $T_e(0) \approx 4\ keV$. In addition I_p is fixed at 2.5 MA. The reference JET pulse was in the hybrid scenario (#62780, see Fig. 2) and two real time controllers (RTC) were used: LHCD to keep q(0) near 1.5 to avoid sawtooth oscillations to simplify the particle transport analysis and Ar main chamber gaz input module actuation to stabilize, at a prescribed value, the Ar^{16+} radiation. The Ar pinch transport, depending on the RF phasing (+pi/2, –pi/2) is observed through the variation of the gaz input rate that follows the demand in Ar radiation. NBI is used for core heating since ICRH is already used for edge Ar heating. Also, a reduction of the RF power (RF notch see Fig. 2), lasting one second, is imposed to allow for an analysis of the power deposition, transport and heating time scales. The experiment produced ten good pulses for analysis.

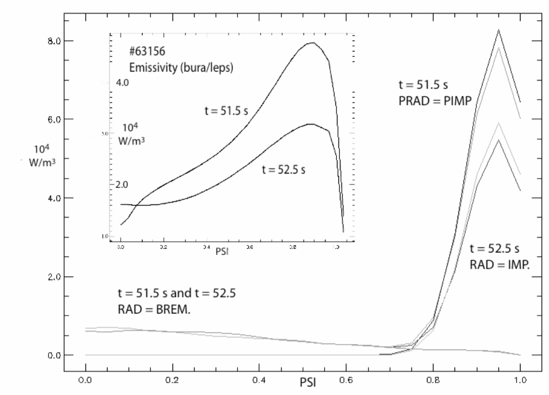

Fig. 4: Radiated power and plasma emissivity before and during ICRH notch.

2. Experimental results

All the shots had unexpected good RF coupling and almost stationary H/D ratio. The RTC on Ar injection worked as foreseen. On the other hand, the q profile control was limited by the available power, thus sawtooth (at frequency 8 – 10 Hz) were not prevented. The main limitation was in NBI power. One of the two neutral beam injectors was unavailable (thus also T_i from charge exchange measurements was not obtained), while the other injector prepared for H_2 injection delivered less power than originally planned.

He^3 (desorption from the walls) with its on-axis resonance layer had a positive effect on $T_e(0)$ as shown in Fig. 3 but a negative one on the H/D MCL that could not appear due either due to the He^3 heating taking most of the available power or due to the plasma composition that had moved the hybrid resonance layer too far into the low field side (LFS) in the direction of the hydrogen resonance layer. Deuterium heating in

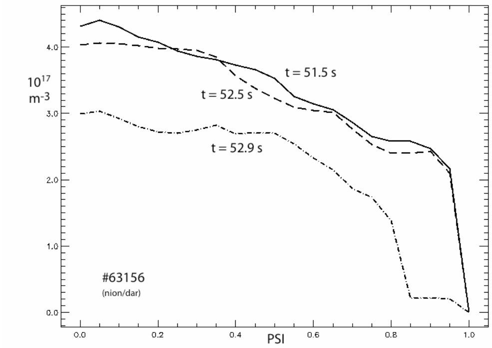

Fig. 5 : Ar profile for pulse #63156 before, during and after icrh notch.

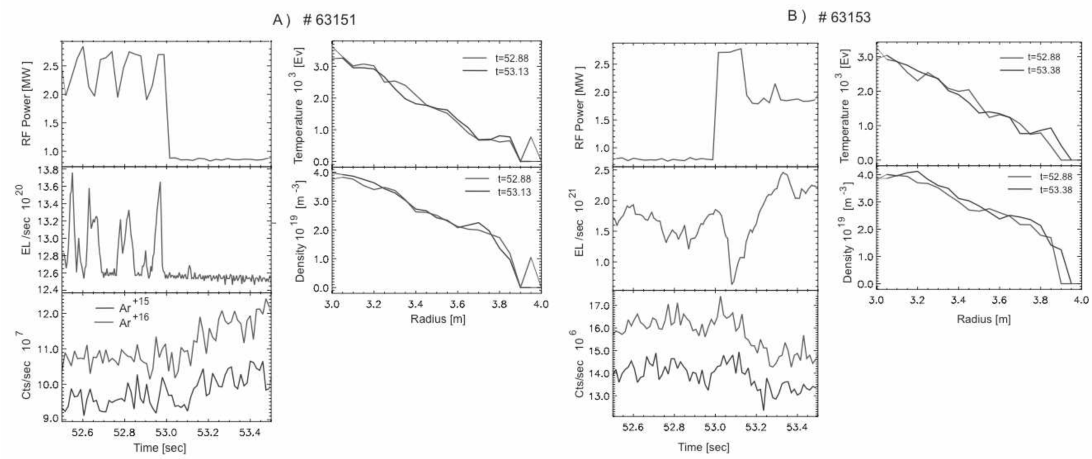

Fig. 6: A comparison of shots #63151(-pi/2) and #63153 (+pi/2): no recognizable pinch effect.

the HFS may be responsible for some of the asymmetry in the temperature profile. The hollow temperature profile forming during the RF notch does not appear to be related to the sawtooth activity (no periodicity found) or to a radiation cooling effect (see Fig. 4) since the Te profile is unchanged in the region where the radiation drops. The effect of RF on the reconstructed Ar profile is shown in Fig. 5. The largest reduction in Ar density is observed for shot #63156 (Highest H2 concentration and Ar injection well controlled by the RTC) at the

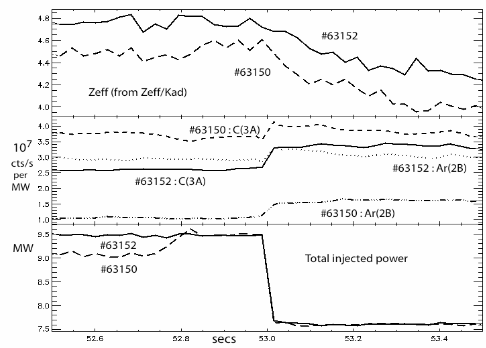

Fig. 7 : Carbon emission compared to the Ar emission for same input power but different Ar injection rates.

end of the ICRH notch. A second effect is noticeable on shot #63151: at constant Ar injection rate the Ar radiation increases during the reduced RF power phase (see Fig. 6). As an attempt to study this effect, Z_{eff}, the C and Ar emissions per unit injected power (LHCD+NBI+ICRH) are compared for shots #63150 and #63152 (Z_{eff} is the highest in this discharge) in the stationary phase at the time right before the ICRH notch starting at time t = 53 s, where the total injected power are equal for both pulses. The comparison is shown in Fig. 7. For shot #63150, Ar = 1.1 10^7 cts/s/unit power, C = 3.8 10^7 cts/s/unit power and Z_{eff} = 4.5 at low H concentration while for shot #63152, Ar = 2.7 10^7 ct/s/unit power, C=3.0 10^7 ct/s/unit power for Z_{eff} = 4.8 at higher H concentration. There might thus be here a change in plasma behavior leading to different Z_{eff} with reduction of C emission for predetermined larger Ar emission (from RTC setup).

3. Numerical simulations

To allow for ICRF impurity heating the RITM transport code [2] has been modified [5]. It now includes a contribution to the particle flux arising from a direct effect of ICRF (for the case of asymmetric antenna spectrum at the second harmonic resonance) [4]. Simulations show that the increase in argon emissivity could be due to a competition between the following processes: a) change in ITG diffusion transport coefficient (as suggested by the hollow electron temperature profile), b) pure atomic processes as ionization or recombination following changes in electron temperature and density. More detailed absorbed power profiles are needed to perform realistic RITM simulations.

4. Conclusions

Contamination of the plasma by He atoms either eliminated the H/D mode conversion layer or had moved it too far into the LFS to be acting on the argon. Since, no mode conversion layer is observed at the Ar^{16+} most probable position the analysis of the experiment can be performed as for a pure second harmonic heating with no dependence on the RF phasing (Fig. 6). A change in Ar^{16+} emissivity of about 10-15% is observed.

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