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HYDROGEN AND DEUTERIUM PELLET INJECTION INTO OHMICALLY AND ADDITIONALLY ECR-HEATED TFR PLASMAS

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Communication présentée à : 14. European conference on controlled fusion and plasma physics
Madrid (Spain)
22-26 Jun 1987

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HYDROGEN AND DEUTERIUM PELLET INJECTION INTO OHMICALLY AND ADDITIONALLY ECR-HEATED TFR PLASMAS

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ABSTRACT :

The ablation clouds of hydrogen and deuterium pellets injected into ohmically and electron cyclotron resonance heated (ECRH) plasmas of the Fontenay-aux-Roses tokamak TFR have been photographed, their emission has been measured photoelectrically. Without ECRH the pellets penetrate deeply into the plasma, the clouds are striated. Injection during ECRH leads to ablation in the outer plasma region. The position of the ECR layer has no influence on the penetration depth which is only a few centimeters. The ablation clouds show no particular structure when ECRH is applied.

EXPERIMENTAL SET-UP

Single solid hydrogen and deuterium pellets were injected into TFR plasmas (major radius $R_o = 0.98$ m, plasma radius $a \sim 0.18$ m) using a pneumatic pellet injector constructed by the SBT CEA Grenoble. The pellet velocities were $v_p \simeq 700$ m/s. $1.3.10^{19}$ atoms per pellet were on the average deposited in the plasma. The pellets were injected in radial direction, the pellet trajectory was observed under an oblique angle $\beta(r)$ with respect to the injection plane, see figure 1. The $H_\beta(D_\beta)$ emission was measured simultaneously by means of a photomultiplier connected to a fast acquisition device.

The electron cyclotron waves of frequency $\nu = 60$ GHz were launched by wave guide antennas placed in the equatorial plane at torus ports opposite to the pellet injection port.

The experiments were carried out under the following conditions : plasma current $I_p \simeq 110$ kA, toroidal magnetic field induction $B_\phi = 2.1$ to 2.4 T corresponding to $r = -1$ to $+11.6$ cm for the position of the resonance layer relative to the center ($r = o$) of the torus chamber. The mean electron density was $\langle n_e \rangle \simeq 1.2.10^{19}$ m^{-3}, the ohmic power $\simeq 150$ kW without ECRH. Additional ECRH was provided by three gyratrons, with 150 kW/gyratron absorbed power in the plasma. During ECRH the ohmic power decreased to a level of appr. 80 to 90 kW. All measurements were carried out during the current plateau of the discharge. The plasma column showed generally strong horizontal displacements five to ten milliseconds after injection of a first pellet. It was therefore not possible to make reproducible multi-pellet injection experiments for these particular plasma parameters.

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RESULTS

1. Injection into ohmically heated plasmas

The time-integrated photographic pictures of the ablation clouds show bright and dark zones (striations) when a pellet is injected into only ohmically heated plasmas (figure 2a and Ref. [1]). The variation of emission along a pellet trajectory is also seen on the photomultiplier H_β signals (so-called ablation profile). Figure 3 shows an ablation profile $I(H_\beta)$ placed at the correct radial position. Also shown is the Abel-inverted radial electron density profile $n_e(r)$ immediately after pellet injection. In the present series of experiments an average penetration depth of $L_p \simeq 12$ cm was measured. The pellets did not reach the q = 1 surface situated at appr. r=4.5cm. The positions of the striations were note reproducible.

2. Injection into ECR heated plasmas

The ablation changes drastically when the pellet is injected during ECRH. Ablation takes place in the very outer region of the plasma column. Time-integrated photographies show no striations, see figure 2b. The visible emission extends in toroidal direction over the whole region covered by the optical device (appr. 25 cm). (In contrast to this, undoped pellets have for injection into only ohmically heated plasmas a toroidal extension of only a few centimeters [1,2]). The photomultiplier signals exhibit no special structure either. Figures 4 and 5 show for two different positions of the ECR layer the H_β ablation profile and the n_e profile. Figure 6 gives the position of the ablation maximum as a function of the position of the ECR layer. The latter has practically no influence on the pellet penetration depth which has on the average a value of $L_p \simeq 4$ to 5 cm. Also the number of applied gyrotrons does practically not affect L_p.

The reduced penetration of the pellet into the plasma during ECRH is possibly due to the presence of suprathermal electrons entering deeply into the pellet thus causing precocious evaporation. A similar effect has been seen during lower-hybrid wave heating [3].

The large toroidal extension of the ablation clouds is probably due to the long ionization time in the outer plasma region compared to the diffusion time of the neutral gaz.

On the basis of these experiments one cannot exclude difficulties in pellet fueling during LH current drive assisted by ECR waves and during powerful ECR heating.

ACKNOWLEDGEMENT

We thank the ECRH team of the FOM-Instituut voor Plasmafysica "Rijnhuizen", The Netherlands, for having ensured the ECR-heating during our pellet injection experiments.

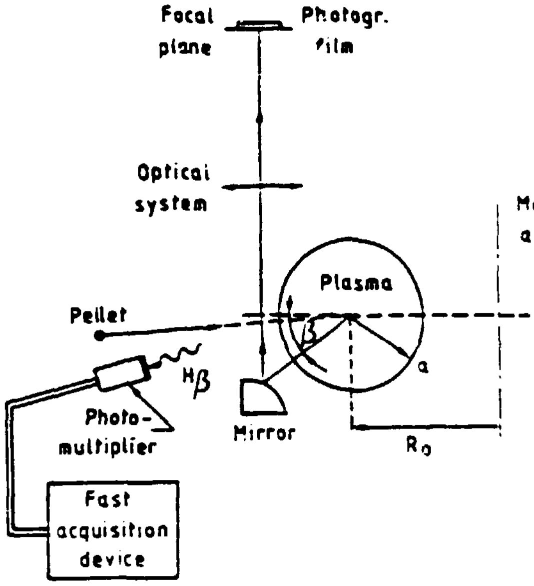

Fig. 1 - Optical measuring system

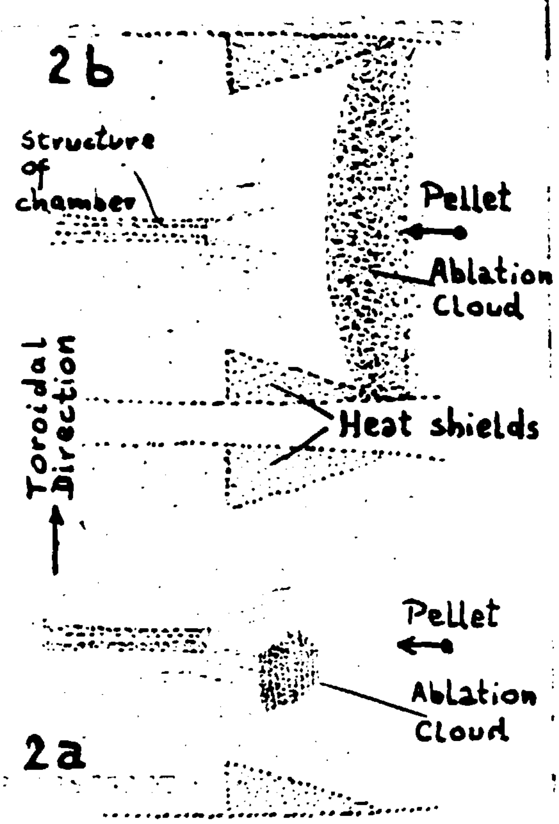

Fig. 2 - Schematic presentation of photographies showing undoped pellet ablation clouds in the TFR chamber.
a. Injection into ohmically heated plasmas
b. Injection into ECR-heated plasmas

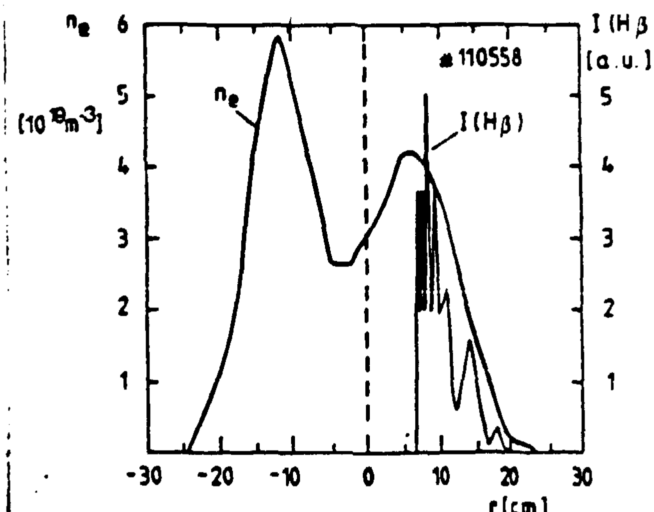

Fig. 3 - Intensity $I(H_\beta)$ of H_β ablation profile and radial n_e profile for injection into ohmically heated plasma.

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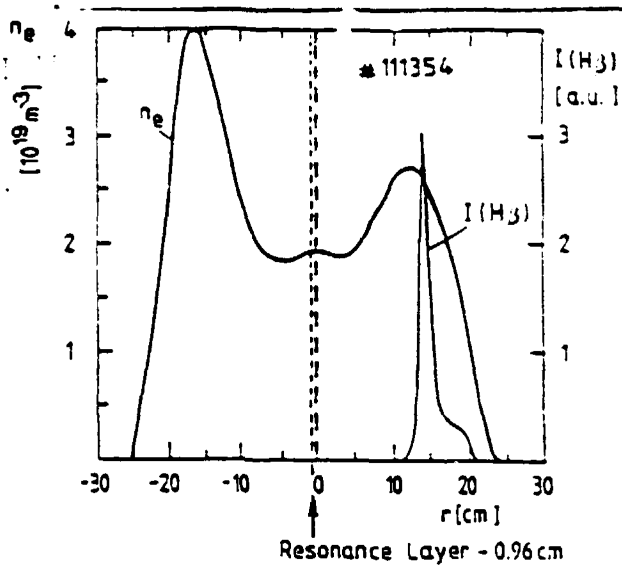

Fig. 4 - As figure 3 but for injection into ECRH plasma. Resonance layer at -0.96 cm.

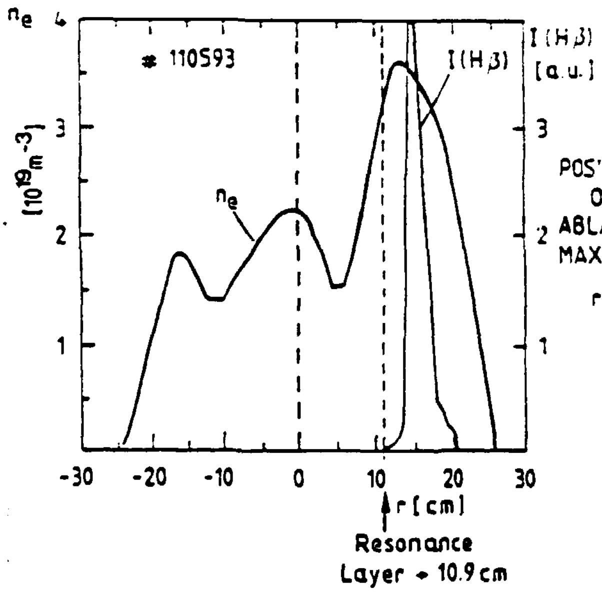

Fig. 5 - As figure 3 but for injection into ECRH plasma. Resonance layer at +10.9 cm.

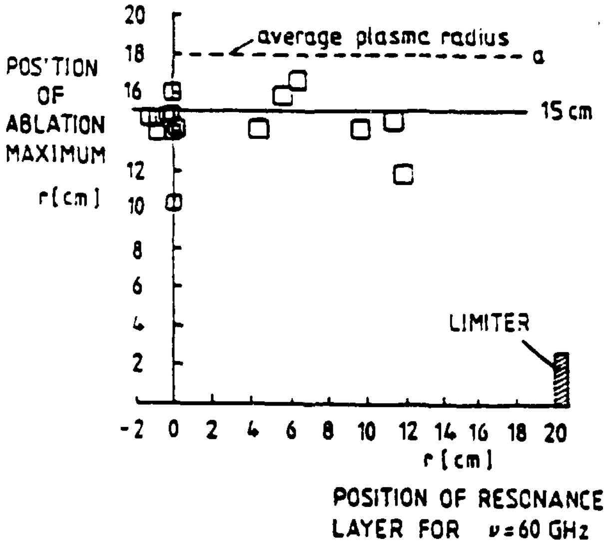

Fig. 6 - Position of the ablation maximum as a function of the position of the resonance layer.

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