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THE EFFECT OF LH WAVE ON THE PERIPHERAL PLASMA OF TM-1-MH TOKAMAK

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The work is devoted to the study of the LH wave effect on the peripheral plasma of the TM-1-MH tokamak. The observed enhancement of the ion saturated current in the limiter shadow is interpreted as heating of the peripheral ions by absorption of decay waves generated in this region due to the nonlinear wave-plasma interaction.

1. INTRODUCTION

As was shown in our previous work [1], the lower hybrid heating efficiency of the plasma core in the tokamak TM-1-MH is relatively low. One reason for that is probably the application of a loop coupler as a wave-launching element. Due to the small front dimensions of this loop ($4 \times 1{\cdot}5$ cm) a very high power flow density is obtained in its near vicinity, which creates favourable conditions for the highly nonlinear wave-plasma interaction in the plasma periphery. As was shown in [1], this interaction is accompanied by the generation of L.F. and H.F. spectra (measured by means of the electrical probe in the limiter shadow). We have supposed that these decay spectra are produced by parametric instabilities.

In this paper the effect of the LH wave on the peripheral plasma of the TM-1-MH tokamak is described. It has been found that HF power manifests the greatest influence on the saturated ion current collected by the langmuir probe in the limiter shadow. During the HF pulse the saturated current is enhanced and this enhancement has a local character with an expressive maximum in the layer with a density of about 5×10^{18} m^{-3}. These experimental results are given in section 2; in section 3 we discuss a possible explanation of these results.

2. EXPERIMENTAL RESULTS

The parameters of the TM-1-MH tokamak are as follows: $R = 0{\cdot}4$ m, $a = 0{\cdot}075$ m, $B_0 = 1{\cdot}3$ T, $I_p = 16$ kA, hydrogen. HF power up to 70 kW at a frequency of 616 MHz has been delivered into the tokamak by means of a loop coupler fed by a coaxial line. The loop is made of titanium and is placed in the limiter shadow, see fig. 1. The probe measurements [2] were carried out by means of a langmuir probe, movable perpendicularly to the toroidal magnetic field in the same cross section as that in which the loop coupler is placed (see fig. 1 as well). The pulse gas puffing by means of which the average density is chosen is placed in this cross section as well.

The main time characteristics of tokamak TM-1-MH discharge are given in fig. 2: loop voltage U_{loop}, plasma current I_p and central plasma density $n(0)$, evaluated from data of a 4 mm interferometer under the assumption of a parabolic profile. At the same time the time dependences of the ion saturated current taken for two positions of the probe – in the shadow (r = 89 mm) and slightly out of the shadow (r = = 72 mm) of the limiter – are shown in the same figure. The full lines correspond

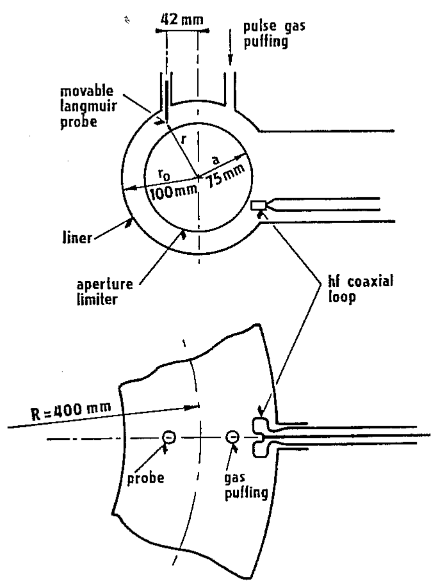

Fig. 1. TM-1-MH side and partial top views showing the location of the langmuir probe, pulse gas puffing and coaxial exciting loop.

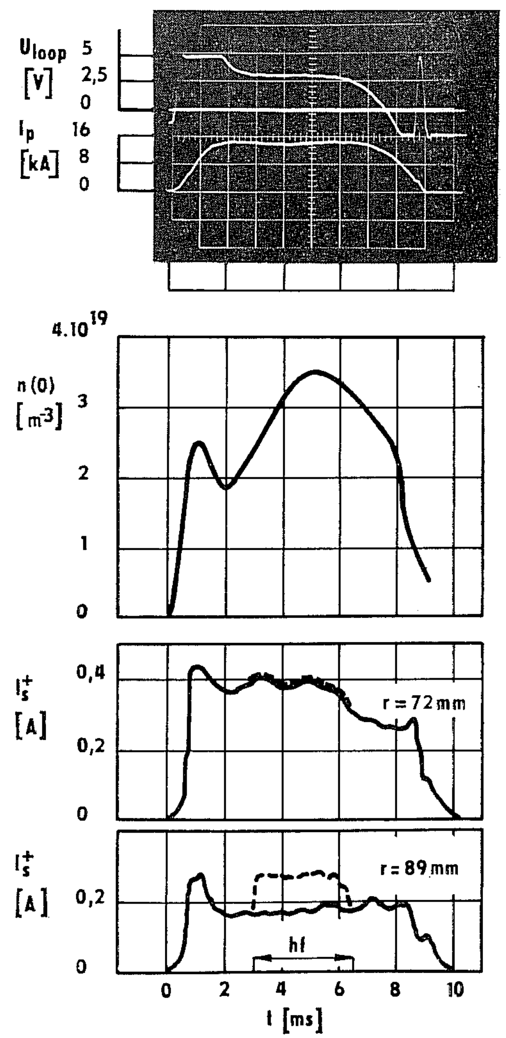

Fig. 2. Time dependences of the loop voltage, plasma current, central electron density and ion saturated current for two probe position.

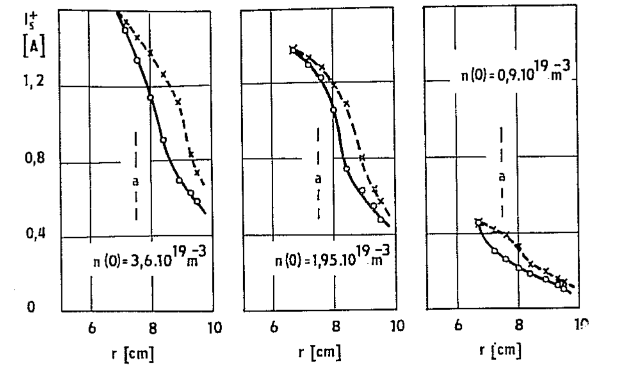

Fig. 3.

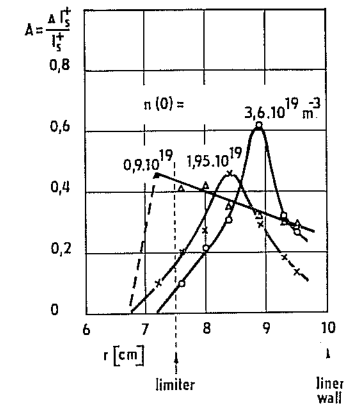

Fig. 4.

Fig. 3. Radial profiles of ion saturated current in the limiter shadow for three values of central electron density $n(0)$.

Fig. 4. Radial profiles of the relative increase of ion saturated current in the limiter shadow for the values of central electron density shown in fig. 3.

to the ohmic heating regime, the dashed lines to the case with additional HF heating. The next figure 3 shows the results of the profile measurements of the ion saturated current for three values of central density $n(0)$ in detail. Again, the full lines concern the case without HF power, the dashed lines the case when the HF pulse is applied. As it is possible to take the relative increase of the ion saturated current $A = \Delta I_s^+ / I_s^+$ as a measure of the plasma-wave interaction, we show this quantity in fig. 4 separately. It may be clearly seen that this interaction has a maximum on certain radius in the limiter shadow (an exception is the case with the smallest density; in this case no maximum was observed). If we look back to fig. 3, we can see that both maxima occur at a radius corresponding in the ohmic regime to the same value of the ion saturated current, approximately 0·7 A. This value of the ion saturated current gives a plasma density of about $5 \times 10^{18}\ \text{m}^{-3}$, see [2]. In the third case such a value of density does not occur in the periphery plasma and so no maximum on the ion saturated current could be observed. The necessity of such density for a maximum HF effect can hardly be explained by the linear theory of the cold lower hybrid resonance because the resonant density is nearly four times higher under our conditions.

3. DISCUSSION OF RESULTS

The increase of the saturated ion current observed during the HF pulse at the periphery can be explained by some effects as follows:

1) The increase of the electron temperature or density due to direct local absorption of the pump wave. The langmuir probe measurements, however, have not

proved any measurable increase of the electron temperature. The additional ionization in the limiter shadow should be negligible, see e.g. [3].

2) Another possible explanation of the heating of the ions in the plasma layer with a density of $5 \times 10^{18}\ \mathrm{m}^{-3}$ is the resonant absorption of the down-shifted decay LH waves generated in the plasma by the high pump power. The LH resonance at this density takes place at a frequency of approximately 400 MHz, which has been observed in the measured decay spectra [1].

3) The heating of ions in the peripheral layer by non-linearly generated ion-sound and/or ion cyclotron waves (10–30 MHz) cannot be excluded. Such low frequency waves have been also observed in our measured spectra at the plasma periphery by HF coaxial probes [1]. These frequencies can be generated locally at the periphery by non-linear interaction of the pump wave with a plasma [1, 4, 5].

As the electron temperature in the limiter shadow in the absence of HF power is approximately $T_e \cong 25$ eV according to probe measurements [2], we can estimate the ion temperature increase ΔT_i which is needed for the ion current increase observed as $\Delta T_i \cong 40$ eV [6]. However, at this enhanced ion temperature the collecting surface of the probe is enlarged in comparison with the plane probe theory under which the probe measurements are usually enumerated. This effect can also contribute to the observed increase of the ion saturated current. But this third mechanism does not explain directly the localization of the observed effect at a layer of a constant density of $5 \times 10^{18}\ \mathrm{m}^{-3}$ and for its validity would be necessary to prove the local character of nonlinear wave-plasma interaction generating the L.F. spectra.

4. CONCLUSIONS

The detailed study of the supplementary ionization and/or heating of the plasma layer in the limiter shadow has been undertaken as a preliminary study of the plasma diffusion at the periphery of a small tokamak during the LH heating experiment. The problem is relevant to the exact determination of the LH heating efficiency. Some possible mechanism of the measured effect has been proposed and discussed, but more detailed measurements with small coaxially shielded probes are still needed. This will be the object of a further study.

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