

INVESTIGATION OF THE PLASMA PERIPHERY IN SPONTANEOUS AND BIASED H-MODE ON TOKAMAK T-10.

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1. Introduction.

Since the first H-mode produced by neutral beam injection in ASDEX [1] H-mode has been induced by means of other method of auxiliary heating [2] and different biasing schemes [3] in many tokamaks.

The regimes with the improved plasma confinement (H-mode) are observed on T-10 at an auxiliary electron-cyclotron resonant heating (ECRH) [4]. These regimes are characterised by abrupt changes of SOL plasma parameters which begin in time $\sim 5\text{-}30$ ms prior to the transition to H-mode. Recently H-mode has produced by the biased electrode inserted into the edge plasma in T-10. The comparison of plasma behaviour in both regimes is presented here.

2. Experimental setup and plasma parameters.

Experiments were performed in the T-10 tokamak. T-10 has a major radius of $R=1.5$ m, a full poloidal graphite limiter with radius of $a=0.33$ m and a graphite rail limiter inserted in the vacuum chamber through the bottom port of the tokamak. The scheme of the rail limiter is presented in ref. [5]. For the experiments described below the minor plasma radius a_L determined by rail limiter was 0.30 m.

The experiments were performed in deuterium. An average plasma density $\langle n \rangle$ measured along a central chord was in the range $1 \cdot 10^{19} \div 4 \cdot 10^{19} \text{ m}^{-3}$, a toroidal magnetic field induction $B_t = 2.42$ T (this value corresponds to the central ECR heating), a plasma current $I_p = 180 \div 330$ kA. Auxiliary electron-cyclotron heating power P_{aux} produced by gyrotrons was varied from 400 kW to 1200 kW. The ECRH power pulse length was 400 ms. Measurements of the SOL parameters were performed using single probes mounted on rail limiter surface and movable triple probes.

A radial electric field was produced by electrode biasing scheme. The graphite electrode was inserted approximately 2 cm past the rail limiter into the plasma. The applied electrode voltage V_b was in the range $-450 \div +450$ V. Biasing experiments were performed

in regimes with ohmic heating and ECR heating. The ECRH power was under a threshold level of the L-H transition.

3. Experimental results.

At high additional heating power P_{aux} ($P_{\text{aux}} \approx 2P_{\text{th}} \approx 1$ MW, where P_{th} is the threshold power of the L-H transition) transitions to the improved confinement are observed through a time interval of $\Delta t = 50 \div 100$ ms after ECH turn-on. The temporal evolution of plasma parameters in regimes with L-H transition at the central ECR heating ($B_t = 2.42$ T) is shown in Fig.1a. Fig.1b shows the time evolution of plasma parameters in regime with biasing. ECR heating power was a half of P_{th} in this case. Essential rise of plasma density, decrease of D_α emission intensity, increase of storage energy, reduction of edge turbulence are observed in both regimes. Most abrupt changes of plasma parameters are found to occur near to Last Closed Flux Surface (LCFS). At that the plasma behaviour at this region is different in these two regimes.

Abrupt changes of plasma potential profile and positive (directed to the wall) radial electric field (40 V/cm) formation are observed in a shadow of the rail limiter (Fig.2a). The plasma potential U_{pl} was calculated from electron temperature and floating potential measurements. The value of electric field corresponds to the poloidal rotation velocity $V_\theta \approx 10^5$ cm/c. During H-mode the density profile shows steepening. Such changes take place prior to the modification of other plasma parameters (average plasma density, D_α emission and soft X-ray intensity et al.). In Fig.1a left dashed line denotes the SOL parameters changes, right – the core plasma parameters changes. The experimental results allow us to conclude that spontaneous L-H transition is determined by behavior of the peripheral parameters (mainly radial electric field) near to the last closed flux surface.

In the biasing experiments no changes of plasma parameters are observed when the electrode is biased negative. It is probably owing to a small electrode ion current ($I_b < 40$ A), that it is not enough to trigger the H-mode. H-mode has only been achieved when the positive voltage is applied to the electrode with respect to the wall. Moreover, more obvious effect takes place in regimes with ECR heating. As against the spontaneous H-mode the biased H-mode is characterised by an absence of a modification of the ion saturation current and the plasma potential gradients in the rail limiter shadow (fig.2b). All changes take place inside of the LCFS.

There is another distinction between the H-modes induced by ECRH and biased

electrode. As known the energy confinement time τ_E in T-10 plasmas depends on density. The τ_E increase in the spontaneous H-mode is associated mainly with the density increase. But the τ_E growth during the biasing is caused by the increase of as the plasma density as the electron and ion temperatures.

4. Conclusions.

Both regimes, spontaneous and biased H-modes, are characterised by the decrease of D_α emission intensity, the rise of average plasma density and soft X-ray intensity, the increase in storage energy, the reduction of edge turbulence. However, the plasma behaviour near the last closed flux surface is different in these two regimes. In regime with spontaneous H-mode the essential changes of plasma parameters are observed outside of the LCFS whereas biased H-mode is characterised by modification plasma parameters gradients inside of the LCFS.

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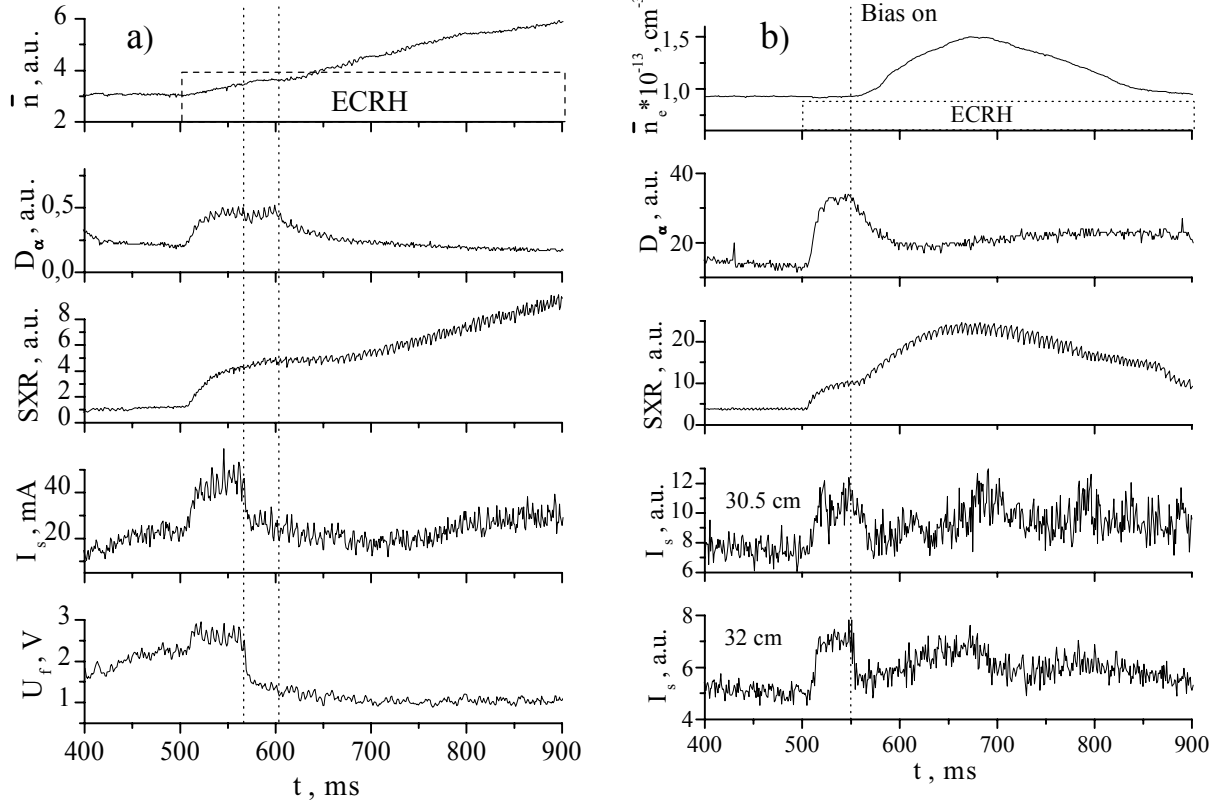


Fig.1 The time evolution of plasma parameters in regimes with L-H transition induced by a) the ECR heating; b) the biased electrode.

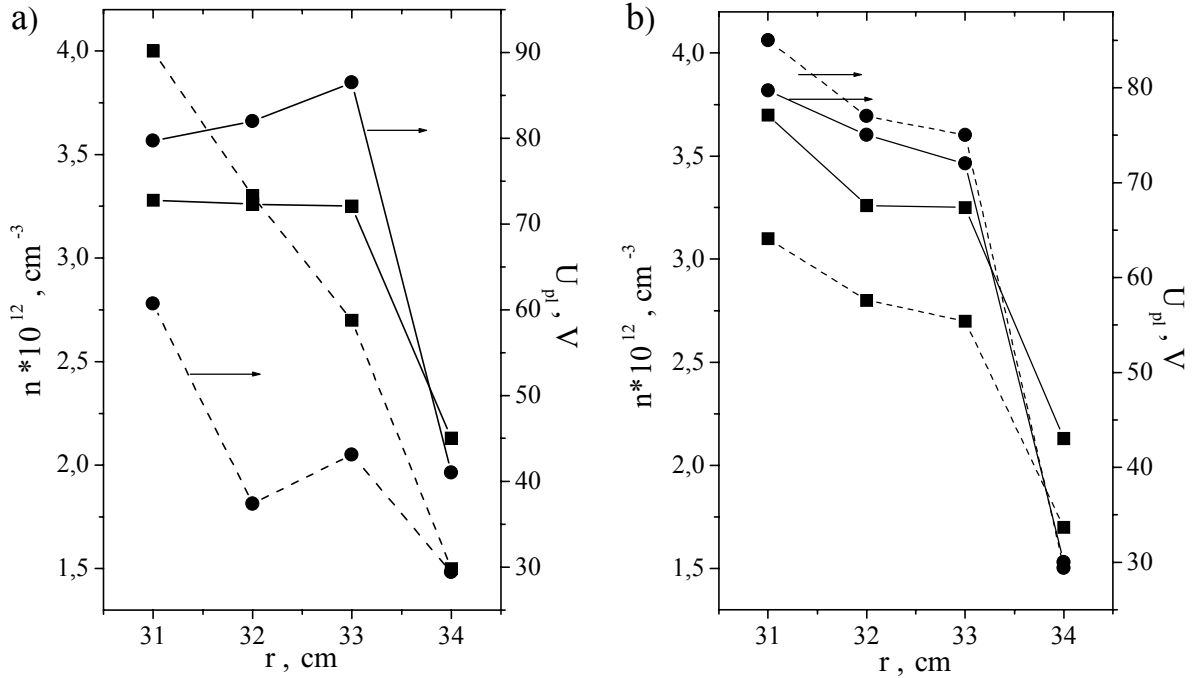


Fig.2. Radial profiles of the plasma potential (circle) and the plasma density (square) in the shadow the rail limiter in H-mode induced by a) the ECR heating; b) the biased electrode (solid line - before transition, dashed line - after transition)