*31st EPS Conference on Plasma Phys. London, 28 June - 2 July 2004 ECA Vol.**28G**, P-4.153 (2004)*

Peripheral radial electric field evolution during the ohmic H-mode transition in the TUMAN-3M tokamak

L.G.Askinazi[1], V.E.Golant[1], V.A.Kornev[1], S.V.Krikunov[1], S.V.Lebedev[1], A.G.Somov[2], A.S.Tukachinsky[1], M.I.Vildjumas[1], N.A.Zhubr[1]

1. Ioffe Insitute, 194021, SPb, Russia
2. SPbPU, 195215, SPb, Russia

The radial electric field is known to play a key role in confinement improvement during the L-H transition. In the recent experiments on TUMAN-3M, central plasma potential was measured using HIBP, and was found to become more negative after the ohmic H-mode transition [1]. However, the potential changed surprisingly slow in these experiments, thus questioning the whole concept of radial electric field influence on the confinement bifurcation. Due to the plasma accesses limitation, the ion beam could not reach the region of peripheral transport barrier in these experiments, so it was proposed to use electrostatic probes to determine the radial electric field behaviour during the H-mode transition. Peripheral plasma in the TUMAN-3M tokamak is not too hot and dense; this allows the probes of proper design and materials to be positioned somewhat inside the last closed flux surface (LCFS) without a risk of damage and plasma contamination.

The experiments described in this paper were performed in typical TUMAN-3M ohmic H-mode shots with plasma parameters as follows: I_p=130kA, B_{tor}=0.7T, $n_{L\text{-mode}}$=1.3 $10^{19}m^{-3}$, $n_{H\text{-mode}}$<4 $10^{19}m^{-3}$. A single poloidal limiter with 4cm depth was located on the LFS of the torus, see Fig. 1a. The probe was mounted at the movable structure which allowed positioning of the probe at different radii in a range r=195…235mm from shot to shot. As a result, in the innermost position probe was 4cm inside the LCFS. The profiles of peripheral plasma parameters (Φ_{float}, T_e, n_e) were obtained moving the probe in a shot-to-shot manner.

Schematic design of the probe is shown in the Fig. 1b. The probe has three molybdenum electrodes. To make the probe more resistant to plasma influence, the pyrolitic boron nitride (BN) was used as a material for probe's insulators. Two electrodes with length difference d=6mm were used for measurement of gradient of the plasma floating potential.

This work is supported by RFBR grant 04-02-17640 and RF President's grant NS-2216.2003.2

The third electrode was used for electron temperature evolution measurement. Then, radial electric field was calculated $E_r = -\nabla\Phi_{float} - 3/e\nabla T_e$. Several techniques was utilized for ∇T_e determination. Initially, it was planned to deduce T_e from I-V characteristic of the single probe. For this purpose, sinusoidal bias 200V/1kHz was applied to the electrode with respect to the vacuum vessel of the tokamak. This method has good spatial resolution, but occurred to have not enough accuracy - manly due to the high level of plasma (density and potential) fluctuations, which did not allow the reliable $T_e(r)$ determination. Moreover, it has not been possible to obtain using this method a temporal behaviour of T_e during the L-H transition - mostly due to the need for temporal averaging over 5 to 10 ms time interval. Alternatively, all three electrodes of the probes were combined in a triple probe circuitry, thus allowing for "real-time" T_e measurement without need for I-V curve analysis. This method was recruited for $T_e(t)$ measurement, although it had obvious disadvantage of poor spatial resolution (since not all three electrodes resided on the same magnetic surface).

Experimentally measured Φ_{float} and T_e profiles before and after ohmic L-H transition are shown in Fig. 2a&b. The position of H-mode heat transport barrier in this scenario is r ~ 150-160mm, whereas particle transport barrier is located somewhat further outwards, at r~190-200mm [2]. Thus, in the innermost probe location r=195mm measurements were carried out outside the heat barrier, but inside the particle barrier. This is why the electron temperature decreases as a result of H-mode transition, see Fig. 3. However, electron temperature gradient remains approximately constant throughout the transition, so the impact of ∇T_e term in total radial electric field $E_r = -\nabla\Phi_{float} - 3/e\nabla T_e$ is not changed due to transition. In total, radial electric field in the innermost probe location changes from slightly positive value $E_r \approx 700$V/m before the L-H transition to rather high negative value $E_r \approx -2000$V/m after the transition. Comparison of $\nabla\Phi_{float}$ and ∇T_e terms in L and H-modes is given in the next table:

	$-\nabla\phi_{float}$	$- 3\nabla T_e$	$E_r = -\nabla\phi_{float} - 3/e\nabla T_e$
L-mode	-530 V/m	1200	670 V/m
H-mode	-3000 V/m	1020	-1980 V/m

Temporal evolution of $\nabla\Phi_{float}$ during the L-H transition is shown in Fig. 3 accompanied by D_α signal. Since ∇T_e term in E_r remains unperturbed, one can conclude that peripheral E_r changes as fast as floating potential gradient does throughout the transition, i.e. with characteristic timescale of ~1ms. The fast change in peripheral E_r complies with theoretical understanding of transport reduction due to the strong sheared radial electric field. On the other hand, it is interesting to compare this to rather slow central potential evolution timescale of ~8ms found using HIBP [1]. These two facts together, namely, fast E_r generation at the edge and slow Φ_{pl} evolution in the centre, may be reconciled only if one assume a potential well formation somewhere in region 0.6<r/a<0.85 just after the L-H transition. Radial electric field changes its sign at the different slopes of the well, so the potential difference between the center and the edge $\Delta\Phi_{pl}=-\int E_r dr$ remains unperturbed. Later on, as plasma density and temperature profiles evolve to a new equilibrium, this potential well gradually disappears, and central potential reacts to the L-H transition with a delay. Note that this hypothetical potential well should exhibit strong dE_r/dr which is beneficial for the turbulence suppression. On the other hand, $E_r \times B_T$ rotation velocity should reverse its poloidal direction across this region. This situation resembles in a way a zonal flow structure known to appear in transport barrier region [3].

References

1. Askinazi L., et al., *AIP Conf. Proc.* V.669, ICPP2002, p.175 (on CD-ROM).
2. S V Lebedev et al., Plasma Phys. Control Fusion **36** (1994) B289-B299.
3. Diamond P H et al., 1998 Plasma Physics and Controlled Nuclear Fusion Research 17th IAEA Fusion Energy Conf. (Yokohama, Japan, 1998) (Vienna: International Atomics Energy Agency) p IAEA-CN-69/TH3/1.

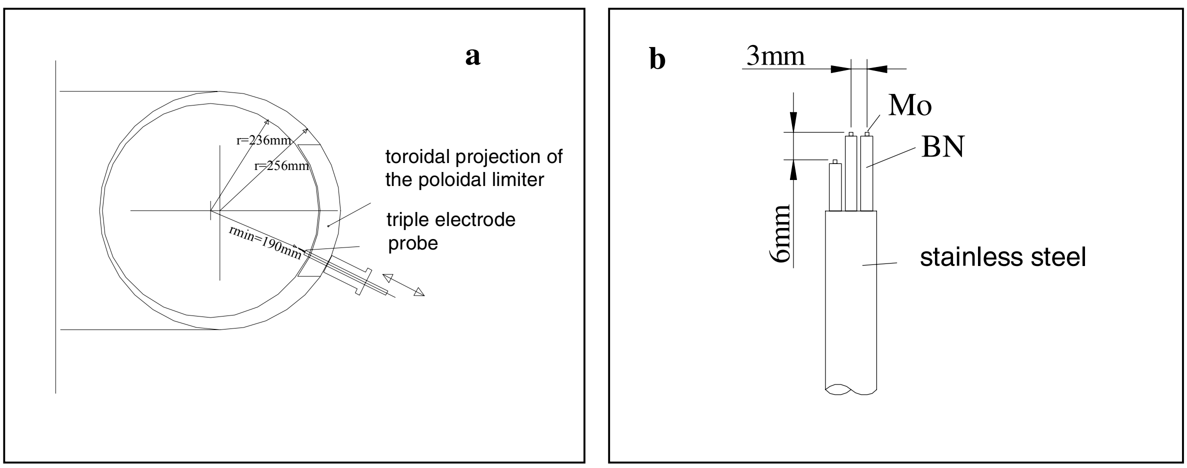

Figure 1. Experimental layout (a) and probe design (b).

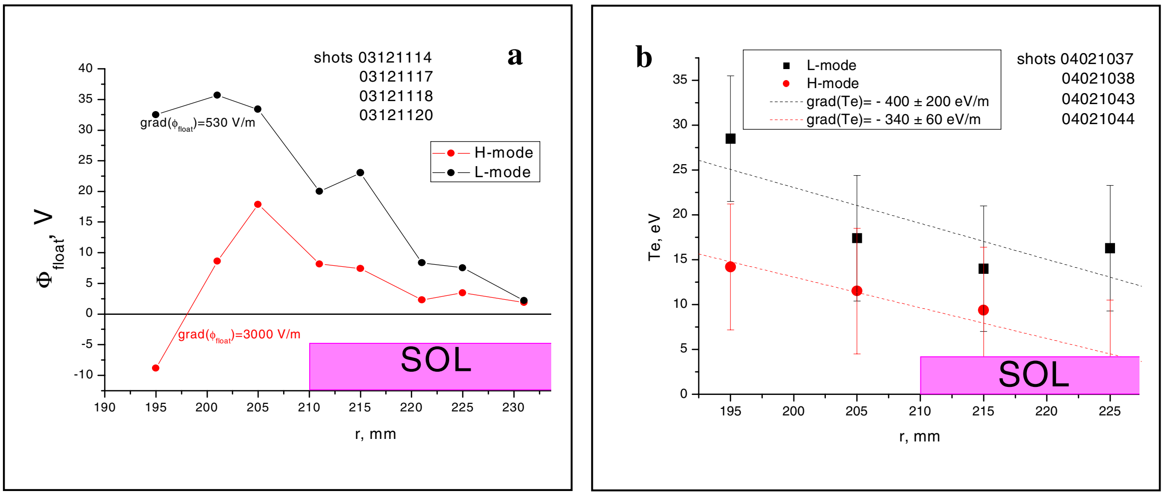

Figure 2. Spatial profiles of (a) floating potential and (b) electron temperature before (black) and after (red) ohmic L-H transition in the TUMAN-3M.

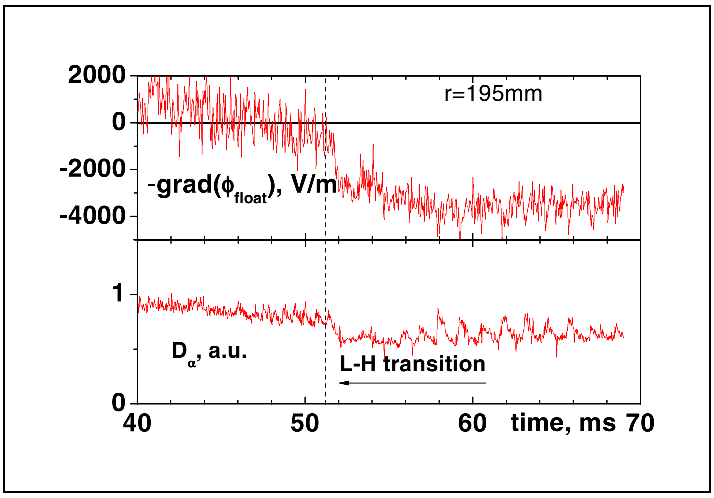

Figure 3. Temporal evolution of the floating potential during the ohmic L-H transition.