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REDUCTION OF THE RF DISCHARGE PLASMA TRANSPORT IN THE U - 3M TORSATRON DUE TO E×B SHEARED ROTATION IN THE VICINITY OF RATIONAL MAGNETIC SURFACES

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1. Introduction

There are some publications [1,2,3] with indications that the formation of internal transport barriers (ITB) in toroidal devices could take place in the vicinity of low order rational surfaces (RS). In presented experiment the attempt to realize the formation of such a barrier with high E_r×B velocity shear near of island chains with t=1/4 and to study its influence on a plasma confinement was undertaken on the Uragan - 3M (U-3M) torsatron. The presupposition was made that the radial electric field profile, $E_r(r)$, in this region will be determined by the increase of a transversal electroconductivity due to a longitudinal motion of electrons in stochastic layers of magnetic field lines near RS. Therefore, the study of the case with sufficient heating power in the region of localization of RS is most interesting for the explanation of ITB formation.

2. Experimental arrangement

Experiments were carried out on the U - 3M torsatron with an open helical divertor (l=3, m=9, R_0=100cm, $\bar{a}_{pl}$=12,5cm) at magnetic field strength B_0=0.7T. The measurements made by the triode and luminescent rod techniques have shown that there is the possibility to realize the magnetic configuration with two chains of islands (t=1/4) which are located in the region of small magnetic shear [4]. Such a configuration takes place at the ratio of vertical magnetic field to longitudinal one $B_\perp/B_0$=1.25%. The outside shift of the magnetic axis from the geometrical axis of helical coils equals to 5.5cm in this case (Fig.1). The frame type antenna was used for RF plasma production and heating in the ion cyclotron range of frequencies (f=8,8MHz, $P_{RF} \le$ 200kW) to provide a sufficient heating power in the region of localization of island chains. Numerical simulations have shown that Alfven waves excited by this antenna absorb at the external part of a plasma column $\bar{r}/\bar{a}_{pl} > 0{,}5$

where RS are located [5]. The multichannel microwave interferometry (λ=2÷8mm) and reflectometry (λ=8÷17mm) were used for the radial density profile reconstruction. The density fluctuation (f=10÷40 kHz) level, δn/n, was estimated from reflected signal phase fluctuations measured by the cross - detection technique. Radial distributions of radial wave numbers, k_r, and the poloidal rotation velocity of plasma, V_θ, were measured by means of the dual - polarization radial correlation reflectometry and the poloidal correlation reflectometry. The radial distribution of electron temperature, $T_e(r)$, was obtained from the data of ECE measurements. The central ion temperature, $T_i(0)$, was measured with the use of NPA. The diamagnetic and saddle type coils were used for the plasma energy content $\overline{nT}$, measurements. The bootstrap current, I_{bs}, measured by Rogovski coil.

3. Experimental results

The transition to the improved plasma confinement regime was observed in the U - 3M with the island magnetic configuration at P_{RF} >140 kW. It was shown that the transition moves to the beginning of the discharge with the increase of P_{RF} (Fig. 2). The decrease of δn/n, fast changes of V_θ and E_r and the widening of n_e (r) were observed in the process of the transition (Fig. 3). The time evolution of plasma parameters in the presence of such a transition is shown in Fig. 4. The transition accompanied by the increase of $\overline{n}_e$, T_e, I_{bs}, $\overline{nT}$ and CV intensity. It is necessary to note that the transition stars when T_e in the region of RS is sufficient to satisfy the condition $\upsilon_{Te}/\nu_{ei} >> 2\pi R_0$ (here υ_{Te} is electron thermal velocity and ν_{ei} is the frequency of ion - electron collisions)

It was shown that after the transition radial distributions of $T_e(r)$ and $V_\theta(r)$ have some peculiarities in the region of RS. In particular, the non - monotonous distribution of $T_e(r)$ took place after the transition (Fig. 5). High plasma poloidal rotation velocity shear was detected in the vicinity of RS (Fig. 6). The radial electric field distribution $E_r(r)$ was calculated from $T_e(r)$, $n_e(r)$ and $V_\theta(r)$ using the force balance equation: $E_r = (Z_i e n_i)^{-1} \nabla P_i - V_\theta B_0 + V_T B_\theta$ in the presupposition $V_T B_\theta = 0$ (Fig. 7).

It is seen that the sharp decrease of E_r takes place in the vicinity of island chains. The observed maxima of k_r are located in the same region (Fig. 8). The plasma with $\overline{n_e} \cong 2 \cdot 10^{12} cm^{-3}$ and $T_e \cong T_i \cong (300 \div 400)$ eV could be maintained after the transition in the improved confinement regime during the whole duration of RF discharge with out any disturbances ($\Delta t \cong 50\tau_E$, $\tau_E \cong 1$ms).

4. Conclusion

It is shown that there is the possibility of ITB formation in the vicinity of RS in a torsatron magnetic configuration. The formation of ITB is accompanied by fast changes of V_θ, E_r and dE_r/dr and the decrease of $\delta n/n$. After the ITB formation the transition to the improved plasma confinement takes place. The transition starts when T_e in the region of rational surfaces is sufficient to satisfy the condition $\upsilon_{Te}/\nu_{ei} >> 2\pi R$. Such a regime can be maintained during the whole duration of RF discharge without any disturbances.

References

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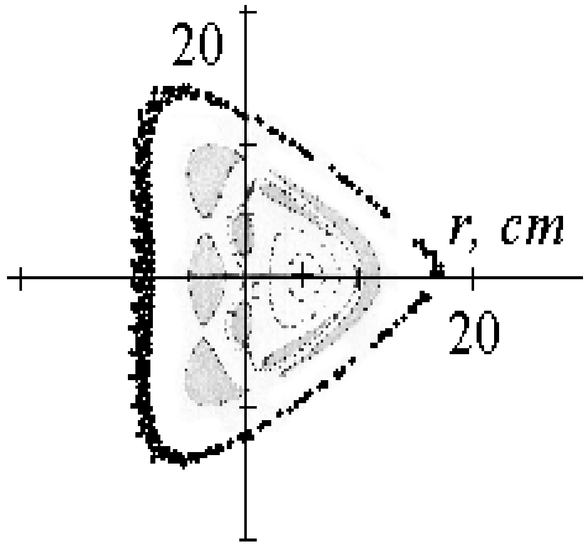

Fig.1 The magnetic configuration of the U-3M torsatron in the cross-section symmetric relative to the middle plane of the torus. The cross indicates the position of the magnetic configuration axis.

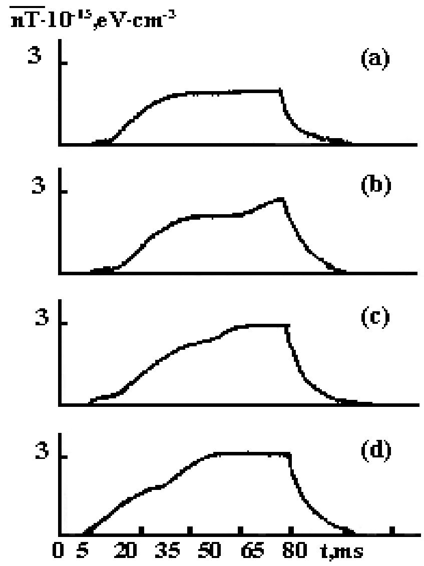

Fig.2 Time evolution of $\overline{nT}$ for discharges with the different P_{RF} . (a) - 120 kW,(b) - 140 kW, (c) - 170 kW, (d) - 220 kW

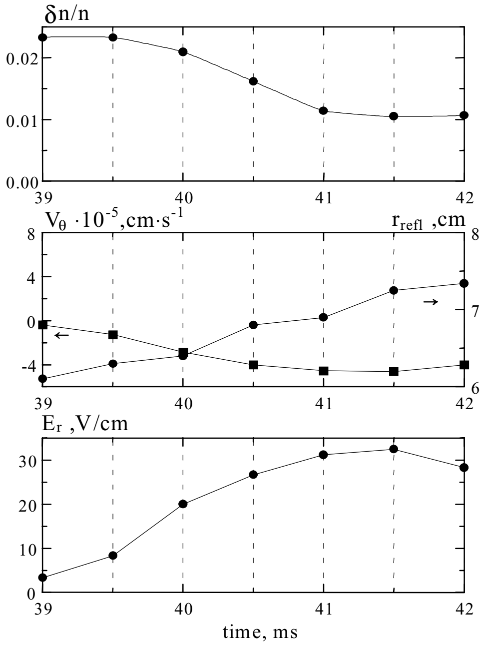

Fig. 3

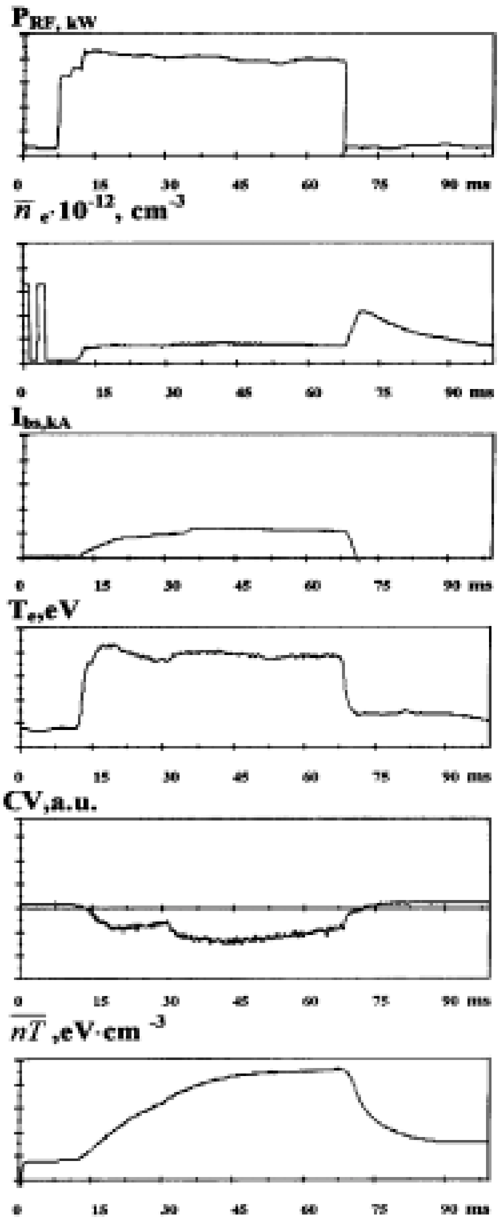

Fig. 4

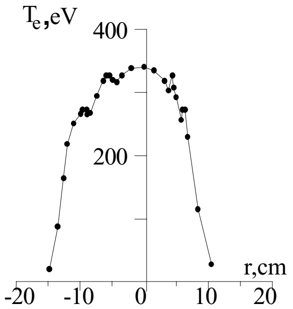

Fig. 5

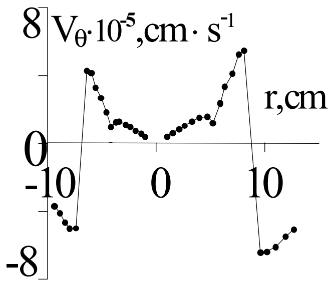

Fig. 6

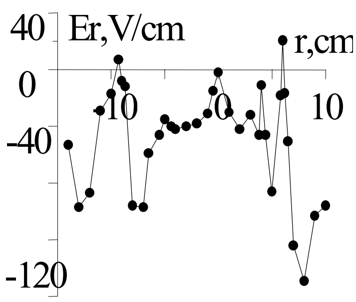

Fig. 7

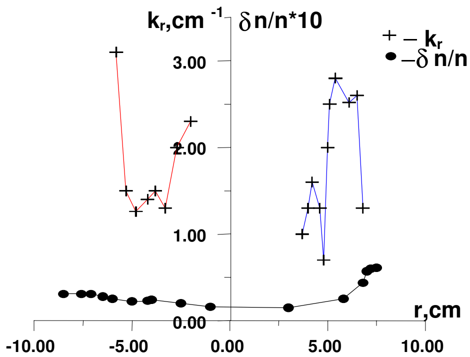

Fig. 8