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EDGE FLUCTUATIONS AND TRANSPORT IN THE TJ-II STELLARATOR

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INTRODUCTION

The importance of the ExB sheared flows in explaining the formation of transport barriers and the transition to improved confinement has been widely demonstrated [1 and references therein]. As a consequence, the development of methods to control the generation of sheared ExB flows is considered a key issue to reduce plasma turbulence and to optimise plasmas confinement. [2, 3 and references therein]. It has been observed that transport barriers in toroidal magnetically confined plasmas tend to be linked to regions of unique magnetic topology such as the location of a minimum in the safety factor, rational q surfaces or the boundary between closed and open flux surfaces. In particular, the radial location of rational surfaces in the plasma appears to be important to determine the generation of internal transport barriers [5, 6]. Recent experimental results have shown the possible influence of low mode island in the formation of edge thermal transport barriers [7].

An increased level of fluctuations has been observed in the proximity of rational surfaces [8]. This increase might tend to deteriorate confinement as suggested by the correlation between energy confinement and the presence of low order rational surfaces at the plasma boundary in W7-AS stellarator.

On the other hand, experimental evidence of ExB sheared flows linked to rational surfaces has been obtained in the plasma edge region of the TJ-II stellarator [9]. If the generation of E×B sheared flows linked to rational surfaces reaches a critical value, this might be beneficial for transport [10].

RESULTS AND DISCUSSION

TJ-II is a four period, low magnetic shear stellarator of the Heliac type with an average major radius of 1.5, average minor radius of ≤ 0.22 m and magnetic field $B_0 \leq 1.2$ T [11]. The rotational transform and the magnetic well depth can be varied in TJ-II over a wide range. Hydrogen plasmas were obtained using ECR heating ($P_{ECRH} \leq 600$ kW) with a pulse length of Δt ≤ 250 ms. Vacuum calculations predict the existence of different rational surfaces at given radial locations, for the magnetic configurations available in TJ-II. The operational flexibility of the device allows magnetic configuration scan, resulting in the motion of the rational surfaces from the scrape-off-layer to the inner plasma.

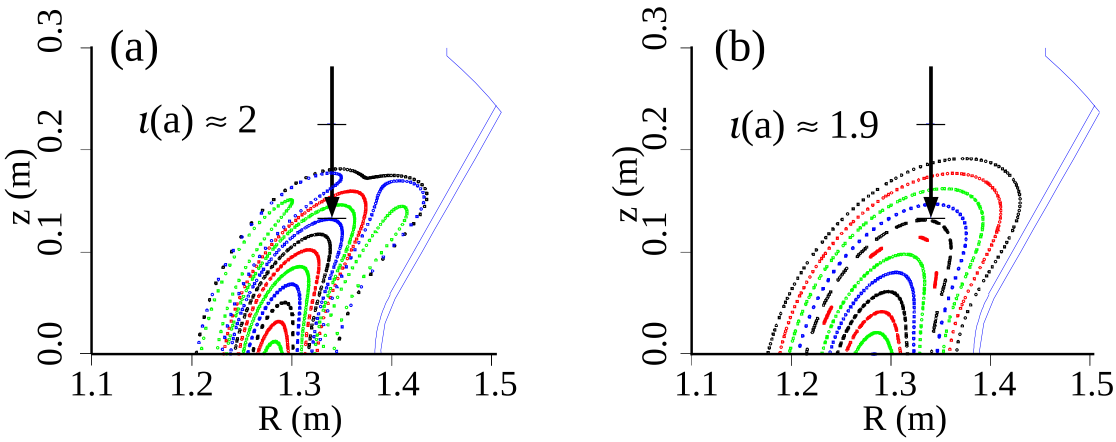

Fig. 1.- Diagram of the magnetic surfaces for two similar configurations: (a) having the 4/2 rational surface located at the plasma edge and (b) not having any low order rational surfaces in the probe measurement area.

Radial profiles and fluctuations of the ion saturation current and floating potential, as well as electron temperature, have been measured in a single plasma shot of the TJ-II using a fast movable Langmuir probe. Profiles have been obtained from the plasma scrape-off layer up to 3 cm inside the last closed magnetic surface (predicted by vacuum magnetic field calculations) for different magnetic configurations, both with rational surfaces present at the edge or free of them. Measurements have been taken in the proximity of the n = 8/m = 5 (ι≈1.6) and n = 4/m = 2 (ι≈2) plasma resonant surfaces, located near the plasma boundary for different magnetic configurations of TJ-II. Figure 1 shows a diagram of the magnetic surfaces for two similar configurations one with the 4/2 rational surface located in the plasma edge and the other without low order rational surfaces in the probe measurement area. The arrows show the position and the approximate fast reciprocating trajectory of the probe.

The presence of the 8/5 and 4/2 rational surfaces, predicted by vacuum magnetic field calculations, have been observed as a flattening in the edge profiles. Figure 2 shows the radial profiles of the ion saturation current, floating potential and r.m.s. of the floating potential measured both when in the 4/2 rational surface was present in plasme edge and when it was not. Strong changes in the profiles are observed close to the theoretically predicted location of this singular surface, as was previously reported for a configuration in which another rational surface (i.e. 8/5) was present [9]. A modification in the root mean squared (r.m.s.) value of fluctuations of the floating potential is observed in the proximity of the 4/2 rational surface. Figure 3 shows the radial profiles of the coherency between the floating potential signals measured by poloidally

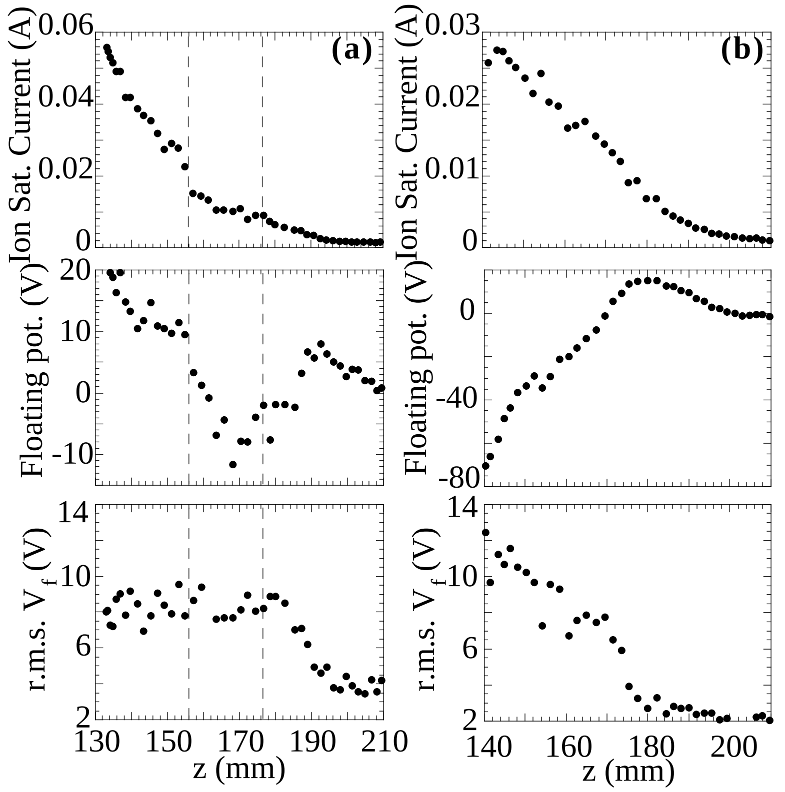

Fig. 2.- Radial profiles of the ion saturation current, floating potential and r.m.s. of the floating potential measured when the 4/2 rational surface was present in the plasma edge region (a) and when it was not (b).

separated probes and the deduced poloidal phase velocity of fluctuations. The poloidal coherency of floating potential fluctuations and the poloidal phase velocity of fluctuations also show radial changes close to the location of the 4/2 rational surface. These modifications can be explained in terms of the influence of the ExB velocity shear and due to the influence of other decorrelation effects. Changes in the shear of ExB flows have been observed near the rational surfaces with values of the decorrelation shearing rate of B^{-1} dEr/dr ≈ 10^5 s^{-1}. The measured radial electric fields are around 10^3 V/m and the poloidal phase velocity of the fluctuations is about 500 m/s. The auto-correlation time of fluctuations is in the range τ ≈ 3-15 µs, showing a significant radial variation and changes in the proximity of the rational surface location. The resulting ExB decorrelation shearing rate is comparable to 1/τ .

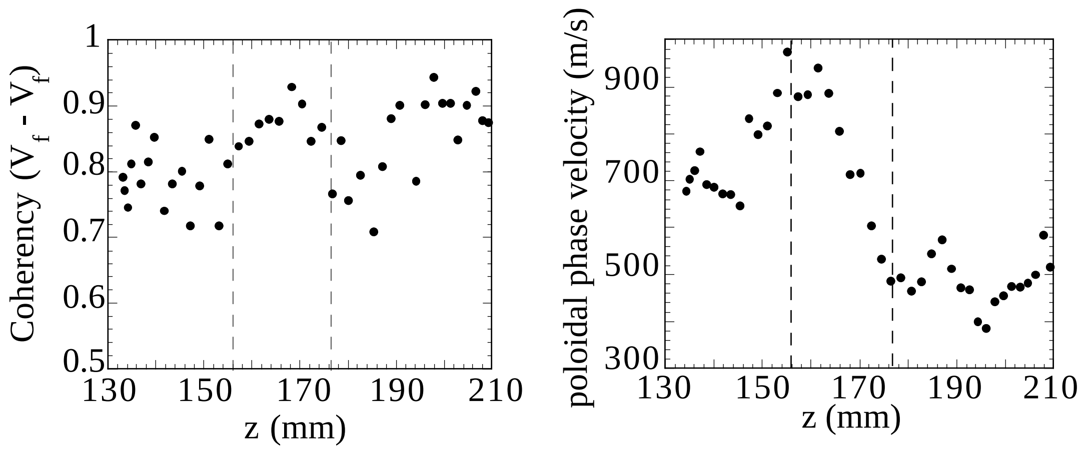

Fig. 3.- Radial profiles of the coherency between the floating potentials measured by poloidally separated probes and the poloidal phase velocity of fluctuations in the presence of the 4/2 rational surface.

At least two mechanisms should be considered for the generation of ExB flows at resonant surfaces: ExB flows driven by non-ambipolar fluxes created in the vicinity of rational surfaces and ExB sheared flows driven by fluctuations via Reynolds stress. A theoretical study of the influence of rational surfaces on turbulence has been carried out for conditions close to those of TJ-II, in terms of the rational surface induced anisotropy and radial non-uniformity in the structure of turbulence. To study the effect of the presence of the magnetic island, associated to the rational surface, on flow generation and turbulence, a resistive interchange model in cylindrical geometry with the rotational transform profile determined by the vacuum magnetic field calculations has been used. The poloidal and toroidal averaged density, and temperature show the flattening caused by the presence of the magnetic island. Another effect of the presence of the vacuum magnetic island is the generation of a global poloidal flow through Reynolds stress. This flow oscillates in time and changes direction in a quasiperiodic manner. The averaged poloidal flow has radial spikes just outside the magnetic island and causes a reduction in the plasma turbulence level.

CONCLUSIONS

In conclusion, the present experiments show evidence of ExB sheared flows linked to rational surfaces in the TJ-II stellarator. The important role of the magnetic topology on transport, in terms of the ExB sheared flows mechanisms linked to rational surfaces has been pointed out. The resulting ExB sheared flows associated to rational surfaces would depend on the competition between the driving and the damping flow mechanisms (i.e. magnetic viscosity, charge exchange damping).

Simulations have shown that the flow structure near the magnetic island associated to the rational surface is the result of coupling of the vacuum field island with a plasma instability. So far the achieved sheared flow has been too small to give rise to transport barrier formation. Nevertheless, perhaps these observations can contribute to the understanding of the mechanism of the spontaneous formation of transport barriers near rational surfaces, and thus open a new research area involving the active generation of internal transport barriers in fusion plasmas.

[1] P. W. Terry, Reviews of Modern Physics 72 (2000) 109

[2] B.A. Carreras, IEEE Trans. Plasma Sci. 25 (1997) 1281.

[3] E. Sydnakowski, Plasma Phys. Control. Fusion 40 (1998) 581.

[4] K. H. Burrell, Phys. Plasmas 4 (1997) 1499.

[5] Y. Koide, M. Kikuchi, M. Mori et al., Phys. Rev. Lett. 72 (1994) 3662

[6] N. J. Lopes Cardozo, G. M. D. Hogeweij, et al., Plasma Phys. Control. Fusion 39 (1997) B303.

[7] N. Ohyabu, K. Narihara et al., Phys. Rev. Lett. 84 (2000) 103.

[8] H. Atsuo, J. Plasma Fusion Res.SERIES, 1 (1998) 9

[9] C. Hidalgo, M. A. Pedrosa et al., Plasma Phys. and Controll. Fusion (2000), in press.

[10] Ch. P. Ritz et al., Phys. Rev. Letters 65 (1990) 2543.

[11] C. Alejaldre et al., Plasma Phys. Control. Fusion 41 (1999) A539.