MAGNETIC CONFIGURATION EFFECTS
IN THE PLASMA EDGE OF TJ-II

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INTRODUCTION

Sheared poloidal flows have been found to play a key role to explain the transition to improved confinement regimes in magnetically confined fusion plasmas [1, 2]. The development of methods to control the generation of sheared ExB flows is an important issue to reduce plasma turbulence and to optimize confinement in magnetically confined plasmas. The presence of rational surfaces appears to play an important role to determine the generation of internal transport barriers: Spontaneous formation of an internal transport barrier has been observed in the proximity of rational surfaces [3]. The possible use of a rotating magnetic island as a method of active confinement control, by changes in the radial electric field induced by changes in the velocity profiles, has been also addressed [4, 5, 6]. On the other hand, resistive pressure gradient driven calculations have shown a link between the location of singular surfaces and poloidal flows driven by fluctuations [7]. In this work we present experimental evidence of sheared ExB flows associated to the presence of rational surfaces in the plasma edge of the TJ-II stellarator.

EXPERIMENTAL SET-UP

TJ-II is a four-field-period low-magnetic-shear stellarator of the Heliac type with an average major radius of 1.5 m, average minor radius of ≤ 0.22 m and magnetic field $B_0 \leq 1.2$ T [8]. One of the main characteristics of TJ-II is the operational flexibility, that means that its rotational transform and magnetic well depth can be varied almost independently over a wide range. Hydrogen plasmas were generated and confined using ECR heating (f = 53.2 GHz, $P_{ECRH} \leq 300$ kW).

Radial profiles of the ion saturation current (I_S) and floating potential (ϕ) have been measured in the plasma boundary region of TJ-II plasmas using a fast movable Langmuir probe system [9]. The Langmuir probe array is inserted into the plasma edge region at a velocity of about 1 m/s, that allows to measure edge plasma profiles in a single shot. At the plasma boundary, Langmuir probes measurements are useful for the experimental localization of low-n rational surfaces. The presence of a magnetic island associated to this rational surfaces [10] show up as: flattening in the edge profiles measured by probes (*i.e.*, ion saturation current and

floating potential), and, as well as, characteristic features observed in the frequency spectra of the studied magnitudes.
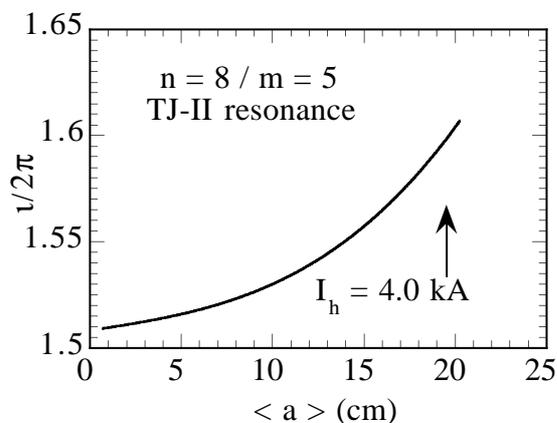

Figure 1.- Rotational transform profile showing the location of the 8/5 natural resonance.

The magnetic field is generated in TJ-II by a system of poloidal, toroidal, vertical and central coils [8]. The central conductors, consisting of a circular coil (I_{CC}) and two helical coils (I_{hx}), provide the flexibility of the TJ-II device. The radial location of rational surfaces can be varied over a wide range of rotational transform values changing the I_{CC} and I_{hx} currents.

To study the effect of rational surfaces within the plasma, it is useful to look for low-n resonances. Because TJ-II has low magnetic shear, the lowest n values may have considerable effect on the global confinement and they can break the fourfold symmetry of the configuration. We have chosen a plasma configurations with an $\iota/2\pi \approx 1.6$ at the plasma edge and focused on the n = 8/m = 5 resonant surface that is located near the plasma boundary. The vacuum magnetic field structure, calculated with a field line following code, has been used to track the position of the resonant surface and the size of the associated magnetic islands. Equilibrium calculations show no variation of the resonant position at the edge when finite pressure and net toroidal current effects are considered. Figure 1 shows the corresponding rotational transform profile.

RESULTS AND DISCUSSION

Radial profiles of the ion saturation current and the floating potential, in two plasma configurations with $\iota/2\pi \approx 1.6$ and $\iota/2\pi \approx 1.5$ at the plasma edge, are shown in Figure 2.
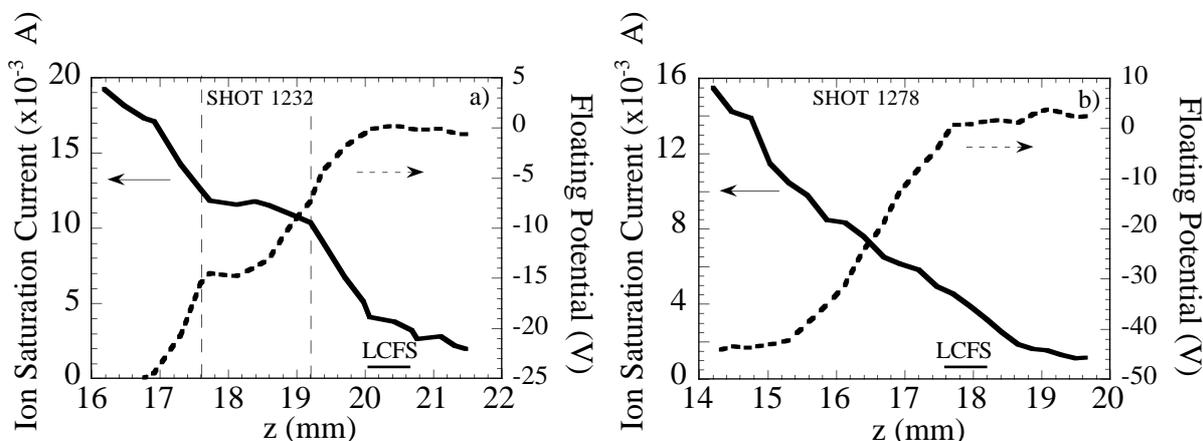

Figure 2.- Ion saturation current and floating potential profiles for plasma configurations with a) $\iota/2\pi \approx 1.6$ and b) $\iota/2\pi \approx 1.5$.

In the first one the 8/5 resonant surface is present in the plasma edge and the second one is a configuration free of natural rational surfaces in the probe radial displacement, as predicted by the equilibrium codes. The natural 8/5 rational surface has been observed as a flattening in the edge profiles as can be seen in Figure 2. The flattening (with a radial extension of about 1 cm) in density and floating potential profiles is not the same.
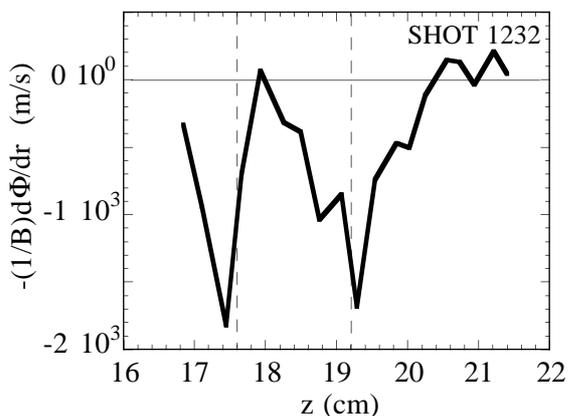

Figure 3.- Radial profile of [dΦ/dr]/B.

Figure 3 shows the radial derivative of the floating potential signal in the plasma configuration with the 8/5 resonance located in the plasma edge region. There is a strong radial variation in the floating potential around the radial position r ≈ 18 cm (dϕ /dr ≈ 10^3 V/m). This result can be interpreted as an increase of the sheared ExB flow linked to the radial location of the 8/5 rational surface with a resulting shearing rate of about 10^5 s^{-1}.

In the plasma configuration with the 8/5 resonance located at the plasma boundary region the cross-correlation and auto-correlation time of fluctuations show a significant radial variation in the proximity of the resonance radi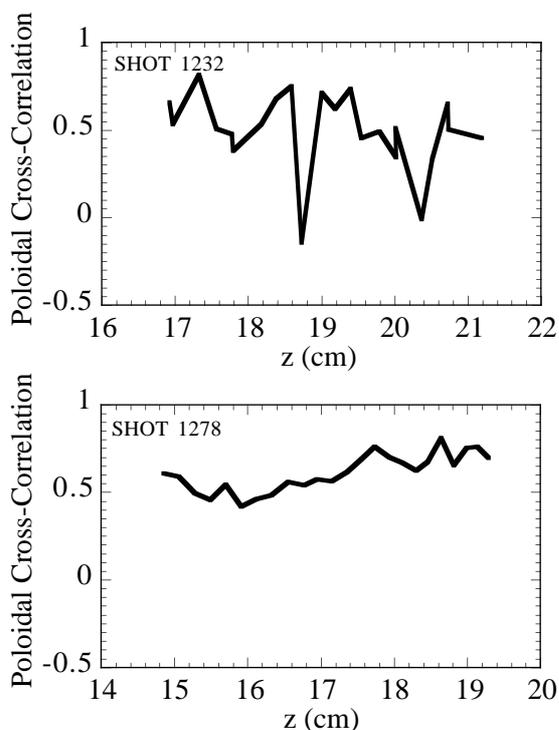al location. In Figure 4 the cross-correlation between two floating potential signals (measured by Langmuir probes poloidally separated 2 mm) computed at zero time delay between them, are shown for the same shots considered in Figure 2. A sharp reduction in the cross-correlation, in the proximity of the resonant surface location, together with an increase in the auto-correlation time, can be observed in Figure 4. This changes can be interpreted in terms of the influence of the ExB velocity of fluctuations measured in the plasma frame of reference and also due to the influence of ExB sheared flows on the cross-correlation of fluctuations. The auto-correlation time of fluctuations is in the range of (5-15) x 10^{-6} s. This means that the ExB decorrelation shearing rate in the proximity of the 8/5 resonance surface (≈10^5 s^{-1}) is comparable to 1/τ, τ being the characteristic decorrelation time of fluctuations. Those

Figure 4.- Cross-Correlation of floating potential fluctuations.

effects are very similar to the previous observed at the plasma edge caused by the naturally occurring velocity shear layer [11].

CONCLUSION

These experiments suggest the formation of ExB sheared flows in the proximity of rational surfaces (8/5) in the TJ-II stellarator. The resulting shearing rate is comparable to the inverse of the correlation time of fluctuations. Results can be interpreted in terms of the accelerating forces resulting from the modification in the degree of isotropy in the radial-poloidal structure of fluctuations (i.e. Reynolds stress) at rational surfaces [12]. When the modification in the degree of anisotropy in the radial-poloidal structure of fluctuations associated to rational surface can build up a significant sheared ExB flow, exceeding the damping effects, a spontaneous transport barriers are expected to be formed at the location of rational surfaces. As a consequence, this mechanism could explain the spontaneous formation of transport barriers at rational surfaces in fusion plasmas and open a research area to induce internal transport barriers in fusion plasmas.

A systematic investigation of the influence of rational surfaces on ExB flows and confinement is under way in the TJ-II stellarator.

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