29th EPS Conference on Plasma Phys. and Contr. Fusion Montreux, 17-21 June 2002 ECA Vol. **26B**, O-2.03 (2002)

Turbulence and transport with constant and spatial-temporal biasing in the scrape-off layer of CASTOR tokamak

J. Stockel[1], P. Devynck[2], I. Voitsekhovitch[3], J. Adamek[1], A. Azeroual[3], G. Bonhomme[4], F. Doveil[3], I. Duran[1], E. Gravier[4], M. Hron[1], E. Martines[5], G. Van Oost[6]

[1]*Institute of Plasma Physics, Association EURATOM-IPP.CR, Prague, Czech Republic*
[2]*Association EURATOM-CEA sur la fusion contrôlée, Saint Paul Lez Durance, France*
[3]*Equipe Turbulence Plasma, Laboratoire PIIM, Université de Provence, Marseille, France*
[4]*Universite Henri Poincaré, Nancy les Vandoeuvre, Nancy, France*
[5]*Consorzio RFX, Associazione EURATOM/ENEA sulla Fusione, Padova, Italy*
[6]*Department of Applied Physics, Ghent University, Belgium*

The results of the first experimental campaign on turbulence synchronization in the scrape-off layer (SOL) of the CASTOR tokamak are presented. The emphasis is put on the analysis of the evolution of the local turbulent flux in presence of externally excited waves and on the comparison of the effects of DC and AC biasing on the turbulence and transport properties.

I. Experimental set-up

CASTOR is a small tokamak with circular cross-section, major radius R=0.4 m and minor radius a=0.085m. In the present experiments the poloidal cross-section is reduced to 0.058 m by using a poloidal limiter (Fig. 1). The experiments are performed in a hydrogen plasma at the toroidal magnetic field $B_t = 1$ T, plasma current $I_{pl} = 6$-7 kA and line average density n_l = 1-1.5*10^{19} m^{-3}. In the SOL region, the plasma density varies in the range 0.2-1 *10^{18} m^{-3} and the electron temperature is 8-12 eV. The control and diagnostic system consists of a poloidal ring of 32 plates surrounding the plasma column at the radius of 61 mm (see Fig. 1 and ref. [1] for details). Each plate is equipped with a flush mounted probe. A rake probe is inserted from the top of the machine to measure the radial profiles. All probes measure the floating potential except one of the probes of the poloidal ring located at the low field side of the torus, which operates in the ion saturation current mode to estimate the turbulent flux.at this poloidal angle. The characteristics of the non-perturbed SOL turbulence are described in [1], [2]Two kinds of experiments, namely DC and AC biasing have been performed.

The DC voltage is applied to an insertable electrode, which is radially located inside the SOL. A pulse of +150-200 V is applied during a time interval much longer than the particle confinement time. In other discharges, a lower DC voltage of the order of the plasma potential (up to 20 V) is applied to the plates of the poloidal ring.

The AC biasing is performed using the poloidal ring. A harmonic voltage (f < 50 kHz) is applied to individual plates so that either a standing or propagating potential wave is formed with a prescribed poloidal periodicity (spatial-temporal modulation). The amplitude of modulated voltage is comparable with the local plasma potential (~20 V).

II. DC biasing

The typical spatial-temporal plot of the floating potential fluctuations in unbiased plasmas displays time periodic structures with a dominant poloidal mode number around 6-8, propagating poloidally with $v_\theta \sim 3$ km/s. At DC biasing produced by the biasing electrode located near the LCFS, the edge turbulence is modified by a sheared radial electric field, which is imposed to this region. Typical radial profiles of the floating potential are shown in Fig. 2 for several positions of the biasing electrode. The poloidal velocity of turbulent structures strongly increases (Fig. 3). The strong variation of the limiter current indicates a global modification in the SOL plasma when the DC biasing is applied.

Measurements of the turbulent flux have been performed in shots where the upper half of poloidal cross-section (16 top plates of the poloidal ring) is polarized. For this shot series the constant voltage is changed from 10 to 30 V on a shot to shot basis. The local turbulent flux is reduced and the large amplitude bursts are suppressed when the biasing voltage is applied (Fig.4).

III. AC biasing

For this experiment a poloidally rotating wave is applied to the 16 top plates of the poloidal ring with a velocity determined by the relationship $\omega = k_\theta v_\theta$ in the same direction as the poloidal velocity of the turbulent structures (Fig. 3 left). The values ω of and k_θ are selected within the wave number and frequency domains of the turbulence. In contrast to DC biasing, the application of the modulated voltage does not change the radial electric field (Fig. 5). Consequently, the modification of plasma properties occurs in this case due to the interaction of oscillating fields with the turbulent structures. The excitation of propagating waves can be clearly seen in the spatial-temporal plots (see for example, the case with the poloidal wave number $m_\theta=6$ and frequency f=12 kHz shown in Fig. 6) and in the frequency spectra. The turbulent particle transport changes in the presence of the rotating wave. The large amplitude bursts propagating outwards are not suppressed but inward bursts are amplified (Fig. 7). The average turbulent flux reduces with biasing and this reduction gets larger when the modulation amplitude of co-rotating waves or the offset voltage is increased (Fig. 8). The reduction of the flux is mainly due to de-phasing of the ion saturation current I_{sat} and of the poloidal electric field fluctuations E_p. Figure 8 shows that the RMS of the I_{sat} and E_p fluctuations remain practically unchanged, while the flux is strongly reduced. It should be also mentioned, that counter-rotating waves with m_θ = 8 and f=30 kHz do not produce any reduction of the local turbulent flux.

The reduction of the local flux is accompanied by a variation of the current on the limiter - similar effect is observed in discharges with constant biasing. Since the flux reduction is provided by a de-phasing effect we checked the link between the cross-phase between the saturation current and poloidal electric field fluctuations and the current on the limiter. The correlation observed in this particular case indicates that the reduction of the local flux is accompanied by global changes in the SOL plasma, see Fig. 9. However, more detailed measurements in the SOL (plasma profiles and flux measurement at other poloidal locations) are required to identify these changes.

IV. Summary

The first experimental campaign on CASTOR dedicated to the turbulence control shows that standing and propagating waves in the frequency range of 10-40 kHz and the wave number range m_θ =2-8 can be successfully excited in the SOL using the poloidal ring of electrodes. The possibility to modify the turbulent flux in the SOL both with constant and modulated biasing is demonstrated. In both cases, a reduction of the local flux is achieved. However the constant and modulated biasing produce different effects on the flux structure and its bursty behaviour. We found that the static field suppresses the large amplitude bursts propagating outwards while the oscillating field produces inward bursts of the flux without suppressing outward bursts. Our results show that the turbulent flux is reduced due to a strong de-phasing between density and poloidal electric field fluctuations in the case of modulated biasing.

However, some uncertainties remain in the determination of the flux because of the probe separation (present separation is of the order of m_θ=16) and the absence of global particle flux measurements. More detailed analysis of the SOL plasma will be the subject of future experiments.

References:

1. M. Hron et al., EPS 2002, Montreux ; P-5.043
2. A. Azeroual, et al., EPS 2002, Montreux , O-3.21

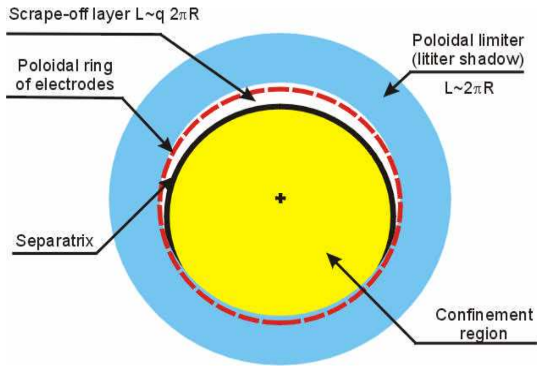


Fig. 1. Respective position of the poloidal ring and the poloidal limiter.

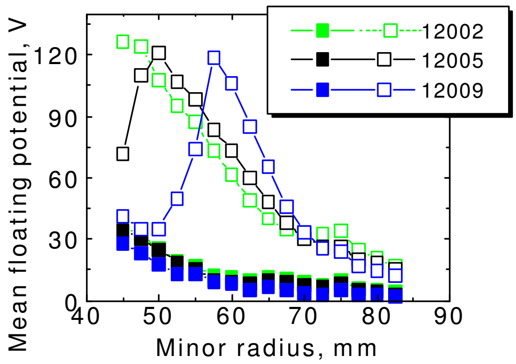


Fig. 2. Radial profiles of plasma potential before (closed symbols) and during (open symbols) the constant 150-200 V biasing

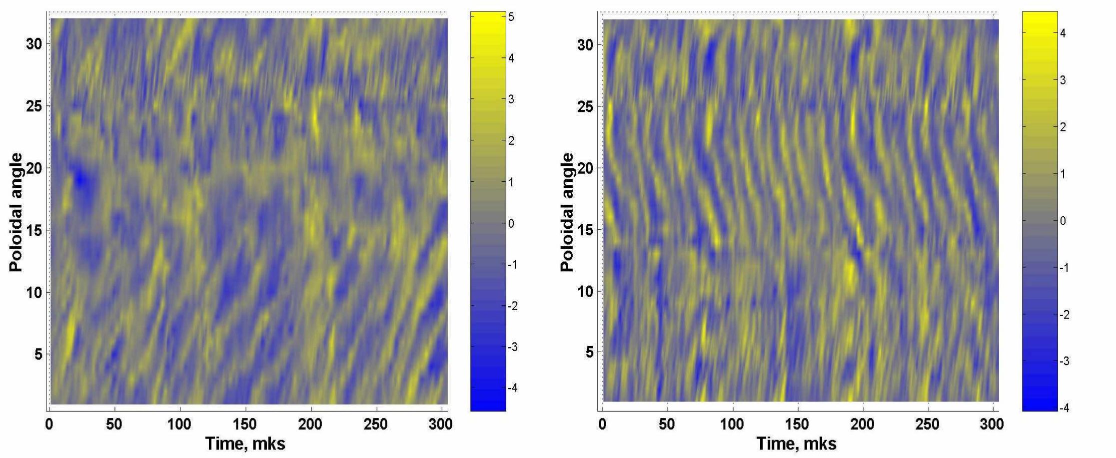
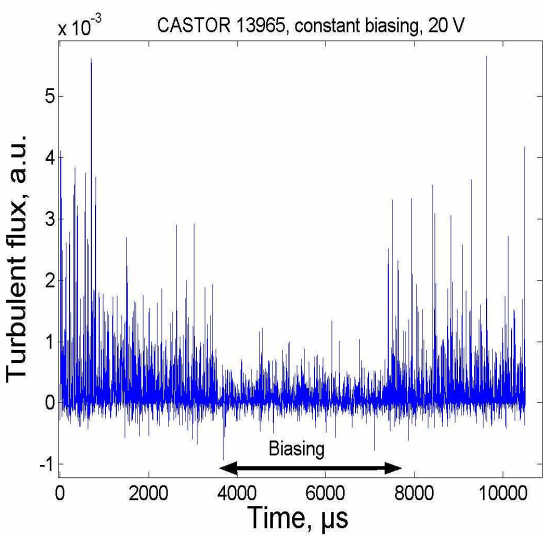


Fig. 3. Floating potential in the poloidal angle-time space before (left) and during DC biasing of the electrode (right) (shot 12002).



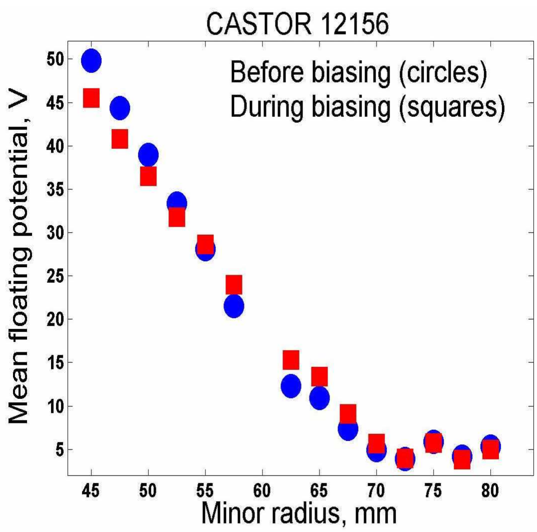


Fig. 4. Time evolution of turbulent flux in a discharge with DC biasing of 16 poloidal plates located at the top of the torus.

Fig. 5. Typical radial profile of the time-averaged floating potential with AC biasing.

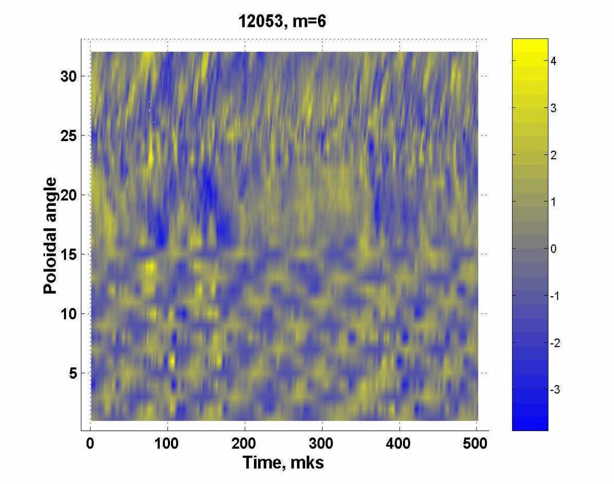


Fig. 6. Spatial-temporal structure of the floating potential fluctuations with AC biasing.

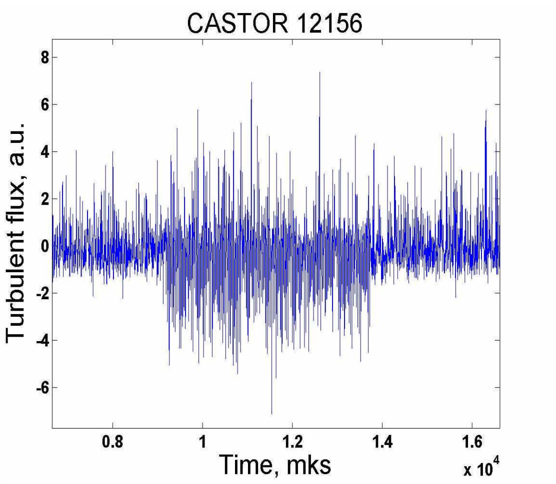


Fig. 7.Evolution of the turbulent flux during a shot with AC biasing, V_{off}*=20V,* V_{amp}*=20 V, f=30 kHz,* m_θ*=5*

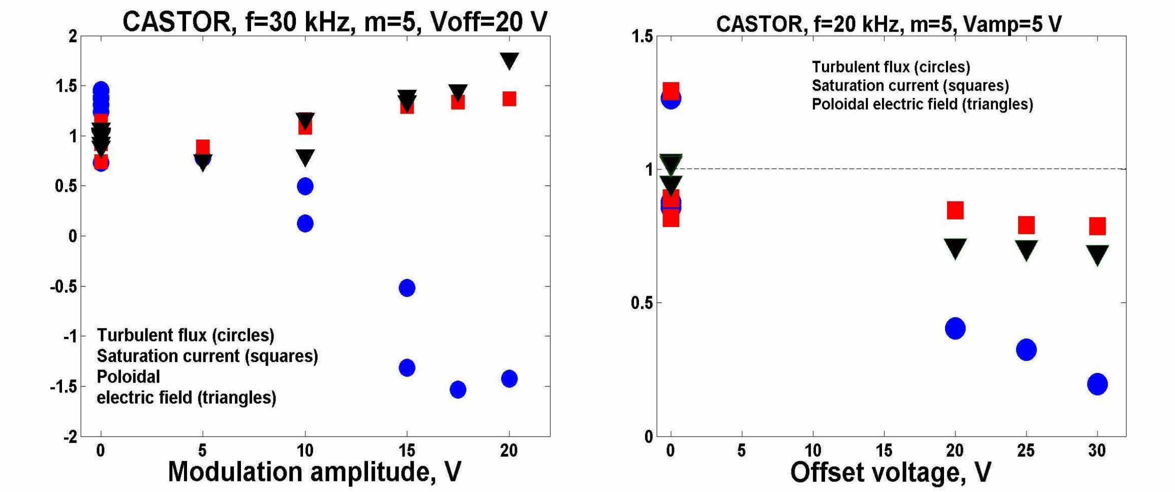


Fig. 8. Time-average turbulent flux (blue circles), RMS values of the ion saturation current (red squares) and poloidal electric field (black triangles) fluctuations versus the modulation amplitude (left) and the offset voltage (right). All quantities are normalized by their values before biasing.

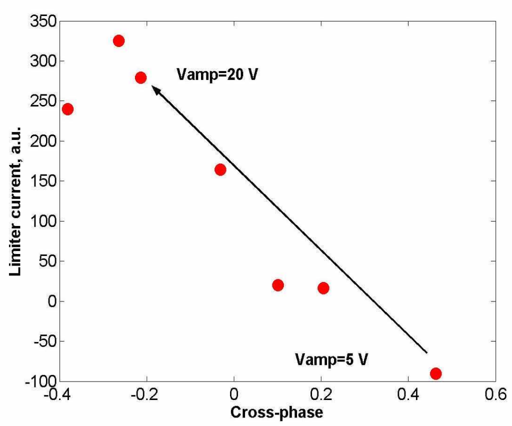


Fig. 9. Limiter current as a function of fluctuation de-phasing for the discharges with scanning of the modulation amplitude.