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Edge Fluctuations at Regimes with Improved Confinement on CASTOR Tokamak

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Abstract

link between the level of electrostatic fluctuations and particle confinement is investiga-d experimentally in two regimes with an improved global particle confinement:
Lower Hybrid Current Drive regime (LHCD).
Edge Plasma Polarization regime (EPP).
has been found that the edge fluctuations are reduced and their character changes at HCD. Preliminary results of the spectral analysis of the fluctuations at EPP regime are esented.

Experiments are performed on CASTOR tokamak ($R = 40cm, a = 8.5cm, B_t =$ $, I_p = 12kA$) at densities $\bar{n}_e < 1.5 \cdot 10^{19} m^{-3}$. The particle confinement time is estimated om the global particle balance. Edge fluctuations are monitored by means of multiple Langmuir probes located at the midplane near the last closed flux surface (LCFS).

HCD regime:

lower hybrid wave ($f_{LH} = 1.25GHz, P_{LH} < 40kW$) is launched into the plasma by a ultijunction grill. Typical evolutions of the LHCD shot (shown in Fig. 1) demonstrate at the line average density increases, while hydrogen and impurity line intensities crease during the LHCD phase of the discharge. The radial density profile broadens the plasma core, while its steepening is observed at the edge region [1]. Therefore, improvement of the global confinement time (by a factor of ~ 2) is deduced from the perimental data. At the same time, the level of electrostatic turbulence is significantly duced in the vicinity of the last closed flux surface. Note also that the HXR intensity om the limiter nearly vanishes during the improved particle confinement phase.

The best confinement and the minimum level of the fluctuations are observed when e LH power is less then the initial OH power input. Simultaneously, the total power $_{H} + P_{LH}$ reaches its minimum. The similar results have been obtained at low power ICD regimes on ASDEX [2].

The spectral analysis shows that the reduction of the edge turbulence is accompanied changes in the character of the fluctuations. Fig. 2 compares the spectral characteristics density fluctuations in the vicinity of the last closed flux surface at OH and LHCD scharge phases, averaged over five similar shots. It may be seen that the mean wave-mbers as well as the width of the k-spectrum decrease. The first fact indicates that poloidal phase velocity of the fluctuations in the laboratory frame increases. The quency spectra are reduced especially at their low frequency part which is probably ised by the enhanced poloidal rotation. Frequency integrated k- spectra are reduced the range of $(0.5 - 2.7) cm^{-1}$. Additional measurements indicate a decrease of the rrelation length of the density fluctuations at LHCD [3].

Fig. 1.
Evolution of LHCD (thick lines) and Ohmic (thin lines) shots for $P_{LH} = 17kW$.
a) Loop voltage U_l. The drop of U_l between 15th and 20th ms indicates that roughly a half of the plasma current is driven non-inductively in this particular case.
b) Line average density (central chord).
c) Peaking factor p of the density profile defined as $n/n^o = (1-x^2)^p$. The drop of p from 0.7 to 0.35 indicate significant broadening of the density profile at LHCD.
d) Intensity of the H_α-spectral line. Similar evolutions of this line are observed at different toroidal locations as well.
e) Resulting particle confinement time τ_p/τ_p^{OH} normalized to its initial Ohmic value.
f) Hard X-ray intensity from the limiter.
g) Incident LH power P_{LH}.

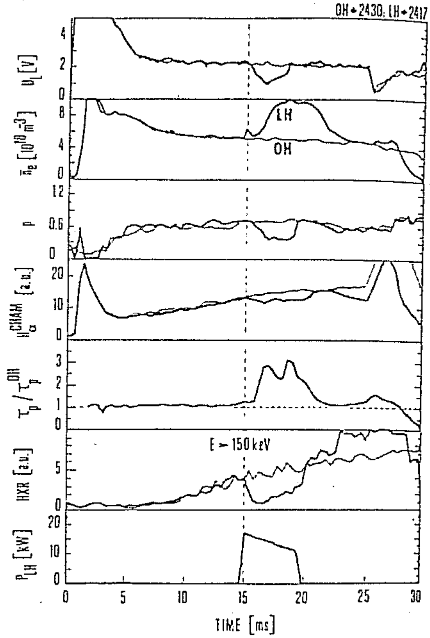


Fig. 2.
Spectral characteristics of the density fluc- uations at $P_{LH} = 37kW$ averaged over five similar shots. The fluctuations are monitored at the midplane, 180° toroidally away from he grill.
) Frequency resolved mean poloidal wave- umbers $\bar{k}_p$.
) The same for the relative width of the wavenumber spectra $\Delta k_p/k_p$.
) Frequency spectrum S(f) integrated over wavenumbers.
) Wavenumber spectrum S(k) integrated over requencies.

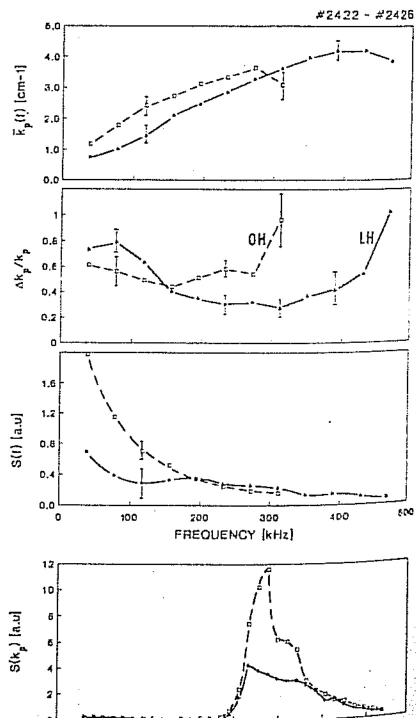


Fig. 3.
Evolution of the shot with limiter biasing, $U_{lim} = +200V$.
a) Loop voltage. b) Line average density.
c), d) and e) Intensities of the H_α-spectral line monitored 180° toroidally away from the limiter, in the limiter section and in front of the waveguide grill.
f) Hard X-ray intensity from the limiter.
g) Resulting particle confinement time τ_p/τ_p^{OH} normalized to its Ohmic value.
g) Limiter current I_{lim}.

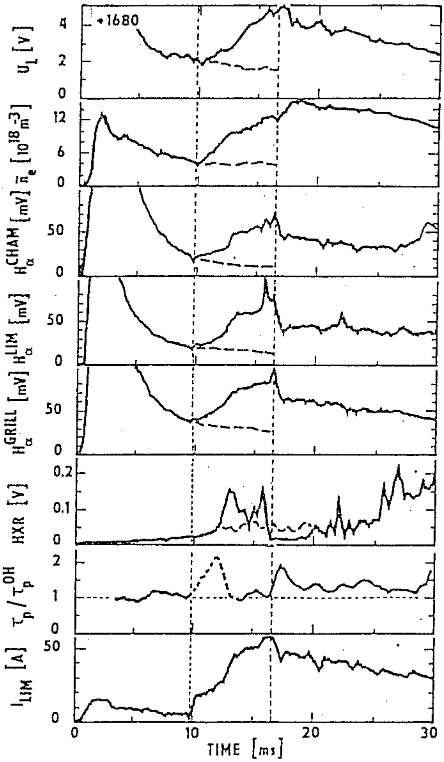
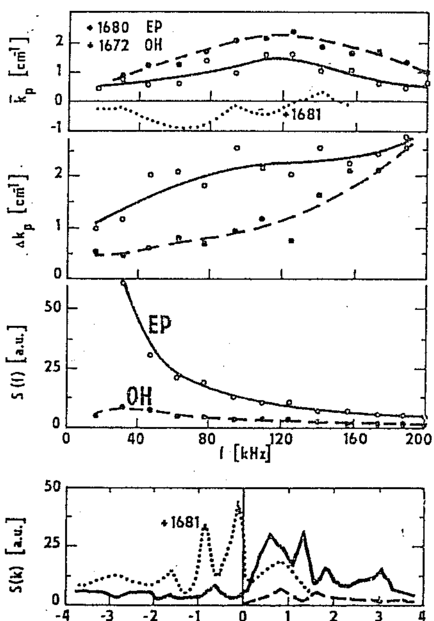


Fig. 4.
Spectral characteristics of the density fluctuations in the shot with limiter biasing. The probe is located in the SOL near the limiter.
a) Frequency resolved mean poloidal wavenumbers $\bar{k}_p$.
b) The same for the width of the wavenumber spectra Δk_p.
c) Frequency spectrum S(f) integrated over wavenumbers.
d) Wavenumber spectrum S(k) integrated over frequencies.



EPP regime:
In this case, the edge plasma is polarized by means of biasing of the circular limiter. Fig. 3 shows an evolution of a shot with limiter biasing ($U_{lim} = +200V$) during a steady state phase of the OH shot. After an initial jump (up to $I_{lim} \sim 20A$), the limiter current increases more slowly. Simultaneously, the line average density and H_α line intensities are increasing as well. This indicates enhanced recycling, which is not, however, localized at the limiter. Radiation of impurities (not shown in the figure), increases as well, but noticeably faster then the hydrogen line intensities. Therefore, we conclude that the initial increase of the plasma density is probably caused by an accumulation of impurities in the plasma.

After reaching the value $I_{lim} \doteq 60A$, the limiter current drops suddenly and a transition to the improved particle confinement occurs. This is manifested by a faster increase of $\bar{n}_e$ and by a sharp drop of H_α and impurity line intensities. The both effects seem to have a transient character. The edge density and the level of the density fluctuations drop at the transition, but not bellow their initial Ohmic values. It is worthwhile to note a sudden drop in the HXR intensity at the transition, starting even before the transition.

The resulting global particle confinement time τ_p, normalized to the corresponding Ohmic value, is shown in the same figure. The initial increase of τ_p (shown by the dashed line) is assumed to be caused by neglecting the multiple ionization of impurities throughout the evaluation. We see that the τ_p/τ_p^{OH} roughly doubles just after the transition, but it remains still slightly enhanced at later time.

It should be noted that a more smooth transition to the improved confinement (but accompanied by a drop of HXR) can be arranged with a lower biasing voltage $U_{lim} = 120 - 140V$. A similar smooth improvement of particle confinement during limiter biasing was reported from HYBTOK-II tokamak [4]. Biasing of the limiter by a negative voltage does not influence the global plasma parameters for $U_{lim} \leq -160V$.

The plasma parameters in scrape-off layer are monitored by a Langmuir probe located near the limiter. Results of preliminary spectral analysis of the probe signals, performed only just after the start of limiter biasing, are depicted in Fig. 4. The poloidal velocity of the density fluctuations roughly doubles in this case. The maximum of the wavenumber spectrum is shifted to lower k-values and, in some shots, it even changes the sign. The last means that, at the given probe radial position, the poloidal rotation of the fluctuations is reversed from ion to electron diamagnetic drift direction. In general, the level of density fluctuations and the width of the wavenumber spectra increase during the initial phase of limiter biasing. The spectral analysis of the edge fluctuations deeper in the plasma and just during the transition is in progress.

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