

THE RESEARCH OF TURBULENCE IN PLASMA CORE ON T-10 TOKAMAK WITH CORRELATION REFLECTOMETRY IN REGIMES WITH PEAKED DENSITY PROFILE AND ECR HEATING

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Introduction

The aim of present work is an analysis how discharge parameters influence on amplitude, spectral and correlation properties of turbulence types determined earlier in [1]. The results of research of small scale plasma density perturbations in frequency range (10÷400) kHz are presented. The correlation heterodyne reflectometer [2] operated in O-mode with probing frequencies 36÷78 GHz corresponding to density range $1.6 \times 10^{13} \div 7.5 \times 10^{13} \text{ cm}^{-3}$.

The measurements were carried out in Ohmic discharges with $T_i \approx T_e$ and limit n_e («S» (SOC) and «B» (IOC) regimes [3]). It was obtained by changing of working gas puff intensity or D₂ pellet injection. High probing frequencies provided the monitoring of turbulence evolution at «S»-«B» transition in core of plasma column characterized by the improved confinement and impurity accumulation.

Experimental results

The parameters of discharge with S-B transition are $I_p = 200 \text{ kA}$, $B_z = 24 \text{ kGs}$, $\langle N_e \rangle = 4.0 \times 10^{13} \text{ cm}^{-3}$. The first stage of discharge conditioned by strong gas puffing. Under critical density gas puffing cut off. Figure 1a displays time typical trace for central interferometer chord. After puffing cut off the process of density profile peaking run. In central part of plasma column electron density continue to increase after cut off but at periphery decay begins (Fig. 1b). This experimental data are in a good agreement with computer simulation results obtained using transport code ASTRA [4] (solid lines, Fig. 1b). Using real discharge parameters as input data for ASTRA the evolution of diffusion coefficients in S-B transition was simulated. The results presented on Figure 1c. Only the presence of transport barrier in model could make agreement between experimental and simulated data (Fig 1b.).

For three probing frequencies 70.2, 75.5 and 78.8 GHz with time resolution 1.25 μs the density fluctuation were measured with reflectometer. In each moment these three probing frequencies correspond to three radii of reflection. Owing to the process of transition after puffing cut off is dynamical process (both density and its gradient vary continuously) the radius reflection is not constant and moving toward the center of plasma column. Transport barrier is moving in the same direction, but its velocity of propagation is higher. Therefore the time shift of turbulence suppression between three radial points is clear seen (Fig. 1d,e,f). The time traces of amplitude are shown for two types of plasma perturbations («broad band» and «quasicohherent» bursts) which compose all observed turbulence in the central part of plasma column in T-10 (Fig. 2).

For different probing frequencies the behavior of turbulence was similar. The high level of turbulence dominated by strong «broad band» fluctuations after the gas puff cut off begin decrease up to its minimum value. After that the amplitude of turbulence start to grow, however this increase provided by other turbulence type - the bursts of quasiscoherent fluctuations. The stage of turbulence suppression was observed later in time at higher probe frequencies. It corresponds to propagation of suppression zone into the center of plasma column. For the first time it was observed the whole suppression of quasiscoherent fluctuations.

The turbulence rotation velocity was studied by means of measurement of shift of cross correlation function maximum. Cross correlation function was calculated for two reflectometry signals receiving from antennas arranged in poloidal direction so the distance between reflection points is about 2-4 cm (conditioned by radius of reflection). The increase of turbulence poloidal rotation velocity from the outside of suppression zone with regard to plasma inside this zone indicates to velocity shear suppression (Fig. 1g). The nature of residual turbulence (after suppression) is not clear yet. Perhaps it concern with electron transport which changes weakly at SOC-IOC transition (ASDEX [3]). The similar suppression of turbulence was obtained also in discharges with D_2 injection, after secondary gas puff and during current ramp down in the final stage of discharge.

Poloidal asymmetry measurements were also found to provide very important information about turbulence physics. It can be obtained by comparison of reflected wave phase fluctuations received by LF and HF sides antennas. Such comparison of Fourier amplitude spectra of frequency discriminators is shown in Fig. 3 for two ohmic T-10 discharges. In discharge 65348 LF side amplitude is higher and differs from HF side spectrum even qualitatively. Two maxima are clearly seen in spectrum of LF side signal, which are several times lower in HF side spectrum. In

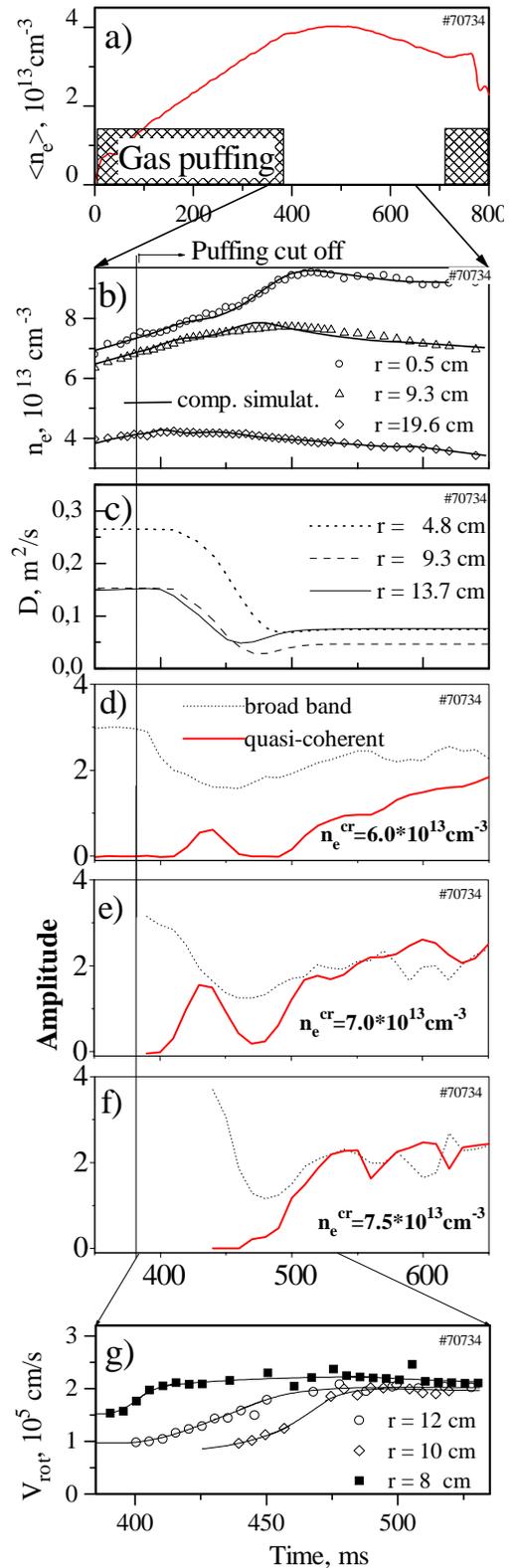


Fig. 1: The behavior of two types of plasma perturbations during S-B (SOC-IOC) transition

contrary in discharge 65486 both spectra practically coincides. The analysis of a variety experimental data of that type give ground to conclude that two different types of a turbulence may be responsible for the observed variation of poloidal asymmetry. The first one appeared as two narrow maxima in discharge 65348 is a previously observed at low field side «quasi-coherent» bursts of monochromatic oscillations. It is highly asymmetrical poloidally and has two peaks in amplitude spectrum. The second is seen in discharge 65486 have a smooth maximum at 160 kHz and is symmetrical poloidally. It is clearly seen that both spectra in discharge 65348 may be explained as a mixture of both kind of turbulence. Experimental data also permit to conclude that an increase of a «broad band» at LF side in discharge 65348 is in some way associated with appearance of «quasi-coherent» bursts. It may be either due to intrinsic nonlinear transformation of energy in spectrum or a result of specific reflectometry broadening of a spectrum.

The measurements were carried out in plasma with $T_e \gg T_i$ heated by ECRH ($P \approx 1\text{MWt}$). The dependencies of turbulence properties on both ECRH power and variation of local gradients obtained with different radial position of ECR heating were studied. The correlation lengths of turbulence during ECRH decrease dramatically. On the other hand, the turbulence amplitude and rotation velocity practically do not vary. The particularities of such measurements were also the presence in reflectometer signals the strong flashes of noise-like fluctuations connected with the bursts of plasma radiation.

References

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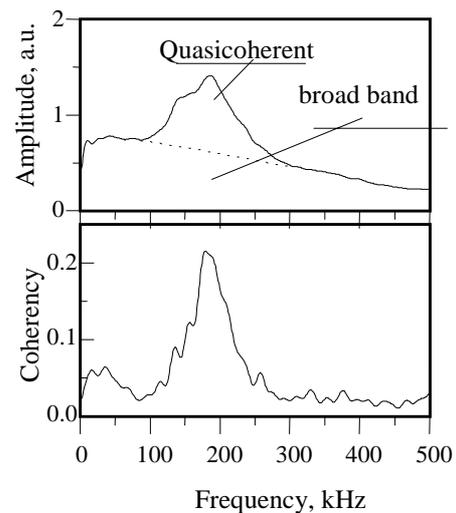


Fig. 2: Two types of plasma density perturbations observed in interior part of plasma column in T-10.

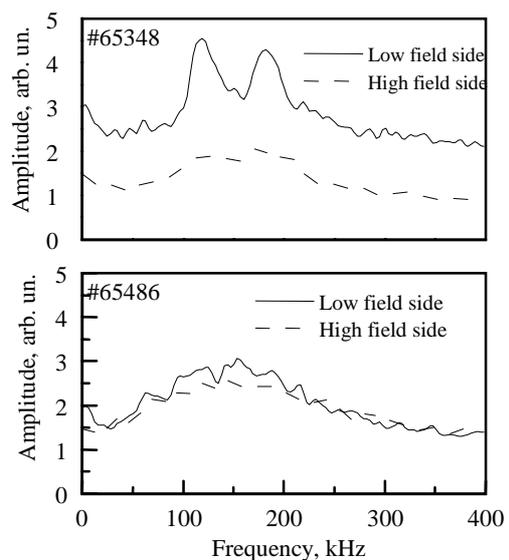


Fig. 3: Amplitude of turbulence for High Field Side and Low Field Side.