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POLOIDAL AND TOROIDAL STRUCTURE OF THE DENSITY FLUCTUATIONS IN T-10 AND TEXTOR TOKAMAKS

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Investigation of turbulence properties could reveals the nature of anomalous transport in tokamaks. Theory predicts that drift waves will be elongated in the magnetic field line direction and points at toroidal curvature as one of the important destabilizing factor [1]. 3D gyrokinetic simulations justify this theory predictions and show strong poloidal asymmetry of turbulence [2]. This paper presents results of systematic investigations of poloidal and toroidal structure of small-scale density fluctuations in T-10 and TEXTOR.

T-10 is a circular cross-section limiter tokamak with major radius R = 1.5 m and minor radius a = 0.3 m, toroidal magnetic field up to 2.6 T, plasma current 330 kA. T-10 has a possibility for additional heating at second harmonic of electron cyclotron resonance. TEXTOR dimensions are R = 1.75 m and minor radius a = 0.46 m, toroidal magnetic field was about 2 T, plasma current 400 kA. Recent upgrade of antennae systems in T-10 and TEXTOR correlation reflectometry system gives the possibility to get the experimental data at different poloidal angles. One could see that both devices have close spatial dimensions, plasma parameters and a similar measurement scheme thus giving the unique possibility to measure turbulence parameters dependence on poloidal angle and to cross-machine comparison. T-10 reflectometry

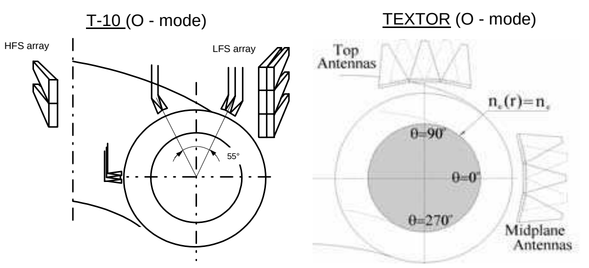

Fig. 1. Positions of correlation reflectometer antennae arrays in T-10 (left) and TEXTOR (right).

system consists of 3 antenna arrays (Fig. 1). Top antennae arrays are situated at cross-section “A”, the equatorial one – in the next cross-section of tokamak (90° in toroidal direction). Antennae arrays on TEXTOR are situated in equatorial plane on the outer side of the torus (E-LFS) and at the top position (TOP) in one cross-section.

Previous experiments have shown strong difference of total turbulence level in T-10 tokamak at E-HFS and TOP-LFS [3]. It was also reported the difference in the turbulence spectra at different poloidal angles. T-10 and TEXTOR discharges with the same dimensionless parameters $q_a \sim 2.8$, $\overline{n}_e / n_{Gr} \sim 0.3$, $r_{refl}/a \sim 0.7$ were chosen for analysis. Poloidal dependence of total turbulence level is presented in Fig. 2. One could see that the results from both devices support each other. The turbulence amplitude has a maximum at the equatorial plane at LFS and a minimum at HFS. It should be noted that TEXTOR data gives higher turbulence level than T-10 data. This fact could be due to the difference in size of the machines. Chosen discharge has a rather low density and only LF QC peak was observed in turbulence spectra. BB component has shown the same poloidal dependence as a total turbulence level. QC oscillations demonstrate strongest poloidal asymmetry. This type of fluctuation is mostly pronounced at equatorial plane at LFS and often not observed at HFS. SLF component seems to have the lowest amplitude and to be independent on poloidal angle in both T-10 and TEXTOR tokamaks.

We suppose that relative amplitude of total level of small-scale density perturbation is varying in poloidal direction according the sine law $\sigma_n / n_e \sim a_0 + a_1\left(\cos(\theta)+1\right)/2$ - where θ is poloidal angle, calculated from the equatorial plane at LFS, a_0 and a_1 – fitting coefficients. Let us determine the asymmetry as the ratio of turbulence amplitudes in the equatorial plane at the LFS and HFS. The a_0 and a_1 coefficients were calculated from experimental data at different poloidal positions and than asymmetry were calculated.

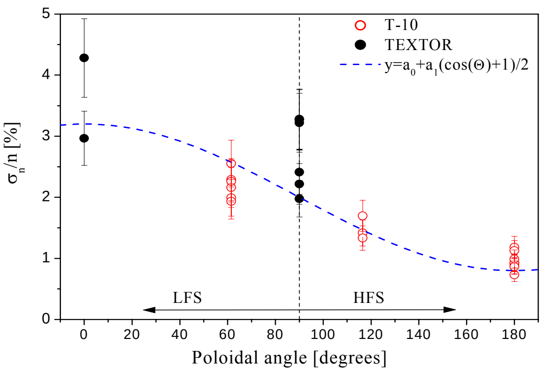

Fig. 2. Poloidal dependence of relative amplitude of density perturbations. Zero angle corresponds to equatorial plane at LFS.

Previous experiments have shown that in ECRH discharges turbulence amplitude significantly increases at LFS whereas the changes at HLS are negligible [3]. This tendency was analyzed in recent experiments. Asymmetry was investigated at $\rho \sim 0.65$ in T-10 discharge with $B_T = 2.4$ T, $\overline{n}_e \sim 2.0 \times 10^{19}$ m^{-3} and two values of plasma

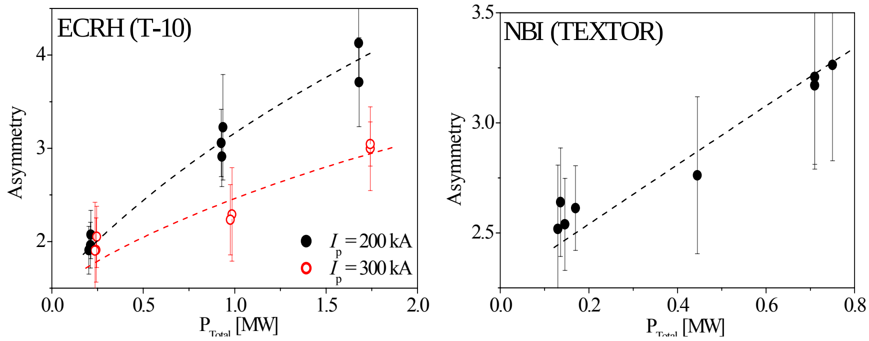

Fig. 3. The dependence of turbulence asymmetry from total heating power in ECR (T-10, left panel) and NBI (TEXTOR, right panel)

current On-axis ECR heating was applied to discharge with total power up to 1.7 MW. Similar experiments were provided in TEXTOR with balanced NBI. The discharge parameters were $B_T = 1.9$ T, $\bar{n}_e = 1.5\times10^{19}$ m^{-3}, $I_p = 200$kA; ρ ~ 0.4. It was shown that asymmetry is significantly increased with the rise of total heating power in discharge for both devices (Fig. 3). It should be noted that both ECRH and NBI give the same dependencies despite of putting main part of power in different types of particle (electrons and ions).

The previous T-10 reflectometry configuration with the presence of two antenna arrays in the top port, separated poloidally at 55° gives possibility to observe long distance correlation (LDTC) along the torus, but there was parasitic cross-talk between LFS and HFS antennas, placed in one port (A). The recent installation of the antenna array (in port D 90° toroidally from port A) enables to repeat LDTC. The toroidal antennas separation guarantees the absence of the cross-talk and increase the available number of resonance q values. The requirement to avoid cross-talk leaves the possibility of only two configurations of antennas: HFSD/HFSA and HFSD/ LFSA. The decrease of the density during one discharge enabled the fine radial (and *q*) scan. The resulted radial distribution of the LF and QC coherency and time delay between the signals are shown at the Fig.4. The black curves correspond to 1/3 and red one to 2/3 antennas. It is seen that the maximum of LF coherency coincide with the resonant q values, while the maximum of the QC coherency is shifted to the lower *q* value. The strong delay variation eliminates possibility of the presence of parasitic correlation and the negative slope of the delay with radius proves that correlations occurred in the expected way. The right geometry of the correlation additionally proved by the radial shift of the

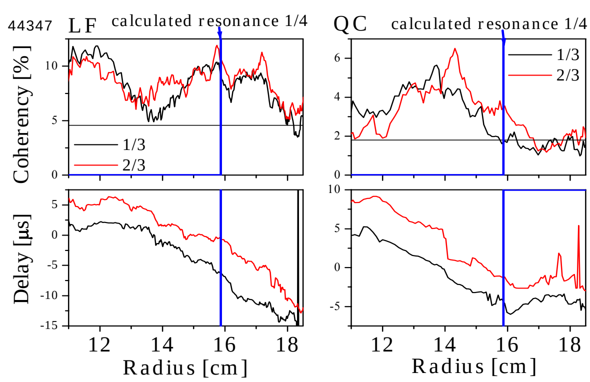

Fig. 4. Top panel: radial dependence of coherency between two toroidally separated antennae. Bottom panel: Lag of the maximum of toroidal cross-correlation function.

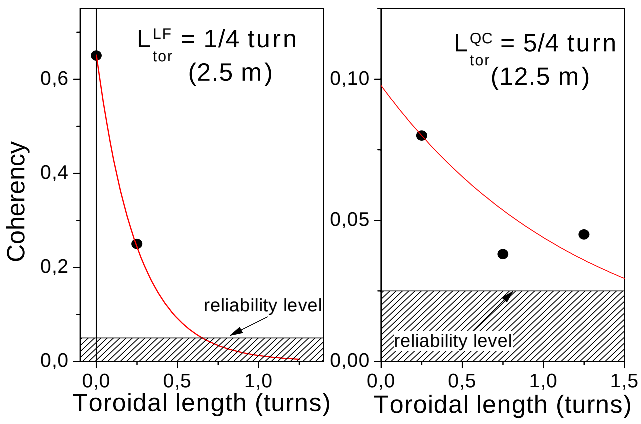

Fig. 5. Toroidal correlation functions for LF (left) and QC (right) oscillations. Points correspond to data points, red curves to approximation. Shadowed regions show

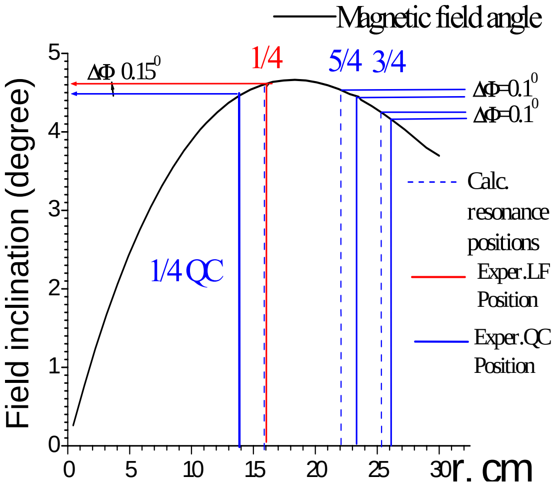

Fig. 6. Radial dependence of magnetic field line inclination.

2/3 with respect to 1/3 delay.

The observed correlation values enable to estimate the correlation lengths of the LF and QC along the magnetic field line (fig. 5). The correlation lengths of the QC along the magnetic field line is longer, as it were seen at 1/4, 3/4 and 5/4 turns around the torus. The estimated correlation length is about 12.5 m. The estimations of the LF correlation length were done with the use of the poloidal correlation value at zero separation, the measured value at 1/4 of the torus and reliability level at 3/4 of the torus. The value of the LF correlation length was estimated in 1/4 of the torus circumference (2.5 m).

Fig. 6 presents the dependence of the magnetic field line angle versus minor radius. The resonant radial positions of the resonances are plotted for both experimental runs by vertical dashed blue lines. The LF 1/4 correlation is shown by solid red line, while the QC maxima by the solid blue lines. It is clearly seen that LF resonance coincides with the calculated values. In contrary, the QC maxima are slightly shifted from calculated positions. As it is seen from the Fig. 6, the maximum QC shifts correspond to the oblique propagation with the angle about 0.1° with respect to magnetic field line. This angle is expected for the drift waves.

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