Dependence of poloidal asymmetries of the edge turbulence on the magnetic configurations in ASDEX Upgrade

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Introduction

Understanding plasma turbulence and transport properties in edge and SOL plasma regions is relevant to improve reliability of a fusion reactor. Most edge measurements are made on the low-field side (LFS) because of easier diagnostics access but since SOL/edge properties are not poloidally symmetric data from the high-field side (HFS) are essential.

Experimental set-up

At ASDEX Upgrade (AUG), the frequency modulated continuous wave (FMCW) reflectometry system provides simultaneous measurements on the HFS and LFS, that is dedicated to density fluctuation measurements in a fixed frequency regime. Operation in O mode provides independent of the magnetic field measurements that is essential for study with different magnetic configurations. Four channels (K, Ka, Q and V bands) on each inner and outer sides of tokamak featuring individual single antennae (located approximately at the tokamak midplane), cover the probing density range from 0.3 to 7 x 10^{19} m^{-3}. The diagnostic is equipped with homodyne detection and phase is extracted by applying the Hilbert transform method. Validation of the method is done by comparison with overlapping data (for the same probing

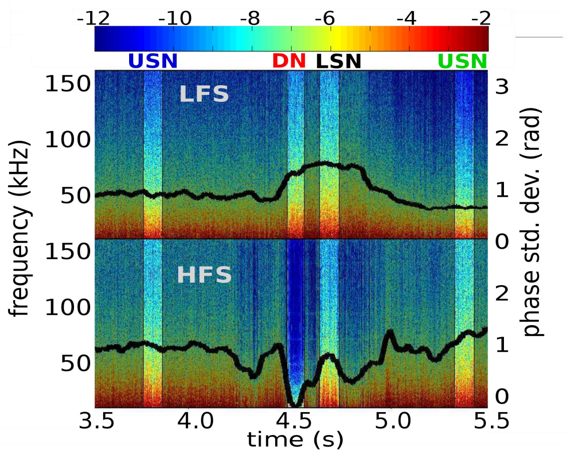

Fig. 1. Spectrograms of phase of reflectometers signals (K band, 0.4 x 10^{19} m^{-3}) at SOL on the LFS (top) and the HFS (bottom) through the L-mode discharge. The four bright zones correspond to different magnetic configurations, from left to right – USN, DN, LSN and back to USN. Results in Figs 2 and 3 refer to those four zones. Black curves are standard deviation of signals phases at the LFS and the HFS.

densities) obtained by hopping reflectometer with detection enabling to extract phase directly.

Experimental results

The results from reflectometry in L-mode discharge #31633 with the magnetic configuration transitions from upper single null (USN) through double null (DN) to lower single null (LSN) and back to USN are presented in Fig.1. Standard deviation of phase is proportional to the density fluctuation level δn/n [1]. Spectrograms of phase and level of standard deviation of phase display the δn/n changes observed in the SOL for different magnetic configurations

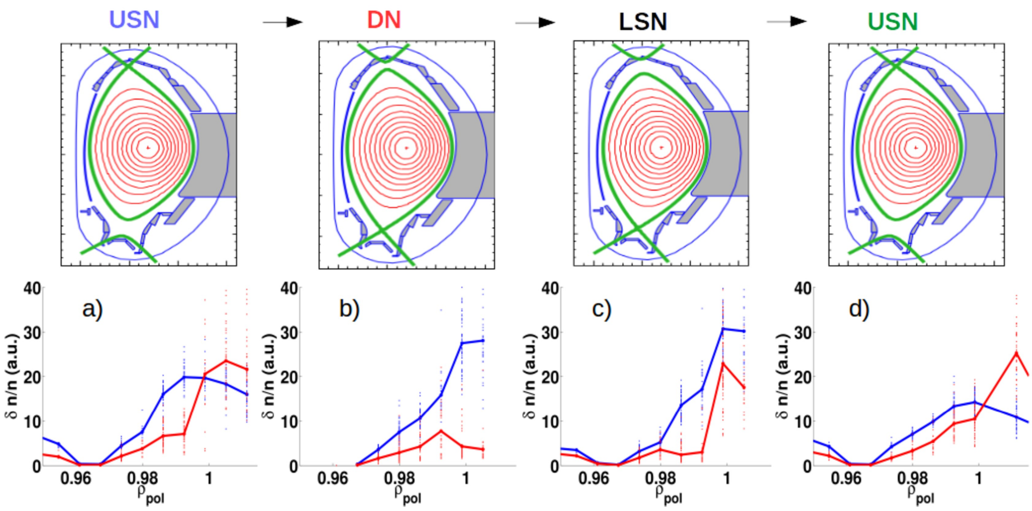

Fig. 2. Density fluctuation profiles at the HFS (red color) and the LFS (blue color) for different magnetic configurations: a) USN at the beginning of the discharge, b) DN, c) LSN and d) USN at the end of the discharge.

(Fig. 1), which are more pronounced on HFS. Radial profiles of δn/n at the HFS and the LFS shown in Fig.2 for the four highlighted zones in Fig. 1, were obtained using 1D C. Fanack model [2]. The effect of magnetic configuration on the poloidal asymmetries of density fluctuations is more pronounced outside the separatrix (Fig. 2 and Fig. 3). A δn/n drop inside the separatrix at around ρ = 0.96 is observed in the region of strong radial electric field Er shear for all configurations (Fig. 3), that is in agreement with the previous experimental results at AUG [3] and turbulence stabilization theories [4]. In LSN configuration the turbulence level is found to be much lower on the edge and SOL HFS (Fig. 2c) in comparison with the LFS. This is expected from common interchange instability mechanism and widely observed on many tokamaks. The highest levels of density fluctuations are observed in LSN and DN configurations on LFS. The lowest fluctuation levels are observed in the DN configuration (Fig. 2b) in SOL HFS, that corresponds to this region becoming isolated from the LFS SOL. On the LFS DN δn/n profiles behaviour is similar with the LSN, see Fig. 3. The strongest HFS/LFS asymmetry of fluctuations occurs outside the separatrix in DN plasma shape that was also seen with three dimensional electromagnetic gyrofluid computations from the GEMR code [5]. In USN configurations it has been observed that the inboard SOL turbulence level exceeds those of the outboard (Fig. 2a, Fig. 2d). That is surprisingly as the common interchange instability is driven by the bad curvature which is located at the outboard side. One possible explanation may come from GEMR simulations.

Comparison of experimental results and GEMR simulations

Recent GEMR simulations have shown the importance of another instability in the near SOL, the so-called conducting wall instability (CWI) [6]. Here temperature fluctuations are driven by the temperature gradient and translated to potential fluctuations. A simulation of the

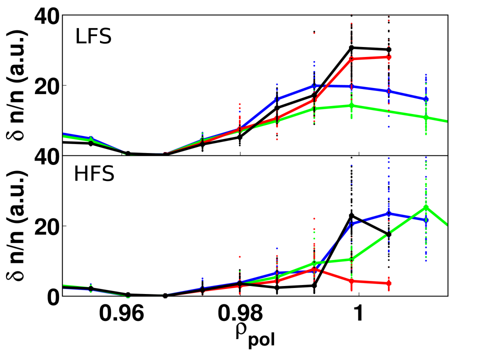

Fig. 3. Density fluctuation δ*n/n* profiles on the LFS (top) and the HFS (bottom) for different magnetic configurations – USN at the beginning of the discharge (blue), DN (red), LSN (black) and USN at the end of the discharge (green). USN δ*n/n* profiles have wider ρ range due to corresponding shifts of density profiles.

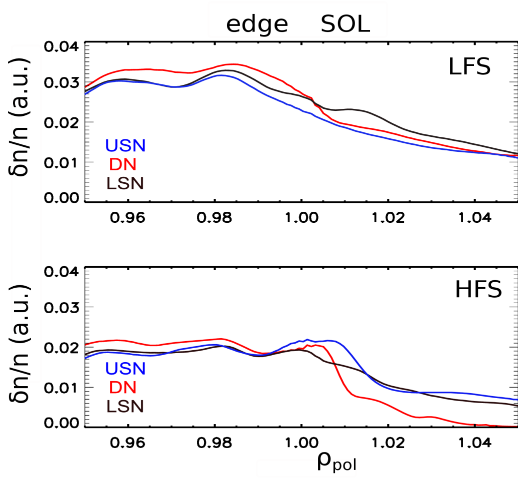

Fig. 4. Density fluctuation profiles δ*n/n* obtained by GEMR simulations on the LFS (top) and the HFS (bottom) for different magnetic configurations – USN (blue), DN (red) and LSN (black).

experiment was performed with the gyrofluid GEMR code with the same parameters for the three configurations. Even though the simulations were done in a circular plasma geometry with varying limiter positions only and therefore without taking the X-point geometry into account, the three configuration are called LSN (black), USN (blue) and DN (red) for easier comparison with the experiment. As the CWI is driven by the temperature gradient a setup with a strong electron temperature gradient $L_n = 3\,L_T$ was chosen with the drawback that density fluctuations are smaller in comparison to cases with steeper density gradient.

Although the simulations are done in a circular geometry and effects of the triangularity are not taken into account, the turbulence levels show differences in the near SOL (Fig.4). In the region close to the separatrix $1 \le \rho \le 1.005$ the δ*n/n* is higher for LSN in comparison with

USN on the LFS and vise versa on the HFS that is in agreement with the experimental results. The $\delta n/n$ for DN configuration is closer to LSN on the LFS and to USN on the HFS. At $\rho > 1.005$ the $\delta n/n$ in the DN configuration strongly drops at HFS. Between $1.005 \le \rho \le 1.015$ the largest difference between configurations is observed. The turbulence level on the HFS is similar to the turbulence level on the LFS in the USN configuration as observed in the experiment. The cross-phase between potential and density fluctuations $\alpha(\tilde{\varphi}, \tilde{n}_e)$ is close to zero at around $\rho > 1.005$ in USN, showing its similarity to a drift-wave instability. At that location, the estimated cross-phase between potential and temperature fluctuations $\alpha(\tilde{\varphi}, \tilde{T}_e)$ is close to zero, which shows that the underlying instability mechanism is the CWI.

Conclusions

Effect of magnetic configuration on the poloidal asymmetries of density fluctuations is mostly pronounced outside the separatrix. The strongest HFS/LFS asymmetry of fluctuations in DN SOL, corresponds to HFS SOL being isolated from LFS. In USN configurations, HFS SOL turbulence increases above the LFS level. This behavior is currently under investigation and might be induced by the CWI driven by different temperature gradients at these locations that are configuration dependent. Drop of density fluctuations inside the separatrix both at LFS and HFS observed in region of strong radial electric field shear for all configurations.

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References

[1] R. Nazikian and E. Mazzucato, Rev. Sci. Instrum. **66 (1)**, 392 (1995)

[2] C. Fanack et al., Plasma Phys. Control. Fusion **38** , 1915 (1996)

[3] J. Schirmer, PhD thesis (2005)

[4] H. Biglari et al., Phys. Fluids **B2**, 1 (1990)

[5] T. T. Ribeiro and B. D. Scott, Plasma Phys. Control. Fusion **50**, 055007 (2008)

[6] P.Manz et al., Phys. Plasmas **22**, 022308 (2015)