DYNAMICS OF TURBULENCE AND ZONAL FLOWS EFFECTED BY TUNGSTEN IMPUITTY IN HL-2A EDGE PLASMAS

[1,2] Q. Zou, [1]J. Cheng, [2]Z.B. Shi, [1]Y. Xu, [2]L.W. Yan, [1]X. Chen, [1]J. Chen, [2]J.M. Gao, [2]Z.H. Huang, [2]N. Wu, [3]C.F. Dong,[2]W.C. Wang, [1]R.X. Huang, [1]Z.S. Shi, [2]X.Q. Ji, and [2]W.L. Zhong

[1]Institute of Fusion Science, School of Physical Science and Technology, Southwest Jiaotong University, Chengdu 610031, People's Republic of China
[2]Southwestern Institute of Physics, Chengdu 610041, People's Republic of China
[3] Key Laboratory of High Performance Scientific Computation, School of science, Xihua University, Chengdu 610039, China
Email: qianzou@my.swjtu.edu.cn

Tungsten (W) has been selected as the plasma-facing components (PFCs) in the international thermonuclear experimental reactor (ITER) due to its high erosion resistance and good thermal conductivity [1, 2]. In general, the level of tungsten impurity concentration in a fusion reactor is roughly steady, but a transient increase might occur in the case of burst events, i.e., edge-localized mode eruptions [3] and strong instability driven by high energy particle [4], which plays a critical role in plasma performance. Therefore, the study of effect played by tungsten impurity on turbulence and the resulting transport has attracted enormous interest in magnetically confined plasmas. Several theoretical works indicate that tungsten has a stabilizing effect on trapped electron mode (TEM) or ion temperature gradient (ITG) turbulence when the impurity ion density profile is inwardly peaked [5, 6], and the impurity can significantly enhance or reduce turbulent ion loss dependent on the effective charge number (Z_{eff}) [7]. In experiments, a reduced turbulence regime due to the injected tungsten was observed in HL-2A tokamak [8]. However, the underlying physical mechanism governing the turbulence activity involved the dynamical interplay between turbulence, mean and zonal flows in the presence of tungsten impurities still remains unclear.

In this work, we extend the analysis of earlier work [8] and address the potential mechanism keeping the low turbulent level observed just after the injected tungsten impurity in HL-2A edge plasmas. In this experiment, the tungsten was horizontally injected into plasma from the outer mid-plane by using the laser blow-off (LBO) system. Plotted in figure 1(a)-(d) are time traces of the line-averaged density, plasma current, spatiotemporal profile of radiation power, electron temperature, density and the density fluctuating level measured by Langmuir probe at Δr = -2.5 cm (inside the LCFS about 2.5 cm). The tungsten impurity is injected at t=900 ms, which results in a remarkable reduction of the edge electron temperature. It could be seen more clearly from the spatiotemporal profile of the radiation power, as shown in figure 1 (c). Just after the tungsten injection, the enhanced radiation is found to mainly localize at the plasma edge, and then this radiation belt starts to inwardly diffuse from edge to core plasma. Meanwhile the electron temperature also rises, whereas the plasma edge density has a slight reduction. Here an important observation is that the edge density fluctuation starts to drop immediately after the tungsten impurity injection, and then it keeps at a low fluctuation level starting from t=920 ms. It seems that the time scale of turbulence drop is comparable with the staying time of radiation belt localized in edge region. A question is naturally raised, what is the physical mechanism sustaining the low turbulence level from t=920 ms. Actually, the enhanced zonal flow was found in the time range of 950-1100 ms in previous work [8], but the trigger for the amplification of zonal flows and the dynamical interaction between turbulence, mean and zonal flows in the time range of 900-940 ms has not been illustrated yet.

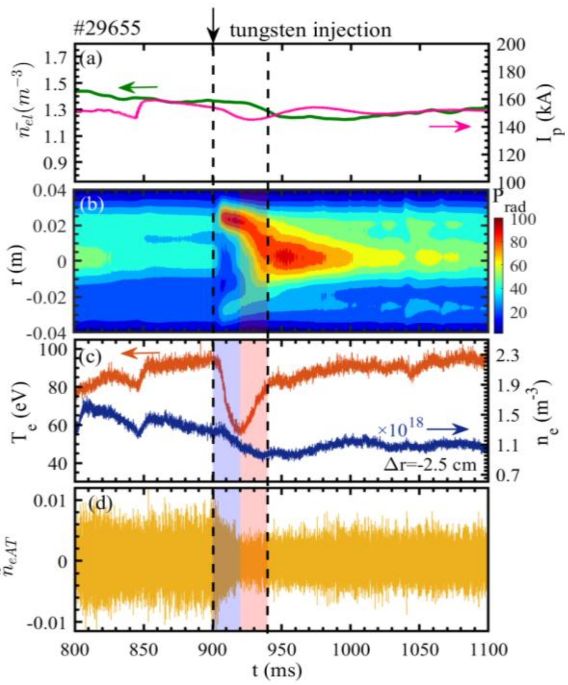

Figure 1. The time traces of the line-averaged density together with the plasma current (a), spatiotemporal profile of radiation power estimated by bolometer (b), electron temperature, density measured by Langmuir probe at Δr = -2.5 cm (c), and the turbulence fluctuating level (d).

For further studying the dynamics of the turbulence and turbulence-driven flows effected by tungsten impurity, the behaviours of mean and geodesic acoustic mode (GAM) zonal flows during $900\ \mathrm{ms} < t < 940\ \mathrm{ms}$ has been analysed. Plotted in figure 2(a) is the time-frequency spectrogram of floating potential fluctuation with tungsten impurity injection. The coherent mode with frequency f=11.7 kHz has been confirmed to be GAM zonal flows in previous work. Actually, the effect of tungsten impurity on the dynamics of turbulence and turbulence-driven flows could be divided into two phases: phase-I from 900 to 920 ms (blue shaded area) and phase-II from 920 to 940 ms (red shaded area), as shown in figures 2(b)-(d). It could be observed that the GAM zonal flows significantly reduce in phase I, which is mainly caused by the increased collisional damping rate (γ_{damp}) due to the reduction in electron temperature, as shown in figure 1(c). And the increased collisionality also results in the sharp reduction of the edge turbulence in phase I, as shown in figure 1(d). However, the effect of tungsten impurity on edge turbulence and GAM zonal flows might become less pronounced as the tungsten impurity propagates towards core plasma in phase II. And an important observation is that the fast recovery of $\mathrm{E} \times \mathrm{B}$ mean flow from $t = 920$ ms, estimated by DBS reflectometer, as shown in figure 2(e). The sequent increase of the $\mathrm{E} \times \mathrm{B}$ mean flow has the ability to promote the energy transferred from turbulence to GAM zonal flows via the so-called straining-out process, which is also confirmed by the enhancement of the summed squared bicoherence as shown in figure 2(d). Thus both the increased zonal flow and $\mathrm{E} \times \mathrm{B}$ mean flow are responsible for the maintaining of the low turbulence level. This work could advance our understanding of the essential effect played by tungsten impurity on turbulence, turbulence-driven flow and the associated transport in edge plasmas. The detailed experimental results will be presented in this conference

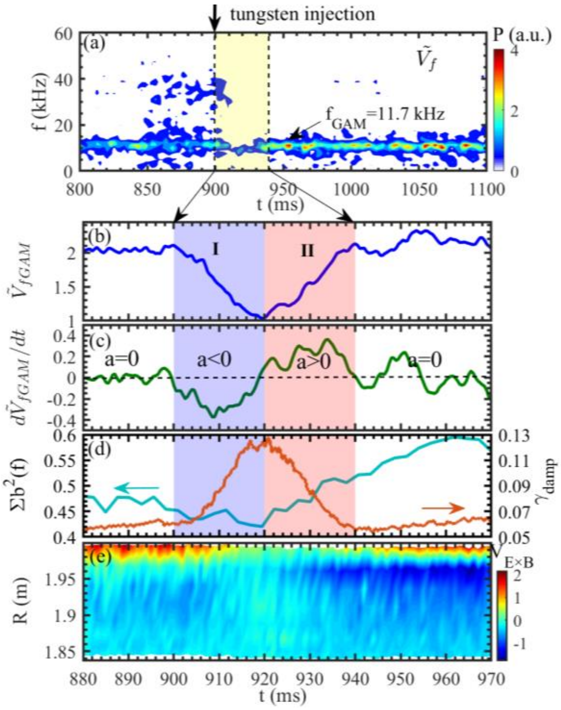

Figure 2. The time traces of the frequency spectrogram estimated by the floating potential (a), the zoomed-in plots: the GAM amplitude (b), the growth rate of GAM (c), the summed squared bicoherence together with the GAM collisional damping rate γ_{damp} (d), and the $\mathrm{E} \times \mathrm{B}$ mean flow velocity estimated by the doppler backward scattering (DBS) reflectometer (e).

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