1.16 Investigation of statistical characterization of radial turbulence in the edge of HL-2A plasma with visible spectroscopy diagnostic

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Transport processes are believed to be driven by plasma turbulence which behaves the plasma parameters with fluctuations and determines or affects the confinement properties of tokamak or other toroidal devices. In order to optimize fusion-energy systems and attain high performance of fusion plasma, it is important to investigate and understand the turbulence dynamics, especially the edge turbulence. In this paper, we attempt to characterize turbulence by the visible spectroscopy measurements and emphasize on its statistical characterizations in the HL-2A edge plasma.

The visible optical diagnostic system for edge turbulence measurement mainly consists of 3 lenses which are designed to reduce spherical aberration and coma, an interference filter for line emission and a photodiodes detector array which has 46 available channels.

![Fig. 1. Scheme of the visible optical diagnostic system, it views the tangential direction of HL-2A to radially measure Dα emission in the edge plasma, the radial resolution is 0.9 cm in the object plane.](image)

For radial turbulence measurement, this diagnostic system is designed to view the tangential direction of the HL-2A low field side (LFS) in the equatorial mid-plane and focus in the radial direction as shown in Fig. 1. Spatial resolution is 0.9 cm in the object plane and the outmost channel corresponds to r = 41 cm.

A comparison of the radial turbulence velocity and correlation length which estimated by time-delay correlation technique between L-mode and H-mode has been done in the HL-2A plasma edge.

The radial turbulence propagation velocities seemed to jump around 1 km/s during the 20ms interval of L-mode, the ensemble average velocity $\langle v_r \rangle = 1.06 \pm 0.53$ km $\cdot$ s$^{-1}$, however, they became flatter after the L-H transition during the 20 ms H-mode phase, and most of them were above 1 km $\cdot$ s$^{-1}$, the average velocity $\langle v_r \rangle = 1.20 \pm 0.49$ km $\cdot$ s$^{-1}$. The correlation length were universally little longer in the H-mode than the L-mode case. In summary, there was a slight increase but no significant change in either the radial turbulence velocity or correlation length between the L-mode and H-mode.

The probability distribution functions (PDFs) calculated at 3 different radial locations each taken for 20 ms time interval are shown, the Gaussian distributions are displayed by the dashed curves, the shapes of PDFs are obviously positive deviated and exhibit non-Gaussian distribution among the three spatial locations. The skewness of fluctuation is positive, which indicates large amplitude events dominant, both the S and K increase with the radial outward as shown. The fluctuations tend to Gaussian distribution toward inner channels. These calculations of high order moments of the PDF further support the appearance of edge intermittency in the SOL.

The normalized PDFs of the radial velocity component at four different threshold values $v_t$ from two consecutive discharges is shown in Fig. 2. All of the PDFs centers are shifted towards positive velocities, which correspond to outward radial propagation. The mean velocity increases with the threshold $v_t$, indicates the smaller amplitude burst events have lower propagation velocities from this statistic analysis. The relationship between the radial velocity and the blob size seems to be roughly consistent with the scaling of $v_r \propto \delta^{1/2}$ in the ideal limit. However, it disagrees with the scaling of $v_r \propto \delta^{-1}$ in the 2D sheath-connected regime and that of $v_r \propto \delta^{-1/3}$ obtained by BOUT simulation of 3D blob dynamics model. Particularly, the

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blob velocity is independent of the blob size when the blob beta is large enough to cause field-line bending.

The radial motion and structure of edge turbulence in the HL-2A tokamak was measured with visible spectroscopy diagnostic system, the radial turbulence propagation velocity and correlation length were evaluated by time-delay correlation technique and there were typically $v_0 = 0.4 \pm 1 \text{ km} \cdot \text{s}^{-1}$ and $L_r = 2 \pm 6 \text{ cm}$, respectively. The edge intermittent events accompanied with turbulence have been observed in plasma edge and propagated outward radially, especially through the scrape-off layer, the fluctuation signals of $D_n$ exhibit strong asymmetric probability distribution functions (PDFs). Their propagation trajectories and radial velocity PDFs were inferred from a special correlation technique and the results indicated the radial velocity of intermittent event depends on its amplitude. Some comparisons with previous measurements and models were also presented.