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Turbulence spreading into edge stochastic magnetic layer induced by MHD activity in toroidal confinement plasma

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The divertor heat load mitigation is a crucial issue for magnetically confined fusion reactors, where the divertor heat flux will increase significantly more than the present-day devices. Control of the power fall-off length is, therefore, mandatory. In order to reduce the heat flux, various schemes are being attempted, such as impurity seeding to dissipate the energy via impurity radiation, magnetic flux expansion of the divertor leg, and resonant magnetic perturbation (RMP) field application to increase radiation volume and/or to enlarge contact area with the divertor plate.

The turbulence in the scrape-off layer (SOL) has been also recognized as a key player determining SOL width [1,2]. Propagation of the turbulence (turbulence spreading) is important to determine the resulting turbulence profile. Theoretical models of turbulence spreading predict that the turbulence excited at a linearly unstable region can propagate to a region of weaker excitation or of linearly stable [3,4,5]. The process appears as a non-locality of transport, where the fluctuation level at one place depends on the destabilizing sources located elsewhere [6]. The theoretical model and the numerical simulation predict that transport barrier formed by flow shear reduces or blocks the turbulence spreading [7,8].

Experimentally, however, direct observation of the turbulence spreading is difficult, because it requires to distinguish the fluctuations excited locally from those propagated remotely from somewhere else. Although a few experiments observed signature of the turbulence spreading [9, 10, 11], there have been no experiments to control the divertor heat load by increasing the turbulence in the SOL region. In this contribution, we present recent experiments on the turbulence spreading and discuss the related mechanism of the spreading and its impact on the SOL plasma.

Turbulence spreading into edge stochastic magnetic layer induced by magnetic fluctuation is observed at the sharp boundary region in the Large Helical Device (LHD) [12]. The density fluctuation excited at the sharp boundary region with a large pressure gradient does not propagate into the boundary region due to the blocking of turbulence spreading by the large second derivative of the pressure gradient. Once the magnetic fluctuation appears at the boundary, the density fluctuation begins to penetrate the edge stochastic layer and the second derivative of the pressure gradient also decreases, as shown in Fig.1. The increase of density fluctuation in this layer results in the broadening and reduction of the peak divertor heat load. It is demonstrated that magnetic fluctuation plays a key role in controlling the turbulence spreading at the boundary of plasma which contributes to the reduction of divertor heat load.

The estimated ExB shear flow rate for the blocking and spreading of the turbulence is found to be consistent with the prediction of ref.[7]. Moreover, effects of stochastic magnetic field structure on turbulence excitation is also important [13]. At the conference, details of the experimental observations and underlying physics are discussed.

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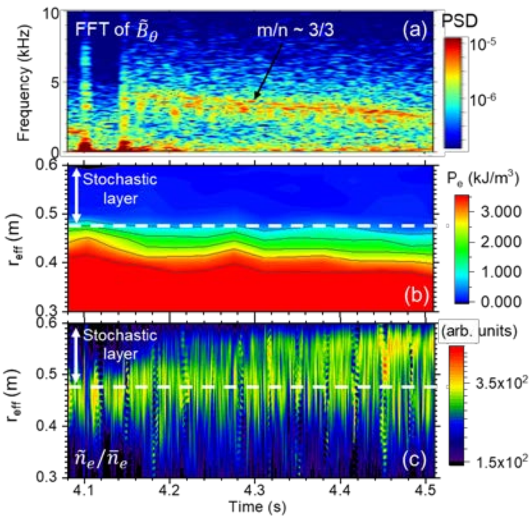

Figure 1 Temporal evolutions of (a) magnetic fluctuation, radial profiles of (b) pressure contour, and of (c) density fluctuation, respectively [12]