Recent progress in edge turbulence studies at the HL-2A tokamak

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Recently, experimental studies in edge turbulence and turbulent transport at the HL-2A tokamak have made significant progress in following areas: (i) physical link between self-organized criticality (SOC) dynamics and non-local heat transport, and the regulation of nonlocal transport by self-generated neoclassical tearing modes; (ii) observation of critical role of the MHD mode crash in triggering the L-H transition with reduced threshold power; (iii) spatiotemporal characterization of zonal flows with multi-channel correlation Doppler reflectometers; (iv) experimental identification of resistive ballooning modes and drift-type ITG-TEM modes at the plasma edge.

— The mechanism governing the transient non-local heat transport has puzzled scientists for many years. In the HL-2A tokamak, we have investigated the properties of self-organized criticality (SOC) dynamics in the transient non-local transport induced by supersonic molecular beam injection (SMBI). Experimental evidence shows that, along with reduction of flow shear at the plasma edge, the SOC or avalanche behaviors are strongly enhanced during the prompt non-local phase by increase in (i) radial correlation length of electron temperature fluctuations; (ii) Hurst parameters on self-similar character of turbulent events and (iii) inward avalanche propagation [1]. These results highlight the importance of the SOC paradigm in governing the transient non-local thermal transport.

In addition, during the non-local experiments at HL-2A, an intimate interaction between the neoclassical tearing modes (NTMs) and the nonlocality has been observed for the first time [2]. Nearby the reversion surface of nonlocality, the increase of local temperature (or pressure) gradient results in onset of NTMs at q=3/2 or 2/1 surface. No visible seeding island was seen. Because of the non-local effect, the NTM can be triggered at lower β_N. Meanwhile, it is found that with the presence of NTMs, the non-local magnitude is reduced due to truncation of inward avalanche propagation, which is caused by enhanced shear flows generated in the magnetic island of NTMs [3].

— In the NBI-heated plasmas ($P_{NBI}\approx$1MW) at the HL-2A tokamak, a kink-type MHD mode routinely occurs and crashes rapidly prior to the L$\rightarrow$I and I$\rightarrow$H mode during the low-intermediate-high (L-I-H) confinement transition. The MHD mode crash evokes substantial energy release from the core to plasma boundary and hence increases the edge pressure gradient and E_r shear, which suppresses turbulence and eventually results in confinement improvement into the H-mode [4].

With increasing heating power by the ECRH (P_{ECRH}=0.4-1.6 MW) added to the NBI, the MHD mode disappears and the plasma enters into the H-mode at higher power threshold. It has been found that with the MHD-mode crash the L-H transition threshold power (P_{th}) is reduced about 10-20% at HL-2A. Under the same NBI heating power, with the increase of plasma density, the magnitude of MHD modes increases as well for the I to H transition, suggesting larger energy release needed for accessing the H-mode regime, in accordance with the empiric scaling of the L-H transition threshold power [5].

— In HL-2A, the oscillations of poloidal plasma flows induced by radially sheared zonal flows are investigated by newly developed multi-channel correlation Doppler reflectometers. The non-disturbing diagnostic allows one to routinely measure the rotation velocity of turbulence, and hence the radial electric field fluctuations. With correlation Doppler reflectometers, a three-dimensional spatial structure of geodesic acoustic mode (GAM) is surveyed, including the symmetric feature of poloidal and toroidal E_r fluctuations, the dependence of GAM frequency on radial temperature and the radial propagation of GAMs. The co-existence of low-frequency zonal flow and GAM is presented. The temporal behaviors of GAM during ramp-up experiments of plasma current and electron density are studied, which reveal the underlying damping mechanisms for the oscillation level of GAM zonal flows [6].

— In the gas-puff modulation experiments, regular oscillations of edge plasma density and electron temperature have been realized in a range of 25 eV $<T_e<$ 110 eV. It has been found that at the low T_e range, the decorrelation time in density fluctuations decreases with increasing T_e, consistent with resistive ballooning modes (RBMs) since the growth rate of the RBM strongly decreases with T_e due to the reduction of the parallel resistivity. At the high T_e range, the turbulence decorrelation time increases with temperature, in agreement with the nature of ITG-TEM modes as they are driven by the edge temperature gradient [7]. These results are in good agreement with the theoretic simulation [8].

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