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Observation of diffusion and convection balanced impurity distribution at the tokamak edge plasma caused by localized turbulence

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Impurity injection in the toroidal fusion devices was shown to be an effective method for controlling the edge localized mode [1], improving the plasma energy confinement [2], and reducing the heat flux on the divertor [3]. It has been observed that plasma instabilities can be excited or changed by the impurity ions in tokamaks. Understanding the mechanisms of the reciprocal interaction among impurities and plasma instabilities is of great interest to these topics.

On HL-2A, specific experiments have been performed to investigate the effect of Neon (Ne) impurity injection on the edge plasma instabilities. For the first time, strong interactions between the localized turbulence and diffusion/convection balanced impurity distribution are observed in the tokamak. As shown in Figure 1(a), the plasma radiation power increases significantly after the Ne impurity injection by SMBI. It is interesting to note that the increase in the radiation power is mainly localized at $\rho = 0.7\sim0.9$ and persists for hundreds of milliseconds, much longer than SMBI pulse length (1.2ms). This indicates that the Ne impurity is concentrated in a localized region, with little or no radial transport (impurity flux equals zero) under free source of impurity. This shows that the diffusion and convection terms of the impurity ions are compensated. A broad-band spectrum of turbulence at frequencies ranging from 25 to 70 kHz is excited after Ne impurity injection, lasting the same time with the impurities as shown in Figure 1(b). Furthermore, this broad-band turbulence is localized at about $\rho = 0.7\sim0.9$, where the Ne impurity is concentrated, as shown in Figure 2. This indicates that the turbulence is excited by the Ne impurity injection. It is inferred that the turbulence could play a role in maintaining edge peaked impurity ions. These results provide reliable support for the development of divertor steady-state and localized radiation layers control by impurity injection in tokamaks.

References
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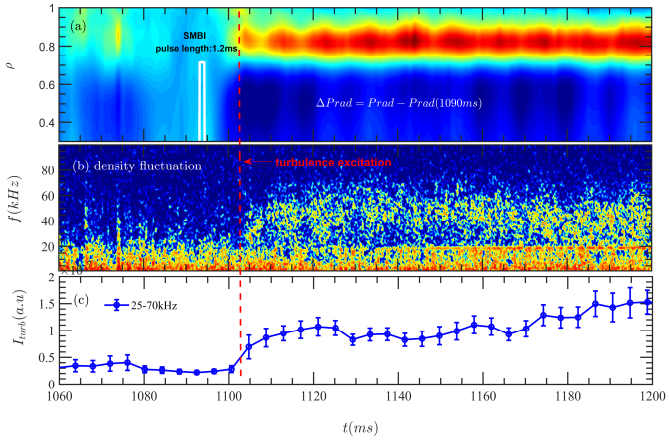

Figure 1. (a) Monitor of the SMBI pulse; and spatiotemporal evolution of the increment of plasma radiation power density after Ne impurity injection, (b) amplitude spectrogram of density fluctuation at ρ = 0.85, and (c) integrated turbulence intensity in the frequency range of 25-70kHz.

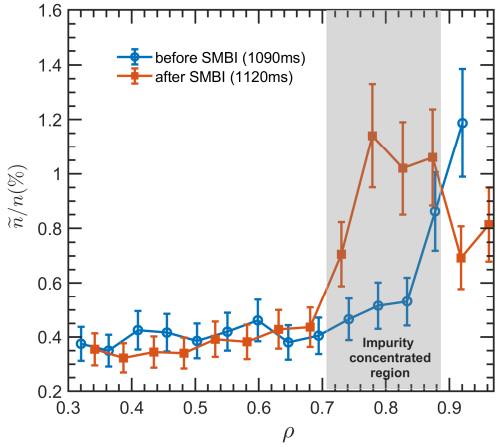

Figure 2. Profiles of the relative intensity of the turbulence (25-70kHz) measured by BES before and after SMBI.