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Excitation of Electromagnetic Turbulence by Edge Self -accumulated and Externally Seeded Impurity in the HL-2A H-mode Plasmas

Wulyu ZHONG
Southwestern Institute of Physics, P.O. Box 432, Chengdu 610041, China

In a burning plasma device like ITER, the divertor heat load could exceed several times the tolerable limits of plasma facing materials (10MW/m^2) [1]. One of envisaged solutions is using impurity seeding technique to lower the heat loads through converting the heat power flux into impurity seed radiation. Furthermore, it has been found that the impurity seeding is benefit for ELM control by affecting the pedestal dynamics and instabilities [2, 3]. However, the role of impurity in here and the underlying mechanisms are hitherto unrecognized and have not been experimentally identified so far [3, 4]. Theoretically, it predicted that the electromagnetic turbulence can be driven unstable by temperature gradient or impurity density gradient even in finite-β plasmas [5-7].

In the HL-2A tokamak, the impact of impurity on pedestal dynamics and instabilities has been investigated recently. Experimental results have shown that, during the H-mode phase, the impurity is gradually accumulated at the edge plasma region, and a broadband (frequency of 50-150 kHz) electromagnetic turbulence is excited. The coherency between density and magnetic fluctuations indicates that the turbulence is located around the pedestal top, revealing that the turbulence is strongly correlated to the accumulation of impurity at the edge plasma region. The correlation between the turbulence intensity and impurity gradient in positive and negative gradient regions shows double impurity critical gradients that are responsible for the excitation of the turbulence [8]. The critical value of $|R/L_{nz}|$ in positive gradient region (~25) is much lower than that in the negative region (~102), as shown in Fig.1a. Theoretical work has predicted that the electrostatic impurity mode can be excited in the presence of impurity ions with an outwardly peaked density profile [9]. However, there were fewer theoretical works that have addressed the electromagnetic model with impurity ions. In this work, the effects of the carbon impurity ions on electromagnetic turbulence have been studied with a gyrokinetic code HD7, which is used to solve the electromagnetic integral eigenmode equations for the study of drift instability [10]. The strong asymmetry of two critical gradients from simulation is consistent with the experimental observation, as shown in Fig.1b. It suggests that the observed electromagnetic turbulence could belong to a kind of drift instability which exhibits an electromagnetic feature.

The electromagnetic turbulence can also be excited by externally seeded impurity in HL-2A. Aluminum impurity has been seeded by Laser Blow-Off (LBO) system in H-mode plasmas. During the impurity seeding phase, the ELM interval is prolonged to several times longer than that of the natural ELMs. The long inter-ELM period is associated with the excitation of the electromagnetic turbulence. In addition to the broadband turbulence, quasi-coherent EM modes can be excited by externally seeded impurities in more recent HL-2A experiments. The effect of impurity species on pedestal instabilities and plasma confinement will be presented.

HL-2A experimental results suggests that the quasi-stationary edge localized impurity profile offers the possibility to actively control the pedestal dynamics and ELMs via pedestal turbulence, which helps to protect plasma facing components.

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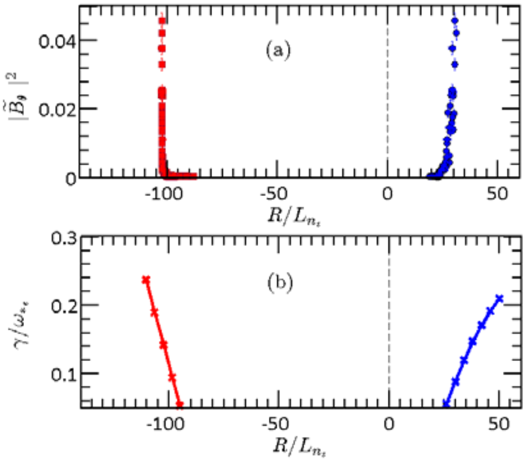

Figure 1.(a) Experimental result: the relation between the intensity of electromagnetic turbulence and the normalized impurity density gradient, (b) simulation results for electromagnetic turbulence: the normalized linear growth rate of electromagnetic turbulence versus the normalized impurity density gradient.