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Transition characteristics and fluctuation evolution in electron cyclotron heated low to high mode transition in KSTAR

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According to the current ITER operation plan, electron cyclotron heating (ECH) will be the dominant heating method in the initial operation. Achieving an early H-mode during this initial operation is necessary to ensure the integrity of the device to achieve the project mission. Therefore, this rekindles the interest in ECH dominant low to high (LH) transition study. The successful LH transition using ECH only has been demonstrated in many tokamak experiments. This result, in fact, has been an evidence of accessibility to the H-mode independent of heating method. In particular, a recent AUG experiment revived an interest in ECH-induced LH transition phenomenology by showing that the steady state H-mode sustained by ECH could be operated in a ELM-free condition8. According to Ref. [1], the ELM-free state is shown to be correlated with the appearance of the quasi-coherent mode (QCM) which emerges during LH transition.

In this work, we explore characteristics of LH transition in KSTAR plasmas that has been achieve with ECH only. Specifically, we characterize main features of LH transition and the H-mode state driven and sustained by ECH. In order to make a systematic study of this phenomenon, we carry out KSTAR experiments scanning the pre-transition density (i.e. the L-mode density) for a fixed maximum ECH power available at KSTAR. In this experimental set-up, then, one expects the appearance of a density window within which the LH transition happens, owing to the existence of the characteristic U-shaped P_{LH} curve in terms of density. It is also of interest if the minimum density value obtained in KSTAR experiments is consistent with an empirical scaling law proposed in Ref. [2]. Indeed, results recuperates the characteristic U-shape curve in transition power (P_{LH}) vs. density, exhibiting minimum density for LH transition. The minimum density, however, is found to be ~27% lower than that predicted by a scaling law in Ref. [2] based on the electron-ion heat equilibration.

A d1etailed study of fluctuation evolution has been also carried out for low-k T_e fluctuations near the edge region. An analysis of the fluctuation characteristics in terms of collisionality and L_{Te} at the L-mode edge suggests that dissipative trapped electron mode (DTEM) would be the possible dominant edge instability. A comparison with a gyrokinetic study supports this observation. During LH transition, we observe a coherent mode which begins at higher frequency (~60 kHz) and chirps down to ~20 kHz as the LH transition proceeds. This observation is consistent with that in AUG where a similar coherent mode is observed during ECH driven LH transition [1]. The coherent mode is found to be localized near the pedestal top without strong evidence that it originates from inside the pedestal. The coherent mode is also observed in high-k core density fluctuations in the core region, suggesting that the mode is likely responsible for both the core/near edge turbulence. Further detailed results on fluctuation evolution during LH transition will be presented at the conference.

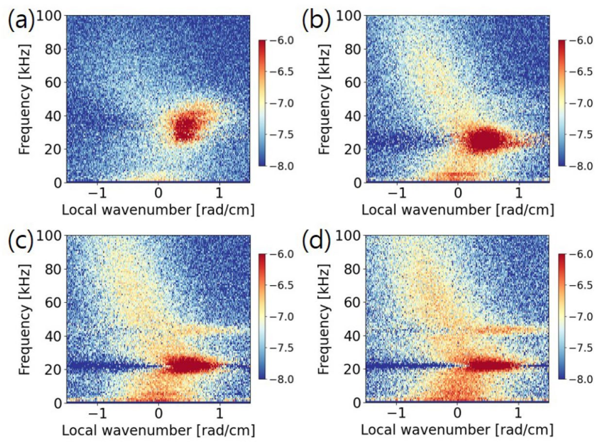

Fig.1 Dispersion plots during and after the LH transition period, clearly exhibiting ECM evolution and recurrence of fluctuations at the H-mode phase. Coherent mode begins to nucleate at t ≈ 7.15 sec with f~ 60 kHz. As a mature H-mode state is established, the ECM frequency declines and eventually fixed. Low frequency modes begin to reappear as the ECM becomes stronger and chirps down. as shown in (b) to (d).

[1] L. Gil et al, Nucl. Fusion **60** (2020) 054003

[2] F. Ryter et al, Nucl. Fusion **54** (2014) 083003