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低ピッチ角の高エネルギーイオンによる 低域混成共鳴周波数付近のイオン サイクロトロン波不安定性

Ion cyclotron wave instabilities near the lower-hybrid resonance frequency caused by energetic ions with low pitch angles

樋田美栄子[a]、伊神弘恵[a]、福山淳[b]、齋藤健二[a]、神尾修治[a]、關良輔[a]
M. Toida[a], H. Igami[a], A. Fukuyama[b], K. Saito[a], S. Kamio[a], and R. Seki[a]

[a]核融合科学研究所　[b]京都大学
[a]National Institute for Fusion Science,
[b]Department of Nuclear Engineering, Kyoto University

In the Large Helical Device (LHD), stair-like frequency chirping in radio frequency radiations in the frequency range of the lower hybrid resonance frequency ω_{LH} was observed when the LHD plasma is initiated by almost simultaneous injections of the electron cyclotron wave and the tangential neutral beam [1]. The energetic ions produced by tangential neutral beam injection (NBI) have low pitch angles, where the pitch angle means the angle between the magnetic field and the energetic ion beam. In order to study the mechanism of the frequency chirping, nonlinear evolution of instabilities driven by energetic ions with low pitch angles has been analyzed by means of a one-dimensional electromagnetic particle code which simulates self-consistently the full ion and electron dynamics and evolution of electromagnetic fields. The simulation has shown that when the plasma density and ω_{LH} increase with time, the stair-like frequency chirping with the riser $\Omega_{i,}$ where Ω_i is the ion cyclotron frequency, appears in the frequency range of ω_{LH}. The frequency chirping observed in the simulation has characteristics similar to the frequency chirping observed in the RF radiations at the plasma start-up phase of the LHD experiments. The chirping is caused by the coupling between the ion cyclotron harmonic waves excited by the energetic ions and the bulk-ion Bernstein mode with frequencies near ω_{LH}.

Although the simulation can qualitatively explain the LHD experimental results, we have some unresolved problems. For example, we have not clarified the condition for the frequency chirping to appear. According to the experimental results, the frequency chirping caused by the tangential NBI are not observed when the electron cyclotron waves are not injected into the plasma. Also, the frequency chirping disappears when the plasma density becomes large. In order to show the condition for the frequency chirping, we have to investigate the condition for the ion cyclotron waves with frequencies near ω_{LH} to be strongly excited by the energetic ions with low pitch angles. In this presentation, we study, using particle simulations, the dependence of the ion cyclotron wave instabilities near ω_{LH} on parameters such as the ion-to-electron temperature ratio, the plasma density, and the velocity distribution of energetic ions.

[1] H. Igami, et al., ``Observation of stair-like frequency tran-sitions of ion cyclotron harmonic emissions in the lower hybrid frequency range in LHD", presented at InternationalToki Conference 2018, P1-80.

[2] M. Toida, et al., Plasma and Fusion Research **14**, 3401112 (2019).