22Aa07

ASDEX-Upgrade プラズマにおけるマルチモードのハイブリッドシミュレーション

Hybrid simulation of multi-modes in ASDEX-Upgrade plasma

WANG Hao [1]，藤堂泰 [1]，LAUBER Philipp[2]，鈴木康浩 [3]，IDOUAKASS Malik[1]，WANG Jialei[1]，ADULSIRISWAD Panith[1]，LI Hanzheng[4]

WANG Hao[1], TODO Yasushi[1], LAUBER Philipp[2], SUZUKI Yasuhiro[3], IDOUAKASS Malik[1], WANG Jialei[1], ADULSIRISWAD Panith[1], LI Hanzheng[4]

核融合科学研究所 [1]，マックス・プランク・プラズマ物理学研究所（ドイツ）[2]，広島大学 [3]，東京大学 [4]

National Institute for Fusion Science[1], Max Planck Institute for Physics (Germany)[2], Hiroshima University[3], University of Tokyo[4]

Recently, a series of experiments demonstrated the coexistence of Alfvén eigenmode (AE) and energetic particle driven geodesic acoustic mode (EGAM) in ASDEX-Upgrade tokamak[1-3]. A hybrid simulation is conducted with MEGA code[4] to investigate the mode properties and the resonant particles. The simulation is based on realistic experimental parameters with slowing-down energetic particle distribution.

The coexistence of these 2 modes was successfully reproduced in simulation. The simulated AE is 103.5 kHz with mode numbers m/n = 2/-1 and 3/-1 where m and n are poloidal and toroidal mode numbers, and the simulated EGAM is 40 kHz with mode number m/n = 0/0. AE and EGAM are located around r/a = 0.6 and 0.5, respectively. The above mode properties are consistent with the experiment. Also, it is found that the EGAM linear growth rate is very low, but in the nonlinear phase, it is exponentially excited and becomes very strong.

The resonant conditions of AE and EGAM are investigated. For AE, $\omega_{AE} = -\omega_\phi + \omega_\theta$, and for EGAM, $\omega_{EGAM} = \omega_\theta$, where ω_{AE} and ω_{EGAM} are mode frequencies, ω_ϕ and ω_θ are particle toroidal and poloidal frequencies.

Preliminary evidence has been found to explain why EGAM can be nonlinearly excited by AE. By analyzing the distribution function in toroidal angular momentum P_ϕ and energy E phase space, it is found that in the linear phase the energetic particle re-distribution happens in AE resonance region. Then, in the nonlinear phase, the particles in between AE and EGAM are gradually affected by the wave-particle interaction, and re-distribution happens there. Finally, the EGAM resonance region is affected, and the re-distribution happens and makes EGAM excited. The above process is also confirmed by analyzing energy transfer between energetic particles and modes in (P_ϕ, E) phase space.

A further investigation will be conducted soon.

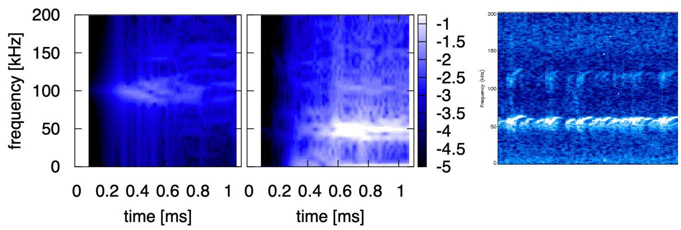

Fig. 1: (Left and middle) Frequency spectrums of AE and EGAM in MEGA simulation; (Right) Frequency spectrum of AE and EGAM in experiment.

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