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Simulation of energetic particle driven geodesic acoustic mode channeling in LHD

核融合研 A

王　瀧 A, 藤堂　泰 A, 長壁正樹 A, 井戸　毅 A, 鈴木康浩 A

A*National Inst. For Fusion Sci.*

H. Wang[A], Y. Todo[A], M. Osakabe[A], T. Ido[A], and Y. Suzuki[A]

In the LHD experiment, anomalous bulk ion heating during the energetic particle driven geodesic acoustic mode (EGAM) activity suggests an energy channel created by EGAM. The phenomenon of EGAM channeling has direct significance for plasma heating efficiency. A hybrid simulation code for energetic particles (EPs) interacting with a magnetohydrodynamic (MHD) fluid, MEGA, is used for the simulation of EGAM. Both the bulk ions and EPs are described kinetically.

An EGAM in LHD is successfully reproduced by MEGA code. The mode frequency in linear stage is 50 kHz, and then, frequency gradually chirps up to 65 kHz in the nonlinear phase. The figure shows the energy transfer of EPs and bulk ions. The bulk ion heating during the EGAM activity is observed. The ions obtain energy when the EPs lose energy, and this indicates that an energy channel is established by EGAM. The EGAM channeling is reproduced by simulation for the first time. The heating power to bulk ions around t = 0.1 ms is 3.4 kW/m^3.

The δf distribution of bulk ions at different times are analyzed in the particle transit frequency f_{tr} space to investigate the mechanism of EGAM channeling. A clump around f_{tr} = 25 kHz is formed. The transit frequencies of bulk ions in this clump increases with time evolution, and this transit frequency is kept at half the EGAM frequency. The resonance condition between EGAM and bulk ions is given by $f_{EGAM} = l \cdot f_{tr,bulk}$, where $l = 2$. The energy transfer rate of bulk ions in f_{tr} phase space is also analyzed. There is a peak around f_{tr} = 25 kHz, and the frequency of this peak gradually increases. This increasing indicates that the bulk ions with half mode frequency are kept resonant with the mode and absorb energy from EGAM. This is the first time to quantitatively reveal the resonance condition between EGAM and bulk ions during the establishment of EGAM channeling.

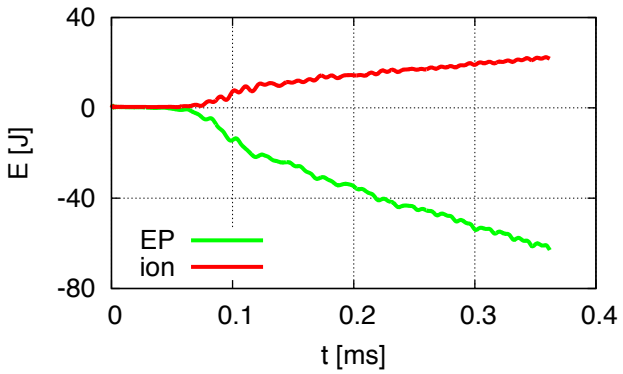

FIG. Energy transfer of EPs and bulk ions.