Nonlinear particle simulation of radio frequency wave in tokamak

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Nonlinear particle simulations of radio frequency waves in tokamak have been carried out for the first time with a real electron-to-ion mass ratio by using the GTC code [1]. Linear simulation of the lower hybrid (LH) wave-packet in the tokamak shows that the wave propagates faster in the high field side than the low field side, in agreement with a ray tracing calculation [2]. Global electromagnetic simulation confirms that the toroidicity induces an upshift of parallel reflective index when LH waves propagate from the tokamak edge toward the core, which modifies the radial position for the mode conversion between slow and fast LH waves. Furthermore, moving LH antenna launch position from low field side toward high field side leads to larger upshift of the parallel reflective index, which helps the slow LH wave penetration into the tokamak core. The broadening of the poloidal spectrum of the wave-packet due to wave diffraction is also verified in the simulation of the LH wave propagation. Both the upshift and broadening effects of the parallel spectrum of the wavepacket modify the parallel phase velocity and thus the linear absorption of LH waves by electrons Landau resonance [3]. In the nonlinear simulation of ion Bernstein wave (IBW) in a tokamak, parametric decay instability (PDI) is observed where a large amplitude pump wave decays into an IBW sideband and an ion cyclotron quasi-mode (ICQM). The ICQM induces an ion perpendicular heating, with a heating rate proportional to the pump wave intensity [4]. Finally, in the electromagnetic LH simulation, nonlinear wave trapping of electrons is verified and a plasma current is nonlinearly driven. In collaborations with Z. Lin, A. Kuley, X. S. Wei, Y. Xiao, W. Zhang, G. Y. Sun, and N. J. Fisch.

[1] J. Bao *et al.*, submitted to PoP (2016).

[2] J. Bao *et al.*, PPCF **56,** 095020 (2014).

[3] J. Bao *et al.*, submitted to NF (2016).

[4] A. Kuley *et al.*, PoP **22**, 102515 (2015).

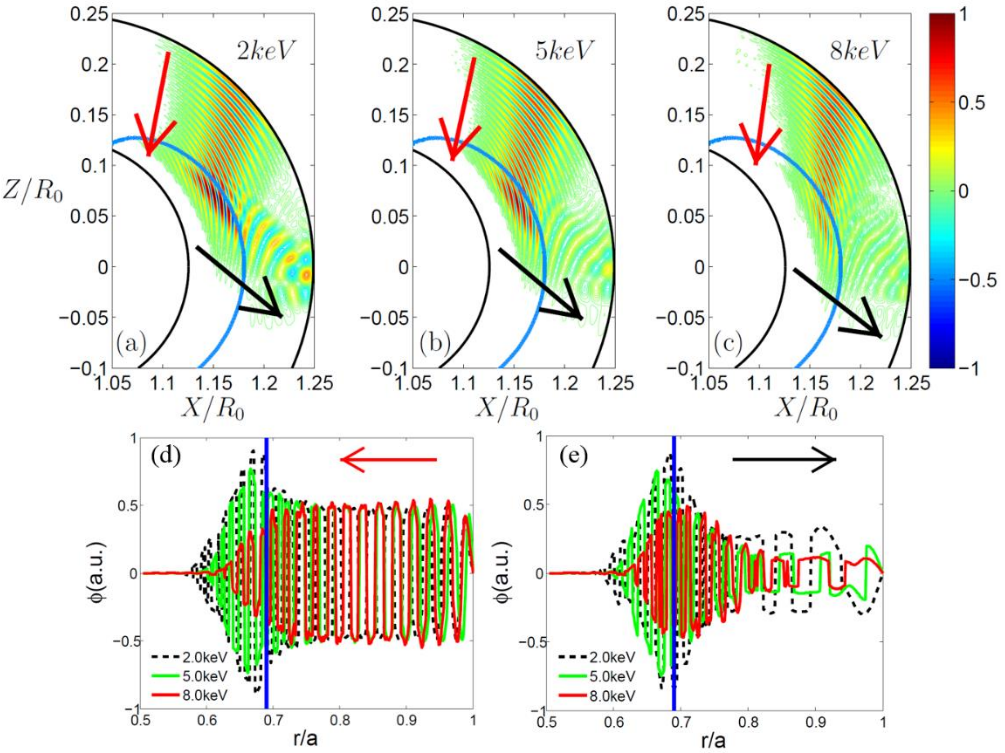

Figure. Panels (a), (b) and (c) are the LH wave structures in poloidal sections with 2.0 keV, 5.0 keV and 8.0 keV electron temperature during mode conversion, respectively. The color scale represents the electrostatic potential ϕ in a. u. unit. Panels (d) and (e) are the comparisons of the radial mode structure of the slow and fast electromagnetic LH waves, respectively. The red arrow and the black arrow represent the radial propagating directions of the slow and fast LH waves, respectively.