

# Gyrokinetic Simulation of Microturbulence during Dominant Electron Heating on EAST Tokamak

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**Abstract:** Linear gyrokinetic simulations using the GTC code have been carried out to study microturbulence in dominant electron heating plasma on EAST tokamak experiments. Results indicate that TEM is the main microturbulence during dominant electron heating. TEM linear growth rate  $\gamma$  is increased with normalized temperature gradient  $R/L_{Te}$ . Moreover, the transition from TEM to ITG mode is observed during NBI combining with other dominant electron heating method. NBI power transfer to ions is larger and broader along minor radius than that to electrons after TEM to ITG transition. Significant variation of  $R/L_{Ti}$  may be the main reason of TEM-ITG mode transition when the other plasma parameters are constant.

## 1. Introduction

Three foremost candidates driving drift instabilities are ion temperature gradient (ITG) mode, trapped electron mode (TEM) and electron temperature gradient (ETG) mode<sup>[1-3]</sup>. Among them, both TEM and ITG mode are in long wavelength range with  $k_\theta \rho_s < 1.0$ <sup>[4]</sup>. The ITG mode threshold mainly depends on normalized electronic temperature gradient  $R/L_{Te} = -Rd(\ln T_e)/dr$  while the TEM threshold depends on several parameters including Normalized density gradient  $R/L_n = -Rd(\ln n)/dr$ , magnetic shear  $\hat{s} = (rdq)/(qdr)$  and effective collisionality  $\nu_{eff}$ <sup>[3,5]</sup>.

The research in Tore Supra [6] shows that microinstabilities in plasma transit from ITG-TEM hybrid mode to pure ITG mode when density increases. TEM has isotopic effect, namely TEM microturbulence growth rate reduces with isotope ion mass increasing [7]. The microinstabilities transited from TEM turbulence to ITG-TEM hybrid mode with dominant ITG mode when ion temperature increases [3].

GTC is applied to the simulation researches on turbulence transport successfully [8-10]. In this paper, simulations of microturbulence in typical shots have been carried out by using GTC code. The experiment data are kinetic-dynamic balanced by EFIT and TRANSP code

analysis.

## 2. Experiment Setup

EAST tokamak is a full superconducting tokamak device with a *D*-shaped poloidal cross-section, and advanced divertor configuration. Its major radius  $R = 1.85$  m, minor radius  $a = 0.45$  m, elongation ratio  $k = 1.2\text{--}2$ , maximum plasma current  $I_p = 1$  MA, and maximum designed center toroidal field (TF) strength  $B_T = 3.5$  T. The auxiliary heating systems of LHW, NBI, ICRH and ECRH have been installed on EAST successively. In experiments, steady state high performance plasmas have been achieved in multiple heating scenarios.

## 3. Gyrokinetic simulation results

Three typical shots with dominant electron heating are studied in this work. The main parameters of these shots are shown in table 3.1. Their toroidal magnetic fields and plasma currents are similar. Their electron temperatures are different own to different auxiliary dominant electron heating.

Table 3.1 Main parameters of typical shot no. #55248, #55670 and #55851

Items	#55248	#55670	#55851
Toroidal magnetic field $B_T$ (T)	~ 2.2	~ 2.4	~ 2.3
Plasma current $I_p$ (MA)	~ 0.45	~ 0.4	~ 0.4
Central electron temperature $T_{e,0}$ (keV)	1.8 – 2.3	~ 1.5	1.0 – 1.4
Central ion temperature $T_{i,0}$ (keV)	~ 1.1	1.2 – 1.4	0.8 – 1.0
Central electron density $n_{e,0}$ ( $10^{19}\text{m}^{-3}$ )	~ 3.0	3.2 – 3.8	1.6 – 2.1
Central safety factor $q_0$	1.7	2.7	1.3
Auxiliary heating tools	ICRF, LHW	ICRF, LHW, NBI	ECRF, ICRF

### 3.1 Gyrokinetic simulation with ECRH or ICRF heating plasmas

Different auxiliary heating method was carried out of shot No.55851. The plasma is heated by electron cyclotron resonance heating (ECRH) during 2.5s to 3.6s and ion cyclotron resonance heating (ICRH) during 3.8s to 5.8s. There is no any auxiliary heating during 3.6s~3.8s.

Physical parameters used for GTC simulation is from Transport analysis by using the TRANSP transport code. Calculation results show that the microturbulences at 3.04s, 3.70s and

4.84s are all TEM turbulences. Figure 1 shows the logarithm of perturbed electric potential and the frequency spectrum of TEM at different times.

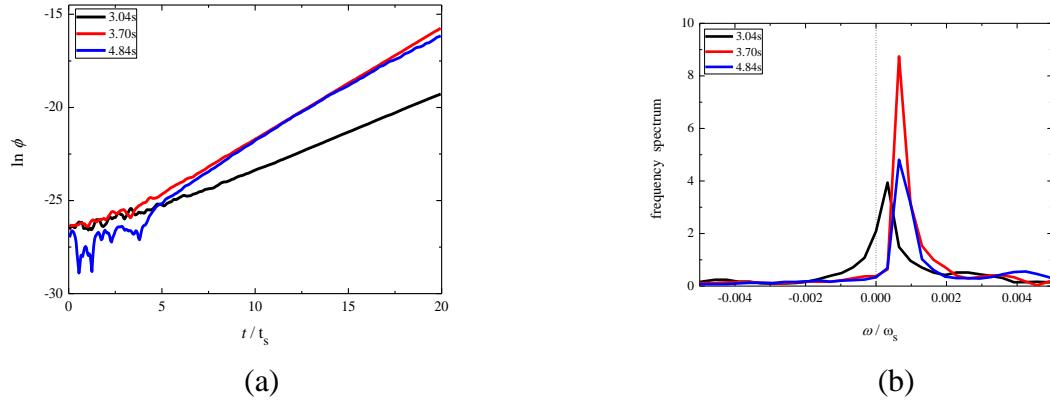


Fig.1 (a) The logarithm of perturbed electric potential and (b).The frequency spectrum of TEM at different times of shot no. 55851.

### 3.2 Gyrokinetic simulation with ICRH and LHW heating plasmas

Another shot no. 55248 is mainly heating by ICRH and LHW. The microturbulence is still TEM at these two times by GTC simulation. Poloidal mode number  $m$  and toroidal mode number  $n$  are near to that of shot no.55851. TEM linear growth rate  $\gamma$  is changed obviously. Figure 2 shows the TEM linear growth rate  $\gamma$  versus  $R/L_{Te}$  at different times of shot no. 55248.

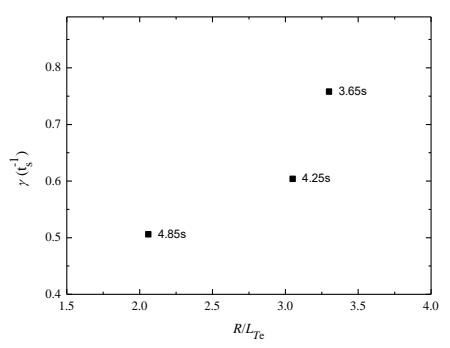


Fig.2 TEM linear growth rate  $\gamma$  versus  $R/L_{Te}$  of shot no. 55248

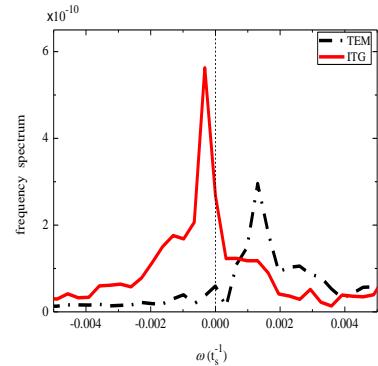


Fig.3 The frequency spectrums of TEM (2.85s) and ITG (3.25s) mode turbulence of shot no.55670

### 3.3. TEM-ITG Transition during dominant electron heating by NBI, ICRF and LHW

Gyrokinetic simulation is taken out for shot no.55670 in this section. TEM transferred to ITG in this discharge, as seen in figure3.  $T_e/T_i$ ,  $v_{eff}$ ,  $n_e$ ,  $R/L_n$ ,  $R/L_{Te}$  and  $R/L_{Ti}$  in core of shot #55670 from 2.85s to 3.45s are shown in fig.4.

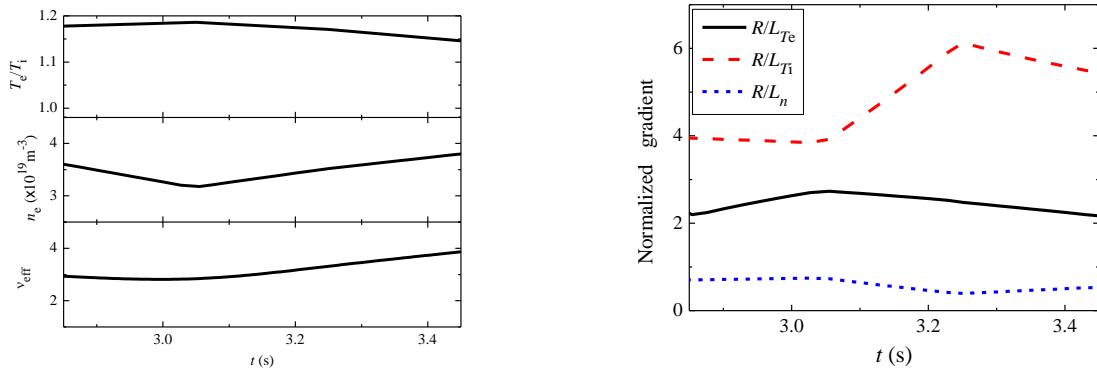


Fig.4 The evolution of  $T_e/T_i$ ,  $n_e$  and  $v_{\text{eff}}$  normalized gradient with time

Seen from fig.4,  $R/L_{T_i}$  is almost constant before 3.05s, but increased rapidly after 3.05s, and then slowly decreased after 3.25s. So  $R/L_{T_i}$  may be the reason for the TEM transferring to ITG when the other parameters are nearly constant.

#### 4. Conclusions

Simulations of microturbulence during dominant electron heating in EAST tokamak have been performed by using gyrokinetic code GTC. TEM is dominant during ECRH、ICRF and LHW heating. But if NBI is turned on combining with other dominant electron heating tools, TEM may transfer to ITG in EAST tokamak. TEM linear growth rate  $\gamma$  is increased with  $R/L_{T_e}$  when other parameters are constant.

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