ITG-TEM Turbulence Transition Causing Edge Temperature Ring Oscillation for Sustaining Stationary I-Mode Plasmas

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ABSTRACT

- Stationary I-mode plasmas (4.4 s) achieved in the EAST Tokamak.
- Low frequency oscillation of the turbulence velocity observed during stationary I-mode plasmas, and it is not GAM.
- Radially localized edge temperature ring oscillation (ETRO) with azimuthally symmetric structure identified.
- Periodic ITG-TEM transition and transport modulation generated by ETRO.
- Turbulence transition controlled by electron temperature gradient.
- Experimental results consistent with the gyrokinetic simulation.

BACKGROUND

I-mode: Improved energy confinement mode (≠I-phase)

ASDEX (Ryter PPCF1998) C-MOD (Mc Dermott PoP2009, Whyte NF2010)

- Stationary I-mode represents a potential and credible solution alternative to H-mode for standard operation scenario in the future fusion reactor (ITER, DEMO)

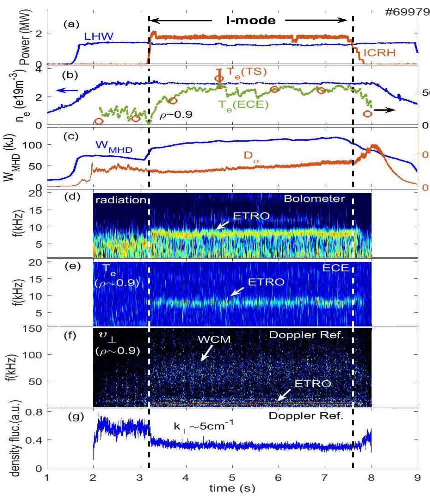
Characteristics of I-mode in comparison with H-mode

- High energy confinement similar to H-mode
- Transport barrier in T_e, but not in n_e
- ELM-free
- Prevent the core accumulation of W impurity
- Removal of fusion ash

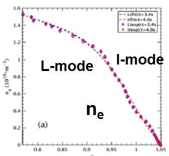
➔ Benefits for steady state operation in fusion reactor

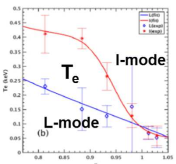
1) WCM (weakly coherent mode): signature of I-mode (Whyte NF2010)
2) GAM concomitant to I-mode on C-MOD and ASDEX-U (Cziegler PoP2013, Manz NF2015), but not essential for EAST I-mode.

STATIONARY I-MODE ON EAST

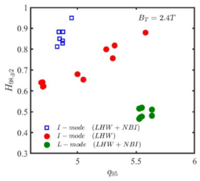


Low frequency oscillation (ETRO) observable on the spectrogram of bolometer and ECE signal.





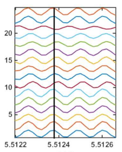
Feng NF2019



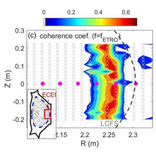
Liu NF2020

IDENTIFICATION OF EDGE TEMPERATURE OSCILLATION

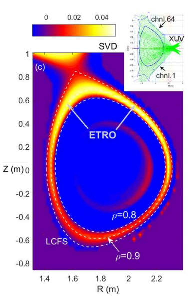
Magnetic signal



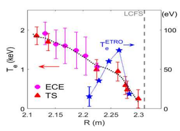
2D ECEI image



Tomography reconstruction from Bolometer array



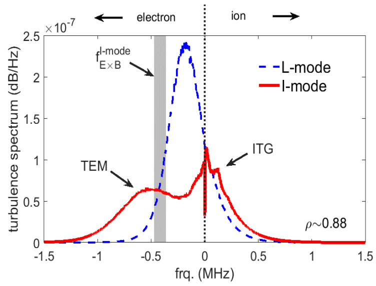
- No toroidal propagation, n=0
- No poloidal structure, m=0
- ETRO: radially localized, ring structure with azimuthal symmetry



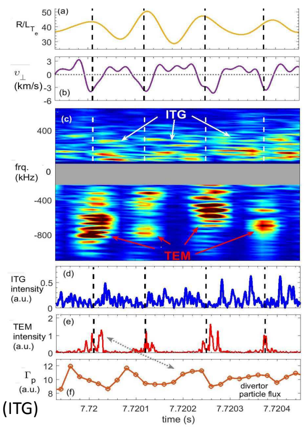
ETRO radial profile

TURBULENCE ANALYSIS

Turbulence Spectra

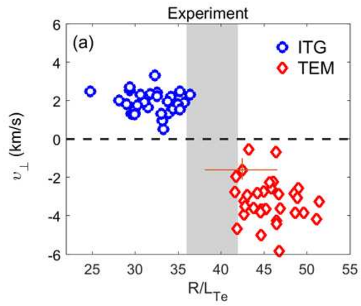


Periodic ITG-TEM Transition

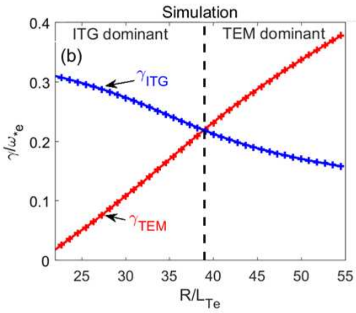


- One peak in L-mode turbulence spectrum
- Two peaks in I-mode turbulence spectrum
- One in electron diamagnetic drift direction (TEM)
- Another one in the ion diamagnetic drift direction (ITG)
- Alternating ITG-TEM transition controlled by electron temperature gradient
- Divertor particle flux modulated by TEM
- Good agreement between experiment/theory

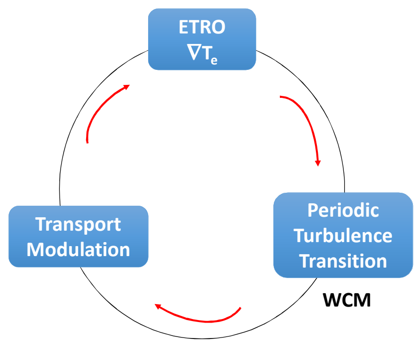
Experiments



Gyrokinetic Simulation



Self-Regulation Mechanism for Stationary I-Mode



CONCLUSIONS

- Alternating ITG-TEM transition controlled by ETRO.
- Self-organizing system including ETRO, periodic ITG-TEM transition and transport modulation plays the key role in stationary I-mode plasmas.
- Possible same origin for WCM and TEM.
- Presence of TEM explaining the absence of the edge particle transport barrier in I-mode plasmas.
- EAST results provide a novel physics basis for accessing, maintaining and controlling stationary I-mode in the future.

REFERENCES

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