Study of pedestal turbulence using Reflectometry on EAST

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Outlines

- Motivation
- Turbulence during L-I-H transition
- Coherent structures observed during the ELM-free phase after L-H transition
- Observation during inter-ELM phase
- Summary
EPED gives good prediction of pedestal parameters

- Pedestal parameters (height and width) is important for overall plasma performance.
- Recent EPED model gives predictions of pedestal height and width consistent with experiments. EPED model based on the assumptions that KBM turbulence limits the local pressure gradient in pedestal and P-B instability induced ELM event gives the hard limit on the pedestal parameters.

P.Snyder, 2013 ITPA-PEP, Fukuoka
Pedestal turbulence important for pedestal evolution?

- DIII-D found high frequency coherent modes (HFCs) showed characteristics of KBM and could be responsible for the saturation of the pedestal pressure.
- Quasi coherent fluctuations (QCFs) on Alcator C-Mod limits the pedestal growth.

Z. Yan, et al 2011 PRL

A. Diallo, 2014 PRL

DIII-D

Alcator C-Mod
Importance of turbulence just inside pedestal

Gyrokinetic analysis on MAST pedestal data shows that the microtreaing mode just inside pedestal (pedestal shoulder) could be also important for pedestal expansion.

D. Dickinson, et al 2012 PRL

FIG. 3 (color online). $\gamma(k_x, \rho_i, t)$ over the ELM cycle at $\Psi_N = 0.95, 0.96, 0.97, 0.98$ in (a)–(d), respectively. $\gamma$ is normalized to $v_{ti}/a$, $v_{ti}$ is the local ion thermal velocity, and $a$ is the minor radius.

Yumin Wang
12th IRW, Jülich, Germany, May 18 – 20, 2015
The presentation will be a collection of results on pedestal turbulence study using reflectometry in past several years on EAST, including the data in 2012 and 2014 campaign.

Set-up in 2012: LFS midplane, share the circuit with density profile reflectometry, single channel.

Set-up in 2014: 15 cm below LFS midplane, two channels.
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L-I-H transition is most easily observed in double null (DN) configuration on EAST.

During I phase, the plasma density and stored energy shows gradual increase, indicating confinement improvement.
During lower $D_\alpha$ amplitude phase (roughly), the reflected wave amplitude shows strong coherent reflection (zero frequency in spectrum), implying turbulence suppression.
Fluctuation modulation occurring only in edge region

- Change probing frequency shot by shot in a series discharges with similar parameters.
- It is determined that the fluctuation modulation only occurs about 2-3 cm inside the separatrix.
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Pedestal coherent structures during ELM-free phase

Coherent mode (CM) with frequency sweeping down is most usually observed in ELM-free phase after L-H transition. This mode generally can not be observed in magnetic fluctuation measured by magnetic probe mounted in vacuum vessel. More analysis on CM is shown later.

In ICRF dominated heating plasma, another coherent structure, harmonic oscillations (HOs), with $n = -1, -2, -3$ was observed by magnetic probe and reflectometry.
CM located in pedestal region

- It has been determined that the CM located in pedestal region just inside the separatrix.

X. Gao, et al 2013 PST
CM is also observed in NBI heated plasma

- In 2014 campaign, co-NBI was installed and has been used to produce H-mode.
- The CM is also observed in the ELM-free phase in NBI heated H-mode plasma.
- The appearance of CM reduced the increasing rate of the pedestal electron pressure, implying an effect of CM on outward pedestal transport.
Characteristics of CM by poloidal correlation analysis

- Poloidal correlation analysis on reflectometry signals give an estimation of $k_\theta$ of CM base mode about -0.5 cm$^{-1}$ to -0.7 cm$^{-1}$, rotating in electron diamagnetic drift direction in lab frame.
- The CM frequency sweeping down is mainly due to the turbulence velocity decrease.
Appearance and disappearance of CM related to electron pressure

- $n_{e,\text{ped}}$ is measured by density refl. and $T_{e,\text{ped}}$ is from the last channel of ECE at about $\psi_N \sim 0.9$.
- Analysis on a series of companion discharges show that the appearance of CM is correlated to the electron pedestal pressure, implying CM is a pressure driven instability. It is also found the disappearance of CM is correlated to pressure.
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During the inter-ELM phase in ICRH heating plasma, mixed ELMs appears and HOs and CM-like structure are observed in between low frequency and high frequency ELMs respectively.
Effect of CM-like mode on edge $T_e$

After ELM crash, the pedestal fluctuation is low and edge $T_e$ shows a fast increase. As the appearance of CM-like mode, the $T_e$ increasing rate is reduced or even stopped.
In between ELMs, pedestal turbulence is usually dominated by broadband (BB) fluctuation.

$k_\theta$ is from 0 to $\sim -3$ cm$^{-1}$, in electron diamagnetic drift direction in lab frame.
Relation between BB fluctuation and pressure increasing rate

1D estimation of $\frac{\delta n}{n}$:

$$\frac{\delta n}{n} = \frac{\delta \phi}{2k_0 L_\varepsilon}$$

$$L_\varepsilon = \frac{1}{1/L_n + (\omega_{ce} \omega_0 / \omega_{pe}^2) / L_B}$$
Turbulence in and inside pedestal

For #48915, the 72 GHz refl. cutoff is just inside pedestal at the first half of inter-ELM phase but moves into pedestal later as pedestal evolves. The fluctuation rotating direction in lab frame changes from ion to electron direction.
For fluctuation just inside pedestal the frequency component with significant coherence can be up to 600 kHz, corr. $k_\theta = 0 - 3$ cm$^{-1}$.

For fluctuation in pedestal, the frequency spectrum is narrower, up to $\sim$200 kHz, corr. $k_\theta = 0 - 3$ cm$^{-1}$.
Summary

- In the past several years, the fluctuation reflectometry was used to study pedestal turbulence and make contribution to the understanding of pedestal transport on EAST.
- Initial results shows that some turbulence modes could be important for the pedestal transport. More work still needs to be done to understand the pedestal evolution on EAST.
Thanks for your attention!