Dual Effect of Laser Blow-off Impurity Seeding on Pedestal Instabilities

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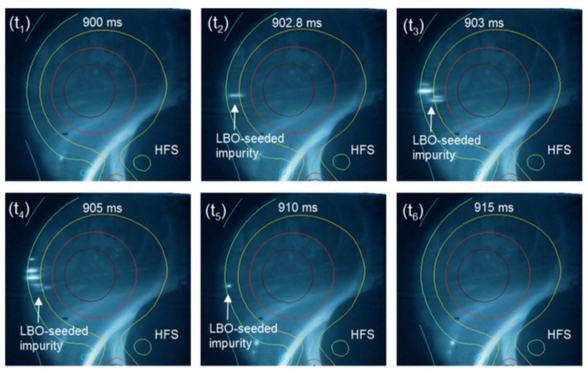
INTRODUCTION

- **ELM and Heat flux control for ITER** P1
  - ✓From simulations and scaling prediction, large ELMs can cause severe erosion on plasma facing components.
  - ✓Effective techniques are highly desirable to achieve external control of the ELM size and the heat load.
- **Existing Mitigation Techniques**
  - ✓ELM mitigation techniques :Pellet pacing, SMBI, RMP, LHCD and other perturbation fields. Recently hot topic impurity injection.
    - ☐Demonstration of the reliability
    - ☐Further investigation on mechanism.



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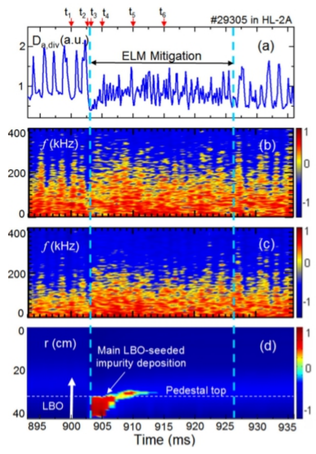
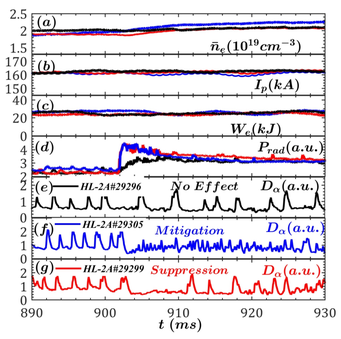
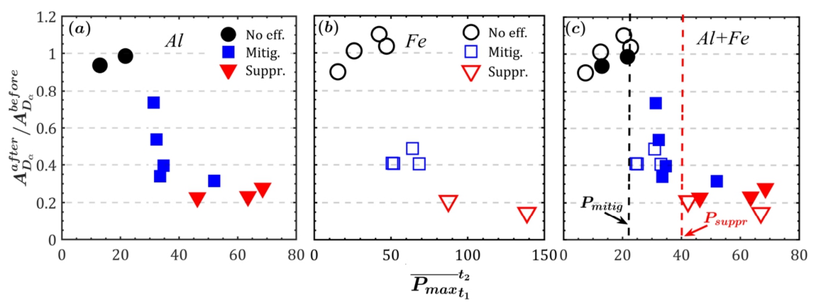


☐In HL-2A tokamak, the impurity seeding is demonstrated to have effect on ELMs (mitigation and even suppression)

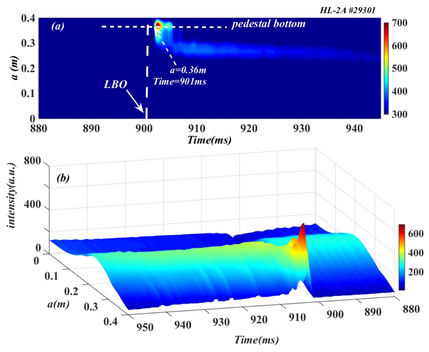
EXPERIMENTAL OBESERVATION

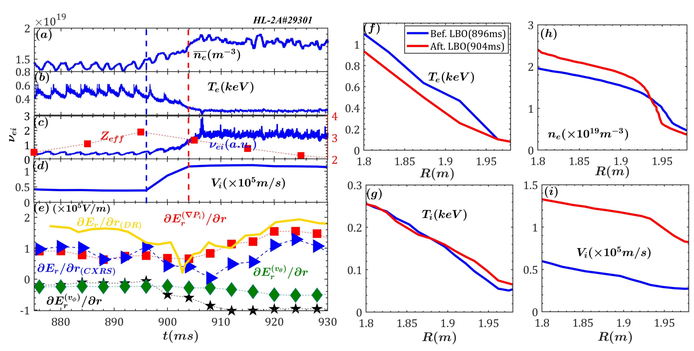


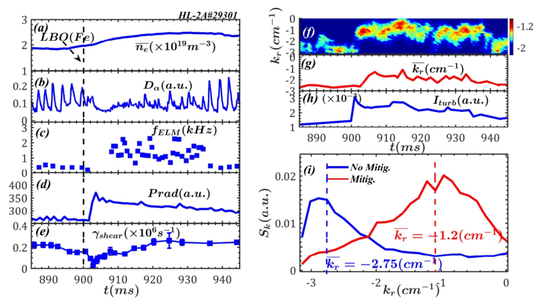


☐**The efficiency:** dependence on the quantity of electron injected with seeded impurity, or Z_{eff} of the impurity.

☐**Reduction of velocity shear rate**: the toroidal term changes a lot. The velocity shear rate drops sharply.







Plausible mechanism :

External source input(impurity seeding)
→ Edge velocity shear decrease
→ Turbulence radial spectral shift
→ Turbulence enhancement
→ ELM mitigation.

SIMULATION ON TURBULENCE

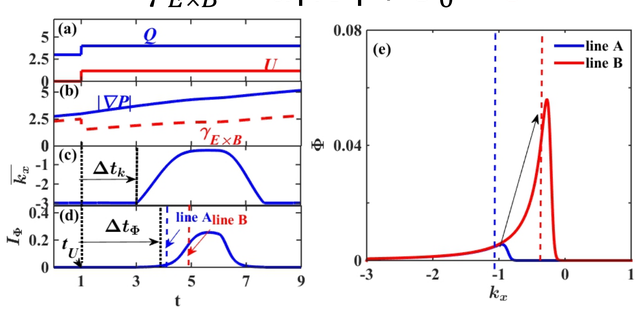
P3

☐Model based on the regulation of the turbulence amplitude by its radial wavenumber spectral shift[1,2] caused by external velocity shear.

$$\partial\phi/\partial t = \gamma_{k_y}\phi + \gamma_{E\times B}k_y\partial\phi/\partial k_x - \left(c_y k_y^2 + c_x k_x^2\right)\phi^2 + D(\partial^2\phi)/(\partial k_x^2) \quad (1)$$

$$\partial|\nabla p|/\partial t = Q - (\chi + \chi_0)|\nabla P| \quad (2)$$

$$\gamma_{E\times B} = \alpha|\nabla P| + U_0 - U \quad (3)$$

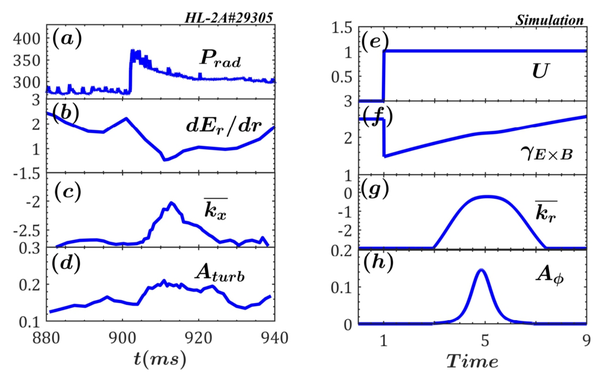


☐U>0, $\gamma_{E\times B}$ drops sharply.

☐Time delay: $U > 0$, $\overline{k_x} \to \mathbf{0}$ with a time delay Δt_k, then turbulence intensity $I_{\boldsymbol{\phi}} \uparrow$.

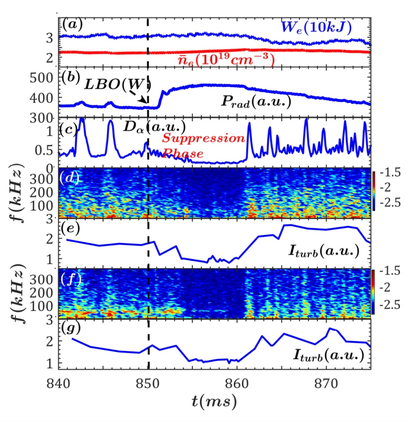
☐Turbulence enhancement: $\overline{\boldsymbol{k_x}} \to \mathbf{0}$, dissipation term$(\sim \boldsymbol{k_x^2}) \downarrow$, pedestal turbulence intensity $I_{\boldsymbol{\phi}} \uparrow$.

[1]G. M. Staebler et al. Phys. Rev. Lett. 110, 055003 (2013)
[2]G.S. Xu et al. Phys. Rev. Lett. 116, 095002 (2016)



☐The turbulence enhancement process observed during experiments has been reproduced by the simulation.

☐Good agreements have been found between the simulation and experimental result.



☐**Turbulence during Mitigation:** Simulation result suggests that turbulence enhancement appears via the turbulence wavenumber spectral shift when Er shear rate are reduced by external actuators.

☐**Turbulence during Suppression**: theoretical simulation suggests that the turbulence suppression in LBO experiments could be induced by the dilution effect, surviving

SUMMARY

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- Experimental results show that $E \times B$ velocity shear could be driven by external source input.
- Pedestal turbulence enhancement is likely due to the radial wavenumber shift, caused by the velocity shear decrease induced by LHCD and impurity seeding.
- Dual effects of LBO on the pedestal instabilities have been observed, dominating in different cases.

ACKNOWLEDGEMENT

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