H-MODE OPERATION IN HELIUM PLASMAS WITH PURE RADIO FREQUENCY HEATING AND ITER-LIKE TUNGSTEN DIVERTOR ON EAST

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ABSTRACT

- Concentration of helium (C_{He}) in the plasma is confirmed to play a critical role in H-mode operation
- At lower C_{He}, EAST achieved the stationary Type-I ELMy H-mode over 80 energy confinement time with the energy confinement slightly above $H_{98,y2}$ scaling ($H_{98,y2}$~1.1) by using pure RF power
- ELM suppression is demonstrated by n=1 resonant magnetic perturbation (RMP) coils
- The density dependence of H-mode threshold power (P_{thr}) exhibits a minimum of P_{thr} at $n_{e,min} \approx 4\times10^{19}$m^{-3}

BACKGROUND

- H-mode operation in hydrogen (H) and/or helium (He, refer to the helium-4 isotope) plasmas is foreseen for ITER early non-nuclear operational phase
- Determining the requirements for L-H transition and predicting the H-mode performance in H and He plasmas under ITER relevant conditions is of high importance for completing ITER research plan
- He experiments results reported show large variation on P_{thr} and H-mode performance, which makes it a challenge to generate a global P_{thr} and confinement scaling expression for He plasmas
  - ➢ Earlier experiments ~40% higher P_{thr} in He than that of D
  - ➢ Later results show a similar P_{thr} in both of He and D
  - ➢ H-mode energy confinement lower in He compared to D
  - ➢ Variations of ELM frequency in He

IMPACT OF HELIUM CONCENTRAION

- ✓ Main plasma parameters B_T = 1.8-2.4T, I_p = 0.4-0.5MA, n_e = 2-6$\times10^{19}$m^{-3}, S = 41-43m^2 at USN configuration with fav. B_T
- ✓ Radio-frequency (RF) wave as heating and current drive techniques
  - ➢ lower hybrid (LH) wave of both 2.45 & 4.6GHz
  - ➢ electron cyclotron (EC) of 140GHz working at X2 mode
  - ➢ icrf power of 34MHz via H minority
- ✓ Helium concentration (C_{He}) is ranging from 40% to 80%
- ✓ P_{thr} is the net power $P_{thr} = P_{Ohm}+P_{abs}-P_{rad}-dW_{MHD}/dt$

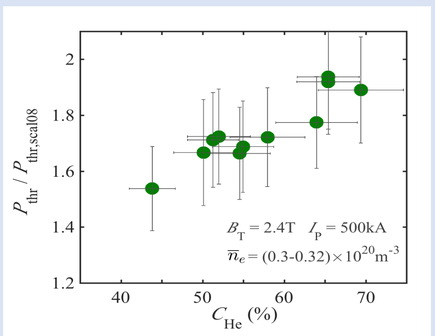


FIG. 1. H-mode threshold power normalized to the scaling value as a function of helium concentration

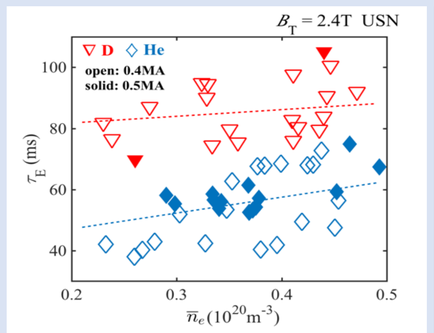


FIG. 2. Density dependence of H-mode energy confinement time for He and D plasmas

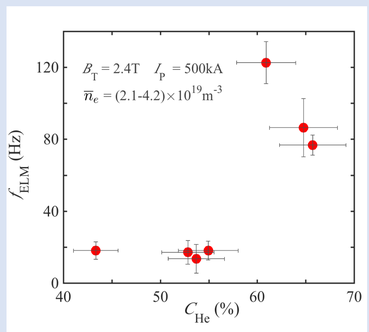
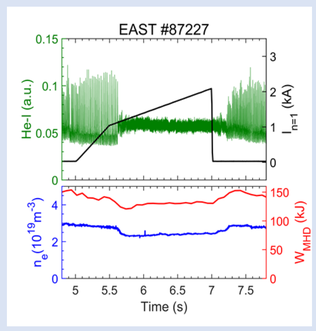
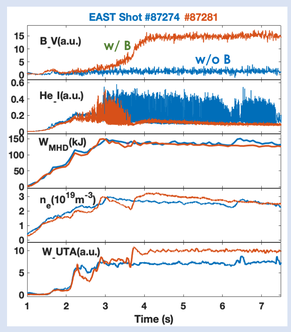


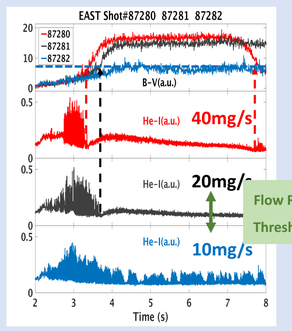
FIG. 3. ELM frequencies as a function of helium concentration

- ✓ L-H transition threshold power in He plasmas is higher with respect to D
- ✓ P_{thr} linearly increases with the He concentration
- ✓ τ_E is found ~30% lower in He plasmas compared to D plasmas
- ✓ ELM frequency was found to increase when increasing C_{He}.

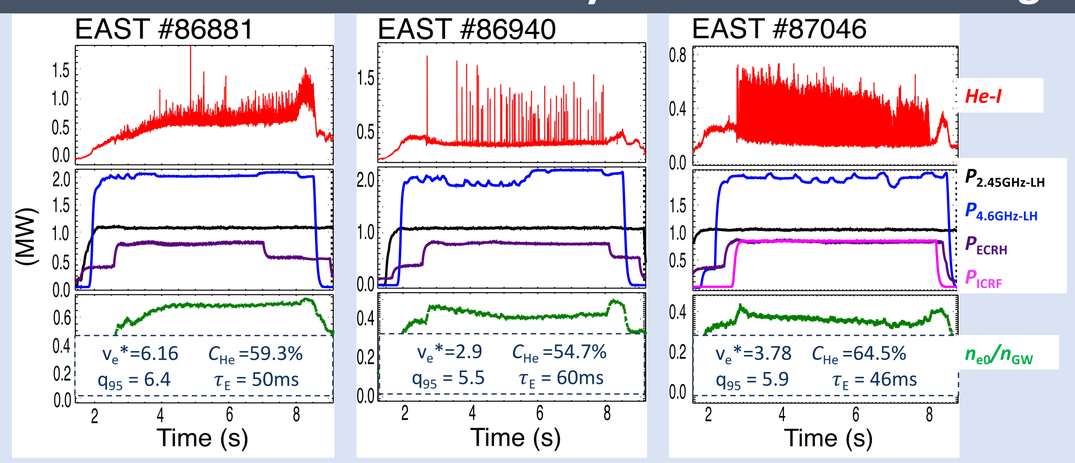
Successful ELM control techniques





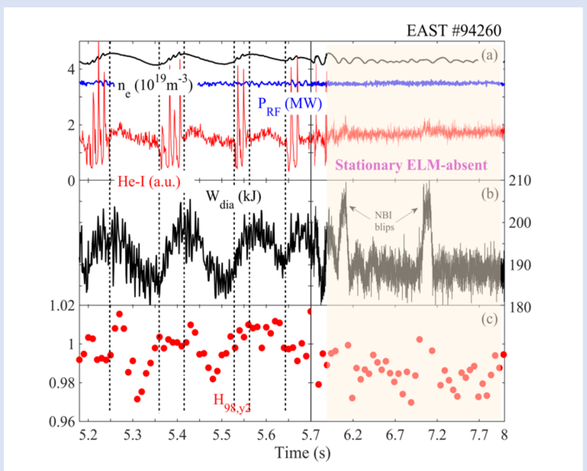


Achievement of various stationary H-mode in RF heating



H-MODE OPERATION AT HIGH CONCENTRATION

- ✓ Repetitive transition between ELMy H-mode and ELM-absent high confinement mode at constant power injection
  - ➢ ELM-absent confinement is comparable to H-mode at similar C_{He}
- ✓ Comparing to the stationary heat flux, ELM-averaged H-mode heat flux was much higher, increased by a factor of 1.5



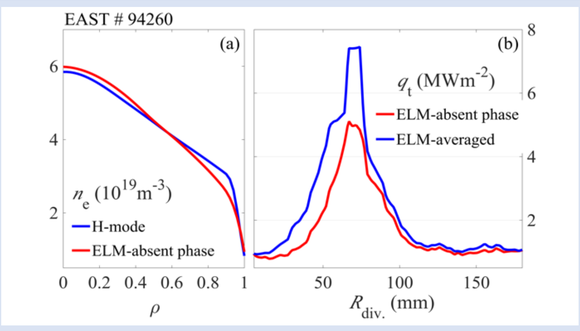


FIG. 4. Comparison of density profile (a) and divertor heat flux (b) at ELM-absent phase (red) and H-mode (blue)

IMPACT OF HE CONCENTRATION ON I_MODE OPERATION

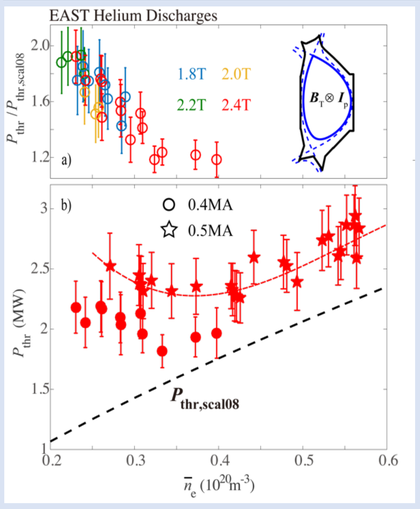


FIG. 5. Experimental L-H P_{thr} values obtained in EAST helium discharges heated by LHCD, ECRH and ICRH shown against $\overline{n}_e$.

- ✓ The normalized threshold power decreases from 2 to 1.2 with plasma density in the range of 0.2-0.4$\times10^{20}$m^{-3}, which is independent of magnetic field
- ✓ I_p = 0.5MA, B_T = 2.4T, a critical density of about 0.4$\times10^{20}$m^{-3} identified
  - ➢ decrease of both $n_{e,min}$ and P_{thr} with decreasing plasma current
  - ➢ follow the scaling with a multiple factor of ~1.2 at high-density side
  - ➢ clear upwards deviation from the ITPA scaling at the low-density side

CONCLUSION

- Concentration of helium is found to be a key parameter in H-mode operation
  - ➢ L-H power threshold
  - ➢ ELM frequency
  - ➢ Energy confinement
- Density dependence of the required power to enter H-mode exhibits a minimum threshold power at $\overline{n}_{e,min} \approx 0.4\times10^{20}$m^{-3}
- ELM suppression by n=1 RMP with pure RF-heating is demonstrated for the first time in helium plasma on EAST

ACKNOWLEDGEMENTS / REFERENCES

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