ENHANCED ENERGY CONFINEMENT AT D_2-PELLET INJECTION INTO ECR HEATED PLASMA ON T-10

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Abstract. Investigation of regimes with enhanced energy confinement due to pellet injection have been performed on T-10. A D_2 pellet was injected into the ECR heated plasma from the outer (low toroidal field) side. The increase of an average plasma density just after pellet injection was $(0.2\text{-}2)\times10^{19}$ m^{-3} depending on the pellet size. The injection of D_2 pellets leads to two different regimes with enhanced energy confinement. In the former (PEC-mode), after the pellet injection the density at first grows and then falls to initial level, but with a more peaked profile. In the latter (H-like mode), the average plasma density remains constant on a level, which was achieved just after pellet injection, during the whole ECRH pulse. The evolution of plasma parameters is similar to one observed at L→H transition: formation of the steep density gradient, and decrease of the radial correlation length of the turbulence at the edge. H-like regimes with enhanced energy confinement were observed in the wide density range up to the Greenwald limit. The experimental energy confinement time for H-like shots well coincides with the ITER scaling for ELMy H-mode. This time is much higher than the energy confinement time in shots with the same plasma parameters but without pellet. The confinement time in the PEC-mode is 30% higher than that in H-like mode.

1. Experiments

The experiments with pellet injection were continued in T-10 tokamak [1]. The scenario of the shot is shown in Fig. 1. The ECRH pulse with time duration up to 400 ms was started on the steady state phase of the discharge. The deuterium pellet was injected at 50-100 ms after ECRH start. The main plasma parameters were as follows: $I_p\approx220\div300$ kA, $\bar{n}_e\approx(3\div8)\times10^{19}$ m^{-3}, $P_{ECRH}\approx0.2 \div 0.85$ MW. The maximum of the pellet evaporation was located at the radius $0.7a_L$, where a_L is the minor plasma radius.

2. The energy confinement

The D_2 pellet injection during ECRH pulse can form two different modes with improved confinement: PEC- [1] and H-like ones. Figure 2 shows a comparison of the experimental energy confinement time $\tau_{E,exp}$ with the ITER(y,1) ELMy H-mode scaling. Also it shows the similar dependence for shots without pellet injection. We see that in the PEC-mode the H_H-factor is about 1.3, while in shots without D_2 pellet injection H_H=0.7 (L-mode). Note that the H-like mode was obtained in a wide range of average plasma densities, (0.4-0.8)$\cdot n_{Greenwald}$ and the H_H-factor in the whole range was about 1 (Fig. 3). Also note that the total heating power in these shots was by a factor of 2-3 lower than the threshold power of the L→H transition determined from the ITER scaling.

3. The plasma density evolution

The average density evolution for the PEC- and H-like modes is shown in Fig. 4,a. The feature of these modes is peaking of the density profiles. The peaking factor $\xi = n(0)/\bar{n}$ for some shots during the Ohmic phase (OH) and in the H-like mode after pellet injection is shown in Fig. 4,b. We see that the peaking increases with the increase of the average density. In both modes the density pedestals appear at the edge (Fig. 4,c). Formation of the peaked density profile is confirmed indirectly by the decrease of the ECRH power absorption after the pellet injection. This decrease originates from the refraction of the microwave beam on the enhanced density gradient. The peaked density profile is sustained during the whole ECRH pulse, and the additional gas puffing after the pellet injection weakly changes it. The peaked density profiles are not sustained in the OH regime.

4. Behavior of the edge plasma turbulence

The D_2 pellet injection dramatically changes the plasma edge turbulence. Figure 5 presents the turbulence characteristics obtained by reflection from the overpedestal region. Clearly seen from the auto- and cross-correlation functions that the turbulence with long correlation times is suppressed practically totally. The poloidal coherency is lost immediately after the pellet injection (Fig. 6,a). Simultaneously in the H-like mode the radial and poloidal correlation lengths close to the steep density gradient region are reduced more than by a factor of 5, but the amplitude of the turbulence spectrum changes little (Fig. 6,b). Formation of steep density gradients at the edge and sharp changes of the plasma turbulence evidence the appearance of the edge transport barrier and the possible decrease of transport in the pedestal region.

Conclusions

1. Injection of D_2 pellet allows us to obtain two types of regimes: PEC and H-like modes, where we observe improved energy confinement with the H_H-factor about 1.3 (PEC) and 1. In the H-like, high-density regimes without pellet, $H_H \approx 0.7$.
2. In the H-like mode the H_H-factor does not decrease when the density approaches to the Greenvald limit up to $n/n_{Gr} \approx 0.8$.

3. The PEC and H-like modes are different possibly due to different recycling on the chamber wall: in the H-like mode the recycling is about 1.
4. After the pellet injection the density profile is peaked. The edge region with a steep density gradient is formed in the H-like mode. The peaking is sustained up to the end of ECRH pulse.
5. After D_2 pellet injection the radial and poloidal correlation lengths of the turbulence are reduced at several folds. The similar effect was observed in T-10 under "usual" H-mode.
6. The sum of presented facts may be interpreted as a formation of the edge transport barrier after the pellet injection.

Reference

[1] Yu.D. Pavlov *et al*. IAEA-CN77/EXP/5/17. 18th Fusion Energy Conference, Sorrento, Italy 2000.

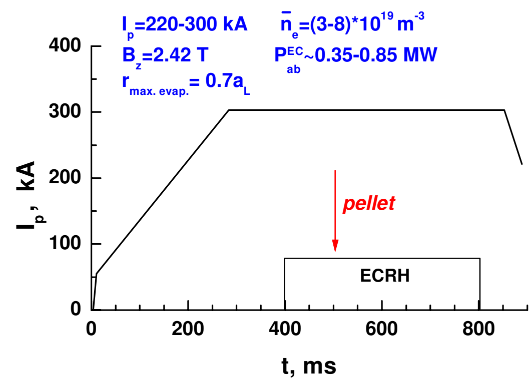

Fig.1. The scenario of the shot with the pellet injection.

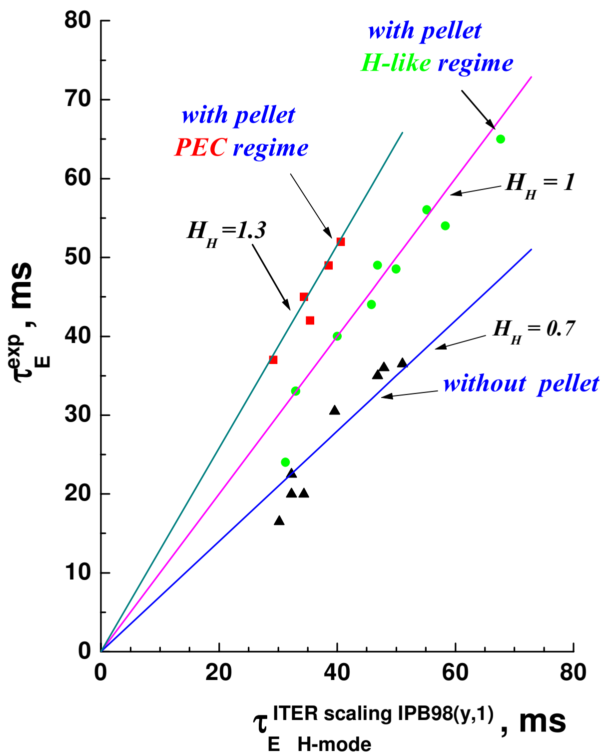

Fig. 2. Comparison of the experimental energy confinement time with the ITER scaling.

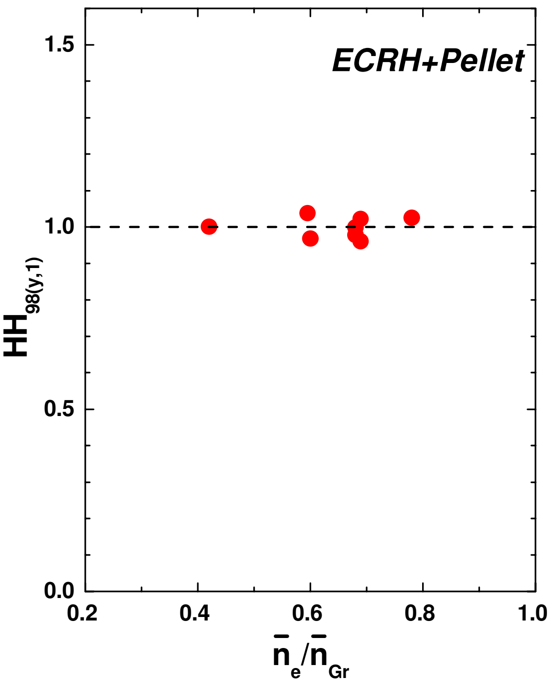

Fig. 3. H_H-factor for shots with the H-like mode after pellet injection.

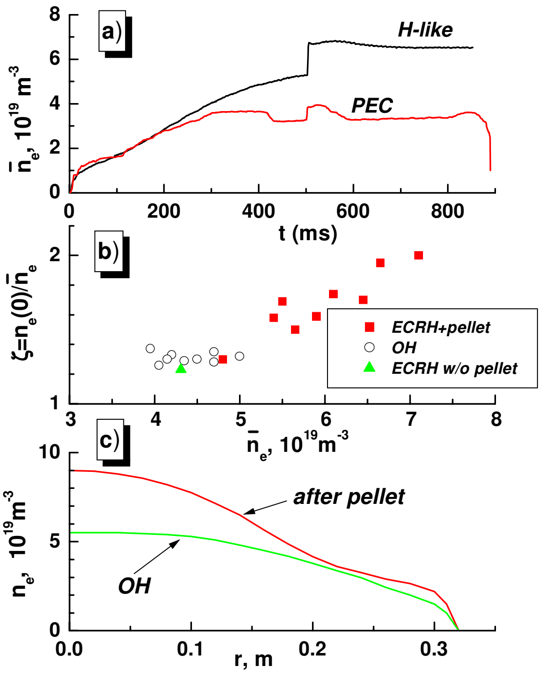

Fig. 4. a) The average density in shots with pellet injection; b) the peaking factor in shots with and without pellet; c) typical density profiles before and after the pellet injection.

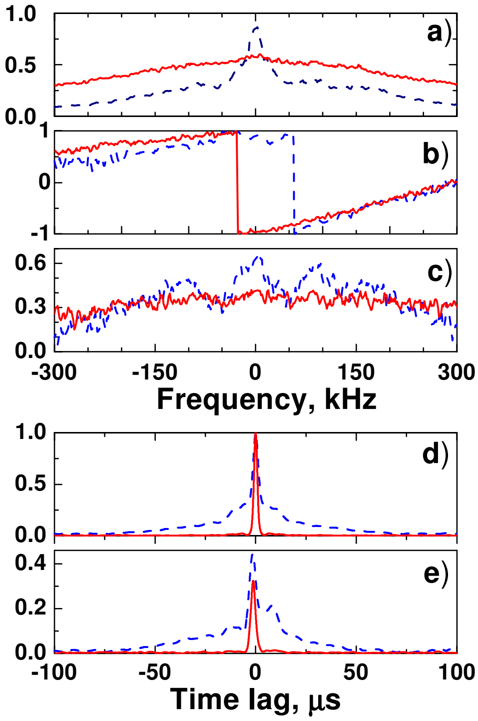

Fig. 5. Spectra of amplitude (a), cross-phase (b), coherency (c), auto- (d) and cross- (e) correlation functions before (blue dash) and after (red full lines) pellet injection obtained by the reflection in the barrier pedestal region, n_{crit}=3.5×10^{13} cm^{-3}.

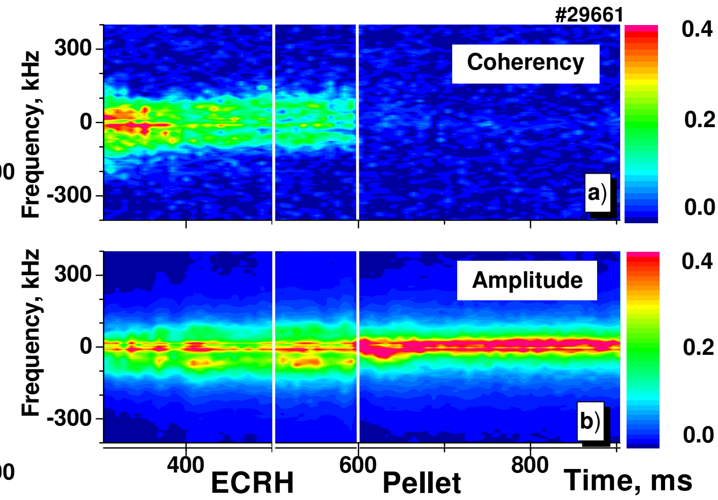

Fig. 6. Behavior of the coherency and amplitude of the plasma turbulence obtained by the reflection in the edge barrier region, n_{crit}=2×10^{13} cm^{-3}.