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Dynamics of recycling processes responding to the local particle and heat load perturbations on TRIAM-1M

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A new diagnostic technique to study the global structure of the recycling among the plasma facing components PFCs has been proposed and tested using the three kinds of perturbations (gas puffing, transport oscillation, and localized heat deposition) at the frequency less than a few Hz . H_α intensities are measured at various toroidal and poloidal positions and FFT analysis shows that the propagation velocity of the neutral hydrogen in the toroidal direction is < 25 m/s for the gas puff modulation. For toroidally uniform transport oscillations, on the other hand, in-out asymmetry of recycling structure is found. The localized heat deposition causes the localized particle source distribution in the torus due to enhanced efflux of the hydrogen particles only fueled from the hot area.

1. Introduction

Experiments aiming at steady state tokamak operation SSTO have been done in TRIAM-1M (R_0= 0.84 m, a = 0.11 m)[1]. One of our concerns with respect to SSTO is the termination of the steady state plasma by plasma wall interaction PWI events. In this paper we study how the PWI driven perturbation influences global structure of recycling among the various PFCs. The contribution of the typical four PFCs, such as the movable limiter ML (~ 0.005 m^2), the fixed polidal limiters PL (3x0.03 m^2), divertor plates DP (~0.8 m^2) and the wall (~ 5 m^2), is investigated. The three kinds of perturbations are considered. First, in order to simulate the problems under the situation that the enhanced recycling from the local PFC occurs, the gas puffing is modulated at a few Hz at the local position in the torus. The change in the torus structure of the recycling is studied. Second, on the contrary, how the toroidally uniform perturbation affects the global recycling structure is simulated by analyzing the relaxation oscillations at a few Hz between the L-mode and the enhanced current drive mode ECD [1]. Finally, the effects of local heat load on the recycling are studied by depositing the high heat flux of several tens of MW/m^2 without gas puffing.

2. Experimental apparatus and Diagnostics

The in-vessel PFCs are all metals. ML, PL, DP are made of molybdenum and wall is stainless steel. By adjusting the ML vertically into the plasma most dominant PWI location could be modified from ML to PLs or vice versa in the limiter configuration. The several diagnostics are used to analyze the change in the global structure of the recycling. An H_α measurement system is used to measure toroidal (seven positions) and poloidal (seven vertical chords along the major radius) distributions. The contributions from the ML, PL, DP and wall can be deduced from this system [1, 2]. In addition to this, seven spectrometers are used to study Balmer and Fulcher series directly viewing at the ML, DP, and the wall. The temperature of a hot spot T_{hot} on the ML is deduced by analyzing the continuum spectrum measured with a spectrometer in the range of 900 – 1600 nm [3].The arrangement of these diagnostics is shown in Fig.1 in ref. [1]

The experimental conditions are as follows: B_t = 6-7 T, P_{rf} = 10-20 kW for 2.45 GHz and 40-300 kW for 8.2 GHz (along with ECH power), n_e = 0.1-4.0 x10^{19} m^{-3}. The gas puff modulation is done at the bottom of the chamber at the port #7 and self relaxation oscillations are found to be triggered when the rf power is just below the threshold power of the enhanced current drive mode [1]. These modulation frequencies are a few Hz, which is much lower than the inverse of transport time scale (~ 5-10 ms). The heat load effects are investigated by high power injection or moving ML during the discharge. In these experiments escaped energetic electrons are lost mainly on ML and localized heat deposition makes a 'hot spot' on ML. Since T_{hot} increases up to the melting temperature in several seconds, the response to the recycling associated with hot spot can be studied.

3. Experimental Results:

3.1 Gas puff modulation:

Fig.1 shows modulation results for n_e, I_p, H_α at various toroidal positions. Since the maximum amplitude of H_α is found at the gas port (@7D), this is used as the reference of the phase correlation. This perturbation causes $\Delta n_e/n_e$ of ~20 %. A change in the recycling structure indicates that puffed H atoms propagate with a characteristic velocity (≤ 25 m/s) within the toroidal length of ~0.6m near the gas port, and no phase delay of H_α at further

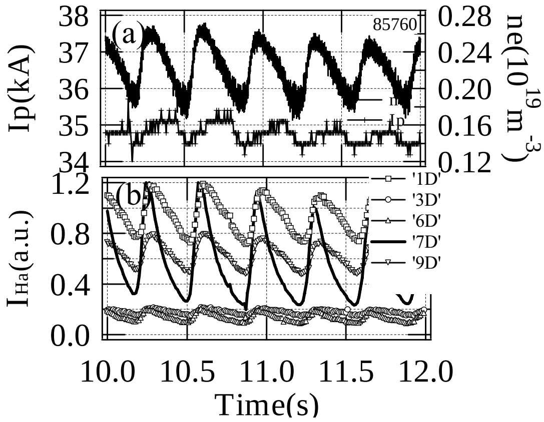

Fig.1 gas puff modulation: (a) Ip and ne, (b) Hα at various toroidal positions.

distance is found, as shown in Fig. 2. The modulation in H_α at further location is mainly attributed to the edge density with a constant time delay of 30 $\pm$10 ms. The phase relation of H_α along the major radius is within 10 degree and this aspect is similar at any toroidal position. Thus injected H_2/H are diffused as neutral near the gas port [4] and once they are ionized charged particles tend to be uniform quickly around the torus.

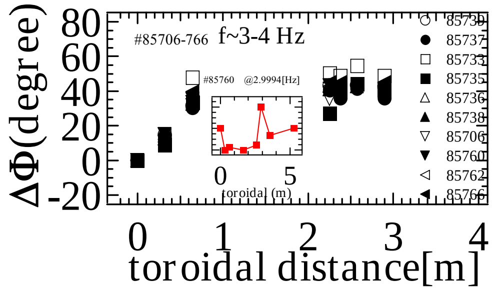

Fig.2 Phase difference along the toroidal direction. Inset is the toroidal profile of the spectrum power at the modulation frequency .The peak corresponds to the gas port.

3.2 Self relaxation oscillation driven by transport improvement:

Fig.3 shows modulation results for n_e, I_p, H_α along the major radius at PL#9. In this case the current modulation precedes the density modulation, suggesting that the enhancement in the current drive efficiency is first triggered and then the particle confinement is improved. T_i is also self-modulated by improvement in ion energy transport. This type of modulation is considered to be the toroidal uniform modulation compared with the local perturbation in the first case [5]. The toroidal recycling structure monitored by toroidal H_α signals along R_0 is delayed by 0.1-0.2 s with respect to the start time of the density rise, but the phase relation is in phase. On the other hand the poloidal structure shows an in-out asymmetry and the radial profile of the modulation amplitude is hollow (as shown in Figs.3,4). This might be attributed to the enhanced recycling near the inner and outer edge caused by in-out shift of the plasma column.

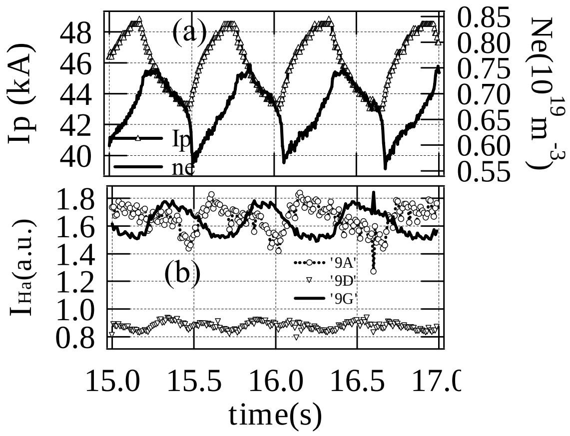

Fig. 3 Transport oscillations. (a) Ip and ne, (b) Hα at PL, inner(A:circles), center D:(triangles), and outer (G:solid line)

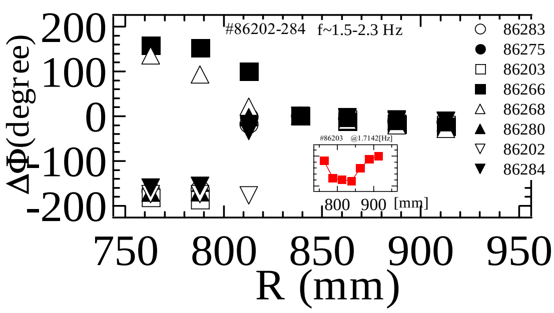

Fig.4 Phase difference along R for transport oscillations. Inset is the R- profile of the spectrum power at the perturbation frequency.

3.3 heat load perturbation by adjusting ML:

Fig.5 shows a typical low power long pulse discharge. T_{hot} on ML, Hα from the ML and waveform of the piezo valve for feed back control of the particle influx are shown. Around t~ 350 sec it became hard to control the influx, since Hα from ML was increasing. For t > 520 sec particles are only fueled from ML associated with increased T_{hot} (see piezo valve was shut off). These perturbations are repeated at ~ 10^{-2} Hz. Since T_{hot} ranges from 1200 K to 2400 K, enhanced emission of Hα has not been expected according to the results in Lab. and tokamak experiments for endothermic metal [6, 7]. It should be noted , however, that retained particles on ML seem not to be empty until at least five heat cycles and the emitted particles dominate the recycling structure, as shown in Fig.6 [1,2].

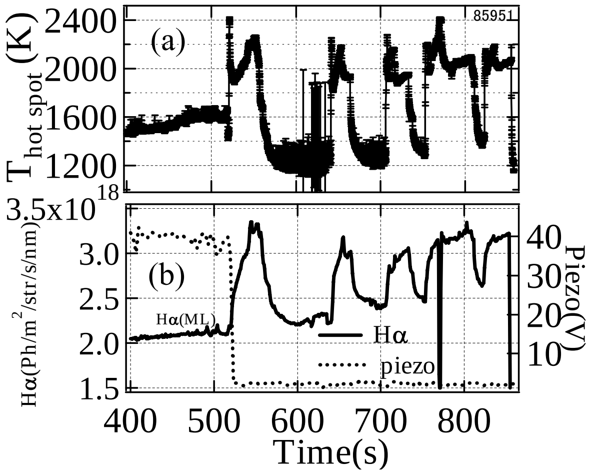

Fig.5 Localized heat load deposition on ML;(a) T_{hot},(b) Hα from ML and the waveform of the gas puffing

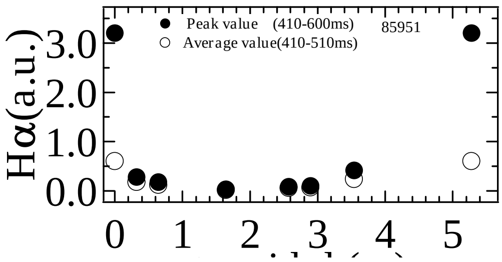

Fig.6 The global structure of the recycling around the torus. The zero position on the horizontal axis corresponds to the ML. The open and closed symbols before and during the first heat perturbation.

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