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Control of plasma profile by gas and impurity injection in TJ-II under Li wall conditions

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1.Introduction.

Recent operation of TJ-II under full lithium wall coating has led to the production of high density, NBI heated plasmas with improved confinement characteristics [1]. One of the most interesting phenomena observed under the new wall scenario is the development of plasma profiles with strong pressure gradients and enhanced central confinement, concomitant to central impurity accumulation. Alternatively, a broader, lower-central Zeff profile can develop under given circumstances. These profiles, whose shapes have been tagged as “bell” and dome” type, respectively, and the transition between them during a shot, are regularly clasified and followed from bolometric data. The larger ratio of edge to core emmisivities found in the dome profile makes them prone to radiative collapse [2] and therefore they are thought to be responsible for the density limit achieved under pure NBI heating, at central densities of ~$0.8.10^{20}$ m^{-3}. In this work, the phenomenology of the transition between these types of profiles is addressed.

2. Experimental details.

In order to get some insight into the driving mechanism of the transition, perturbative experiments have been carried out in neutral beam heated TJ-II plasmas (two injectors co and counter, 400 kW each). Namely, short pulses of hydrogen were injected into the bell-type plasmas at densities below the critical and the transition to the broader profiles was achieved. Alternatively, hydrogen-diluted neon pulses were used to force the transition and the changes in the so- induced emissivity profiles were recorded. Particle fluxes, Q_{in}, < $7x10^{20}$ e/s were used for pure H_2 injection, and mixtures having a 5% and a 15% on Ne were injected when required. Besides the standard monitors of TJ-II [3], the set of diagnostics directly used in this work are a supersonic Helium beam to obtain peripheral profiles of electron density and temperature [4] and bolometer arrays to determine the time evolution of plasma emissivity profiles [5].

3. Results and discussion.

Series of discharges with different target densities (before launching the heating beams) were produced in order to explore the time evolution of electron density from the density-limited collapsing pulses to the stable low-density discharges. In Fig. 1 (up) the time history of electron density and total radiated power from three discharges, heated by the co-NBI beam, with decreasing gas puffing are represented with full symbols. In all of them, the change in the slope of the density trace marks the spontaneous radiation profile change from peaked to dome. It is also shown, in red and open symbols, the traces corresponding to a discharge (# 21705) pre-programmed with the lowest initial gas puffing (same as for # 21702) and a further 3 ms length H_2 pulse (see the H_α signal below the density plots). It can be seen that the resulting density time evolution transits from the lowest to the intermediate density pulse. The corresponding total radiated power also exhibits the same transit, but with a delay of about 8 ms with respect to the density change. However, when non global but local parameters are compared, in this case, plasma emissivity (several examples are shown in Fig.1 down), it can be seen that profiles changes immediately, and that flattened shape lasts until the discharge end.

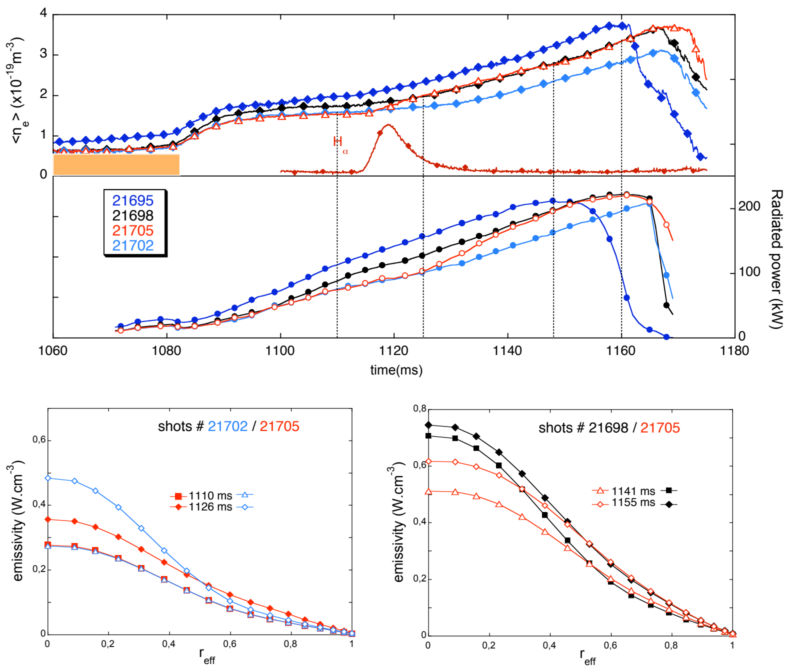

Fig. 1. up) Time evolution of electron density and radiated power from 4 NBI-heated shots (see main text). down) emissivity profiles at the times marked with dotted vertical lines

With the counter-injected neutral beam, less bell-shaped (little higher edge radiation and electron density) plasmas, as compared with co-injected case, have been obtained so far. Nevertheless, the transitions shown here, from rather peaked to fully dome profiles are also observed when average electron density exceeds $2.10^{19}m^{-3}$.

Detailed perturbative experiments were performed in series of more easily controlled density discharges (under co-NBI) to get some insight into the profile evolution and control. Figure 2 shows the time evolution of the radiation peaking factor, ($Prad_{center}/Prad_{edge}$), during a series of shots with variable level of injection of pure H_2. In a plasma discharge whose radiation profile is strongly peaked, like shot # 21328, the

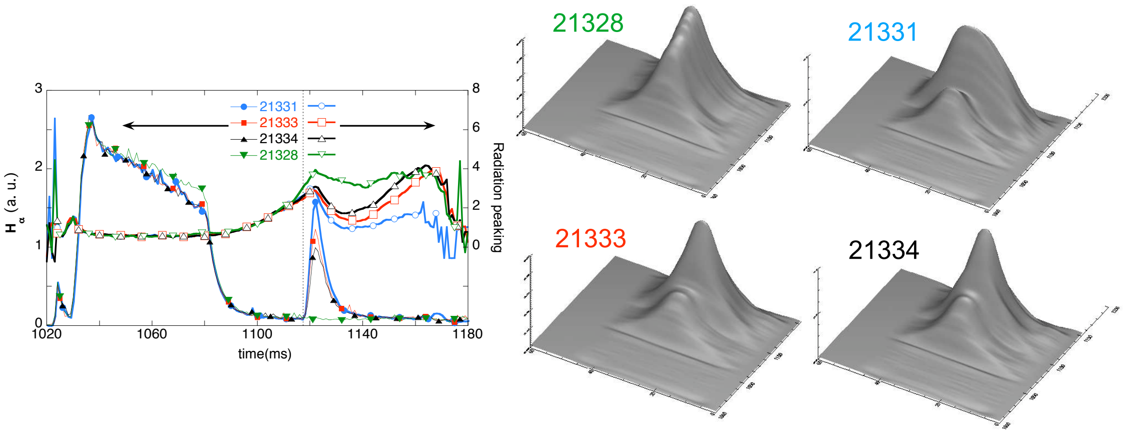

Figure 2. left) Time stories of Hα (pufing scheme) and radiation peaking factor for a series of decreasing fuelling perturbation. right) time evolution of emissivity profiles showing the changes from starting peaked (#21328 reference shot) to dome (#21331), and back to peaked (#21333 and #21334) profiles.

injection of a hydrogen flow can trigger the transition to a broad radiation profile (as occurs in shot #21331). Decreasing the level of the injected flow, the transition may be "softer" and even reversible, i.e., the bell profile can be recovered (shots # 21333 and # 21334), so that a good external control of the plasma radial profile can be achieved by this method. It is worthy to mention that, since the point of view electron density and radiation profiles evolution, the forced transition to the dome profile right after the injection is quite similar to the observed in spontaneous transitions (see Fig. 4).

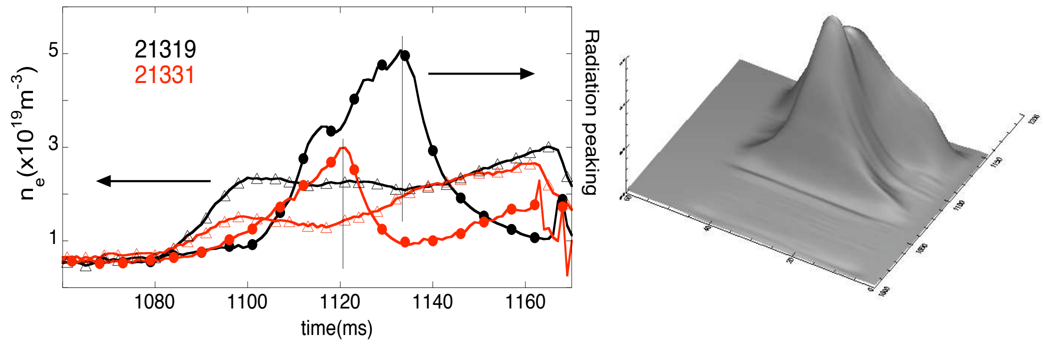

Figure 3. left) Time stories of electron density and radiation peaking factor for two shots with forced (#21331) and spontaneous (#21319) bell-dome transition. right) time evolution of emissivity profiles showing the changes from peaked to dome profiles (shot #21319).

Next, mixtures of H_2+ Ne (in volume concentrations of 5 and 15%) were also tried to trigger the transition in discharges with moderate (far from the "spontaneous" transition conditions) electron densities. Preliminary analyses show that the profile-change dynamics is "the same" as in hydrogen-pulse perturbed discharges, namely an almost simultaneous edge increase and core decrease (even sharply observed in central soft x-ray signals) of radiation. Complementary information is achieved by following the edge profiles associated to the different conditions. In figure 4, the radial profiles of electron density and temperature determined with the supersonic He beam diagnostic and recorded right before and after gas-pulse injections of different intensities, are shown. A marked decrease of Te by about 20 eV can be seen under the highest puffing conditions leading to the profile transition. The measured electron temperature reduction was essentially the same under Ne-seeded H_2 injection, even when a much higher effect was expected according to the corresponding cooling rates. Decreasing the gas inflow, the temperature perturbation is lowered until no effect is detected, although the most external radiation detectors still showed a slight and transient signal increase. It must be mentioned that, although the electron density does not appear to be perturbed in this plasma region, the Thomson scattering profiles in the gradient region (0.3 - 0.7 r_{eff}) show changes quite similar to the observed in the radiation profiles shown in Fig. 1.

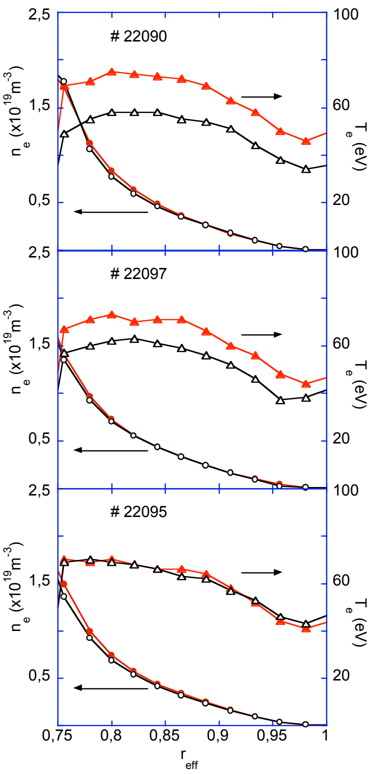

Fig.4. Edge profiles of electron density and temperature before (red lines) and after Ne-seeded H_2 (black lines) injections.

From the observations presented here, it can be concluded that profile shapes are indicative of how the fast, NBI neutrals couple with the plasma core. In this sense, enhanced peripheral charge exchange process could be a candidate to explain the profile dynamics. Some consequences of the relevance of this mechanism in a high-ripple, low-Z device like TJ-II would be: i) the prevention of central heating; ii) contribution to the observed decrease in edge plasma potential and iii) inducing the conditions for a thermal instability-driven plasma collapse.

[1] F.L. Tabarés et al. Plasma Phys. Control. Fusion **50,** 124051 (2008)
[2] M.A. Ochando, F. Castejón and A. P. Navarro Nucl. Fusion **37** 225 (1997)
[3] J. Sánchez et al., J. Plasma. Fusion Res. SERIES **1** 338 (1998)
[4] A. Hidalgo, et al. Rev. Sci. Instrum. **75** 3478 (2004)
[5] M. A. Ochando et al., Fusion Sci. Technol. **50** 313 (2006)