Nitrogen-injection effects on NBI heated TJ-II plasma profiles under Li wall conditions: impurity screening and role of rational surfaces

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1.Introduction.

Since TJ-II started operation under full lithium wall coating, better control of electron density and improved confinement characteristics are reached in NBI heated plasmas [1]. At present, the NB pulse length is limited to about 0.1 s, so it is of most interested in shortening the ECR to NBI plasma heating transition time without risking density control. It is well known that density profile peaking may be tailored with activation/suppression of base gas puffing all along the discharge [2]. In this sense, we have reported on 'spontaneous' behaviours of TJ-II plasma profiles and for the external attempts to modify them [3, 4]. In particular, short gas puffing injections were performed using either pure H_2 or mixtures of H_2 + Ne (up to 15% in volume concentration) into neutral beam heated TJ-II plasmas to force bell to dome-shaped radiation (and density) profile transition. It was observed that the dynamics of profile change consisted in an almost simultaneous edge increase and core decrease of radiation, and it was essentially the same under diluted Ne or H_2 injections. This response was found compatible with enhanced peripheral charge-exchange processes that diminish the coupling of fast neutrals with the plasma core (i.e., reduces density peaking), and may favour the development of thermal instability-driven plasma collapse.

The interest of mild injections of low-Z impurities into TJ-II plasmas is mainly trying to find a method to control the density rise through the reduction of wall sputtering via edge radiation cooling [5, 6].

Recently, other non-intrinsic impurity species, namely N_2, whose radiation strength is two orders of magnitude lower than that of Ne but closer to the values of the main TJ-II impurities, has been puffed into low-power NBI-heated TJ-II plasmas. This was done in several magnetic configurations to determine whether the presence of rational surfaces may affect profile dynamics. The results presented in this paper show that short gas pulses injected into density peaked discharges trigger the development of a quasi-stationary (lasting longer than the spontaneously seen) radiation enhanced region at the plasma periphery. Observations compatible with impurity screening are reported and the role of rational surfaces is also addressed.

2. Experimental details.

Like in the previous studies, we have followed the radiation profile change as a result of different puffing schemes in series of reproducible discharges. Plasma-wall interaction in TJ-II is strong and presents a high sensitivity to the freshness of the lithium coating, so that hydrogen puffing is always the first step of our gaseous impurity injection experiments. Fig.1 shows the progressive flattening of radiation profiles after increasing H_2 pulse lengths. This time, we could adjust the relative base/puffing gas levels to obtain a more stationary and longer lasting enhanced edge radiation.

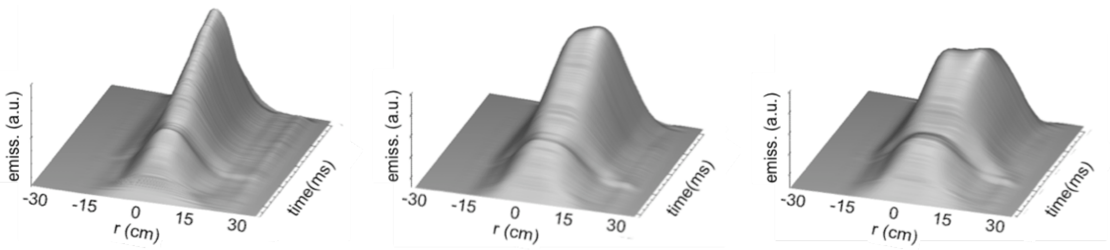

Figure 1. Time evolution of plasma emissivity profile from bell to dome-type achieved by increasing the length of H_2 pulse. Time interval represented is 100 ms.

Once the evolution of the profile peaking is known with controlled hydrogen pulses, we injected different amounts of pure N_2 until the radiation collapse is developed. As well, reference discharges without injection were produced to monitor the detailed effect of pulses all along the plasma radius. As an example, Fig. 2, shows the evolution of local plasma emissivity from one of the studied series of discharges with slightly increasing base density and fixed N_2 pulse intensity.

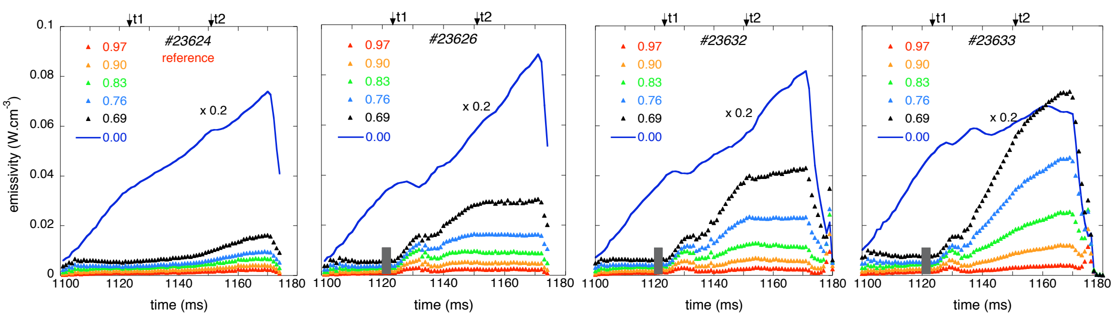

Figure 2. Time evolution of plasma emissivity at the indicated effective radii. Global parameters n_e, P_{rad}, and W, exception made of core electron temperature, increase to the right [see Baião P5.101, this conference]. The 4 ms length N_2 pulse starts at 1120 ms and edge profiles are measured at t1 and t2.

The relative concentrations of the impurity species in the studied shots have been roughly estimated with the help of the multi-filter soft x-ray diagnostic [7], and the edge electron density and temperature profiles have been obtained with a supersonic He-beam every 25 ms [8]. We have plotted in Fig.3 the experimental radiation strength at the edge ($R = L(T, Z)\, n_Z/n_e = P_{rad}/n_e^2$) as a function of the local temperature (T_e) for several of the studied shots, including H_2 and N_2 seeded ones. For each shot, two values of R, one right after the injection (t1) and another 25 ms afterwards (t2), have been included (for simplicity, only the velvet arrow has been drawn; upward tip indicates time progressing, and applies to all shots except to #23624). Assuming the abovementioned deduced plasma compositions, the effective radiation strength at the plasma periphery would not reach a positive dependence with temperature, i. e., $dR/dT > 0$. Then, the observed behaviour, namely, the marked increase of R at constant temperature, or even the increase of R with T_{ed}, points to an increase of effective impurity concentration, n_Z/n_e, in the plasma periphery. When doing the same exercise for global plasma parameters, using averaged electron temperature and density and total radiated power, the tendency is opposite. As an example, the 'global' radiation strength for shots #23624 and 23632 have also been plotted (encircled symbols). The comparison of global and local behaviours, leads to the conclusion that a sort of impurity screening has occurred at the edge of seeded discharges.

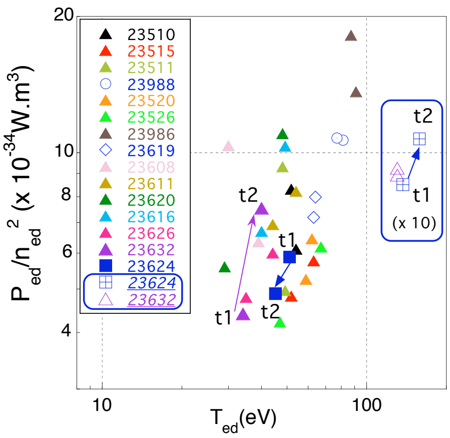

Figure 3. Experimental edge radiation strength (see text). Blue squares correspond to reference shot of Fig.2. Decreasing R means reduction of n_Z/n_e at the edge (full symbols) and increasing global R, (crossed symbols) means increase of n_Z/n_e in the plasma bulk, i. e., in the non-seeded discharge #23624, impurity profile peaks.

By comparing discharges with injection and their reference shots in different magnetic configurations, what we found is that the deepest radial location in which we see the maximum positive perturbation in radiation due to impurity entrance varies, and coincides with the nominal location of significant rational surfaces. That is represented in Fig. 4. There it can be seen the local radiation increment at the indicated radii. The highlighted spatial locations correspond to the maximum increment in radiation for the three magnetic configurations, whose Poincaré plots are displayed underneath.

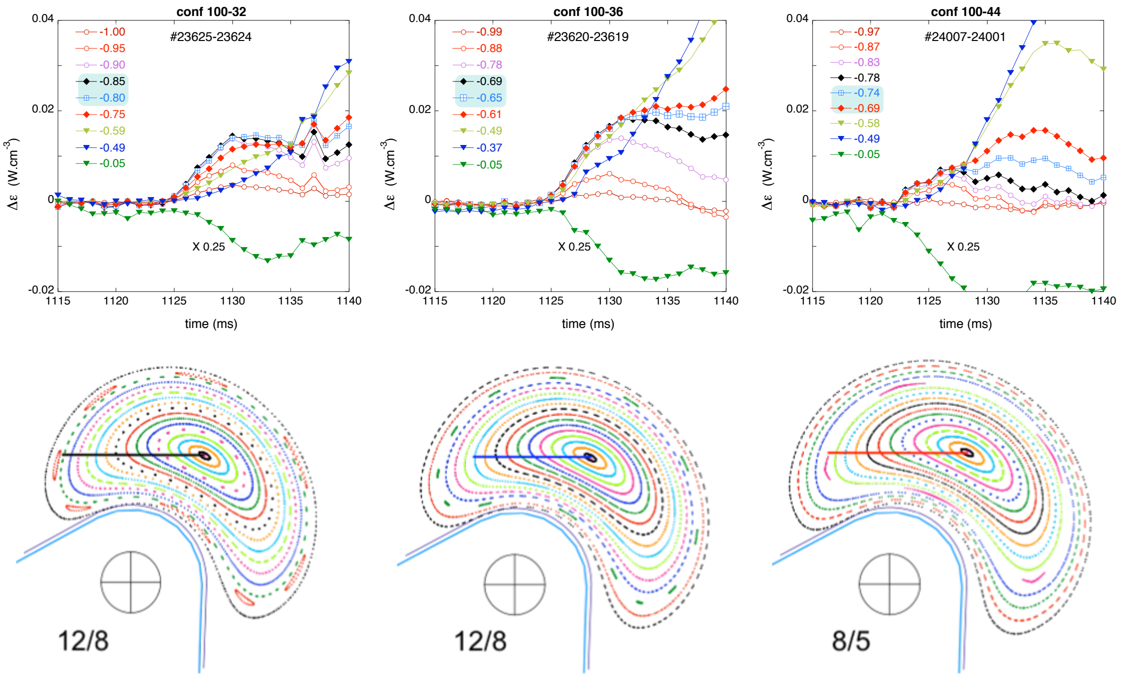

Figure. 4. Incremental local emissivities of discharges with gas pulse injection over their reference shots in three magnetic configurations. Left bar ends over the Poincaré plots mark the rational surfaces 12/8 and 8/5 positions.

3. Conclusions and future work

Injection of adequate amounts of suitable impurities is a useful tool to modify and control profiles in low NBI power heated TJ-II plasmas. Full lithium coated walls has enabled for achieving controlled highly radiative plasma edges. Local and global analyses of the effective radiation strength suggest that, as a result of the controlled edge cooling, impurities are screened near the periphery. For the studied magnetic configurations, it could be concluded that low order rational surfaces seem to act as particle transport frontiers in this moderate low-shear stellarator device. A wider magnetic configuration scan is planned for the immediate future. Besides, the combination of ASTRA/EIRENE/IONEQ transport codes will be used to clarify the impurity dynamics role on the experimentally observed TJ-II plasmas behaviour.

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