T-10 DISCHARGE CONTROL BY METHOD OF LITHIUM PELLET-INJECTION AND BY INJECTION OF SUPERDENSE SUPERSONIC GAS JETS

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Introduction

The high temperature plasma discharge control is one of important tasks in the program of the controlled fusion achievement [1]. The first wall lithium (Li) conditioning in T-11M, TFTR, CDX-U tokamaks was found as a factor of an essential increase of plasma energy content, energy confinement time due to obtaining the lower Z_{eff} discharge with low impurity content [2-4]. On the other hand it had not been confirmed in either Heliotron E [5] or Alcator C MOD [6] Li pellet experiments. Results of the sequential Li pellet injections in T-10 aiming to study its conditioning capability are presented. Recently, supersonic jets of hydrogen and impurity gases are being considered for plasma fueling [7] and disruption mitigation [8]. First operation of the T-10 supersonic helium jet injector is described in the report.

Discharge conditioning experiments

In experiments, cylindrical pellets of 0.75-0.78 mm in diameter and 0.9±0.1 mm in length which corresponds to (1.6–2.2)x10^{19} content of lithium atoms were injected. The pellet size was limited by the injector barrel diameter. Prior to loading of Li pellets in the injector they were coated by the nitride shell (LiN_3) of the 10 mkm thickness. This procedure was used for avoiding the undesirable effect of the lithium sticking with injector material and allowed to accelerate Li pellets up to 650 m/s velocities into the plasma with fairly good reproducibility. The pellet ablation was observed using CCD camera, wide-view photodetector and a set of the narrow collimated photodetectors. Details of the injector experimental setup are described in Ref. [10]. Injections were carried out in the ECRH heated plasmas with following main parameters: $\langle n_e \rangle = 3 \times 10^{13}$ cm^{-3}, a_L= 30 cm, I_{pl} = 270 kA, B_t = 2.4 T, P_{ECRH} = 800 kW. In these conditions, Li pellets penetrated up to r/a_L = 0.3 and deposited a main part of lithium nearby a half of plasma minor radius a_L.

Li pellet injection time was 600 ms from the plasma current start-up and with the 100 ms delay relative to the start of ECRH heated pulse. A special regime of the discharge shutdown without the toroidal magnetic field cessation has been used to exclude the lithium washout at this discharge stage. A sequence of 4 shots with the Li pellet injection was realized (##42313, 42315, 42316, and 42317). Two reference shots without Li injection before (#42312) and after (#42319) this sequence has been analyzed in order to observe conditioning effects. In the shots #42314 and #42318 where were no plasma due to technical reasons.

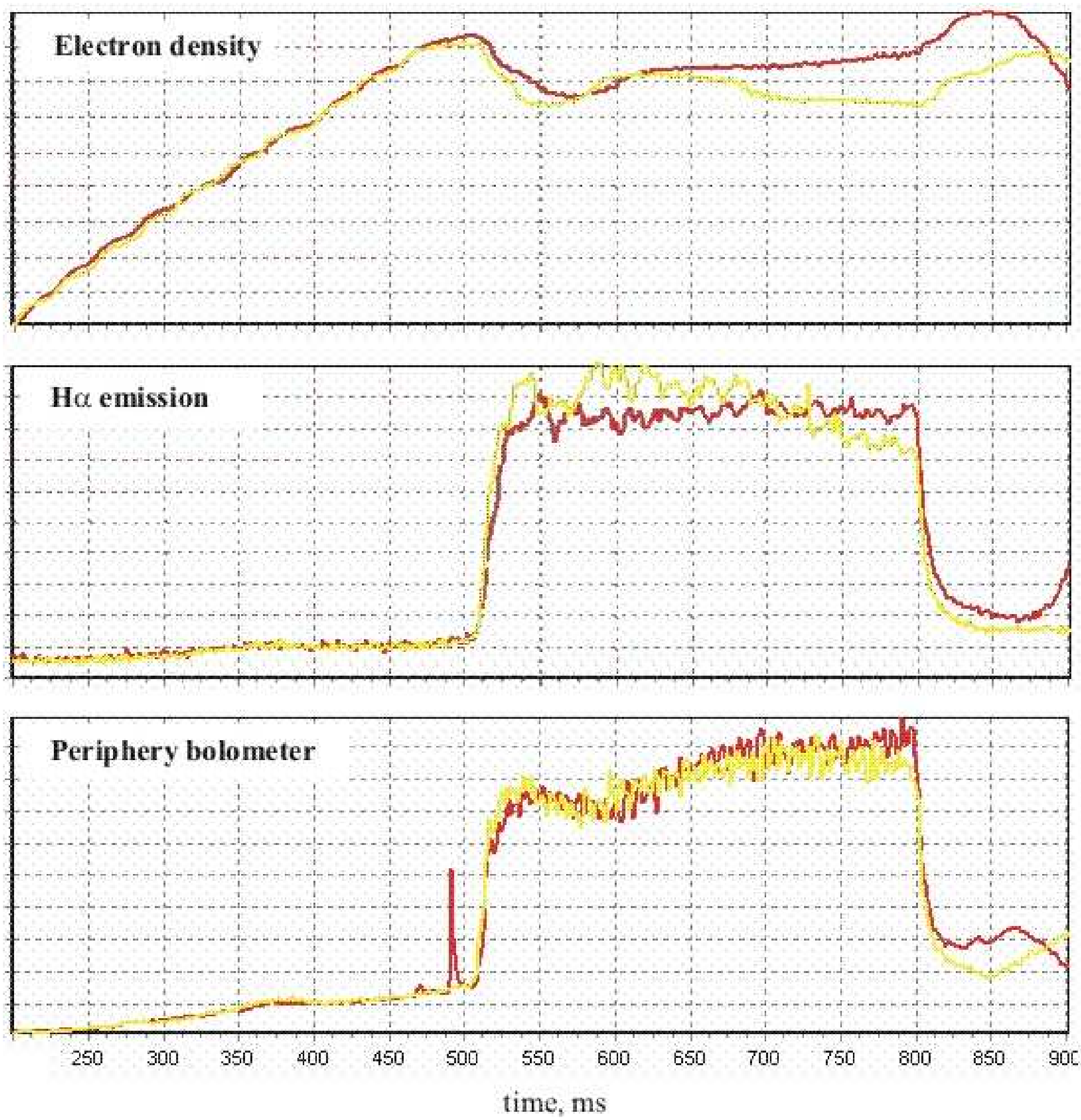

Fig. 1. Evolution of main plasma parameters in the reference shots before (#42312 red curve) and after (#42319 yellow curve) series with Li injection. All data are in arbitrary units.

The time evolutions of signals measured by the microwave interferometer, Hα detector and one of peripheral AXUVD bolometer channels (30 cm of minor radius) are presented in Fig. 1. It is seen that there are no obvious effects of discharge conditioning. In particularly, Hα signal did not decrease after a sequence of Li pellet injections as might be expected for successive conditioning experiments (see Ref. [3]).

Considering the peripheral bolometer signal in Fig. 1, one can conclude that a qualitative composition of peripheral impurities had no noticeable disturbance after Li pellet injections. No difference of main impurities lines radiation (CIII, OII) behavior before and after Li injections confirms this suggestion as well.

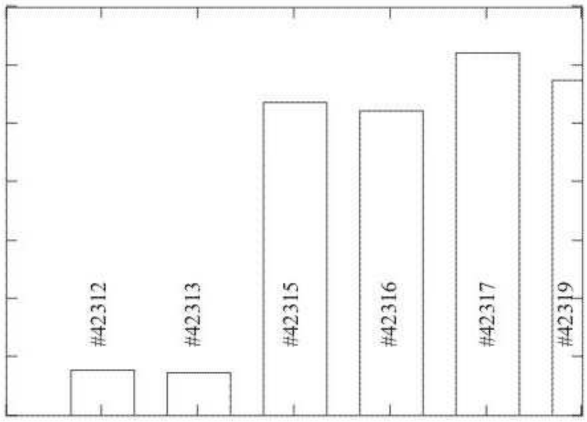

Fig. 2. Comparative increasing of hydrogen puffing during series of Li injection.

Electron density evolutions in Fig. 1 have an indication of decreasing the hydrogen recycling. Behavior of the density till 600 ms is provided by feed-back operation of the programming gas puff. After 600 ms gas puff was switched off in all shots. Therefore, lower plasma density (t > 600 ms) in shot #42319 after a sequence of Li pellet injections indicates lower particle flux from the wall. The same conclusion can be done by analysis of the total gas puff amount (shown in Fig. 2) which is needed to provide the programming electron density behavior till 600 ms of the shot. From Fig.2 one can see that it was necessary to increase the total gas puff amount in shots after Li pellet injections. It means that Li pellet injection gradually decreased the hydrogen recycling from the wall.

The possible reason of absence of the conditioning effects was insufficient total amount of the injected Li atoms to cause conditioning effect on the vacuum vessel. Estimation of a lithium amount for the monolayer coating of the T-10 first wall surface gives a number of $2.5x10^{20}$ atoms that 10 times higher than the pellet content. On the other hand it is enough $\sim10^{18}$ Li atoms to coat the T-10 limiter surface. One can propose to perform the further conditioning experiments with smaller limiter radius to increase the limiter coating by the available lithium content of the pellet injector. A peripheral Li jet injection can be also proposed for increasing the Li amount in order to improve the conditioning efficiency.

Supersonic He jets injection

The gas injection was arranged using the supersonic jet source developed and mounted at T-10 recently. The source is based on an electromagnetic fast valve with a Laval nozzle. The nozzle has 3 mm in length and 0.3 mm throat size. The valve was opened during about 2 ms that allowed to inject $(1\text{-}20)x10^{19}$ He atoms depended on the P_{He} gas pressure (P_{He} = 5-100 bar) at the valve inlet. A formation of the compact helium jet with ~1.5 km/s velocity was expected. He jet was injected from top to bottom toward the plasma core. Injections were carried

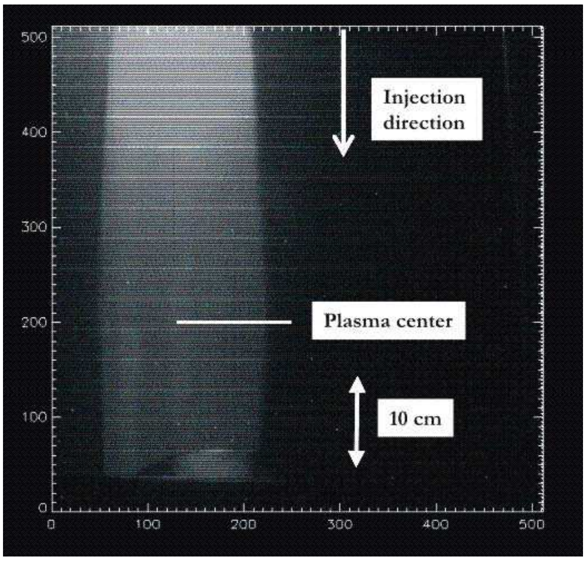

Fig. 3. He supersonic jet penetration in T-10 plasma.

out in Ohmically heated plasma with $<n_e>$ = $3x10^{13}$ cm^{-3} and I = 270 kA and a varied number of injected helium atoms. It was shown that injection of more than $3x10^{19}$ He (P_{He} > 15 bar) atoms caused a T-10 discharge minor disruption. In a case of injection of the moderate amount atoms, high deposition efficiency of the He jet was found. For instance, in shot #42683, the $1.2x10^{19}$ He atom amount calculated the from nozzle flow dynamics was found in a good agreement with those measured in test-bed experiments ($1.6x10^{19}$ atoms) with the jet source and evaluated from the electron density jump after injection ($1.5x10^{19}$ atoms).

The jet emission in plasma was observed using the CCD camera (see Fig. 3). The luminescent part of the plasma periphery gives a rough estimation of the jet penetration up to r/a_L = 0.6. The further experimental program studies of jet penetration depth versus jet velocity, sort of injected gas, and density are foreseen. Furthermore discharge shutdown experiments with a massive Ar gas jet injection is planned.

Acknowledgements

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