EXPERIMENTAL INVESTIGATION OF DEUTERIUM AND NITROGEN-SEEDED H-MODE PLASMAS IN KSTAR WITH NEW W DIVERTOR

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1. INTRODUCTION

KSTAR has recently replaced the lower divertor material from carbon to tungsten. The divertor geometry was also modified, necessitating the development of new edge plasma operation scenarios suitable for the new divertor, which aims to control particle and heat fluxes onto the targets, i.e. divertor detachment. The installation of the new W divertor was predicted to require extrinsic impurity seeding for achieving divertor detachment. This study reports on the first experimental results of deuterium and nitrogen seeded H-mode plasmas in KSTAR with new W divertor.

2. EXPERIMENTAL RESULTS

Target H-mode discharges in the study had a total heating power of 6.0-6.5 MW (5.5-6.0 MW of neutral beam injection and 1.0 MW of electron cyclotron heating) with a plasma current of 0.5 MA and a toroidal magnetic field of 1.9 T, which corresponds to q_{95}~6.0. Without D_2 fuelling or impurity gas seeding, gradual reduction in total radiated power was observed, which can be explained by flushing of W impurity introduced at the early phase of discharges, by ELMs with frequency of ~100 Hz [1]. In the between-shot D_2 fuelling rate scans, ELM frequency was increased up to a factor of ~2 and consequently core radiated power was reduced by increased ELM flushing. Concomitant increase in divertor radiated power made an increased total radiated power with D_2 fuelling. Before the fuelling, strong radiative region was shown in the inner far-SOL region, which can be an evidence for a presence of a high-field-side high-density region [2]. In contrast, with the previous C divertor, the peak radiation in the inner divertor was shown in the near-SOL region. Up to the highest tested fuelling rate, the outer target particle flux (j_{sat}) remained largely unchanged while the inner target j_{sat} sharply increased 2-3 seconds after D_2 fuelling began, then gradually degreased to about half of its peak value. Further analysis with target electron density and temperature measured by a voltage sweeping Langmuir probe will be performed.

While deuterium puffing effectively reduced core radiation, nitrogen seeding increased core radiation despite a reduction in tungsten sputtering indicated by W I line emission along with an increase in ELM frequency, similar to the D_2 seeding experiment (Fig. 1). This implies that tungsten transport changed in a way that enhanced core accumulation. During N_2 seeding, the peak outer target j_{sat} dropped significantly, by up to a factor of 4, whereas the inner target j_{sat} showed an abrupt increase, similar to the D_2 fuelling case, but did not decrease afterward. This detachment in/out asymmetry aligns with previous findings from D_2 fuelling and impurity seeding experiments with the C divertor. This implies that the asymmetry is mainly attributed to the divertor geometrical effects, as the V-shaped structure, which is considered a culprit for asymmetric distributions of neutral particles [3], has maintained even after the new W divertor. The analysis of radiation power distributions in the divertor region revealed that with massive nitrogen gas seeding, the strong inner divertor radiation front moved toward the X-point region and even extended into the high-field-side SOL just adjacent to the X-point (Fig. 1).

It is worthwhile to note that in contrast to other tungsten-faced tokamaks, where gas puffing improved core confinement performance by reducing tungsten sputtering and radiation, core confinement in KSTAR always degraded with fuelling and/or impurity seeding. Additionally, experiment with N_2 seeding turned off at the middle of discharge were also performed to analyse re-attachment phenomenon. During 6 s after the N_2 seeding was turned off, the outer target peak j_{sat} remained stationary, while the inner target peak j_{sat} was gradually increased, following the trend of N II line emission (399.5 nm) near the inner divertor.

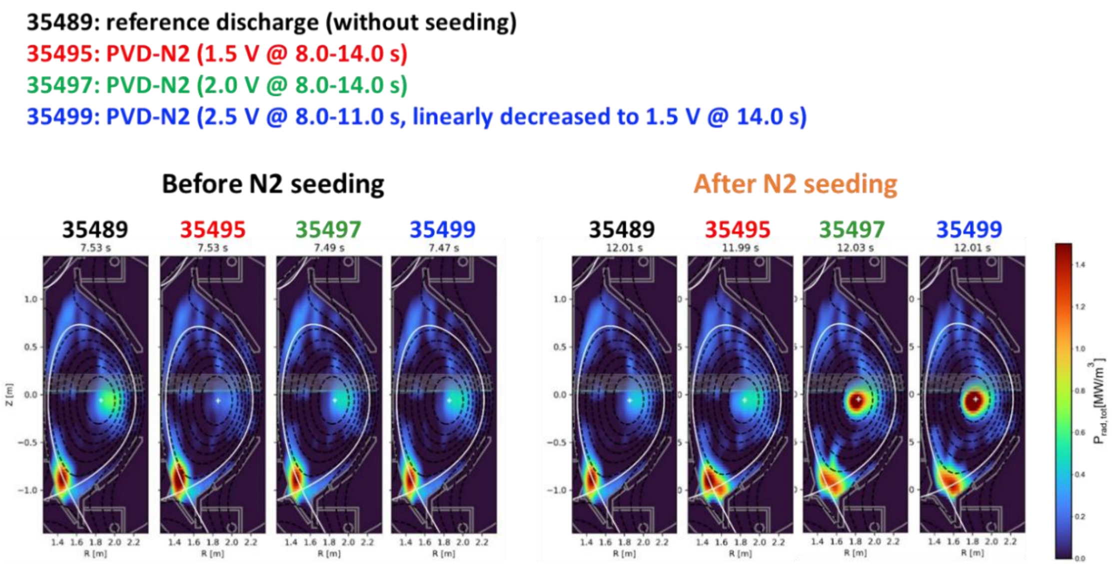

Fig. 1 Two-dimensional radiated power distributions for a non-seeding reference discharge and three N_2-seeded discharges with different seeding rates. Two time points before (7.5 s) and after (12.0 s) N_2 seeding were selected.

3. CONCLUSIONS

This study presents the first experimental findings on deuterium- and nitrogen-seeded H-mode plasmas in KSTAR with the newly installed W divertor. Deuterium fuelling increased ELM frequency, promoting tungsten flushing and reducing core radiation. In contrast, nitrogen seeding increased core radiation despite lower tungsten sputtering, indicating transport changes similar to those observed in WEST. Without N_2 seeding, a strong radiative region was observed in the inner far-SOL, while heavy nitrogen seeding shifted the radiation front toward the X-point. Notably, D_2 fuelling and N_2 seeding exhibited distinct in/out detachment asymmetries. Experiments with reversed toroidal field direction will help distinguish the relative contributions of divertor geometry and ExB drifts. Additionally, ongoing SOLPS-ITER modelling of these discharges will provide the underlying physics of these experimental observations, including mechanisms of distinct evolutions in particle flux at each divertor target and radiated power distributions during fuelling and nitrogen seeding rate scans.

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