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Control of impurity influx with external perturbation field in high-density plasmas on LHD

LHD 高密度プラズマにおける外部摂動磁場による不純物流入の抑制

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Impurity behavior in high-density plasmas with super dense core (~2x$10^{20}$$m^{-3}$) has been investigated. Radiation profile measurements showed a remarkable temporal increase of core radiation due to intrinsic metallic impurities. The operational regime is in impurity accumulation window on n - P_{nbi} diagram for impurity behavior. Impurity influx control with an external induced magnetic island at the plasma edge was demonstrated and impurity accumulation in the core was suppressed.

1. Introduction

Super Dense Core (SDC) plasmas with Internal Diffusion Barrier (IDB) for particle transport can be produced by particle fueling with pellet injection in LHD. The development of repetitive pellet injector enables us to maintain the SDC plasmas for long time. As a result, a quasi-steady state discharge with IDB ($n_{e\text{-}bar}$ = 2 x 10^{20} m^{-3}) was achieved over 3 s. In this discharge, radiation profile measurements by AXUVD silicon photodiode arrays showed a temporal peaking of radiation profile. Therefore, impurity behavior in quasi-steady state discharges with internal diffusion barrier is studied and then control of impurity influx with an external perturbation field is investigated.

2. Impurity behavior in SDC plasmas

2.1 *Super Dense Core (SDC) plasma*

A super dense core operational regime was found in LHD [1-2]. SDC plasmas are spontaneously produced by injection of multiple pellets in the magnetic configuration with the major radius of more than R = 3.75 m. A core region with densities as high as 1.0 x 10^{21} m^{-3} and temperatures of 0.85 keV is confined by an internal diffusion barrier (IDB) with very high-density gradient, which is located at normalized minor radius ρ ~ 0.5. The SDC plasmas can be also maintained by controlling the plasma density with repetitive pellet injection.

2.2 *Impurity behavior in long pulse discharge*

Figure 1 shows a typical long pulse SDC discharge with IDB. The average plasma density rapidly builds up to a high-density level of 3 x 10^{20} m^{-3} with high repetitive pellet injection. Then the average plasma density is controlled so as to keep more than 2 x 10^{20} m^{-3} by a feedback control loop with CO_2 laser interferometer signal. In spite of keeping the average plasma density, the density profile changes with time. The density profile becomes peaked remarkably until 5.2 s, and then the central density decreases and the density in the peripheral region increases with time. The radiation profiles are measured by a system of two 20-channel fan-beam cameras with AXUVD silicon photodiodes. Local radiation is reconstructed with a tomographic imaging technique. As shown in the last column, a remarkable peaking of radiation profile is observed despite of keeping the density and temperature profiles. This suggests that impurities are accumulated in the core plasma. The suppression of impurity accumulation in the second half period of the discharge is related to impurity shielding due to the increase of edge density.

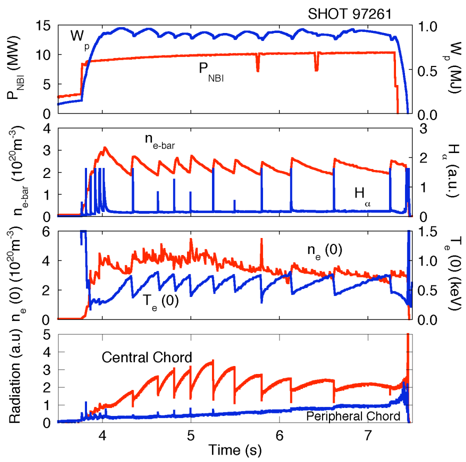

Fig. 1. Long pulse SDC discharge with IDB

2.3 *n - P_{nbi} diagram for impurity behavior*

Impurity behavior in LHD can be distinguished in the operational regime on n - P_{nbi} diagram as shown in Fig. 2. The impurity transport largely depends on radial electric field and impurity shielding effect in ergodic layer [3], which are unique features of helical system. In this diagram, we can find the impurity accumulation window [4] in ion root regime ($E_r < 0$) and impurity screening region in high-density regime. The impurity behavior in SDC plasmas is consistent with that in the operational regime on n - P_{nbi} diagram.

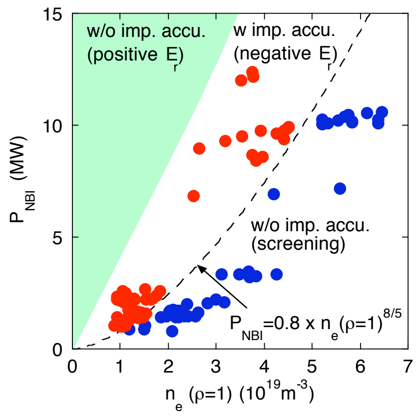

Fig. 2. n - P_{nbi} diagram for impurity behavior

3. Control of impurity influx

In the previous LHD experiments [5], the influence of magnetic islands on impurity behavior was observed by using external perturbation coils, which produce an *n/m = 1/1* magnetic island near the plasma edge. This method is applied to SDC discharges and the impurity accumulation control is demonstrated. Figure 3 shows typical discharges with and without the perturbation field. In this case, the perturbation field is applied before the discharge and decreased with time. The plasma density in both discharges is kept constant level (~2 x 10^{20} m^{-3}). In the discharge without the perturbation filed (#104258), a remarkable peaking of radiation profile and the increase of metallic impurity line intensity (Fe XIX) are observed after the density ramp up phase as shown in Figs. 3-4. On the other hand, we can see the suppression of impurity accumulation by reducing the impurity influx in the discharge with the perturbation filed (#104268). The physical mechanism of impurity accumulation suppression will be investigated in future.

4. Summary

Long pulse SDC discharges showed impurity accumulation just after plasma density ramp up phase. The successful control of impurity accumulation was demonstrated with a perturbation field (a magnetic island near the plasma edge).

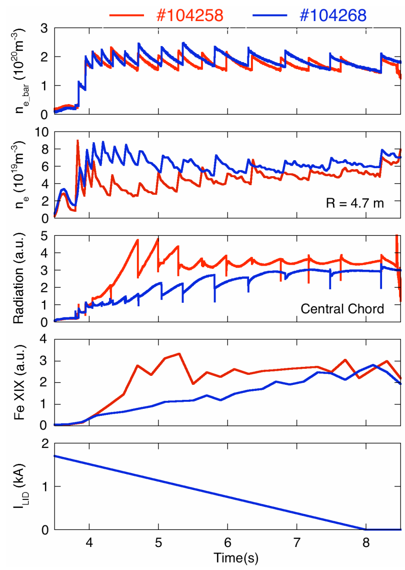

Fig. 3. Discharges with and without LID field

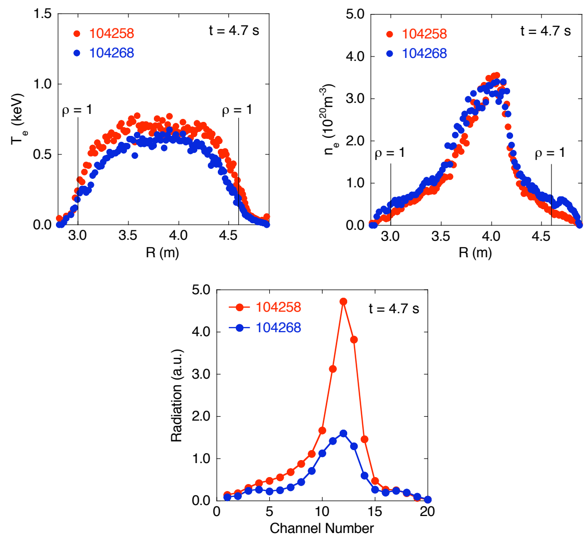

Fig. 4. Profiles of temperature, density and radiation

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