CONF-9706131--22

EDGE PLASMA CONTROL USING AN LID CONFIGURATION ON CHS*

by

S. Masuzaki, A. Komori, T. Morisaki, N. Ohyabu, H. Suzuki, C. Takahashi, S. Sakakibara, K. Watanable, T. Minami, S. Morita, K. Tanaka, S. Ohdachi, S. Kubo, N. Inoue, H. Yamada, K. Nishimura, S. Okamura, K. Matsuoka, O. Motojima
National Institute for Fusion Science
Oroshi, Toki 509-52, Japan

and

C. C. Klepper, J. F. Lyon, A.C. England
Fusion Energy Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee, U.S.A.

to be presented at the
European Physical Society Meeting
Berchtesgaden, Germany
9-13 June 1997

*Research sponsored in part by the U.S. Department of Energy, under contract number DE-AC05-96OR22464 with Lockheed Martin Energy Research Corporation.

DISCLAIMER

Edge plasma control using an LID configuration on CHS

S. **Masuzaki**, A. Komori, T. Morisaki, N. Ohyabu, H. Suzuki, C. Takahashi, S. Sakakibara, K. Watanabe, T. Minami, S. Morita, K. Tanaka, S. Ohdachi, S. Kubo, N. Inoue, H. Yamada, K. Nishimura, S. Okamura, K. Matsuoka, O. Motojima
National Institute for Fusion Science, Oroshi, Toki 509-52, Japan
C.C. Klepper, J.F. Lyon, A.C. England
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, U.S.A.

1. Introduction

A Local Island Divertor (LID) has been proposed to enhance energy confinement through neutral particle control [1]. For the case of the Large Helical Device (LHD), the separatrix of an m/n=1/1 magnetic island, formed at the edge region, will be utilized as a divertor configuration. The divertor head is inserted in the island, and the island separatrix provides connection between the edge plasma region surrounding the core plasma and the back plate of the divertor head through the field lines. The particle flux and associated heat flux from the core plasma strike the back plate of the divertor head, and thus particle recycling is localized in this region. A pumping duct covers the divertor head to form a closed divertor system for efficient particle exhaust. The advantages of the LID are ease of hydrogen pumping because of the localized particle recycling and avoidance of the high heat load that would be localized on the leading edge of the divertor head. With efficient pumping, the neutral pressure in the edge plasma region will be reduced, and hence the edge plasma temperature will be higher, hopefully leading to a better core confinement region. An LID configuration experiment was done on the Compact Helical System (CHS) to confirm the effect of the LID[2,3]. The typical effects of the LID configuration on the core plasma are reduction of the line averaged density to a half, and small or no reduction of the stored energy. In this contribution, the experimental results which were obtained in edge plasma control experiments with the LID configuration in the CHS are presented.

2. Experiment

The CHS is a heliotron/torsatron type device whose major radius is 1.0m and average plasma minor radius is 0.2m, respectively. The toroidal magnetic field is 0.9T, and the magnetic axis is fixed at R = 99. 5 cm in this experiment. Plasma was produced with ECH or ion Bernstein heating, and was heated by neutral beam injection (0.82MW, 38kV). The separatrix of the m/n=1/1 magnetic island formed by 8 pairs of additional coils was utilized for the LID configuration. A cryogenic pump (21,000L/sec) was installed behind the divertor head for particle exhaust. Fueling was done by gas puffing. Edge plasma modifications by the LID configuration were measured using Langmuir probes, a Lithium beam probe and Hα detectors, as shown in Fig.1. There are two types of Langmuir probes, one movable (#1-#3) and the other attached to the back of the LID head. The Li beam probe is located 135° (CCW direction) from the LID port, and the beam line comes into the plasma from the bottom port [4].

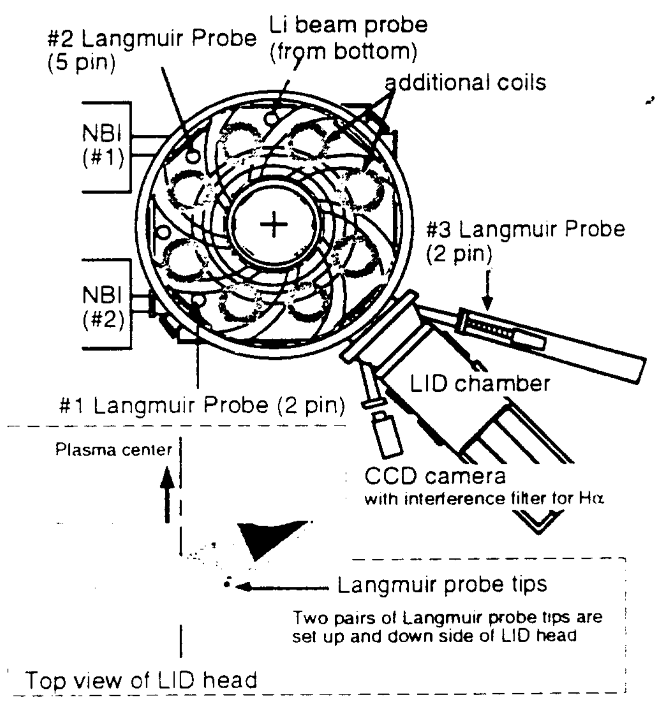

Fig.1 Schematic view of experimental setup

The edge plasma was controlled with the m/n = 1/1 magnetic island and insertion of the LID head. The island's phase can be changed as follows; O-point of the magnetic island is formed at the position of the LID insertion port (normal case) andat the opposite side of the torus

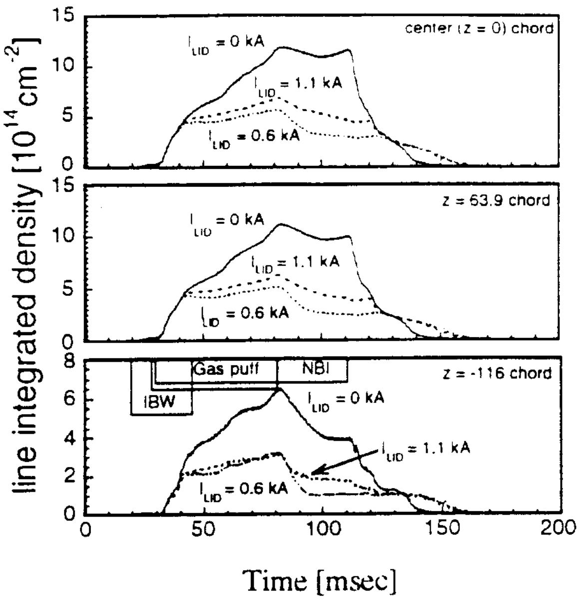

Fig. 2 Time development of line integrated density, upper: center(z=0) chord, middle: z= 63.9 chord, bottom: z=-116 chord.

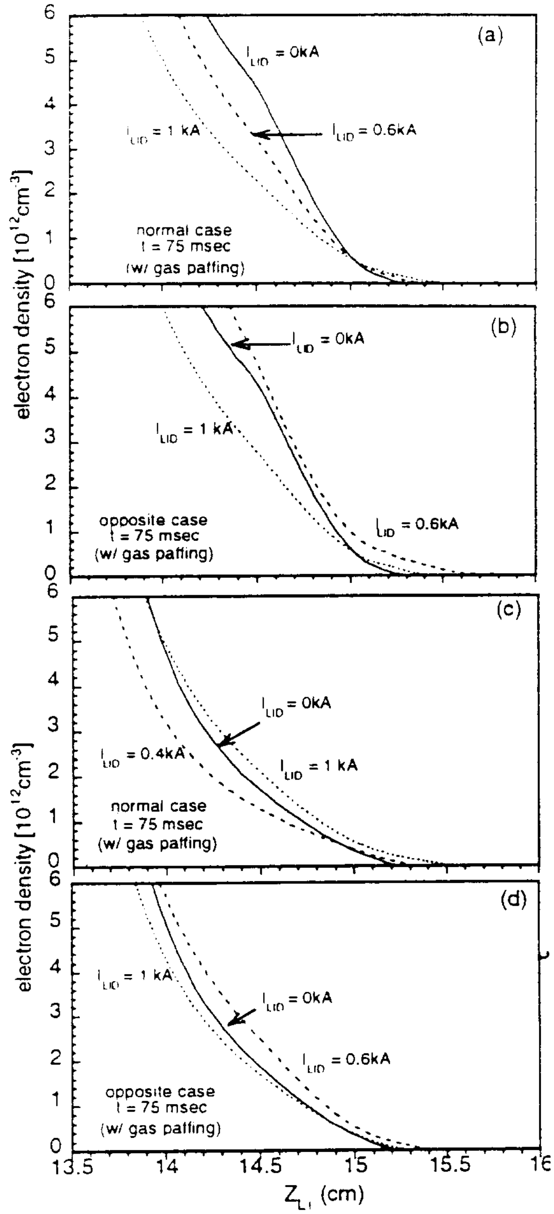

Fig. 3 Edge electron density profiles obtained by Li beam probe: (a) and (b) are normal and opposite case, respectively, without insertion of LID head. (c) and (d) are normal and opposite casse, respectively, with insertion of LID head.

(opposite case) , and the island width can be changed by controlling the coil current (I_{LID}). The LID head can be moved from outside the vacuum chamber to inside the magnetic island.

3. Experimental results

3-1 Edge density profile

Scince one of the typical LID effects is the decay of the line-integrated center-chord density, the change of the density profiles with the island is very important for understanding the LID experimental results. Figure 2 shows the time developments of the line-integrated density for 3 chords [z = 0 (center chord), z = 63.9 mm, z = -116 mm, z: vertical axis]. The density reduction caused by the island occurs in not only the center chord but in the other chords as well. The reduction rate is almost the same in all the chords except in the 'normal case' without LID head. In this case, the reduction rate is larger in the outer chord(z = -116 mm) than the other chords.

Figure 3 shows the edge density profiles obtained using a Li beam [4]. The horizontal axis (Z_{Li}) is the position on the Li beam line whose origin is on the equatorial plane. Figures 3(a) and (b) show the density profiles without insertion of the LID head, and Figs. 3(c) and (d) are with insertion of the head. In the 'normal case', the O-point of the island is opposite the Li beam probe port, and is on the Li beam side in the 'opposite case'. In Fig. 3(a), the density profile shrinks with increasing I_{LID}. This is considered to be due to a change in magnetic structure, that is, the ergodic region surrounding the last closed magnetic surface (LCFS) is broader near the X-point of the island. On the contrary, in Fig. 3(b), the density profile is slightly spread outward with increasing I_{LID} until I_{LID} reaches 0.6 kA due to the existence of the island separatrix farther out the LCFS without the island. The tail density (Z_{Li}>15cm) also increases with I_{LID} until 0.6 kA, and decreases at larger I_{LID} values. This result suggests that too large a value of I_{LID} destroys the closed

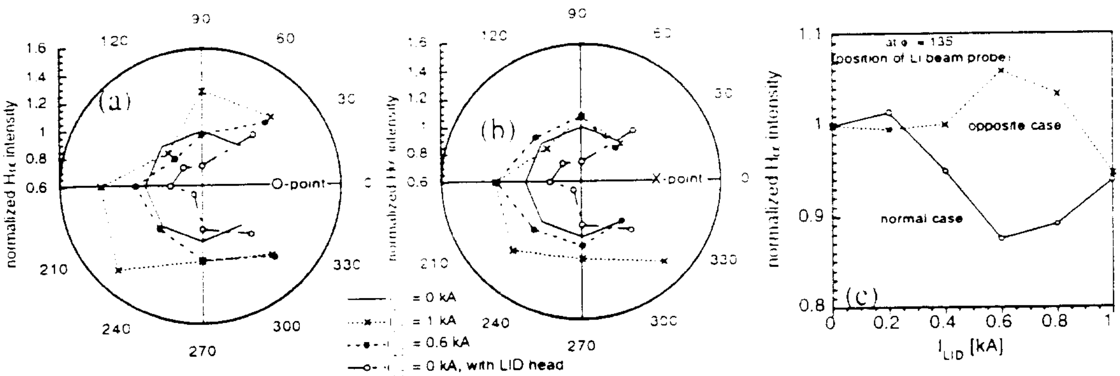

Fig. 4 Toroidal distributions of normalized Hα intensity. All signals are normalized by the corresponding values for the case of no I_{LID} and LID head. (a) for normal case, (b) for opposite casse. (c) At the position of toroidal angle of 135∞ (Li beam probe position)

magnetic surface in the edge region, and spreads the ergodic layer. This is clearly indicated in the case of I_{LID} = 1 kA in Fig. 3(b).

In Figs. 3(c) and (d), the position on the Z_{Li} axis corresponding to the edge of the LID head is Z_{Li} = 13.3 cm. The edge plasma is scraped off by the LID head, and the density profiles reflect that [4]. The effects of the island are qualitatively similar without insertion of the LID head qualitatively, though a discrepancy occurs for the 'normal case' with the LID head inserted.

3-2 Particle Recycling

Hα intensities were measured for various I_{LID} values to make the effect of the LID configuration on particle recycling clear. Figures 4(a) and (b) show the toroidal distributions of the normalized Hα intensity for different I_{LID} values for the 'normal' and the 'opposite' cases, respectively. The toroidal angle is defined CCW from the LID position. It is very clear that the Hα intensity decreases when the LID head is inserted except in the region near the LID head. In this case, the LID head plays the role of a normal limiter. In Fig. 4(a), near the LID position (0°) where the island has its maximum width, the Hα intensity increases even without insertion of the LID head. On the other hand, in Fig. 4(b) for the opposite case, the Hα intensity decreases near the LID position where the X-point of the island is located. In the case of I_{LID} = 1 kA, the ergodic region spreads outward, and the particle recycling increases. At the toroidal angle of 135°, the Hα intensity change for various I_{LID} values can be compared with the edge electron density profiles measured by the Li beam probe. In Fig. 4(c), normalized Hα intensities at this point for various cases are shown. For the opposite case, the Hα intensity increases with increasing I_{LID} up to 0.6 kA, and decreases at larger I_{LID} values. This change is similar to the change in the tail density mentioned in the previous section. On the contrary, the 'normal case' is not so simple. In this case, the Hα intensity depends not only on the tail density but also on the density profile near the LCFS. It is reasonable for the case with the LID head inserted that the Hα intensity decreases because the LID head scrapes the edge density as shown Fig. 3(c), (d). These results suggest that particle recycling closely depends on the magnetic field structure, so that moderate I_{LID} values and insertion of the LID head can be used for particle recycling control.

3-3 Distribution of the Particle flux on the LID head

The amount of the particle flux to LID head, and its distribution on the head, are important in determining the LID pumping efficiency. They are estimated using Langmuir probes attached on the up and down sides of the LID head, respectively. Figure 5 shows the distribution of the particle flux on the LID head for various NBI cases. The toroidal field direction corresponding to the NBI direction is CW for NBI(#1) counter and NBI(#2) co injection, CCW for NBI(#1) co and NBI(#2) counter injection. The horizontal axis is the LID head position, and the origin of this axis is the normal position of the LID head where the edge of the head is at the center of the island. A negative sign means that the head is retracted outward from its normal position. This figure is for the 'normal case', that is, the outer separatrix of the island strikes the LID head. All distributions have a peak at the position corresponding to the outer separatrix striking point. Though the up and down side probes were set symmetrically, the striking point is asymmetrical. The down side striking points are 1-2 cm farther in than that of the upper side. The reason for this asymmetry is not clear. One possibility is that the phase of the island is moved due to an error field. A small error field was shown to exist in the CHS by magnetic surface mapping and its strength and direction estimated [5], but it is not enough in this case. The decay length of the particle flux on the LID head is estimated with the assumption that the particle flux decreases exponentially. The results are also shown in Fig.5. The decay length for the particle flux distribution on the upper side is larger than that on the down side, though the decay length for the case of NBI(#2) co-injection is relatively short. So this asymmetry does not depend on the direction of NB injection (co or counter), but rather on the toroidal field direction.

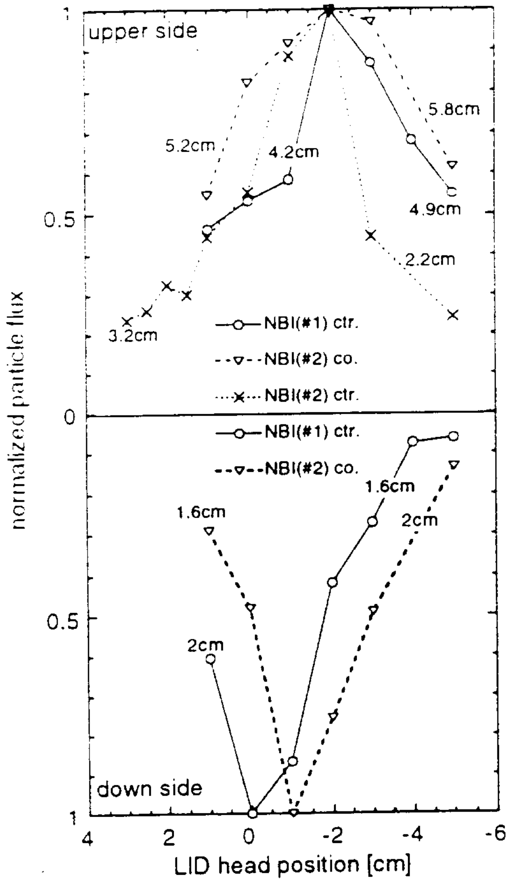

Fig. 5 Distributions of normalized particle flux for various NBI directions, and decay length of them.

4. Summary

To understand the mechanism of improved confinement, edge plasma control experiment using this configuration was done.

Line integrated densities for 3 chords mainly inside the LCFS and edge density profiles were measured by an interferometer and a Li beam probe, respectively. Former results suggest that the density profile in the core region is not changed that much by the island. The edge density profiles clearly show the effect of the LID configuration. The density profiles which reflect the broadened ergodic region due to destruction of closed magnetic surface were observed in the case of relatively large I_{LID} values.

Measurement of the toroidal distribution of the Hα intensity was done for various I_{LID} values to understand the effect of the LID configuration on particle recycling. Insertion of the LID head decreases the Hα intensity except near the head. For the case without LID head, the distribution depends on I_{LID}. Due to a broadened ergodic region, the Hα intensity increased significantly in the case of a relatively large I_{LID} value. This is consistent with results from Li beam probe measurements.

Measurement of the particle flux on the LID head was done using Langmuir probes attached to the LID head. The particle flux distribution on the LID head has a peak at the position corresponding to the outer separatrix of the island for the 'normal case'. Two types of up and down particle flux distribution asymmetry were observed. One is the peak position, and the other is the decay length. The latter is considered to be related to the toroidal field direction.

References

[1] N. Ohyabu, et al., J. Nucl. Mater. 145-147 844 (1987).
[2] A. Komori, et al., Proc. 12th International conference on plasma surface interactions in controlled fusion devices (1996). (to be published in J. Nucl. Mater.)
[3] A. Komori, et al., Proc. Plasma Physics and Controlled Nuclear Fusion Research, Montreal, 1996, IAEA-CN-64/C1-2.
[4] T. Morisaki, et al., Proc. 12th International conference on plasma surface interactions in controlled fusion devices (1996). (to be published in J. Nucl. Mater.)
[5] H. Yamada, et al., Rev. Sci. Instrum., 61, No.2 (1990).

Report Number (14) CONF-9706131--22

Publ. Date (11) 199707

Sponsor Code (18) DOE/ER, XF

UC Category (19) UC-400, DOE/ER