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Measurement and numerical analysis on the end-loss flux during the plasma heating in anchor region of GAMMA 10/PDX tandem mirror

GAMMA 10/PDXアンカー部加熱実験におけるエンド部フラックス挙動の計測と数値計算による解析

Kazuya Ichimura, Yousuke Nakashima, Hisato Takeda, Miki Iwamoto, Yasunari Hosoda, Keita Shimizu, Kazuma Fukui, Mafumi Hirata, Ryuya Ikezoe, Takurou Yokoyama, Shuhei Sumida, Kensuke Oki, Masayuki Yoshikawa, Mizuki Sakamoto, Tsuyoshi Imai and Makoto Ichimura

市村和也，中嶋洋輔，武田寿人，岩元美樹，細田甚成，清水啓太，福井良磨，平田真史，池添竜也，横山拓郎，隅田脩平，大木健輔，吉川正志，坂本瑞樹，今井剛，市村真

Plasma Research Center, University of Tsukuba
1-1-1-, Tennoudai, Tsukuba-shi, Ibaraki 305-8577, Japan
筑波大学プラズマ研究センター　〒305-8577　茨城県つくば市天王台1-1-1

In GAMMA 10/PDX, the additional plasma heating in the anchor regions by new configurations of ICRF (ion cyclotron ranges of frequency) antenna were performed. As a result, the ion particle flux was increased to the value of 1.7×10^{23} particles/m^{2}sec. During the ICRF injection, axial distribution of plasma density quite different from a standard operation of GAMMA 10/PDX was observed. Numerical calculation with a modeling of multi-cell mirror confinement was newly developed and applied to GAMMA 10/PDX in order to analyze the process of end-loss ion flux production. By the calculation, experimental results were qualitatively reproduced.

1. Introduction

The aim of this research is to understand the mechanism of enhancement for the plasma flow into end regions of the tandem mirror. Due to the difficulty of producing plasma of high temperature in simple linear devices, plasma temperatures in most divertor simulating linear machines are much lower in comparison with expected values of fusion reactors. Therefore, experimental research of linear divertor simulator plasma with high temperature range is needed. A large tandem mirror device, GAMMA 10/PDX is a powerful tool to perform such experimental research since the machine is able to produce the end-loss plasma particle flux which has high temperature in simple geometry [1-4]. In previous research, the current density of the end-loss ion was measured and the particle flux estimated from the ion current density was 5×10^{22} particles/m^{2}sec. The new antennas for additional ICRF have been installed to increase the density of the end-loss flux. In the presentation, results of the experiments with new ICRF antenna configurations are reported and discussed both experimentally and numerically.

2. Experimental Setup

GAMMA 10/PDX has 27 m machine length and plasma radius larger than 10 cm. The machine consists of five mirror cells and two end regions: the central-cell, anchor-cells, plug/barrier-cells and end-regions.

As a main diagnostic tool for the end-loss ion flux, end-loss ion energy analyzer (ELIEA) is installed in the end cells, which observes the energy distribution and the current density of the end-loss ion flux incident to the end region [5,6].

3. Experimental Results

Figure 1 shows results of the experiments with new antennas. As a result of ICRF heating by the new configuration of antennas (East Anchor + West Anchor), the particle flux has been increased to 1.7×10^{23} particles/m^{2}sec. The increase of the ion flux depends largely on the electron line density in the central-cell (NL_{CC})

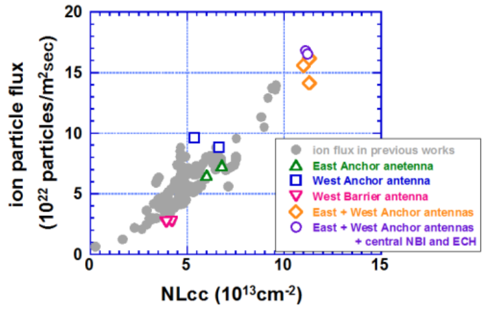

Fig.1. Ion particle flux during the ICRF experiments plotted against the line density in the central cell.

4. Numerical Analysis

In the experiments, ICRF wave is mainly superimposed to the anchor-cells. Therefore the change of plasma parameters, including the particle flux, is caused not only by the change of the plasma in the central-cell but also the change of plasma in the anchor-cells. Hence it is important to investigate the mechanism of the plasma transport from anchor-cell to the central-cell, and that NL_{CC} affects the particle flux.

In order to analyze the experimental results, a plasma build-up simulation code [7] with new idea of axial plasma transport from the mirror cell to other mirror cell was developed. Since the original code took only central-cell into account, we extended the calculation region to include anchor regions. The coefficients of particles' axial transport between each mirror cell were determined by dwell time, confinement time and length of each cell.

The initial plasma parameters for the calculation, such as plasma density and temperatures are given from the measurement and the increase of the plasma density in anchor-cell was used as the changing factor in order to simulate the external change of plasma density observed during the additional ICRF heating. We defined three cases of calculations in order to simulate the present experiments. Case (1) simulates the standard operation mode plasma of GAMMA 10/PDX without new ICRF. In case (2), plasma heating by East Anchor antenna and West Anchor antenna are simulated by increasing the plasma density in east and west anchor-cells. In case (3), only the plasma density in east anchor-cell was increased in order to reproduce the case of the additional ICRF heating by East Anchor antenna only.

Figure 2 shows the results of numerical calculation by the upgraded plasma build up code. Case (1) is the case without an additional ICRF heating and the plasma density is assumed to be equally distributing to the three cells. In condition (2), large increase of the NL_{CC} and the particle flux were evaluated. Also, in case of condition (3), propagation of the plasma density from the east anchor to the west anchor region by cell-to-cell transport was estimated. From the calculations, it was found that the degree of the particle flux increase is quite similar to the degree of the plasma density increase in the central-cell, as seen in the experiments. Therefore we conclude that the calculation was qualitatively successful and some parts of mechanisms in the particle flux enhancement by ICRF antennas in anchor-cells were revealed. In future, calculations with more detailed modeling of the cell-to-cell transport will be performed in order to reproduce the experimental results quantitatively.

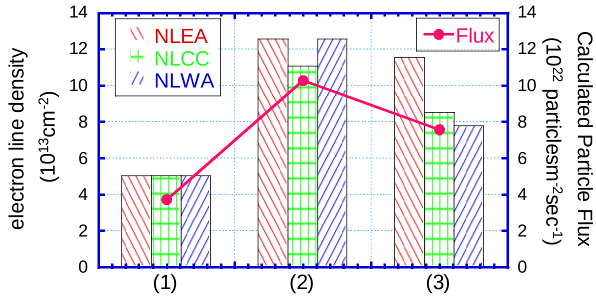

Fig.2. Calculated electron line density in each cells and particle flux for three cases; (1) without additional ICRF, (2) additional ICRF by East + West Anchor antennas, and (3) ICRF by East Anchor antenna.

5. Summary

By using the new configuration of ICRF antennas, the particle flux in the end region of GAMMA 10/ PDX was strongly enhanced to the value of 1.7×10^{23} particles/m^{2}sec. By the numerical calculation using the new idea of cell-to-cell transports of multiple mirror confined plasmas, some parts of experimental results were qualitatively reproduced. Especially, the dependency of the particle flux to the electron line density in the central-cell, which was observed in the experiment, was qualitatively reproduced for the first time.

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