§8. Wave Excitation in the Anchor Cell of GAMMA 10 with Nonaxisymmetric Configuration

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To control high performance plasmas with ion cyclotron range of frequency (ICRF) waves is one of the main subjects in GAMMA 10. The high end-loss particle and heat fluxes are required for the boundary plasma research, such as divertor simulation experiments. The study of the wave excitation and propagation in the nonaxisymmetric mirror configuration is important because the formation of high-pressure plasmas in the anchor cell is required for Magneto-Hydro-Dynamic (MHD) stabilization. In the standard discharge, ICRF waves excited in the central cell propagate to anchor region and heat ions at the ion cyclotron resonance layer. The direct anchor heating with anchor antennas has started from 2009. From 2010, experiments with phase-controlled antennas in the central and anchor cells have been performed. More effective anchor heating is expected owing to interactions between excited waves by antennas in the central and anchor cells[1].

By use of a three-dimensional full wave code (TASK/WF3), the wave excitation in the anchor cell has been studied to analyze the experimental observations in GAMMA 10[2]. This code solves the Maxwell's equation for the wave electric-field as a boundary-value problem using the finite element method. In the model, it is assumed that a cold and inhomogeneous plasma is surrounded by the conducting walls. The power absorption through the collisional damping is described by introducing effective collisions in the dielectric tensor.

Figure 1 shows the temporal evolution of the line density in the east anchor cell with direct anchor ICRF heating experiment. As shown in the figure, the line density starts to increase from anchor ICRF (RF3) applied with additional gas injection. It is observed in the experiment that the line density becomes almost ten times larger than the normal operation (before RF3). This remarkable increase of the line density is sensitive to the phase difference between both central and anchor antennas. However, this remarkable increase of the line density has not been observed yet in the west anchor cell. In 2013, additional ICRF antenna has been installed in the west anchor cell in order to realize the high-density plasma production.

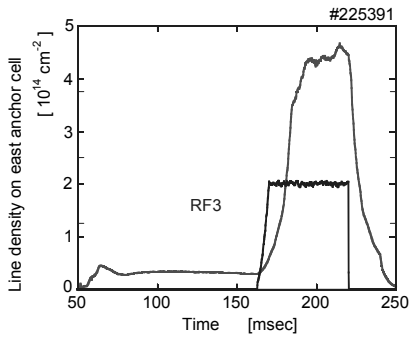

Fig.1 Temporal evolution of the line density in the east anchor cell when direct ICRF power (RF3) is injected in the anchor cell.

It has been observed that the end-loss particle flux increases with the central cell density. It will be possible to increase the density in the central cell when the ion confining potentials are formed in both east and west anchor cells with the increase of the density. Figure 2 shows temporal evolution of the line density on the east achor, the central and the west anchor cells when ICRF powers are injected directly in both east and west anchor cells as indicated by dotted blue lines in the figure. The additional gas is injected on the same timing of west anchor ICRF. The phase differences between antennas are adjusted as their optimum values on east and west anchor cells. When the west ICRF and additional gas are injected, the line densities in east and west anchor cells starts to increase clearly. The line density in the central cell also increases and reaches 10^{18} m^{-2}. A remarkable increase of the end-loss flux up to 10^{23} $m^{-2}sec^{-1}$ has been observed when ICRF waves are injected in both east and west anchor cells at the same time.

The optimization with the wave analysis for the high-density plasma production experiments is continued.

[1] T. Yokoyama, M. Ichimura, A. Fukuyama, et al., "Analysis of ICRF wave excitation in phase-control experiment on GAMMA 10", 23rd Int. Toki Conf. on Large-scale Simulation and Fusion Science, Toki, Nov.18-21, 2013.

[2] T. Yokoyama, M. Ichimura, A. Fukuyama, et al., "Study of ICRF heating in a complex magnetic field on GAMMA10/PDX", 30th Annual Meeting of The Japan Society of Plasma Science and Nuclear Fusion Research., Tokyo Institute of Technology, Dec.3-6, 2013.

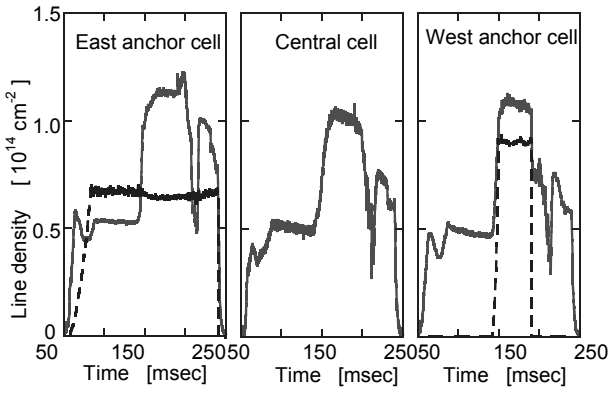

Fig.2 Temporal evolution of the line density in the east anchor, central and west anchor cells when direct ICRF powers are injected in both east and west anchor cells.