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ECH Power Modulation Experiments in GAMMA 10 Tandem Mirror
GAMMA 10におけるECHパワー変調によるプラズマ制御実験

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Electron cyclotron heating (ECH) power modulation experiments in GAMMA 10 have been started in order to generate and control the high heat flux and to make the ELM (edge localized mode) like intermittent heat load pattern for divertor simulation studies. ECH for potential formation at plug region (P-ECH) produces electron flow with high energy along the magnetic filed line. Heat flux during ECH injection corresponds to the steady-state heat load of the divertor plate of ITER. In this paper, the preliminary experimental results in P-ECH power modulation are reported.

1. Introduction

Electron cyclotron heating (ECH) is a promising way to heat magnetically confined plasmas. Besides the plasma heating, ECH has been recognized as a useful tool for plasma production, current drive, plasma profile modification, magnetohydrodynamics control, and transport study. Particularly, in the GAMMA 10 tandem mirror, ECH is recognized as a primary scheme to produce plasma-confining potentials.

In the GAMMA 10, fundamental ECH at the plug region (P-ECH) generates the axial ion confining potential ϕ_c. Experimental observation shows that ϕ_c increases with the P-ECH power, and no saturation has thus far been observed as long as the electron density is kept at a certain level. The P-ECH drives a portion of the heated electrons into the loss cone and induces an intense axial flow of warm electrons. A portion of the axially flowing electrons is observed as end loss electrons.

The new program to simulate the divertor plasma which utilizes the mirror advantages have been started, in addition to the core confinement studies as the mainframe 6 year work plan[1]. The peak heat-flux of 9 MW/m^2 was obtained during the ECH injection. It continues to increase with ECH power and is expected to be achieved more than 10 MW/m^2 within the available power of ECH (≤450 kW). This value almost corresponds to the steady-state heat load of the divertor plate of ITER. The ECH power modulation is expected to enhance and control the high heat flux and to simulate the ELM like intermittent heat load patterns, though we need substantial upgrade of the heating power to approach the ITER level ELM energy density.

In this paper, the first experimental results in P-ECH power modulation are reported.

2. Experimental apparatus

The GAMMA 10 is the world largest tandem mirror device (full length of 27 m), featuring the MW level high power heating systems. The plasma confinement is achieved by a magnetic mirror configuration as well as positive and negative potentials at the plug/barrier region formed by ECH. The main plasma confined in the central cell of GAMMA 10 is produced by ion cyclotron range of frequency (ICRF) wave. Figure 1 shows the axial magnetic field intensity and locations of the heating systems used in the preliminary P-ECH modulation experiment.

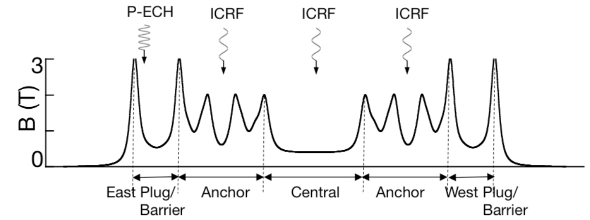

Fig.1. Axial magnetic field intensity and locations of heating systems for P-ECH modulation experiment.

3. Experimental results

Experiment for ECH power modulation in the east plug region is carried out by the use of a plasma discharge after the time of t=150 ms (Fig. 2).

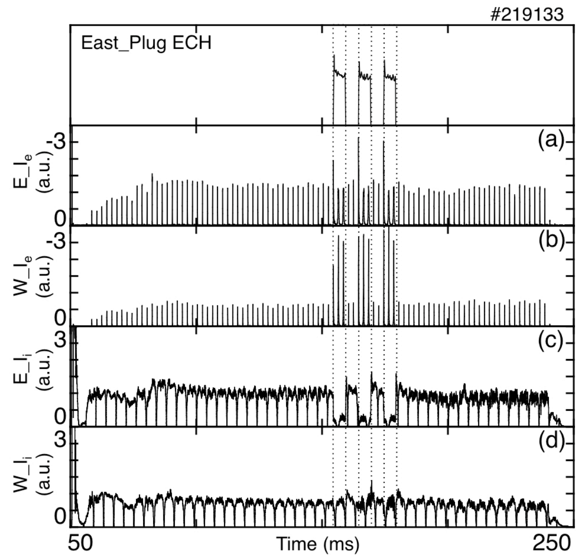

Fig.2. Temporal evolution of end loss electron current at the (a) east end, (b) west end, and end loss ion current at the (c) east end, (d) west end. The P-ECH power of about 200 kW is applied from t =150 ms to 180 ms with 100%, 100 Hz square wave power modulation.

During ECH from t =150 ms to 180 ms, the pulse of ECH power of about 200 kW is applied three times by 100%, 100 Hz square wave power modulation [between dot-lines in Fig. 2]. The end loss electron current at the west end is increased during ECH injection [Fig. 2(b)], while the end loss electron current at east end is not so increased during ECH injection [Fig. 2(a)]. The end loss current is measured with a multi-gridded electrostatic energy spectrometer. The pulse train of the electron current is due to sweep of the repeller voltage for energy analysis. Its envelope represents the electron current.

In Fig. 2, the end loss ion current at the west end is a little increased during ECH injection [Fig. 2(d)], while the end loss ion current at east end is decreased during ECH injection [Fig. 2(c)]. Also its envelope represents the ion current.

The P-ECH has two functions on electrons by driving two types of velocity space diffusion. The first type of diffusion enhances mirror reflection beyond the plug position, which results in the plug potential. When ECH is applied only to the east plug region, the end loss ion current at the east end decreases owing to the potential reflection of low energy ions [Fig. 2(c)], while the end loss ion current at the west end increases owing to the ions reflected by the east plug potential [Fig. 2(d)]. The second type of diffusion creates the electron flow [Fig. 2(b)]. These data indicate that the P-ECH is able to control the end loss ion and electron fluxes by the use of power modulation, which can also produce the arbitrary heat load pattern like the various type of the ELM. The absolute value of the one pulse energy density at present is still far lower than ITER level, but it is expected to approach to the ITER level by the upgrade and combination of the all heating systems (ECH, NBI and ICRF).

4. Summary

ECH power modulation experiments in GAMMA 10 have been started in order to generate and control the high heat flux for divertor simulation studies. P-ECH is able to create the plug potentials and the electron flow. From power scaling of confining potential and electron flux in GAMMA 10, the higher ECH power generates the higher confinement potential and higher electron flux. According to the increasing and modulating ECH power, it is expected that the heat flux is enhanced and controlled, which enables the ELM resembling heat load pattern.

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References

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