22P119-P

Reconstruction of Phase Imaging Measurement System and Two Dimensional Density Measurement in GAMMA 10
位相イメージング計測システムの再構築とGAMMA10西プラグ部の2次元密度分布計測

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Two dimensional (2D) plasma image analysis is important to study the improvement of plasma confinement in magnetically confined fusion plasma. A 2D phase imaging interferometer is installed in the west plug/barrier cell in GAMMA 10 to measure the 2D plasma density distribution and its fluctuation. We have reconstructed this system to measure these parameters more stably and by using fewer plasma shots. A calibration experiment was conducted to check the system, and it operated well. We show 2D density distribution measured in the west plug/barrier cell in GAMMA 10.

1. Introduction

GAMMA 10 is the tandem mirror machine, consisting of a central cell, two anchor cells, and two plug/barrier cells. In addition to a magnetic potential, an electrostatic potential which is created by electron cyclotron resonance heating (ECRH) in the plug/barrier cells is used to improve an axial confinement of plasma in GAMMA 10. We have investigated plasma electron density and its fluctuation by using microwave interferometers, an ultrashort pulse reflectometer, and a Fraunhofer diffraction method in GAMMA 10.

In the plug region, the plasma parameters varies both axially and radially, so two dimensional (2D) image analysis is useful to study the mechanisms of plasma confinement improvement by the formation of confinement potential. A 2D interferometer system with phase imaging method is installed in the west plug cell in GAMMA 10. Irradiating plasma with a expanded sheet beam, this system can measure broad area of plasma by using a few plasma shots. For adding channels, we made new phase detector circuits and a reference detector circuit. We checked the system by comparing the phase difference between the transmission wave in a dielectric plate and reference wave. We improved the phase detection circuits of the system, then we have successfully obtained the 2D plasma density distribution of 8 spatial points in a single plasma shot. It was 4 spatial points before this improvement.

In this report, we show the 2D phase imaging measurement system and the measured 2D plasma density distributions under conditions with and without confinement potential by application of ECRH.

2. Experimental Apparatus

GAMMA 10 has the z axis which is parallel to the magnetic field, the x and y axes which are perpendicular to the magnetic field in the vertical and horizontal directions, respectively. The 2D imaging interferometer system is installed in the west plug cell at z = 9.69 m. Figure 1 shows the heterodyne-type interferometer using two IMPATT microwave oscillators (69.85 and 70 GHz, output power of 500mW). A probe beam is expanded by off-axis parabolic mirror installed inside the vacuum vessel to cover upper-half of the plasma. After passing through the plasma, the beam is focused onto detector array by an ellipsoidal mirror, a flat mirror and polyethylene lenses. The imaging array consists of beam-lead GaAs Schottky barrier diodes bonded to 2D (4×4) bow-tie antennas. Channels are arranged in vertical and axial directions of GAMMA 10, respectively. The phase difference is proportional to the line density of plasma. The expected vertical and axial direction resolutions are about 0.016 and 0.005 m, respectively. The size of plasma of 0.090×0.060 m^2 corresponds to 4×4 pixels on the image plane. The sampling rate of A/D converter of the data processing is 50 kHz.

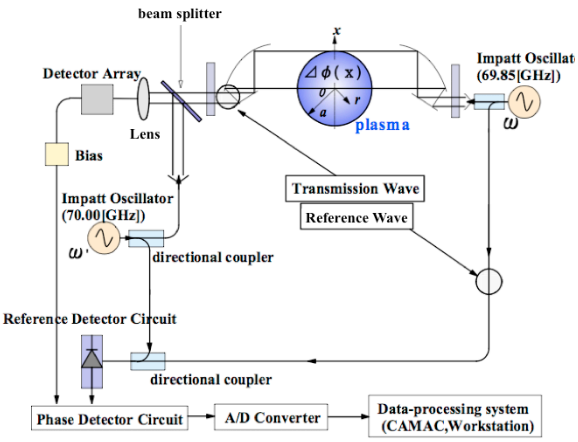

Fig. 1. Schematic of the 2D phase imaging system

3.Experimental Results

The plasma was produced from at 50 ms and sustained to 250 ms by ion cyclotron range of frequency (ICRF) wave. Then barrier-ECRH (B-ECRH) of 150kW is applied between 210 to 240 ms to create thermal barrier potential and plug-ECRH (P-ECRH) of 300kW is applied between 215 to 235 ms to create confinement potential. Central-ECRH (C-ECRH) of 100kW is applied between 220 to 230 ms to increase electron temperature. central-ECRH of 100kW. We used a single shot to measure the electron density distribution in the region between z = 9.69 m and z = 9.705 m at x positions of 0, 0.03, 0.06, and 0.09 m, respectively. Assuming the plasma is axial symmetry, we apply the Abel transform technique to the radial line density profiles to obtain the radial density profile at each measuring x positions. In Fig. 2, 2D density distributions without application of P-ECRH (a) and with application of P-ECRH (b) in the plug region are shown. During the period without application of P-ECRH, the electron density distribution becomes smaller along with the direction of z axis, since the strength of the magnetic field in the plug region becomes larger along with the z axis. However, with P-ECRH, the electron density decreases considerably. The electrons are swept out from plug region for forming the positive electrostatic potential which is created around z = 9.61 m by application of P-ECRH.

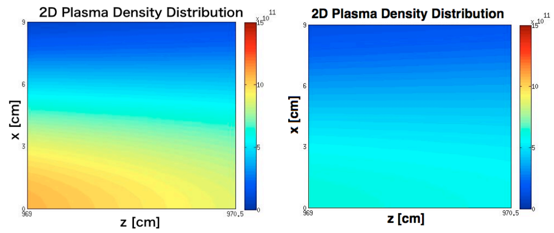

Fig. 3. 2D density distributions (a) without application of p-ECRH and (b) with application of p-ECRH in the plug region.

4. Summary

In summary, we have reconstructed the 2D imaging interferometer system, the 2D density distributions have been successfully obtained by using the system in the tandem mirror GAMMA 10. The 2D density distributions under conditions with and without electrostatic potential with application of P-ECRH were compared. Without P-ECRH, the electron density profiles decreases along the strength of the magnetic field. With P-ECRH, the electron density profiles decreases by formation of confinement potential. Then, we have improved the useful diagnostic tool for studying the plasma confinement improvement.

Acknowledgements

The authors would like to thank members of GAMMA 10 group of the University of Tsukuba for their collaboration.

References

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