# §4. Imaging Study of Dynamic Behaviors of Plasma Using Phase-Imaging Interferometer

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In tandem mirrors, an electrostatic potential is created in order to improve axial plasma confinement. The radial electric field due to this potential causes an $\boldsymbol{E}\times\boldsymbol{B}$ rotation shear and suppression of instabilities such as a drift-wave mode. The verification of this effect is one of the most critical issues to understand the physics basis for recent confinement improvement. Understanding the mechanism of this effect requires the use of sophisticated diagnostic tools for measurement of plasma profiles and their fluctuations. Significant advances in microwave and millimeter wave technology have enabled the development of a new generation of imaging diagnostics as visualization tool of plasma parameters. This report describes the development of millimeter wave imaging diagnostic system, so called phase imaging interferometer, applied to the GAMMA 10 tandem mirror.

The imaging system is installed in the west plug cell of GAMMA 10.[1)] A probe beam is expanded by an off-axis parabolic mirror installed inside the vacuum vessel to cover upper-half of the plasmas. The cross section of the probe beam is 200mm×200mm at the plasma axis. The receiving optics, an ellipsoidal mirror, a flat mirror, and polyethylene lenses, are designed by using a ray-tracing code to focus radiation signals onto the detector array. The imaging array consists of beam-lead GaAs Schottky barrier diodes bonded to two dimensional (2D) ($4\times4$) bow-tie antennas. The quadrature phase detection system (I-Q detector) provides the phase difference between two intermediate frequencies (IF) signals obtained by mixing the transmitted signal (RF) and the local oscillator signal (LO). The phase difference is proportional to the line density of plasmas.

In FY2008, 2D profiles of electron density and density fluctuations have been obtained by using present phase imaging system.[2)] The 2D profiles of the density fluctuations are shown in Fig. 1 together with the profiles of the drift velocity. Before application of the plug ECRH power, the fluctuations exit axially through an entire plug/barrier cell, however, they localize in radial direction at $r$~3 cm, which corresponds to the strength of the drift velocity. When the ECRH power is applied to the plug/barrier plasma, the fluctuations localize axially in the plug/barrier cell due to the formation of the confining potential near the position of $z$=962 cm. They distribute radially in broader region around $r$= 3 cm. The fluctuations seem to be a drift-wave mode for the case of (a) and the flute mode for the case of (b).

We have also tested a new-type of I-Q phase detector[3)] by utilizing the interferometer at the throat region as shown in Fig. 2. It consists of IF module and LO module. The LO signal is passed through an band-pass filter (BPF) with 150 MHz, amplified by 44 dB, and fed to another amplifier with automatic gain control (AGC). The frequency of the amplitude controlled signal is doubled by a multiplier, and fed to an I-Q demodulator chip in the IF module. The IF signal is also passed through a BPF, an amplifier, and an AGC amplifier, and fed to the IF port of the I-Q demodulator. After mixing with the LO signal, the IF signal is treated by I-Q detection. One of the problems in a conventional I-Q detector is lack of reliability caused by unstable input signal to the detector. When the input signal is small, the system often does not work well or causes phase error. The I-Q detector with AGC was confirmed to give stable sin$\phi$ and cos$\phi$ outputs which give reliable phase component.

In summary, the 2D profiles of density and density fluctuations have been obtained by using a 2D imaging array and multi-channel I-Q phase detectors. A new I-Q phase detector with automatic gain control system was completed and tested at the experiment of GAMMA 10.

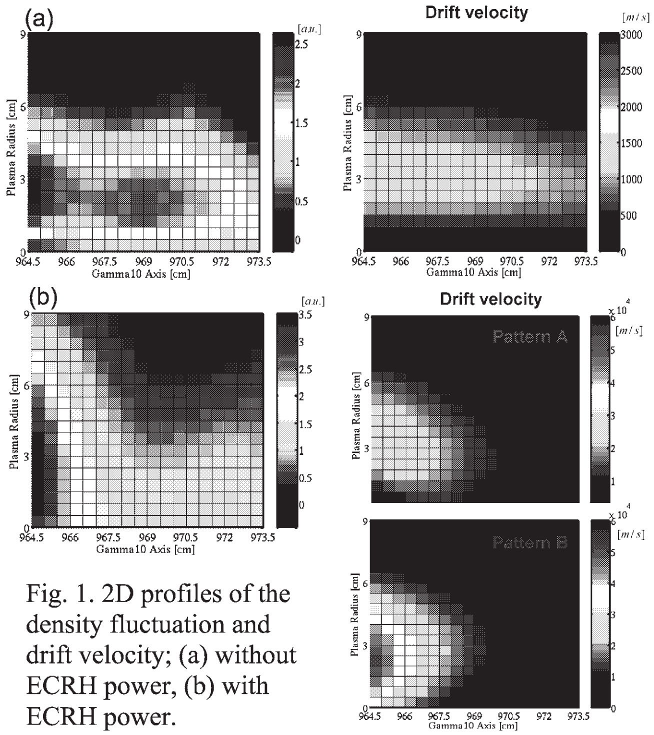


Fig. 1. 2D profiles of the density fluctuation and drift velocity; (a) without ECRH power, (b) with ECRH power.

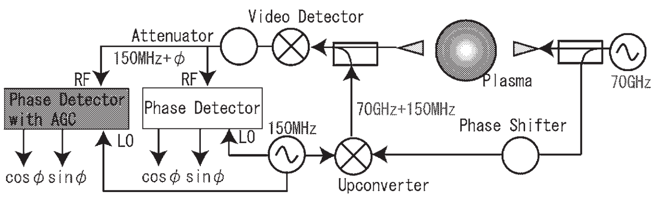


Fig. 2. Application of the I-Q phase detector with AGC.

1) Mase, A, Kogi, Y *et al.*, Plasma Device and Operations **17** (2009) 1.
2) Negishi, S., Yoshikawa, M. *et al.*, JSPF Ann. Meeting 2008, Utsunomiya (Dec. 2008). (in Japanese)
3) Ogawa, K., Kogi, Y., and Mase, A., The 4th Korea-Japan Diagnostic Seminar, POSTECH (Aug. 2008)