# OBSERVATION OF THE FLUTE-TYPE FLUCTUATION BY USING THE GOLD NEUTRAL BEAM PROBE IN GAMMA 10

Fumiaki YAGUCHI, Masayuki YOSHIKAWA, Yoshiaki MIYATA, Masanori MIZUGUCHI,Youhei OONO, Nanako MATSUDA, Hidetaka MURATA, Tatsuya MURAKAMI, Tsuyoshi IMAI

*Plasma Research Center, Univ. Tsukuba, Tsukuba Ibaraki 305-8577, Japan*
*yaguchi_fumiaki@prc.tsukuba.ac.jp*

*In magnetic nuclear fusion plasmas, plasma particle transport causes the decrease of density and stored energy. Plasma particle and thermal energy are lost across the confinement magnetic field lines by the turbulence of thermodynamics force and instability. We studied the characteristics of flute-type fluctuation by using the gold neutral beam probe (GNBP) and electrostatic probes.*

## I. INTRODUCTION

In magnetic fusion plasmas, particle and energies are lost by the anomalous transport [1]. In order to improve the particle confinement, it is important to figure out the various instabilities in plasmas. Recently, the drift-type instability is suppressed by application of electron cyclotron heating [2-5].

In GAMMA 10, the plasma is created by plasma guns, and heated and sustained by using ion cyclotron heating (ICH) systems. The x-axis and y-axis are defined as vertical and horizontal directions, respectively. They are perpendicular to z-axis which is parallel to magnetic field line. The mid-plane of GAMMA 10 is z = 0 cm. The ion and electron confinement potentials are produced by using plug/barrier-electron cyclotron heating (P/B-ECH) at both sides of main confinement region, respectively. Plasma potential at main confinement region is measured by GNBP system [2,4-6]. The fluctuation of the plasma potential and the fluctuation of electron density can be estimated by using GNBP [2,4-6]. In GAMMA 10, the flute-type fluctuation is observed during application of P/B-ECH periods. With the confinement potential formation by ECH, electron line density and stored energy (diamagnetism) increase at first. However, the fluctuation of electron line density increases gradually and the electron line density starts decreasing phase. At the same time, diamagnetism starts decreasing phase. When the electron line density and stored energy are decreasing, the fluctuations of plasma potential and electron density are also increasing quickly. With the Fast Fourier Transform (FFT) analysis, this fluctuation is mainly observed at frequency peak of about 5 kHz in the core plasma. In the edge plasma, the fluctuation with the same frequency peak is observed by the electrostatic probes (ESPs)[7]. Moreover this fluctuation's rotation is anti-clockwise and has no wave number along the magnetic field lines. From these results, we concluded that this fluctuation was caused by flute-type instability. The radial particle flux is estimated by the potential fluctuation, electron density fluctuation and phase difference between potential fluctuation and electron density fluctuation also increase. We thought that this fluctuation has the relation to the reduction of electron line density and stored energy.

In this paper, we show the results of the potential fluctuation measurements by using GNBP and electrostatic probes during the P/B-ECH periods. The fluctuations of frequency peak of about 5 kHz are observed by GNBP and ESPs. Then, we discuss the characteristics of these fluctuations.

## II. EXPERIMENTAL APPARATUS

### II.A．GOLD NEUTRAL BEAM PROBE

Figure 1 shows the schematic view of GNBP system. GNBP is a kind of heavy ion beam probe. In GNBP, the negative gold ion beam ($Au^-$) is produced by Cs gas sputtering. $Au^-$ beam is adjusted its trajectory and focused. Next, it is neutralized by the $H_2$ gas and injected to GAMMA 10. Injection beam energy is 11.781 keV and incident angle is 40 degree to horizontal direction. The incident angle can be adjusted its horizontal and vertical position by the two pair of electrostatic plates, respectively. Using the vertical electrostatic plates, the radial profile can be obtained. The typical beam intensity is about 2 µA by Faraday cup before neutralizer. The primary beam is ionized by the electron collisions in plasma, and to be ionized beam ($Au^+$), secondary beam, is accelerated by the plasma potential. The secondary beam is injected to the parallel plate type electrostatic energy analyzer. The secondary beam is detected by the micro channel plate (MCP). In GNBP, plasma potential, potential fluctuation and electron density fluctuation at ionization point can be measured simultaneously.

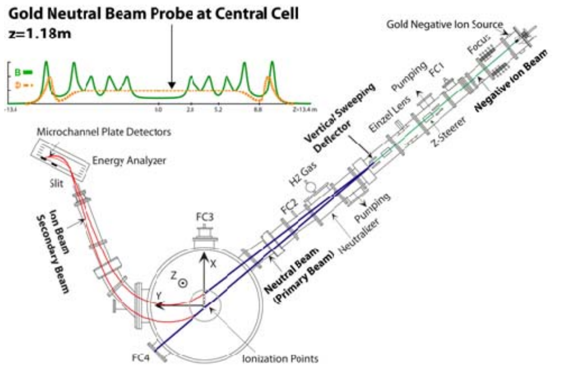


Fig.1. GNBP system in GAMMA 10. By changing vertical sweeping deflector voltage, it is possible to earn the radial distribution.

### II.B. ELECTROSTATIC PROBE

ESPs are used for measuring plasma potential, temperature and density. We used the ESPs to measure the plasma density fluctuation. There are seven ESPs at z = 28.2cm and an ESP at z = 125cm. We used three ESPs of them. One pair is used to measure the circumferential mode number and their circumferential angle is 90 degree. Another pair is used to measure the axial wave number. The mode number of circumferential direction is estimated by a pair of ESPs. The circumferential angle between the pair of ESPs is 90 degrees. On the other hand, the axial wave number is estimated by another pair of ESPs which is installed about 1 meter away to the axial direction.

## III . EXPERIMENTAL RESULTS

Plasma potential, potential fluctuation and electron density fluctuation at central cell are measured by using GNBP. The plasma is created by plasma guns and heated and sustained by ICH. In addition, the confinement potentials are created by P/B-ECH at both sides of the central cell. B/P-ECH are applied from 160 to 200 ms and 165 to 195 ms, respectively. During the confinement potential formation periods, electron line density and diamagnetism increase at first. However, they saturate and gradually increase the fluctuation of electron density. On the other hand, diamagnetism decreased. The potential, potential fluctuation and electron density fluctuation are measured by GNBP at about R ~ 0cm. Ion current at edge plasma is measured by ESPs.

Figure 2 shows the time variation of electron line density and diamagnetism. In Figure 2, at 10ms after injection of P-ECH, electron line density and diamagnetism are in the increasing phase. However after that, they saturate. From 182 ms, the fluctuation of electron line density is in increasing phase and diamagnetism is in the decreasing phase. Figure 3 shows the time variation of potential and beam current measured by GNBP near the center of the central cell. For more detailed analysis, FFT analysis is used. Figure 4 (a) and (b) show the potential and electron density fluctuation spectra from 1 to 20 kHz, respectively. There is no clear peak of fluctuation in only ICRF period, B-ECH period and former part of P-ECH period. But in latter part of P-ECH period, there is a large fluctuation peak at about 5 kHz.

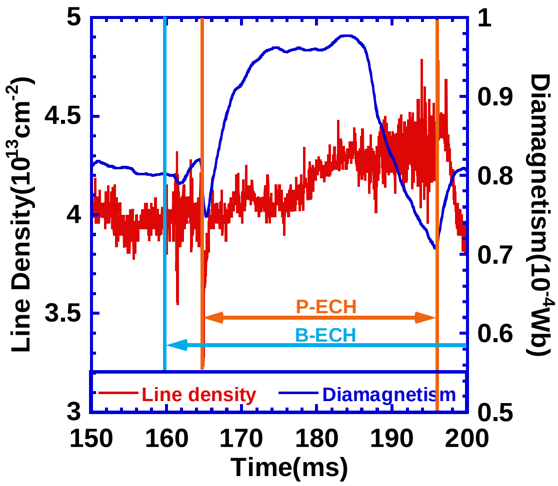


Fig.2. Time variation of electron line density and diamagnetism in the central cell.

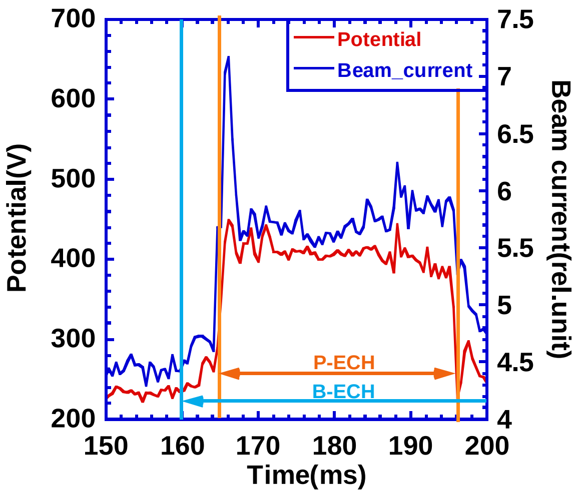


Fig.3. Time variation of plasma potential and beam current in the central cell R ~ 2cm measured by GNBP.

Furthermore, this fluctuation is also measured by ESPs at the periphery and it is shown in Figure 5. There is a large fluctuation peak at 5 kHz in the same as GNBP measurements. Then, it is thought that this fluctuation is the global mode for radial direction. And more detailed analysis, mode number of this fluctuation is measured by using three ESPs. From the phase analysis, this rotation of fluctuation is anti-clockwise and it has no wave number along the magnetic lines. From ESPs measurements, these fluctuations are flute-type fluctuation.

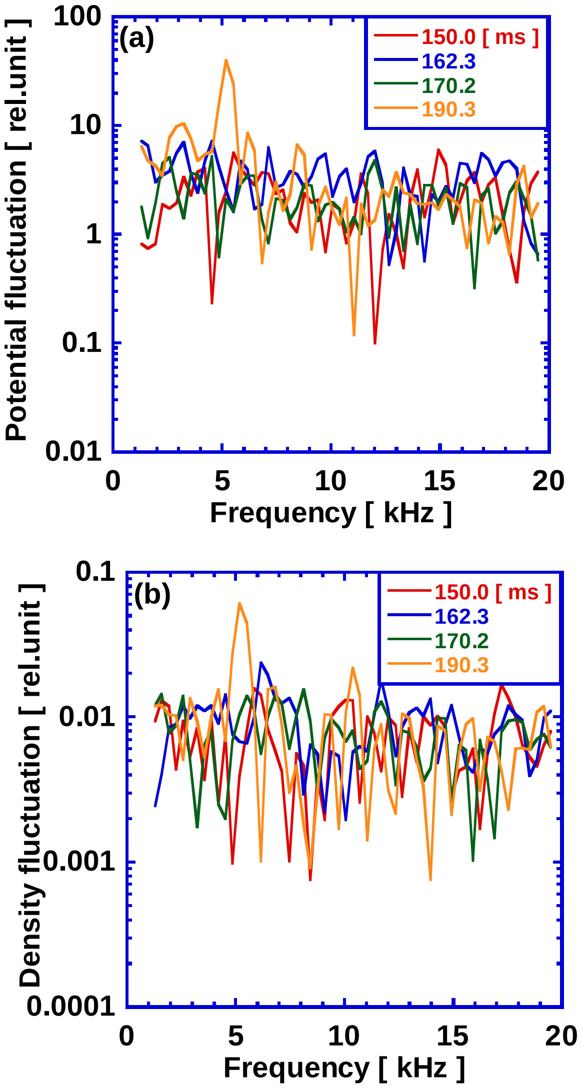


Fig. 4 (a) Potential fluctuation spectra, (b) Electron density fluctuation spectra. 150ms, 162.3ms and 170.2ms and 190.3ms represent that before P/B-ECH period and during B-ECH period, P/B-ECH periods, respectively.

## IV. SUMMARY

The phenomenon that the electron line density and diamagnetism increase stops though the heating power continuously injecting is observed. To investigate this reason, we use GNBP system and ESPs and measure the fluctuations in the central cell. There is a large fluctuation at the frequency peak of the 5 kHz. This fluctuation appears only the period when electron line density and diamagnetism are in decreasing phase. So, this is one of the reasons which electron line density and diamagnetism do not increase continuously.

By GNBP and ESPs measurements, this shows that fluctuation is the global mode for radial direction. Furthermore, this fluctuation has no wave number for axial direction and the rotation direction of fluctuation is anti-clockwise. Considering these characteristics, this fluctuation is flute-type fluctuation. From more detailed analysis, we will be able to improve the plasma confinement at P/B-ECH periods.

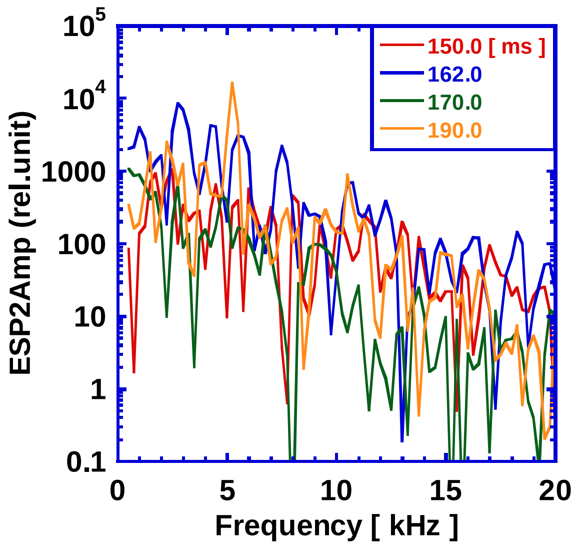


Fig.5. FFT analysis of ESP. The time is same as Fig.4.

## ACKNOWREDGEMENT

The authors would like to thank members of GAMMA 10 group of the University of Tsukuba for their collaboration. This work was partly supported by NIFS collaboration research program, No NIFS04KUGM009.

## REFERENCES

1. B. FISCHER et al., Plasma Phys. Control. Fusion **31**, 453 (1989).
2. Y. MIYATA et al., Plasma Fusion Res. **2**, S1101 (2007).
3. M. YOSHIKAWA, et al., Rev.Sci. instrum **77**, 10E906 (2006)
4. M. YOSHIKAWA, et al., Plasma Fusion Res, **2**, S1036 (2007)
5. M. YOSHIKAWA, et al., Fusion Sci. Tech **57**, 312 (2010)
6. Y. MIYATA et al., Trans. Fusion. Tech. **55**, 168 (2009)
7. S. TANAKA et al., Rev. Sci. Instrum. **70**, 979 (1999).