§22. Effect of Spontaneously Excited ICRF Waves on the End-loss Energetic Ions in GAMMA 10

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End-loss flux of GAMMA10 includes high-energy ions of the order of kilo-electron volts, which are axially transported along field lines from the mirror trapped region where the high-energy ions are produced by ICRF heating. Further understanding of axial transport mechanism is important for divertor simulation experiments utilizing high ion-temperature flux of GAMMA 10 and also for the clarification of beta-limit of mirror confinement.

An end-loss high-energy ion detector using a semiconductor showed the contribution of the fluctuations with the difference frequencies between Alfvén-Ion-Cyclotron (AIC) waves to the axial transport of high-energy ions. The fluctuations with the difference frequencies were found to be excited by nonlinear coupling between the AIC waves near the core region of the central cell plasma.[1),2)] This find was obtained by using a microwave reflectometer. While the reflectometer can give access to the core region where the wave-particle interaction of interest acts with high spatial resolution, complex interpretation is needed for the relation between density fluctuation and wave electric fields. Furthermore, multipoint measurement is required to see the spatial distribution of waves. Since the multipoint measurement is based on the premise that obtained data have high coherence at the wave frequencies, we improved the reflectometer system and analysis method in FY 2015, and confirmed the availability of the reflectometer for the study of the spatial distribution of high-frequency waves.

Figure 1 demonstrates a two-point measurement using the developed reflectometer. Density fluctuations of the AIC waves in the MHz range are clearly seen in the spectrum shown in Fig. 1(a). Similar spectrum was simultaneously obtained at axially separated position. Figure 1(b) shows the calculated coherence between these two density fluctuations. High coherence near unity is attained while it is transiently. Reflected microwave contains both phase and amplitude modulations. We succeeded in the clear separation of phase and amplitude modulations in the MHz range. Figures 1(c) and 1(d) show coherences of the separated amplitude modulation components and phase modulation components, respectively. Fig. 1(c) indicates that the amplitude modulations at the AIC waves frequencies have negligible coherence and, therefore, the phases of the modulations at axially separated positions are random each other. While generation mechanism of the amplitude modulation component is not clear so far, this result will be a key for its clarification. On the other hand, for the phase modulation components, coherence at the AIC waves frequencies remains high in time, and makes its correlation analysis meaningful. As the AIC waves are globally excited with satisfying the boundary condition, high coherence is expected at wide spatial region and the result shown in Fig. 1(d) actually reflects its physical picture.

In summary, we verified the usefulness of the clearly separated phase modulation component, included in the reflected microwave of the reflectometer, for the study of the spatial distribution of the AIC waves in GAMMA 10. This measurement will be used to clarify the detailed wave-particle interaction causing the axial transport of high-energy ions.

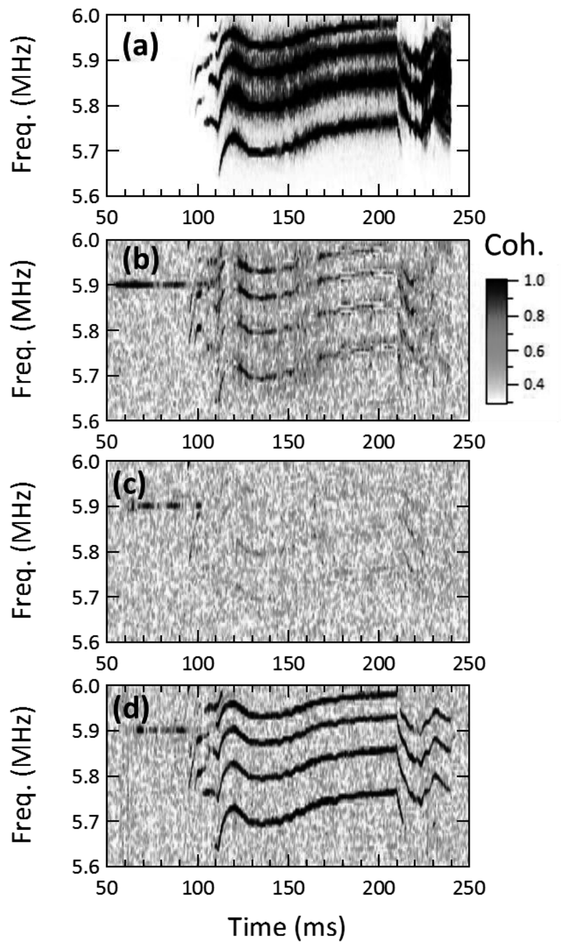

Fig. 1. Frequency spectrum of the density fluctuation measured by a reflectometer in the GAMMA 10 central cell showing the AIC waves (a) and the coherences of two density fluctuations obtained at axially separated positions (b)-(d). (b) is calculated for original raw signals of the reflectometer, and (c) and (d) are calculated for the amplitude and phase modulation components separated from the raw signals, respectively.

1) Ikezoe, R. et al.: Phys. Plasmas **22** (2015) 090701.
2) Ikezoe, R. et al.: 57th Annual Meeting of the APS Division of Plasma Physics, 2015. 4589.