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

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Confined ion energy in the main confinement region of GAMMA 10 saturates after Alfvén ion-cyclotron (AIC) waves are spontaneously excited due to strong ion-temperature anisotropy. Since there is strong correlation between the excitation of the AIC waves and the saturation of the confined energy, the AIC waves should play a key role on the beta-limit of mirror confined plasma through some processes. One of such processes is related to the nonlinear excitation of waves with difference frequencies of the AIC waves at around 70 – 200 kHz; burst-like axial loss of energetic ions are periodically observed at the frequencies corresponding to the difference frequencies of the AIC waves.[1)] This kind of direct measurement of axially transported ions is a distinctive advantage of linear machine like GAMMA 10. Clarification of detailed wave-particle interaction affecting the axial transport in high temperature plasma utilizing this advantage is the object of this study.

To clarify the transport mechanism, we started by progressing the measurement and analysis about nonlinear wave-wave coupling among ICRF waves including the AIC waves.[2)] Figure 1 shows the squared bicoherence of the density fluctuation measured in the main confinement region, where the AIC waves are spontaneously excited, by using a reflectometer. The frequencies of the AIC waves and the ICRF wave externally excited for ion heating (RF2) are denoted by dashed lines in Fig. 1. High bicoherence above statistical noise level indicates that a part of its component is generated by three-wave interaction and it is not fully independent wave. In Fig. 1, significance level is well below 1 % and, therefore, statistically meaningful high bicoherences are found at the difference coupling between RF2 and the AIC waves and also at the difference coupling between each AIC wave.

Density fluctuations were measured at several radial positions from core to periphery in a series of discharges by changing the probing microwave frequency of the reflectometer and bispectral analysis was applied to each data set. To see the radial dependence of the nonlinear coupling, squared bicoherence is summed over all the combinations of f_1 and f_2 which satisfy $f_1 + f_2 = f_3$ (f_3 is const.). This summed value is shown in Fig. 2 as a function of f_3. It is found that significant radial dependence exists in this nonlinearity; waves with the difference frequencies of the AIC waves (about 70, 90, 160 kHz) are strongly excited by three-wave interaction in the core region but not so in the other radial positions. This locality of wave-wave coupling might be related to the stability of generated waves. Those stability and parameter dependence of the nonlinearity will be studied in the future. On the other hand, strong nonlinearity is seen in the low frequency range below 100 kHz at the periphery, which leads to the spectral broadening; nonlinear coupling with background turbulence might be concerned.

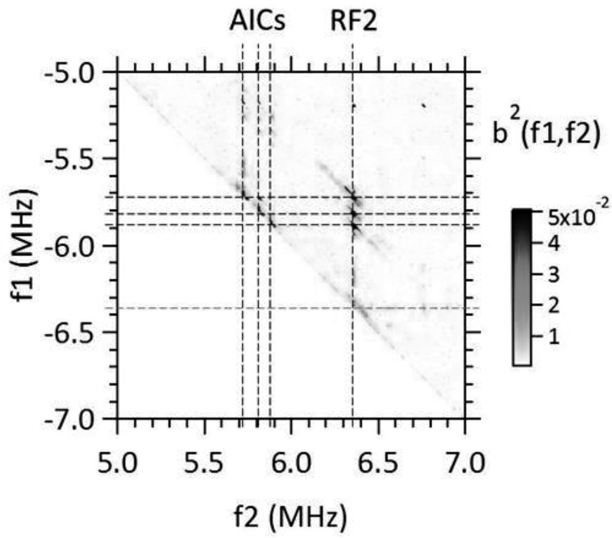

Fig. 1. Squared bicoherence of the density fluctuation measured at the GAMMA 10 central cell by a reflectometer.

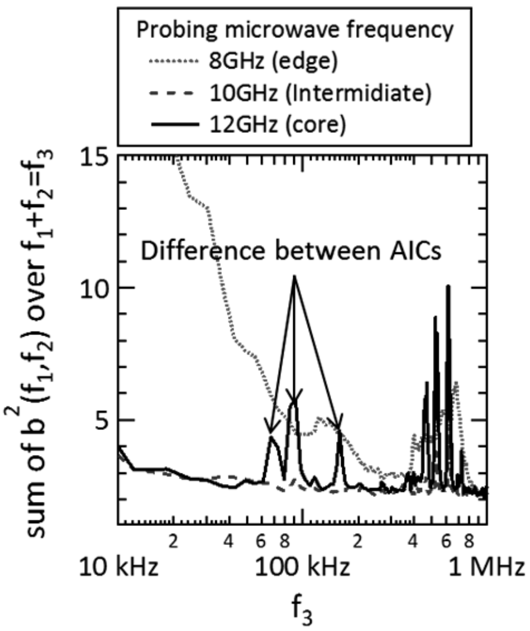

Fig. 2. Radial dependence of summed squared bicoherence.

1) Ikezoe, R. *et al.*: Nucl. Fusion **53** (2013) 073040.
2) Ikezoe, R. *et al.*: 56th Annual Meeting of the APS Division of Plasma Physics, 2014.10.27-31, New Orleans, US, BP8.00056.