§9. Propagation and Radiation of Cyclotron Waves and Excitation of Fluctuations Due to High Power Plug ECRH

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The electron cyclotron wave (ECW) is an important plasma wave in the fields of basic plasma physics, thermonuclear fusion, and some applications. Especially, high power electron cyclotron resonance heating (ECRH) is hoped to be the most effective method for the formation of thermal transport barrier in tandem-mirror devices,[1)] where localized strong electron heating in the perpendicular direction against the magnetic-field lines is demanded. Although the localized wave absorption is necessary for efficient and strong electron heating as mentioned above, the Doppler shift effect by high energy electrons expands the cyclotron resonance region, namely, broadens the wave absorption region.

In Tohoku University, on the other hand, it was reported that a left-hand polarized wave (LHPW), which has been believed not to be related to electron cyclotron resonance (ECR), is also unexpectedly and sharply absorbed near the ECR point.[2,3)] In addition, the experimental results demonstrated that the damping region of the LHPW is more localized than that of the right-hand polarized wave (RHPW). Although the mechanism has not been entirely clarified, we believe that the localized LHPW absorption can lead to the localized and strong electron heating. When this new damping mechanism of the ECW is applied to the efficient electron heating in large fusion devices such as the tandem-mirror device using the high power ECRH, it is necessary to clarify the nonlinear effects of the strong wave field on the propagation and radiation of the ECW.

Based on these backgrounds, the purpose of the present work is to clarify the propagation and radiation characteristics of the ECW, including the nonlinear effects such as parametric decay which can cause the degradation of the heating efficiency.

Experiments are carried out with a plasma in the west plug/barrier cell of the GAMMA10 tandem mirror. This cell is an axisymmetric mirror that is connected to the central solenoid through a quadrupole mirror cell along the magnetic-field lines. The plasma is produced in the central solenoid by radio-frequency (RF) wave heating, and a potential barrier created by ECRH in the plug/barrier cells at the machine ends prevents the plasma from flowing out along the field lines. The ECRH power at 28 GHz is delivered to the fundamental resonance layer of 1 T for the plug and to the second harmonic layer of 0.5 T near the mid-plane for the thermal barrier. The heating power, variable up to 500 kW, is generated in a newly developed gyrotron, transmitted through a cylindrical corrugated wave-guide system in HE_{11} mode and radiated to the resonance layer with newly designed mirrors. We have set up a measurement system for receiving and analyzing electromagnetic radiation in the electron cyclotron range of frequencies, which consists of a movable receiver antenna, a heterodyne mixer with a Gunn oscillator (28 GHz, 13 dBm), and a spectrum analyzer.

Figure 1 shows the observed frequency spectrum of radiated electromagnetic waves from the plug region, where the launched plug ($\omega_1/2\pi$ =28.06 GHz) and barrier ($\omega_2/2\pi$ =28.0 GHz) ECRH powers are 240 kW and 100 kW, respectively. A continuum radiation is observed extending over several hundred MHz above the fundamental electron cyclotron frequency. Moreover, a sharp peak is observed below the frequency $\omega_2/2\pi$ of the second harmonic heating wave by the difference $(\omega_1 - \omega_2)/2\pi$, possibly due to a nonlinear effect of the strong wave field, such as the parametric instability.

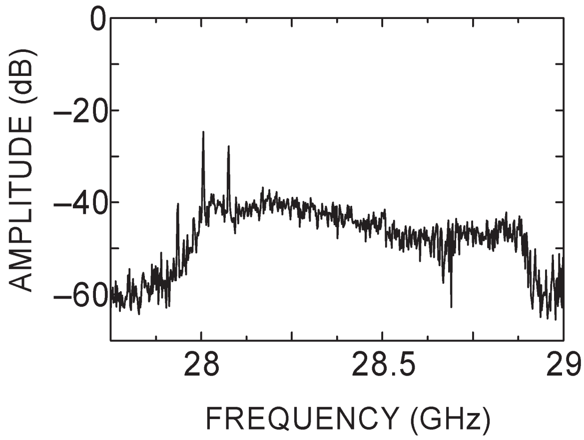

Fig. 1. Frequency spectrum of radiated electromagnetic waves at the plug region, where the plug and barrier ECRH powers are 240 kW and 100 kW, respectively.

Reference

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