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

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An 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.

On the other hand, it was reported that a left-hand polarized wave (LHPW), which has been believed not to be related to ECR, is also unexpectedly and sharply absorbed near the ECR point through the mechanism of polarization reversal.[2,3] In addition, the damping region of the LHPW is found to be more localized than that of the right-hand polarized wave (RHPW). 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. The plasma is produced in the central solenoid region 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. 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 circuit with a Gunn oscillator (27.9 GHz, 13 dBm), a balanced mixer, and a spectrum analyzer.

Figure 1 shows observed frequency $\omega_{rec}/2\pi$ spectra of electromagnetic waves radiated from the plug region in the cases that (a) the plug ECRH ($\omega_1/2\pi$ = 28.0 GHz, P_1 = 240 kW) or (b) the barrier ECRH ($\omega_2/2\pi$ = 28.06 GHz, P_2 = 100 kW) is separately launched. A broadband radiation extending over several hundred MHz above 28 GHz in Fig.1(a) originates from electron cyclotron emission due to the high energy electrons produced by the plug ECRH. Sharp peaks detected at $\omega_1/2\pi$ labeled by "P" [Fig.1(a)] and $\omega_2/2\pi$ labeled by "B" [Fig.1(b)] indicate the launched plug and barrier ECRH, respectively.

When these plug and barrier ECRH are superimposed, on the other hand, several sharp peaks are observed around $\omega_1/2\pi$ and $\omega_2/2\pi$ at intervals of 20MHz as shown in Fig.1(c). Since this interval frequency is near the ion cyclotron frequency in the plug region, the sharp peaks are considered to be caused by nonlinear interaction between the strong electromagnetic wave for plug/barrier ECRH and an ion cyclotron wave excited in the plasma.

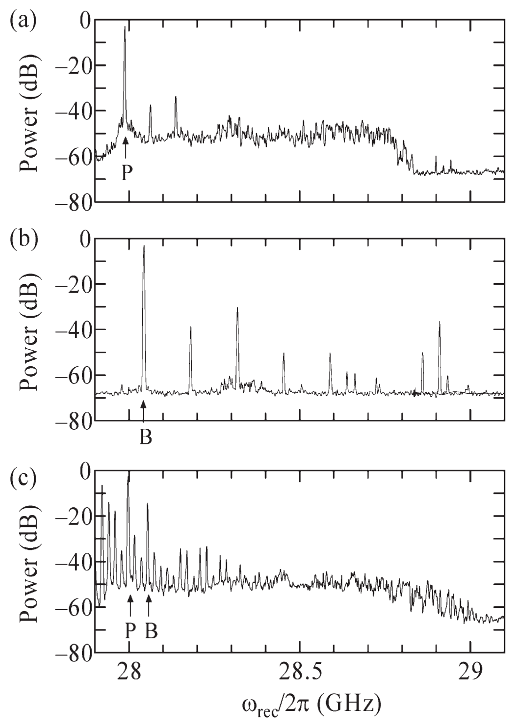

Fig. 1. Frequency spectra of electromagnetic waves radiated at the plug region in the cases that (a) plug ECRH ($\omega_1/2\pi$ = 28.0 GHz, P_1 = 240 kW) or (b) barrier ECRH ($\omega_2/2\pi$ = 28.06 GHz, P_2 = 100 kW) is separately launched, and (c) the plug and barrier ECRH are superimposed.

Reference

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