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Excitation of Lower-Hybrid Wave by Beating of Two Electron-Cyclotron Waves

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Abstract. The first experiment is described on the excitation of lower-hybrid wave by the beating of two extraordinary electron-cyclotron waves. Electron wave frequencies were near 1 GHz, the lower-hybrid wave was in the frequency range 1-3 MHz. The resonance dependence of excitation of the ear wave on the magnetic field was proved.

1. INTRODUCTION

During the last years in plasma physics there is the continuous interest to the problem of induced excitation of plasma waves by the beating of two incident waves / 1-3 / . Primary this interest is connected with the excitation of langmuir waves due to the mixing of two laser beams for investigation new efficient methods of electron acceleration / 4 /. Excitation of lower-hybrid waves in a magnetised plasma by beating process mechanism seems rather interesting too . This way of wave excitation may be proposed as a new method for creating lower-hybrid waves widely used for plasma heating and current generation in toroidal devices. For the first time, the lower-hybrid wave was created by the beating of two oblique langmuir waves in /5,6/. The local build-up of the beat lower-hybrid wave was accompanied by the electron heating with maxwellization of the electron velocity distribution function. In this article, we present the first results on the observation of the lower-hybrid wave excited by the beating of two electron-cyclotron waves.

2. EXPERIMENTAL TECHNIQUES AND APPARATUS

The experiment was carried on in a model linear device TAU-1 /7/. The plasma was produced by the electron beam ($U_b = -50V - -150V$, $I_b = 50 - 150$ mA). We used argon as a working gas at pressure of $3 \cdot 10^{-4}$ torr, the intensity of the magnetic field was $H = 0.4 - 0.6T$. Plasma density on the axis - $n_e(0) = 7 \cdot 10^9 - 4 \cdot 10^{10} \text{ cm}^{-3}$, electron temperature - $T_e(0) = 5 - 7$ eV, ion temperature - $T_i(0) = 0.1T_e(0)$.

Two electron-cyclotron waves were excited in plasma by means of two pairs of loop antennas. The angle between the antennas in the pair was 90° . High frequency signals were sent from two magnetrons through ferrite rectifiers onto antennas. Magnetron frequencies were close to 1.8 GHz. The resonance

condition ($\omega = \omega_{He}$) was satisfied in a field $H = 0.64T$. The phase shift between the waves from different antennas in pairs was $\pi/4$ because of different cable lengths. As a result, the extraordinary electron-cyclotron waves were excited in plasma. Two 1kW-magnetrons operated in step; the pulse duration varied from 1 to 13 ms. The difference in the frequency between the magnetrons could be changed in the range of 1-3 MHz, that corresponds to lower-hybrid range of plasma waves. Plasma frequency ratio in the experiment was the following: $\omega_s < \omega_{Li} \sim \omega_{LH} < \omega_{01}, \omega_{02} < \omega_{Le}, \omega_{He}$, where ω_{He} is the electron gyrofrequency; ω_s, ω_{LH} are ion-sound, lower-hybrid frequencies; ω_{Li}, ω_{Le} are ion and electron Langmuir frequencies, respectively.

We used the probe technique to measure the main plasma parameters and the low-frequency fluctuations of plasma density. The averaged low-frequency spectra were obtained by using a fast Fourier transform routine with the preliminary choice of appropriate window and numerical filtration. The high-frequency spectra were measured by the loop probes and the spectrum analyser.

3. EXPERIMENTAL OBSERVATIONS

The high-frequency spectrum of two extraordinary electron-cyclotron waves is shown in Fig.1. The magnetic field differs from resonance value for these waves by 2%. The amplitude of waves decreases when the magnetic field approaches the resonance value, while the absorption of these waves in plasma increases.

Fig.1. Spectra of two electron-cyclotron waves, excited in plasma near resonance value of magnetic field.

We observed the arising of the low-frequency beat wave in the pump field of two electron-cyclotron waves. The frequency of this wave is the same as the frequency shift between two high-frequency waves, i.e. is the frequency of lower-hybrid plasma wave. The intensity of this wave depends on the magnetic field value for the beat wave is plotted against the value of the magnetic field for two plasma densities (Fig.2): $7 \cdot 10^9 \text{ cm}^{-3}$ (a) and $3 \cdot 10^{10} \text{ cm}^{-3}$ (b). The difference in frequency between two magnetrons was 2 MHz. There are two peaks in the curve, that represents excitation of the low-frequency wave. Two peaks in the curve are displaced with respect to the resonance value of the magnetic field. The amplitude of the two low frequency wave produced by beating of two electron-cyclotron waves depends on the intensity of the pump waves and conditions of lower-hybrid wave excitation. The amplitude of pump waves is defined by two factors: the dispersion relation of extraordinary electron-cyclotron waves and condition of the

wave propagation in the beyond-cutoff waveguide filled with plasma. Interaction of all these factors completely defined the curves in Fig.2.

Fig.2. Dependence of the beat wave amplitude on the magnetic field value for two plasma densities : $7 \cdot 10^9 \text{ cm}^{-3}$ (a) and $3 \cdot 10^{10} \text{ cm}^{-3}$ (b). The difference in frequency between magnetrons is 2 MHz.

For example, in the cyclotron resonance case no lower-hybrid wave is observed because of the full absorption of electron-cyclotron waves. The difference between maximum peaks for two plasma densities ($H > H_{\text{res}}$ and $H < H_{\text{res}}$) is determined first of all by difference beyond-cutoff conditions for pump electron-cyclotron waves. The dependence of the beat wave excitation of plasma density in defined plasma density region is the same as for the previous experiments with the excitation of lower-hybrid wave by two oblique langmuir waves.

Fig.3. Averaged (8 realizations) low-frequency spectra for plasma density $7 \cdot 10^9 \text{ cm}^{-3}$ in maximum of beat wave excitation. The difference in frequency between magnetrons 1.5 MHz.

The averaged low-frequency spectra of lower-hybrid wave excited by the beating and corresponded to peak in Fig.2 for magnetic field less then resonance value is shown in Fig.3.

4. CONCLUSIONS

In this issue the first experiment is described on the excitation of lower-hybrid wave by the beating of two extraordinary electron-cyclotron waves. Electron wave frequencies were near 1 GHz, the lower-hybrid wave was in the frequency range 1-3 MHz. The resonance dependence of excitation of the beat wave on the magnetic field and plasma density was proved.

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REFERENCES.

1. Kroll et al. Phys. Rev. Lett. 13(1964) 83-93.
2. Tang C.M. Appl.Phys. Lett. 45 (1984) 375-377.
3. Porsland D.W. et al. Phys.Rev.Lett. 54(1985),558-562.
4. Fainberg Ya.B. Plasma physics. 13(1987) 607-621.
5. Batanov G.M. et al. Plasma physics,17(1991),1026-1031.
6. Batanov G.M.F et al. XXI ICPIG, Bochum, Germany, 3(1993),336-346.
7. Batanov G.M. et al. Proc. Lebedev Inst., Moscow, 160(1985),122-134.