INTERACTION OF WAVES AND TRAPPED PARTICLES

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Introduction.

Different types of ion-acustic instabilities has been study with a DP device [1-5]. Most of them are originated in ion - beam plasma systemsand reciently related to ion - phase vortices [6-7]. Other appears as strong wave-wave interaction [8]. When coherent waves are launched in a plasma the mechanism of chaotic behavior is also observed [9-10]. Here we report a different Kind of instability in which side band waves appear and growth when a large amplitude coherent ion wave is launched in an Argon plasma produced in a DP device. Observation of side band growth was first reported by Wharton et al. for electronic waves [11]. They found that frequency separation between satellite and the main wave was roughly the bounce frequency of the electrons in the potential troughs of the wave,

$$\omega_B = k_0 (e \Phi_0 / m)^{1/2} \qquad (1)$$

wehre Φ_0 and k_0 are the main - wave electric potential and wave number respectively.

Subsecuent experiments with electrons waves [12-14] and ion acustic waves [15] showed that the side band waves satisfy the linear dispersion and that their frequency are predicted by the formula

$$\omega = k v_0 \pm \omega_B \qquad (2)$$

which is just the bounce frequency Doppler shifted by the main - wave velocity

$$v_0 = \omega_0 / k_0 \qquad (3)$$

We report here the observation of many lower and upper satellites with frequencies given by

$$\omega_s = \omega_0 \pm n \Delta\omega \qquad (4)$$

which it will be shown is equivalent, together with the dispersion relation $\varepsilon(k,\omega) = 0$ to Eq.(2)and a low frequency coherent oscillation

$$\omega_c = \Delta\omega \qquad (5)$$

where

$$\Delta\omega = \{ (\partial\omega/\partial k)_{k0} / [v_0 - (\partial\omega/\partial k)_{k0}] \} \omega_B \qquad (6)$$

Our satellites has well defined frequency with a narrow peak in contrast with the broad spectrum found by other experimenters [15]. The separations between the satellite frequencies are almost equal. We are also reporting the appearance of a coherent low frequency wave at $\omega_c \leq \omega_B$. The growth rate of the satellites scale as Φ_0^2 and their treshold amplitude for the main wave.

II. EXPERIMENTAL SETUP AND MEASURAMENTS.

The experiment was carried out in a DP machine described previously [10-18]. The apparatus consist of two identical but electrically independent conducting vacuum chambers, made of 45 cm diam. cylinders of length 50 cm each. The plasma parameters are as follows : plasma density $n = 2 \times 10^9$ cm^{-3}, electron temperature $T_e \sim 3$ eV, Argon gas presure $(3-5)\times10^{-4}$ Torr. The Debye length is 5×10^{-3} m. The waves are detected by a small Langmuir probe and/or a velocity analyzer. The reference signal is taken from a stationary probe near the grid and is amplified by a narrow active filter working in the principle of the heterodyne amplifier. The signal and the reference amplifier are fed to a lock - in amplifier for standard interferometry . When the main waves amplitude is increased from very low levels and the perturbed to unperturbed density ratio n/n_0 reaches a value of the order of 1 %, very narrow satellites and a coherent low frequency wave appear provided the frequencies of the main - wave and of the satellites are near a frequency region (optimum region) around $\omega_{pi}/4$. The width of this region increases with the main wave amplitude. The least linear damping of the test wave is also in this region. Fig. 1 shows the frequency spectra at x=4 cm .

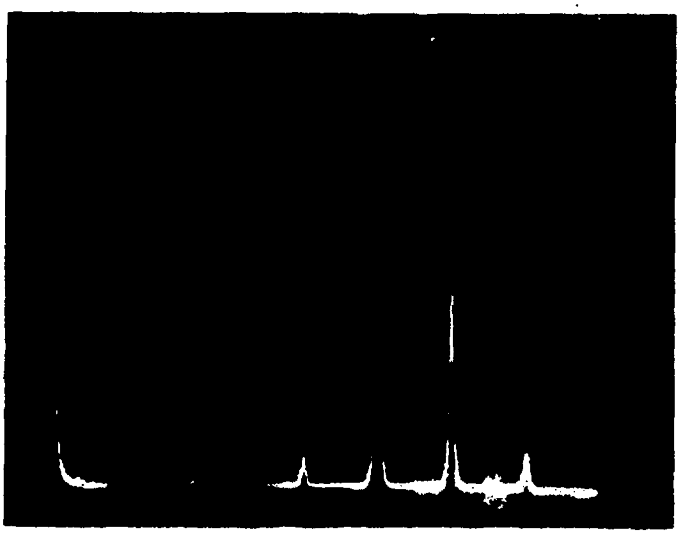

FIG. 1.

Frequency spectra at x=4 cm

Fig.2 shows the frequency separation $\Delta\omega$ as a function of : a) the main wave amplitude and b) the main wave length. The concordance with the Eq.(6) is excellent.

Fig.3 shows the optimum region as a function of the square root of the plasma density ($n_0^{1/2} \sim \omega_{pi}$). This region was made visible(unstable) by studyng the decay of large amplitude wave (not as large to produce satellites) into its subharmonics as a functions of the electron density. For each plasma density n_0 the bar indicates the region where the subharmonics was maximum. The optimum was also studied by measuring the damping rate of test waves as a function of the main wave amplitude and frequency for wave amplitude not enough to produce satellites. Details of these experiments will be reported elsewhere. The reason for this well defined region near $\omega_{pi}/4$ is not clearly understood but is well known that linear Landau damping at high frequencies (near ω_{pi}) and collisional damping at low frequencies inhibits the propagation of ion acustic waves. This leaves only a region near a region $\omega_{pi}/4$ $\omega_{pi}/2$ for the instability to set in. Some inhomogeneities in the plasma (specially near the separating grid) are not excluded as responsable for this prefered region.

Fig.4) shows the amplitude (at x = 4 cm) of the coherent wave as a function of the main wave amplitude ϕ_0 the appearance of threshold is clearly visible.

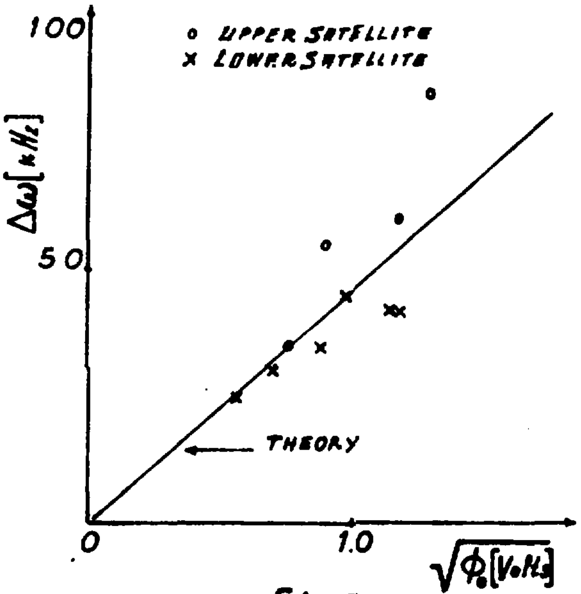

Fig. 2a

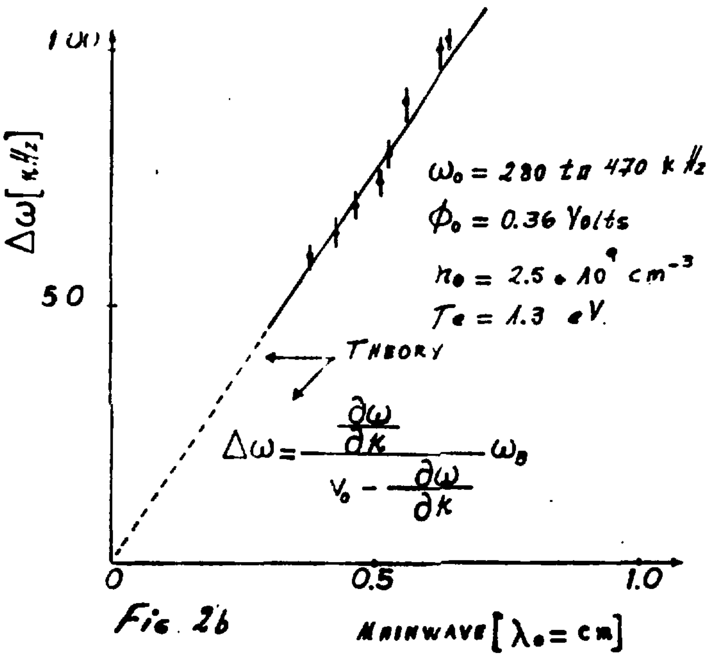

Fig. 2b

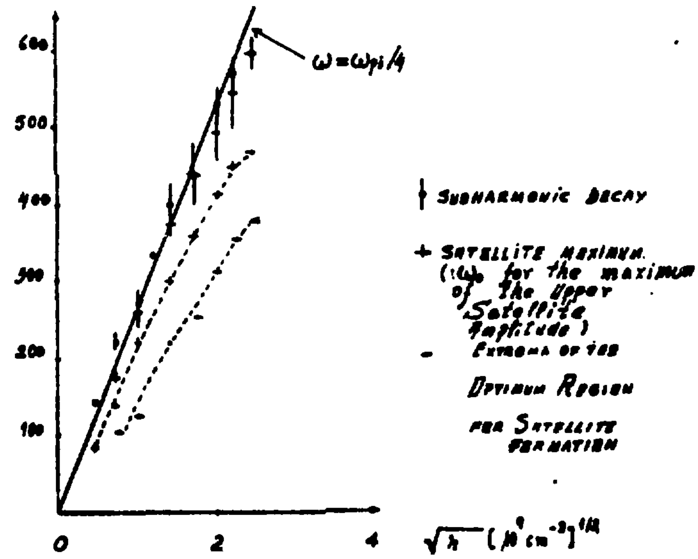

Fig. 3 Optimum Region.

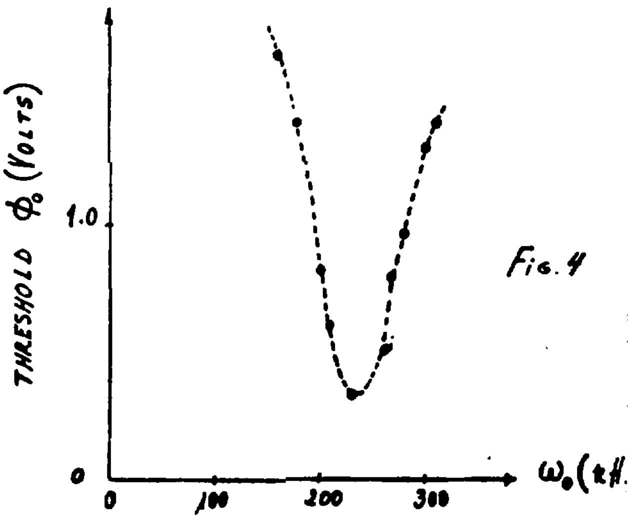

Fig. 4

III. CONCLUSIONS

Observations of the sideband instability was observed in an equilibrium plasma with $T_e/T_i \approx 12$. The observation of the coherent wave $\omega_c = \Delta\omega$ for the first time and of many upper and lower satellites seperated from the main wave by $\Delta\omega \ll \omega_B$ and the measurements of the frequency spectrum, threshold and growth rate as a function of the main wave amplitude and frequency clearly supports the bounce resonances model of the parametric theories .The existence of an optimum frequency region near $\omega_{pi}/4$ for this instability to occur was measured experimentally and its relation to the less linearly damped frequency region was determined.

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