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EXCITATION OF AN ION CYCLOTRON WAVE BY AN ION BEAM IN PLASMA WITH DENSITY RIPPLED

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ABSTRACT

Ion shafts are susceptible to ion cyclotron precariousness. An ion ray has effective eventuality to excite the ion cyclotron surge. Ion cyclotron surge having large resemblant phase haste whereas the ion ray might drive ion cyclotron surge with lower resemblant phase haste via Cerenkov commerce. The maximum growth rate of each mode will be attained as the transverse surge number of swells becomes inverse of Larmor compass. The graphical results and discussion depicts that the growth rate of swells is increases with viscosity ripple and static glamorous field. This proposition of excitation might of ion cyclotron surge be applicable to applicable in emulsion tube.

KEYWORDS: Ion Cyclotron Wave, Ion Beam, Cerenkov Interaction, Larmor Radius, Landau Damping

Ion cyclotron waves have been crucial to the radio frequency heating of tokamak throughout the past few decades. The plasma transport property can be impacted by a significant coupling between a large amplitude ion Bernstein wave and low frequency turbulence (Li *et al.*, 2001). Using a gyrating ion beam, Kumar and Tripathi investigated the excitation of ion cyclotron waves in a plasma column. Here, when Landau damping is taken into account, the growth rate reaches its maximum (Kumar and Tripathi, 2012).

Many researchers have been theoretically and experimentally studied the excitation mechanism of ion cyclotron wave. Reynolds and Ganguli (1998) theoretically investigated a scheme of ion cyclotron wave excitation by using the two transverse flow layers of plasma. They found that when the two flow layers of plasma are close, the coupling of becomes too strong. In tokamak reactor core, the ion Bernstein wave plays an crucial role for radio frequency heating via finite-Larmor-radius mode (Petrov, 1994; Ono, 1993). Jain and Christiansen have theoretically studied the multiple cyclotron harmonic wave excitation via the electron beam in thin plasma species (Ram and Schultz, 2000; Yoon *et al.*, 1999; Jain and Christiansen; 1981). Ion cyclotron wave is excited by linear mode conversion theory of fast wave during the current drive experiment. The resonant excitation of wave was observed due to Landau damping (Brambilla, 1998). In tokomak Fusion Test Reactor, as the fast energetic ion beam interacts with electrostatic wave, lost ions were observed lost ions with enormous heating upto several MeV. the mode conversion attains the very small poloidal phase velocity (Valeo and N. J. Fisch (1994).

In this paper, we theoretically excite the ion cyclotron waves by the interaction of an ion beam with rippled density plasma. The theoretical formalism of growth rate of ion cyclotron wave are discussed in Sec. 2. The results and discussion of this study is presented in Sec. 3. Finally, in Sec. 4, summary and conclusion is included.

ION CYCLOTRON WAVE

The velocity perturbation due to ion cyclotron wave at $\omega, \vec{k}$ is

$$\vec{v}_{\omega,\vec{k}} = v_{x,\omega,\vec{k}}\hat{x} + v_{y,\omega,\vec{k}}\hat{y} + v_{z,\omega,\vec{k}}\hat{z}, \qquad (1)$$

Electron Response

The electron density perturbation due to ion cyclotron wave at $\omega, \vec{k}$ is

$$n_{e,\omega,\vec{k}} = \frac{k^2\epsilon_0}{e}\chi_{e,\omega,\vec{k}}\phi_{\omega,\vec{k}}, \qquad (2)$$

where, $\chi_{e,\omega,\vec{k}} = \frac{2\omega_p^2}{k^2 v_{the}^2}\left(1 + i\sqrt{\pi}\frac{\omega}{k_z v_{the}}\right)$ for $\omega \ll k_z v_{the}$.

The electron density perturbation due to ion cyclotron wave at $\omega, \vec{k} + \vec{q}$ is

$$n_{e,\omega,\vec{k}+\vec{q}} = \frac{\{k_x^2 + (k_z+q)^2\}\epsilon_0}{e}\chi_{e,\omega,\vec{k}+\vec{q}}\,\phi_{\omega,\vec{k}+\vec{q}}\,, \qquad (3)$$

where $\chi_{e,\omega,\vec{k}+\vec{q}} = \frac{2\omega_p^2}{\{k_x^2+(k_z+q)^2\}v_{the}^2}\Big(1 + i\sqrt{\pi}\frac{\omega}{(k_z+q)\,v_{the}}\Big)$ for $\omega \ll (k_z+q)v_{the}$.

Nonlinear Dispersion Relation

Substituting the value of $n^L_{\omega,\vec{k}}$ from Eq. (03), $n^{NL}_{\omega,\vec{k}}$ from Eq. (05), $n_{e,\omega,\vec{k}}$ from Eq. (07) and $n_{b,\omega,\vec{k}}$, one obtains

$$k^2\left[1 + \chi_{\omega,\vec{k}} + \chi_{e,\omega,\vec{k}} - \frac{(k_x^2/k^2)\omega_b^2}{\{(\omega - k_z v_{0b})^2 - \omega_{cb}^2\}} - \frac{(k_z^2/k^2)\omega_b^2}{(\omega - k_z v_{0b})^2}\right]\phi_{\omega,\vec{k}} = \frac{\omega_q^2}{\omega}\left[\frac{\omega k_x^2}{(\omega^2 - \omega_{ci}^2)} + \frac{k_z(k_z+q)}{\omega}\right]\phi_{\omega,\vec{k}+\vec{q}} \qquad (4)$$

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Growth Rate

The growth rate of Ion cyclotron wave may be written as

$$\gamma = \left[\frac{\left((k_x^2/k^2)\omega_b^2\right)}{2\omega_{cb}} \cdot \frac{1}{\left(\frac{\partial G}{\partial \omega}\right)_{\omega=\omega_R}}\right]^{1/2}. \qquad (5)$$

RESULTS AND DISCUSSION

Figure 1 shows the variation of normalized growth rate as a function of normalized ion cyclotron wave frequency for different values of normalized thermal velocity $k_\perp v_{thi}/\omega_{ci}$. The variation of normalized growth rate as a function of normalized ion cyclotron wave frequency for different values of normalized beam cyclotron frequency ω_{cb}/ω_{ci} is shown in Figure 2. Here, we can see that the growth rate of ion cyclotron wave frequency rapidly decreases with the variation in ion cyclotron wave frequency. Further we can notice that the growth rate of ion cyclotron wave is increased with increase in beam cyclotron frequency. Since the beam cyclotron frequency causes to energize the ions species in plasma and results the much more excitation of ion cyclotron wave. This leads to increase the growth rate of ion cyclotron wave with increase in beam cyclotron frequency.

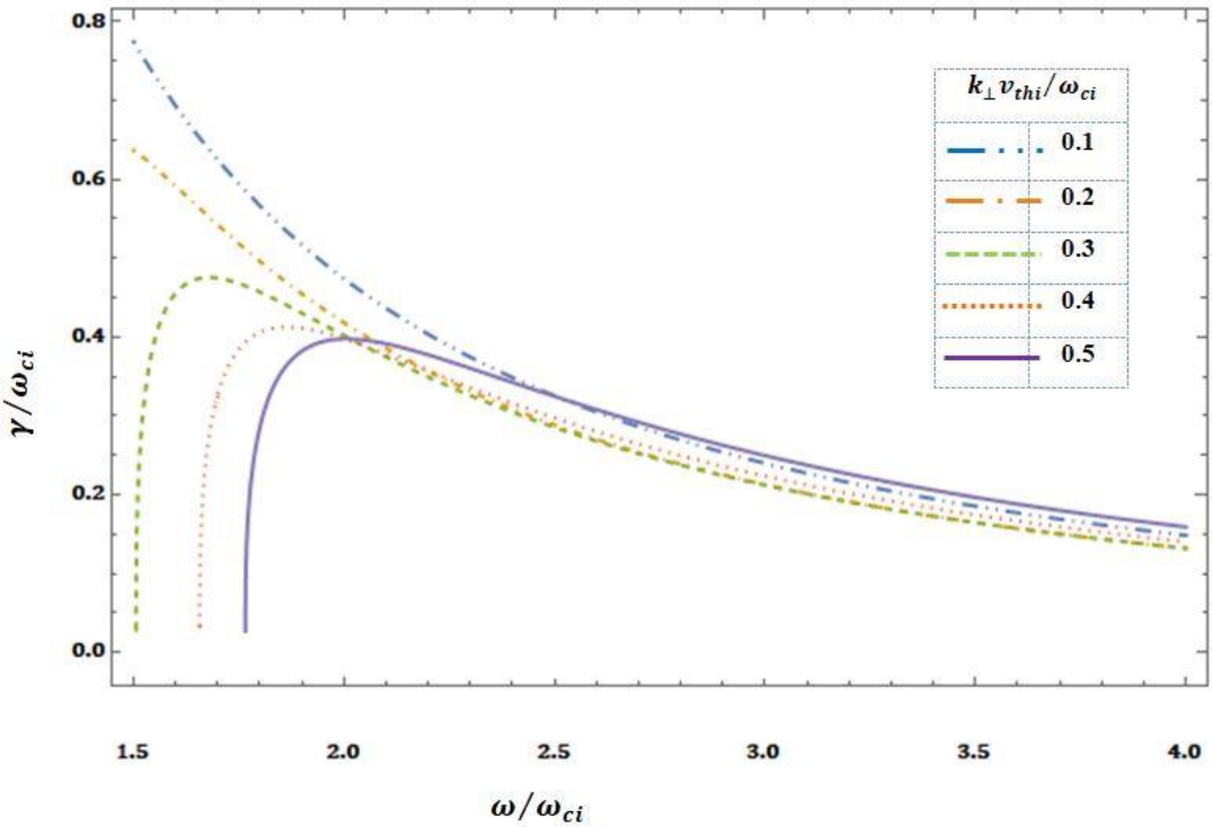

Figure 1: The variation of normalized growth rate as a function of normalized ion cyclotron wave frequency for different values of $k_\perp v_{thi}/\omega_{ci}$ in the case of Cerenkov interaction. The parameters are: $\omega_{cb}/\omega_{ci} = 0.4$, $\omega_q/\omega_{ci} = 0.5$, $\omega_b/\omega_{ci} = 0.8$, $k_z v_{thi}/\omega_{ci} = 0.2$, $q v_{thi}/\omega_{ci} = 0.9$, $v_{0b}/v_{thi} = 40$, v$\omega_p/\omega_c = 1$, $\omega_c/\omega_{ci} = 4000$ and $v_{the}/v_{thi} = 1000$.

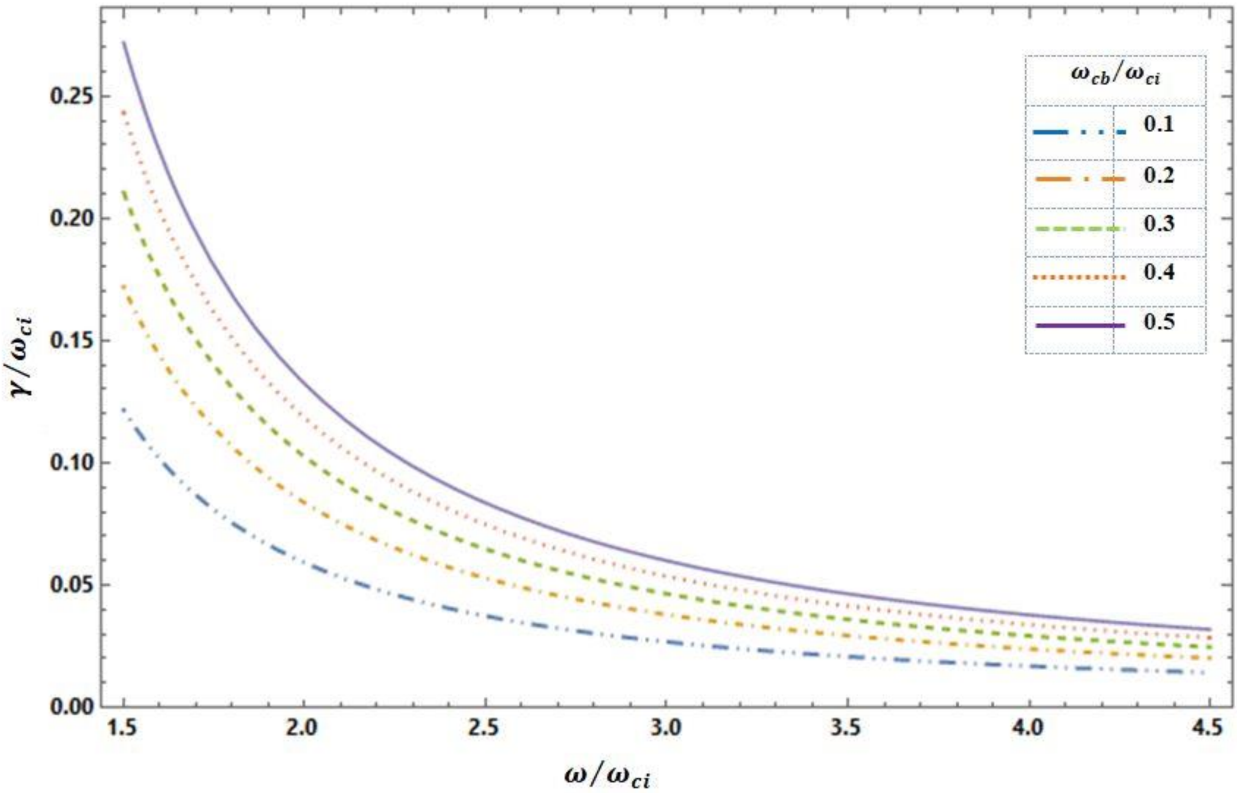

Figure 2: The variation of normalized growth rate as a function of normalized ion cyclotron wave frequency for different values of ω_{cb}/ω_{ci} in the case of slow cyclotron wave. The parameters are: $k_{\perp}v_{thi}/\omega_{ci} = 0.1$, $\omega_q/\omega_{ci} = 0.1$, $\omega_b/\omega_{ci} = 1.5$, $k_z v_{thi}/\omega_{ci} = 0.3$, $qv_{thi}/\omega_{ci} = 0.3$, $v_{0b}/v_{thi} = 30$, $\omega_c/\omega_{ci} = 4000$ and $v_{the}/v_{thi} = 200$.

SUMMARY AND CONCLUSION

In this paper, we study the excitation of ion cyclotron wave via the interaction of an ion beam with rippled density plasma. The Vlasov theory is used to obtain the response of ion beam with ion cyclotron wave. The growth rate of ion cyclotron wave is obtained via Cerenkov interaction and and slow cyclotron interaction. The obtained growth rate of these waves was found maximum as the wave number becomes inverse of Larmor radius. The growth rate of wave is dependent on beam cyclotron frequency, ion thermal velocity and rippled density of plasma. This excited scheme of ion cyclotron wave might be relevant in fusion plasma and parametric instabilities.

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