iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** III **Month of publication:** March 2018

DOI: http://doi.org/10.22214/ijraset.2018.3019

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

Cyclotron Interaction of Lower Hybrid Wave with Charged Particle Beams

Ved Prakash[1]
[1]India Meteorological Department, Ministry of Earth Sciences, Lodi Road, New Delhi-110 003, India

Abstract*: Theoretical studies of the lower-hybrid-beam-plasma instability have been carried out. A dispersion relation is derived detailing the effect of a population of charged dust grains on the growth of lower hybrid waves excited by an electron beam and an ion beam in dusty plasma. The frequency and the growth rate of the unstable mode increase with the relative density of negatively charged dust grains. The dust charge fluctuations reduce the growth rate of the mode in the presence of beam. No growth of wave is observed for fast cyclotron interaction between the beam modes and lower hybrid mode. The growth rate is comparatively more for ion beam interaction with lower hybrid wave, as the beam is propagating along the wave, perpendicular to the external magnetic field.
Keyword: Cyclotron, dispersion, frequency, growth rate, Lower hybrid

I. INTRODUCTION

The instability of waves in a beam-plasma system [1-10] is studied with great interest because their behavior is of physical interest and also because of their possible application to electron acceleration or ion heating. Whenever there is a non-thermal perpendicular distribution of ions or parallel distribution of electrons, lower hybrid waves may play a role in redistributing the energy. Such distributions occur in heliosphere, near magnetic reconnection sites, in the Earth's magnetotail and in the solar corona. The presence of a distribution of charged dust particles can modify the instability. Massive and highly charged grains are quite common in natural systems, such as the plasmas in the planetary atmospheres, rocket exhausts, cometary tails, interstellar clouds, etc. and laboratory plasmas, such as industrial processing plasmas, fusion devices, etc. The dusty plasma can give rise to modifications or additional waves and instabilities [11-15]. It is therefore interesting to study the effect of a dust grain population on the growth of electrostatic waves. Lower hybrid waves can interact resonantly with electrons as well as ions, mediate the transfer of energy between the two plasma species and therefore lead to ion heating or electron acceleration. The lower hybrid waves are generated by different mechanisms such as by electron or ion beams propagating in the plasma. Seiler *et al*. [1] have studied the excitation of LH wave instability by a spiraling ion beam in the linear Princeton Q-1 device and their frequency measurements show that the instability occurs at just above the cyclotron harmonics due to the coupling of the beam cyclotron mode with the lower hybrid mode. Papadopoulus and Palmadesso [2] have demonstrated that the lower hybrid waves can be generated by an energetic electron beam streaming through plasma along the magnetic fields. Sharma and Tripathi [3] have studied the excitation of lower hybrid waves by a gyrating beam in a magnetized plasma cylinder. Prakash *et al.* have studied electron beam [4] driven and ion beam [5] driven lower hybrid waves in a dusty plasma and have discussed the dependence of the growth rate on the beam velocity. Torney *et al.* [6] have studied the effect of a population of charged dust grains on the growth of LHWs excited by a ring distribution of ions in a plasma.

In this paper, we study the excitation of lower hybrid waves by electron and ion beam in magnetized dusty plasma. The electron and ion beams propagating through a magnetized dusty plasma drive electrostatic lower hybrid waves to instability via cyclotron interaction. In Sec. II, the instability analysis for lower hybrid wave excitation by electron beam is carried out. Sec. III gives the theory of ion beam excited lower hybrid waves. The plasma and beam responses are obtained using fluid treatment. Results and discussions are given in Sec. IV. Finally, the conclusion part is given in Sec. V.

We consider a three component plasma of electrons, ions and massive charged dust grains with respective densities n_{eo}, n_{io} and n_{do}, immersed in a static magnetic field B_s in the z-direction. The quasineutrality condition at equilibrium is given by $en_{io} \pm en_{bo} \pm Q_{do}n_{do} = en_{eo}$, where –e is the electronic charge, Q_{do} is the dust grain charge and e is the positive ionic charge. A + sign in beam term is for ion beam and a – sign is for electron beam. Similarly, a + sign in dust term is for positively charged dust grains and a – sign for negatively charged dust grains. Let us consider a low frequency electrostatic lower hybrid mode, propagating nearly perpendicular to the external magnetic field with propagation wave vector **k** lying in the x-z plane.

©IJRASET (UGC Approved Journal): All Rights are Reserved

II. EXCITATION BY ELECTRON BEAM

An electron beam is considered propagating along z-axis parallel to the magnetic field with beam density n_{bo} and equilibrium beam velocity $v_{bo}\,\hat{z}$. The equilibrium is perturbed by an electrostatic perturbation to the potential

$$\phi = \phi_0 e^{-i(\omega t - k_\perp x - k_z z)} . \quad (1)$$

The equation of motion, governing the perturbed velocity of plasma electrons, plasma ions and beam electrons is

$$m_e\left[\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v}\cdot\nabla\,\mathbf{v}\right] = -e\,\mathbf{E} - \frac{e}{c}\mathbf{v}\times\mathbf{B_s} \cdot \quad (2)$$

On linearizing Eq. (1), we obtain the perturbed electron beam velocities as

$$v_{b1x} = -\frac{ek_\perp(\omega - k_z v_{b0})\phi}{m_e[(\omega - k_z v_{b0})^2 - \omega_{ce}^2]}, \quad (3)$$

$$v_{b1y} = -\frac{iek_\perp \omega_{ce}\phi}{m_e[(\omega - k_z v_{b0})^2 - \omega_{ce}^2]}, \quad (4)$$

and

$$v_{b1z} = -\frac{ek_z\phi}{m_e(\omega - k_z v_{b0})}, \quad (5)$$

where $\omega_{ce} = \frac{e\mathbf{B}_s}{m_e c}$ is electron cyclotron frequency. Substituting the perturbed velocities given by Eqs. (3), (4) and (5) in the equation of continuity, we obtain the perturbed beam current density as

$$n_{b1} = -\frac{n_{b0}\,e\phi}{m_e}\left[\frac{k_\perp{}^2}{[(\omega - k_z v_{b0})^2 - \omega_{ce}{}^2]} + \frac{k_z{}^2}{(\omega - k_z v_{b0})^2}\right]. \quad (6)$$

Considering $\omega_{ci} << \omega << \omega_{ce}$, the perturbed electron density n_{e1} is obtained from Eq. (6) as:

$$n_{e1} = -\frac{n_{eo}\,e\phi}{m_e}\left[-\frac{k_\perp^2}{\omega_{ce}^2} + \frac{k_z^2}{\omega^2}\right]. \quad (7)$$

The perturbed ion density n_{i1} and perturbed dust density are obtained by considering ions and dust grains to be unmagnetized and are given as

$$n_{i1} = \frac{n_{io}\,e\phi}{m_i}\frac{k^2}{\omega^2}, \quad (8)$$

and $$n_{d1} = \frac{n_{d0}Q_{d0}\phi}{m_d}\frac{k^2}{\omega^2} . \quad (9)$$

Now applying probe theory to a dust grain [6], we obtain the dust charge fluctuation as

$$Q_{d1} = \frac{i|I_{eo}|}{(\omega + i\eta)}\left[\frac{e\phi}{m_i}\frac{k^2}{\omega^2} + \frac{e\phi}{m_e}\left(-\frac{k_\perp^2}{\omega_{ce}^2} + \frac{k_z^2}{\omega^2}\right)\right] \quad (10)$$

Using Eqs. (6) – (10) in the Poisson's equation, we obtain:

$$\left(\omega^2 - \omega_{lh}^2\right)(\omega + i\eta) + i\beta'\omega^2 = \omega_{pb}^2(\omega + i\eta)\frac{1}{K}\left[\frac{k_\perp^2}{k^2}\frac{1}{\left(\overline{\omega}^2 - \omega_{ce}^2\right)} + \frac{k_z^2}{k^2}\frac{1}{\overline{\omega}^2}\right], \quad (11)$$

©IJRASET (UGC Approved Journal): All Rights are Reserved

where $\omega_{pe} = \left(\frac{4\pi n_{eo} e^2}{m_e}\right)^{1/2}$, $\omega_{pi} = \left(\frac{4\pi n_{io} e^2}{m_i}\right)^{1/2}$ and $\omega_{pd} = \left(\frac{4\pi n_{do} Q_{do}^2}{m_d}\right)^{1/2}$ are the electron, ion and dust plasma frequencies, respectively, $\bar{\omega} = \omega - k_z v_{bo}$, $K = 1 + \frac{\omega_{pe}^2}{\omega_{ce}^2}\frac{k_\perp^2}{k^2}$ and

$$\beta' = -\beta\left(\omega_{pe}^2 \frac{k_z^2}{k^2} + \omega_{pi}^2 \frac{k_\perp^2}{k^2}\frac{n_{eo}}{n_{io}}\right) \Big/ K\omega^2 .$$

From Eq. (11), we obtain the dispersion relation, in the limit of vanishing beam density as

$$\omega_{lh}^2 = \omega_l^2 \left(1 + \frac{k_z^2}{k^2}\frac{m_i}{m_e}\frac{1}{\delta} - \frac{\omega_{pd}^2}{\omega_{pi}^2}\right), \tag{12}$$

where

$$\omega_l^2 = \omega_{pi}^2 \Big/ \left(1 + \frac{k_\perp^2}{k^2}\frac{\omega_{pe}^2}{\omega_{ce}^2}\right).$$

In cyclotron interaction $(\omega - k_z v_{b0})^2 \approx \omega_{ce}^2$, therefore second term on RHS of Eq. (11) can be neglected and can be rewritten as

$$\left(\omega^2 - \omega_{lh}^2\right)(\omega + i\eta) + i\beta'\omega^2 = \omega_{pb}^2(\omega + i\eta)\frac{1}{K}\frac{k_\perp^2}{k^2}\frac{1}{\left((\omega - k_z v_{b0})^2 - \omega_{ce}^2\right)}, \tag{13}$$

where $(\omega - k_z v_{b0}) + \omega_{ce} \approx 0$ corresponds to slow cyclotron interaction,

and $(\omega - k_z v_{b0}) - \omega_{ce} \approx 0$ corresponds to fast cyclotron interaction.

For slow cyclotron interaction, assuming perturbed quantities $\omega = k_z v_{b0} - \omega_{ce} + \Delta$, $\omega = \omega_{lh} + \Delta$ and $\omega = -i\eta - i\beta' + \Delta$, we get the growth rate , i.e., the imaginary part of Δ, as

$$\gamma = \text{Im}\ (\Delta) = \frac{\sqrt{3}}{2} A^{1/3} + \frac{B}{6} A^{-2/3}, \tag{14}$$

where $A = \omega_{pb}^2 \omega_{lh}^2 \frac{1}{K}\frac{k_\perp^2}{k^2}\frac{1}{4\omega_{ce}}$, and

$$B = \omega_{pb}^2 \omega_{lh} \eta \frac{1}{K}\frac{k_\perp^2}{k^2}\frac{1}{4\omega_{ce}}.$$

For fast cyclotron interaction, assuming perturbed quantities $\bar{\omega} = \omega_{ce} + \Delta$, $\omega = \omega_{lh} + \Delta$ and $\omega = -i\eta - i\beta + \Delta$, we get the growth rate as

$$\gamma = \frac{B}{3} A^{-2/3}. \tag{15}$$

In the absence of dust charge fluctuations, i.e., β = 0 and η=0, we get the growth rate for slow cyclotron interaction of lower hybrid mode with electron beam as

$$\gamma = \text{Im}\ (\Delta) = \left[\frac{\omega_{pb}^2 \omega_{lh} \omega_{ce}}{4\omega_{pe}^2}\right]^{1/2} \tag{16}$$

©IJRASET (UGC Approved Journal): All Rights are Reserved

For fast cyclotron interaction, however we get

$$\gamma = 0 \tag{17}$$

III. EXCITATION BY ION BEAM

An ion beam is considered propagating along x-axis perpendicular to the magnetic field with density n_{bo} and equilibrium beam velocity $v_{bo}\,\hat{x}$. Proceeding in the same manner as in previous section, we get the dispersion relation of lower hybrid wave as

$$\left(\omega^2 - \frac{1}{K}\omega_{pe}^2\frac{k_z^2}{k^2} - \frac{1}{K}\omega_{pi}^2\frac{k_\perp^2}{k^2} - \frac{1}{K}\omega_{pd}^2\frac{k_\perp^2}{k^2}\right)(\omega + i\eta) + i\beta'\omega^2 = \frac{k_\perp^2}{k^2}\frac{1}{K}\frac{\omega_{pb}^2\omega^2(\omega+i\eta)}{(\omega - k_\perp v_{b0})^2}, \tag{18}$$

Considering slow cyclotron interaction and assuming perturbed quantities

$\bar{\omega} = \omega_{ci} + \Delta$, $\omega = \omega_{lh} + \Delta$ and $\omega = -i\eta - i\beta + \Delta$,

we get the growth rate as

$$\gamma = \frac{\sqrt{3}}{2}A'^{1/3} + \frac{B'}{6}A'^{-2/3}, \tag{19}$$

where $A' = \omega_{pb}^2\omega_{lh}^2\frac{1}{K}\frac{k_\perp^2}{k^2}\frac{1}{4\omega_{ci}}$, and

$$B' = \omega_{pb}^2\omega_{lh}\eta\frac{1}{K}\frac{k_\perp^2}{k^2}\frac{1}{4\omega_{ci}}.$$

Foe fast cyclotron interaction, assuming perturbed quantities $\bar{\omega} = \omega_{ci} + \Delta$, $\omega = \omega_{lh} + \Delta$ and $\omega = -i\eta - i\beta + \Delta$, we get the growth rate as

$$\gamma = \frac{B'}{3}A'^{-2/3}. \tag{20}$$

In the absence of dust charge fluctuations, i.e., $\beta = 0$ and $\eta=0$, we get the growth rate for slow cyclotron interaction of lower hybrid mode with ion beam as

$$\gamma = \left[\frac{n_{bo}}{n_{eo}}\frac{\omega_{+}\omega_{ce}}{4}\frac{m_i}{m_e}\right]^{1/2}. \tag{21}$$

For fast cyclotron interaction between ion beam and lower hybrid mode in absence of dust charge fluctuations, we get

$$\gamma = 0. \tag{22}$$

IV. RESULTS AND DISCUSSION

We have used the dusty plasma parameters for numerical calculations, as taken in our previous works and some of the experimental works on dusty plasma: number density of plasma ions $n_{io}=10^9 cm^{-3}$, external static magnetic field B_S=320G, mass of ion $m_i=39\times1836 m_e$ (Potassium-plasma), temperature of electron T_e=3 eV, temperature of ion T_i=0.2 eV, number density of beam electrons/ions $n_{bo}=2.5\times10^8$ cm^{-3}, mass of dust grain $m_d = 10^{12}$ m_i and dust grain size $a=10^{-4}$ cm. The relative density of negatively charged dust grains δ $(=n_{io}/n_{eo})$ has been varied from 1 to 6.

The lower hybrid waves are said to be produced when $k_z/k \approx \sqrt{m_e/m_i}$ or $k_z/k \approx 0.00374$. For $\omega_{lh}=\omega_{pi}$ and k_z/k =0.0083, the frequency of lower hybrid wave remains constant irrespective of the change in the value of δ [4], i.e., the effect of dust charge fluctuations become negligible when the frequency of lower hybrid mode approaches the plasma ion frequency. Therefore, we concentrate in the region $0<k_z/k<0.008$ and $\omega_{lh}<\omega_{pi}$, for lower hybrid waves which seems to be important with respect to ion heating. Using Eq. (16), we have plotted in Fig. 1 the normalized growth rate γ/ω_{pi} as a function of k_z/k for different values of the relative density of negatively charged dust grains δ, for slow cyclotron interaction between electron beam and lower hybrid mode in the absence of dust charge fluctuations. It can be seen that the growth rate of the unstable mode increases with k_z/k for all values of δ. Fig. 2 shows the variation of growth rate γ (rad/sec) with lower hybrid mode frequency, plotted using Eq. (16). For slow cyclotron interaction, the resonance condition for the growth of lower hybrid mode is $\omega \approx k_z v_{b0} - \omega_{ce}$. The lower hybrid wave grows when it interacts with the gyrating beam. At low mode frequencies, such an interaction does not take place, and hence there is no growth, as is evident from Fig. 2, which shows that the growth rate appears when lower hybrid frequency is 1.8×10^7 rad/sec. As the relative density of negatively charged dust grains increase, the lower hybrid frequency increase [cf. Eq. (12)], and therefore the growth rate starts at a higher frequency. As the lower hybrid frequency approaches the plasma ion frequency, the growth rate disappears, as lower hybrid modes exist only for $\omega_{lh} < \omega_{pi}$ [4].

Using Eq. (21), we have plotted in Fig. 3, the normalized growth rate γ/ω_{pi} as a function of the relative density of negatively charged dust grains δ, for slow cyclotron interaction between ion beam and lower hybrid mode in the absence of dust charge fluctuations. Fig. 4 shows the variation of growth rate γ (rad/sec) with lower hybrid mode frequency for ion beam-lower hybrid wave interaction. The results of Fig. 3 and Fig. 4 are quite similar to the results obtained in Fig. 1 and Fig. 2. However, the growth rate values are more for ion beam interaction as compared to the electron beam interaction with lower hybrid mode. For fast cyclotron interaction in both the cases, there is no growth, as the beam in this case, could not interact with the wave mode in lower hybrid regime.

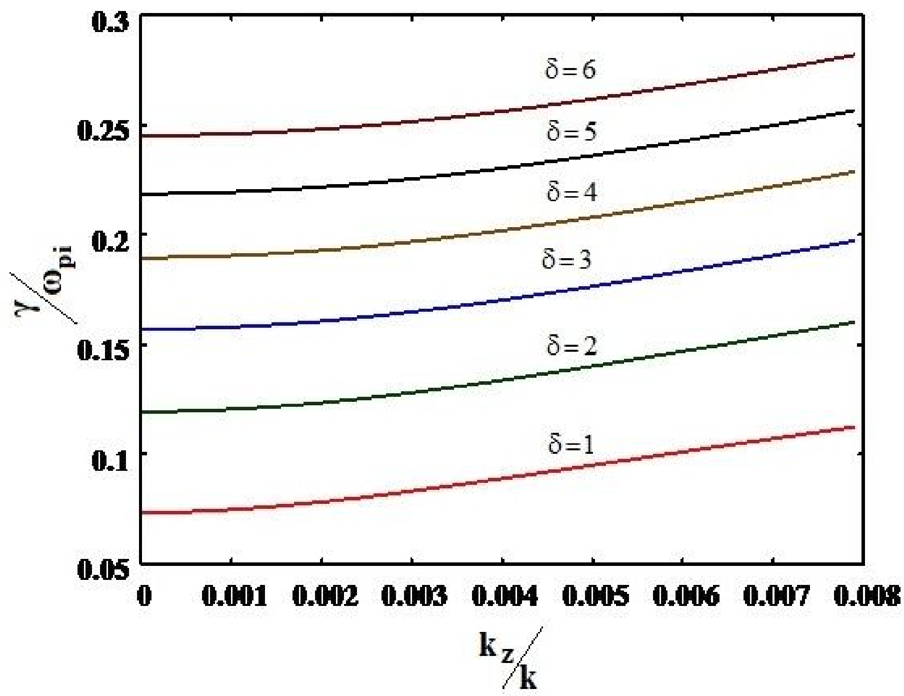


Fig. 1 Normalized growth rate γ/ω_{pi} of the unstable mode as a function of normalized wave number k_z/k for different values of δ, for
slow cyclotron interaction with electron beam in absence of dust charge fluctuations

©IJRASET (UGC Approved Journal): All Rights are Reserved

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue III, March 2018- Available at www.ijraset.com

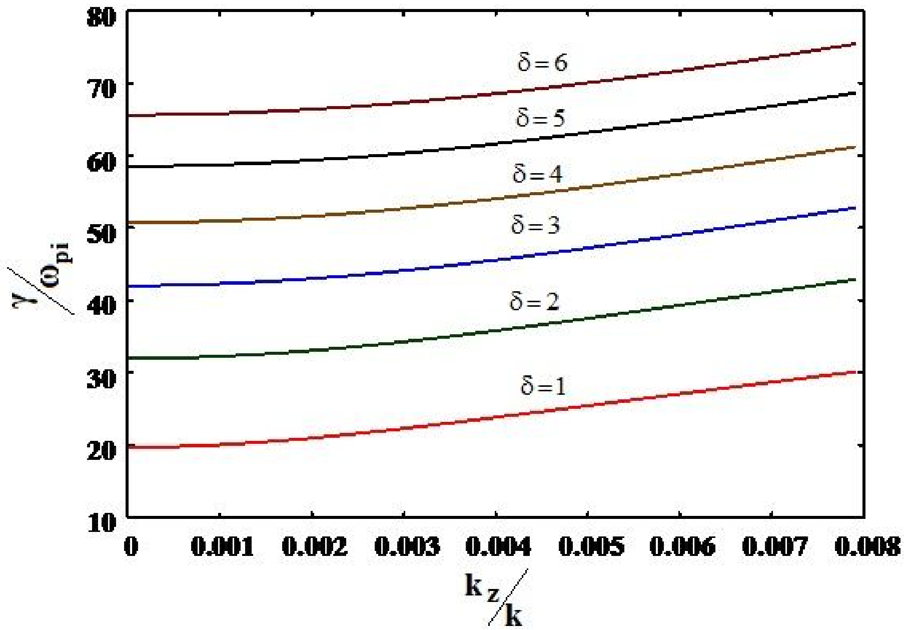


Fig. 2 Growth rate γ (rad/sec) of the unstable mode as a function of wave frequency ω_{lh} (rad/sec) for different values of δ, for slow cyclotron interaction with electron beam in absence of dust charge fluctuations

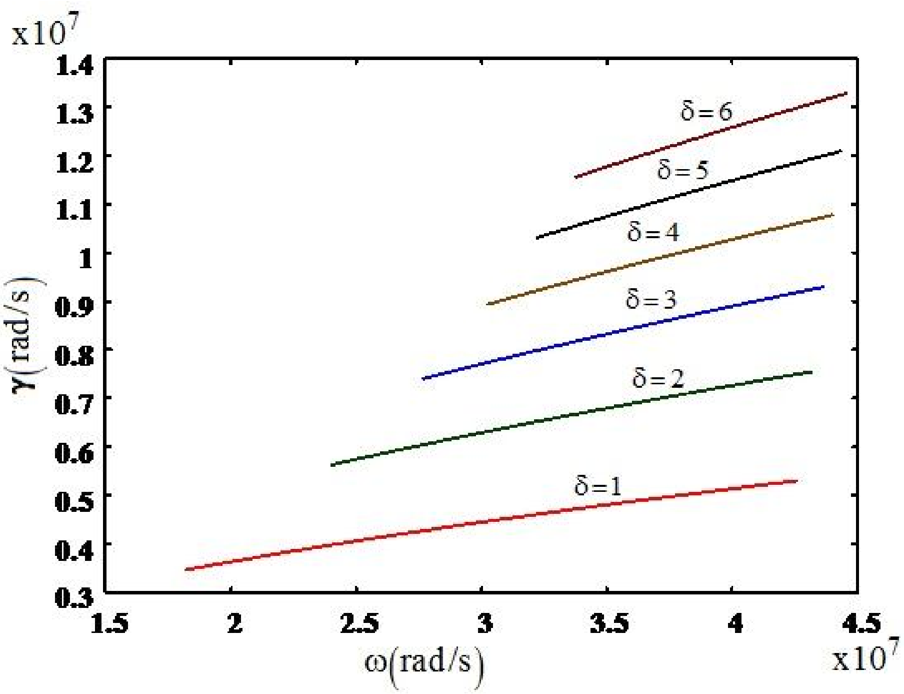


Fig.3 Normalized growth rate γ/ω_{pi} of the unstable mode as a function of normalized wave number k_z/k for different values of

δ,

for slow cyclotron interaction with ion beam in absence of dust charge fluctuations

©IJRASET (UGC Approved Journal): All Rights are Reserved

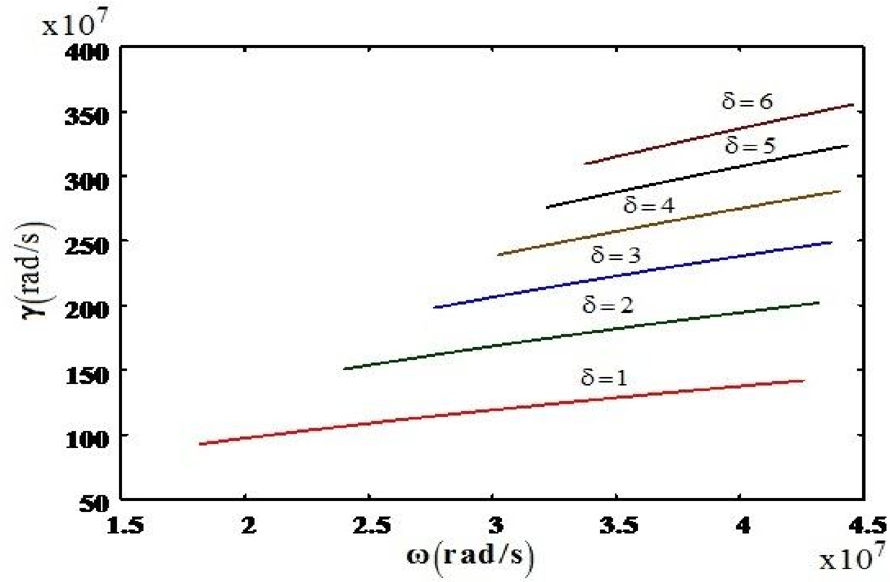


Fig. 4 Growth rate γ (rad/sec) of the unstable mode as a function of wave frequency ω_{lh} (rad/sec) for different values of δ, for slow cyclotron interaction with ion beam in absence of dust charge fluctuations

In Fig. 5, we have plotted the normalized growth rate γ/ω_{pi} as a function of k_z/k for different values of the relative density of negatively charged dust grains δ, for slow cyclotron interaction between electron beam and lower hybrid mode in the presence of dust charge fluctuations. The growth rate of the lower hybrid mode increases with k_z/k for all values of δ, as observed in Fig. 1. However, the growth rate values decrease due to the presence of dust charge fluctuations, indicating the usual damping of wave modes in presence of dust charge fluctuations [12-13]. Fig. 6 shows the variation of the the normalized growth rate γ/ω_{pi} as a function of k_z/k for different values of δ, for fast cyclotron interaction between electron beam and lower hybrid mode in the presence of dust charge fluctuations. The wave modes show a damping of very small order, along the magnetic field for all values of δ. It indicates that the lower hybrid modes will grow across the magnetic field in the direction of their propagation during fast cyclotron interaction.

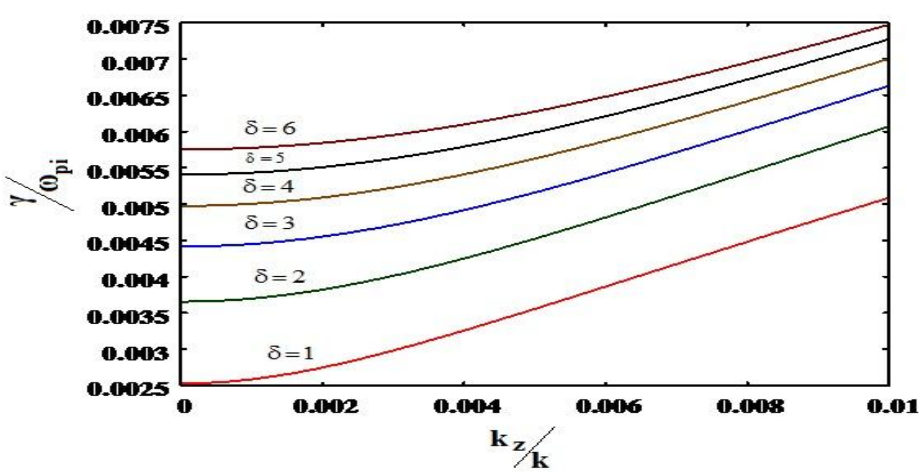


Fig. 5 Normalized growth rate γ/ω_{pi} of the unstable mode as a function of normalized wave number k_z/k for different values of δ, for slow cyclotron interaction with electron beam in presence of dust charge fluctuations

©IJRASET (UGC Approved Journal): All Rights are Reserved

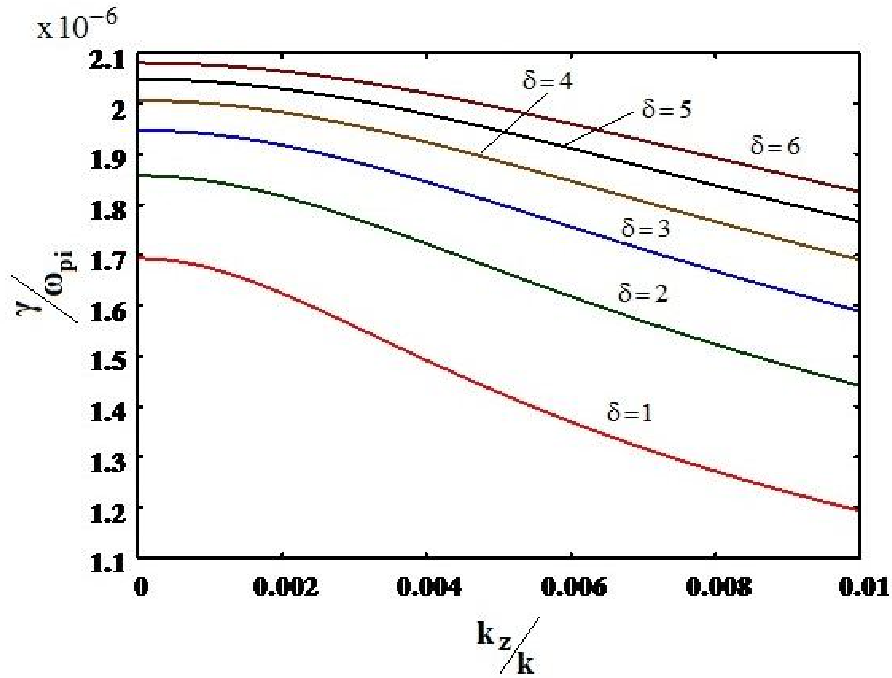


Fig. 6 Normalized growth rate γ/ω_{pi} of the unstable mode as a function of normalized wave number k_z/k for different values of δ, for fast cyclotron interaction with electron beam in presence of dust charge fluctuations

Similar results are obtained for ion beam and lower hybrid mode interactions, shown in Fig. (7) and Fig. (8). The growth rate values are comparably higher in case of ion beam interaction. It may be attributed to the fact that the ion beam is propagating along the lower hybrid wave, across the magnetic field, and therefore transfer of energy from the wave to the plasma mode can take place efficiently.

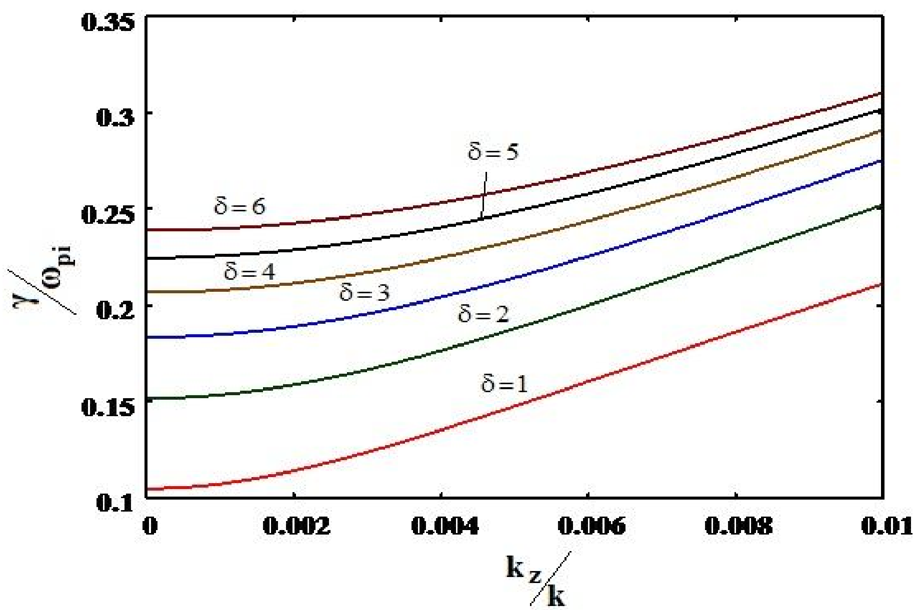


Fig. 7 Normalized growth rate γ/ω_{pi} of the unstable mode as a function of normalized wave number k_z/k for different values of δ, for slow cyclotron interaction with ion beam in presence of dust charge fluctuations

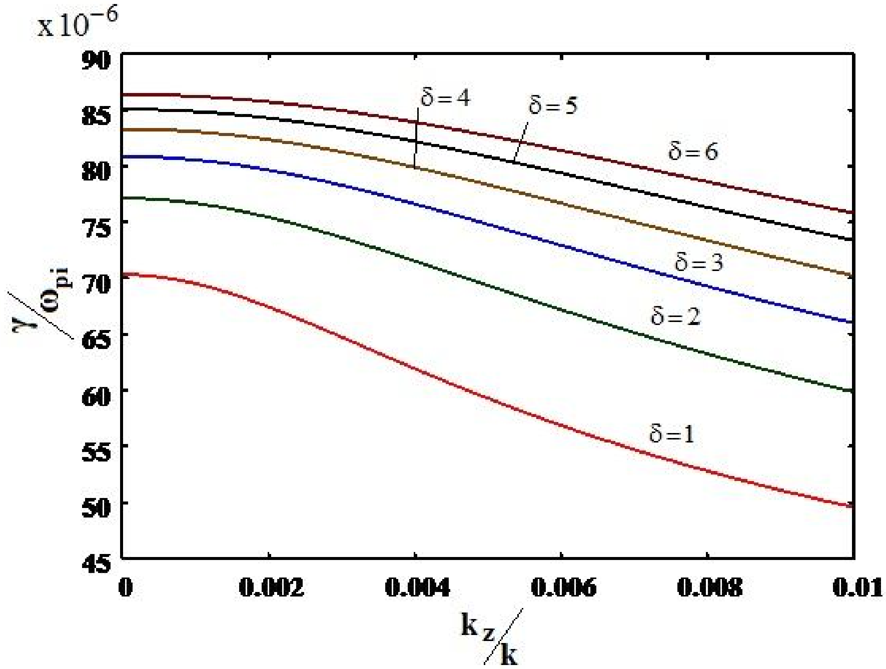


Fig. 8 Normalized growth rate γ/ω_{pi} of the unstable mode as a function of normalized wave number k_z/k for different values of δ, for fast cyclotron interaction with ion beam in presence of dust charge fluctuations

IV. CONCLUSION

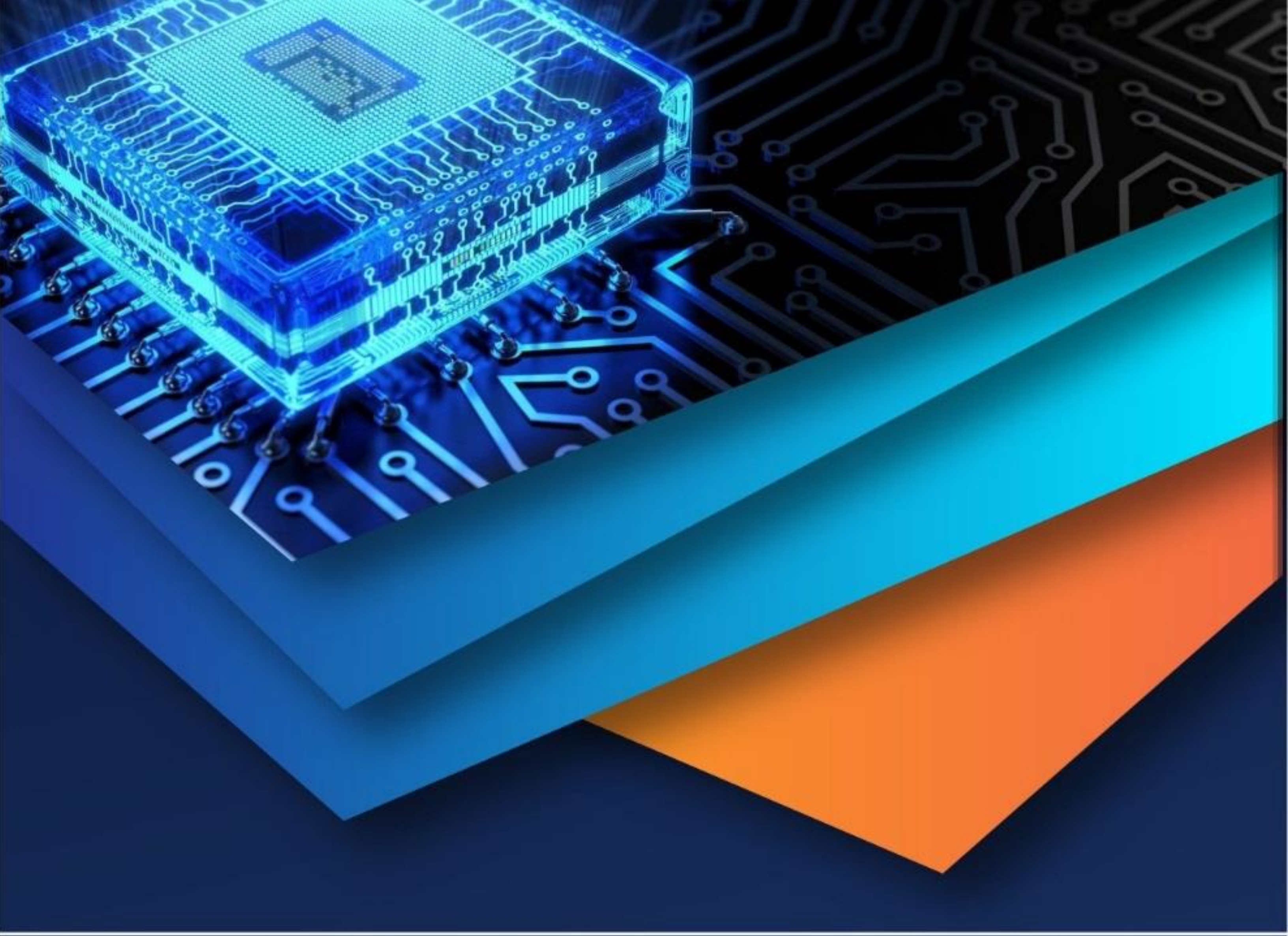
The electrostatic lower hybrid waves were driven to instability by an electron beam travelling parallel to the magnetic field and an ion beam travelling perpendicular to the magnetic field, via cyclotron interaction. The frequency and the growth rate of the lower hybrid mode increases with the relative density of negatively charged dust grains. In the absence of dust charge fluctuations, growth rate is observed only for slow cyclotron interaction and is zero for fast cyclotron interaction. The dust charge fluctuations induce a damping, however, the lower hybrid mode still shows a growth rate due to beam-plasma interaction. The growth rate values are very small for fast cyclotron interaction as compared to the values for slow cyclotron interaction. As the relative density of negatively charged dust grains δ increases, the electron plasma density n_{eo} decreases with respect to ion plasma density n_{io}. Thus, the ions have an effective mass that is less than m_i, and their greater mobility leads to increased wave generation. Lower hybrid waves excited by electron beam and ion beam also satisfied the condition for efficient energy transport and the energy transferred from the parallel electron beam to the perpendicular ions resulted in ion heating, necessary for thermonuclear plasma and fusion plasma.

REFERENCES

[1] S. Seiler, M, Yamada, and H. Ikezi, “Lower hybrid instability driven by a spiraling ion beam” Phy. Rev. Letter, Vol. 37, No. 11, pp. 700-703, 1976.
[2] K. Papadopoulos and P. Palmadesso, “Excitation of lower hybrid waves in a plasma by Electron beams” Phys. of Fluids, Vol. 19, No. 4, pp. 605-606, 1976.
[3] A. Sharma and V. K. Tripathi, “Excitation of lower hybrid waves by a gyrating ion beam in a magnetized plasma cylinder” Phy. of Fluids,
[4] V. Prakash, Vijayshri, S. C. Sharma, and R. Gupta, “Electron beam driven lower hybrid waves in a dusty plasma” Physics of Plasmas, Vol. 20, pp. 0537011-0537016, 201
[5] V. Prakash, Vijayshri, S. C. Sharma and R. Gupta, “Ion-beam driven lower hybrid waves in a magnetized dusty plasma” Phy. of Plasmas, Vol. 20, pp. 063701-1-063701-6, 2013
[6] M. Torney, C. Marmolino, U. De Angelis, A. Forlani and R. Bingham, “Excitation of lower-hybrid waves in dusty plasmas” J. Plasma Physics, Vol. 71, pp. 475-486, 200
[7] R. P. H. Chang, “Lower-hybrid beam-plasma instability” Phy. Rev. Letters, Vol. 35, No. 5, pp. 285-288, Aug. 1975
[8] M. M. Shoucri and R. R. J.Gagne, “Excitation of lower hybrid waves by electron beams in finite geometry plasmas. I - Body waves. II – Surface waves”, J. Plasma Physics, Vol. 19, pp. 281-299, 1978
[9] S. C. Sharma, M. P. Srivastava, M. Sugawa and V. K. Tripathi, “Excitation of lower Hybrid waves by a density-modulated electron beam in a plasma cylinder” Phys. of Plasmas, Vol. 5, pp. 3161-3165, 1998
[10] M. Rosenberg, P. A. Bernhardt and S. E. Clark, “Excitation of ion waves by charged dust beams in ionospheric aerosol release experiments” Planetary and Space Science, Vol. 59, pp. 312-318, 2011

©IJRASET (UGC Approved Journal): All Rights are Reserved

[11] M. R. Jana, A. Sen and P. K. Kaw, "Influence of grain charge-fluctuation dynamics on collective modes in a magnetized dusty plasma," Physica Scripta, Vol. 51, No. 3, pp. 385-389, 1995
[12] M. R. Jana, A. Sen, and P. K. Kaw, "Collective effects due to charge-fluctuation dynamics in a dusty plasma" Physical Review E, Vol. 48, No. 5, pp. 3930-3933, 1993.
[13] R. K. Varma, P. K.. Shukla and V. Krishan, "Electrostatic oscillations in the presence of grain-charge perturbations in dusty plasmas" Physical Review E, Vol. 47, No. 5, pp. 3612-3616, 1993
[14] Chunshi and J. Goree, "Fluctuations of the charge on a dust grain in a plasma" IEEE Transactions on Plasma Science, Vol. 22, No. 2, pp. -158, 1994
[15] P. K. Shukla, "Low-frequency modes in dusty plasmas" Physica Scripta, Vol. 45, No. 5, pp. 504-507, 1992.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)