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Radiation Characteristic of Waves Propagation in Weakly Coupled Dusty Plasma Medium

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Abstract: *With the advent of communication engineering the concept of wave propagation through plasma medium gives rise to tremendous area in the research field. Therefore, in the present paper attempt has made to study about the characteristics of wave propagation in weakly coupled dusty plasma medium. For this purpose both types of weakly coupled wave , the dust acoustic wave (DAW) and the dust ion acoustic wave DIAW) are considered. For the derivation of the DAW, the equation of continuity, the momentum equation and Poissions equation for the dust species are used .With the help of these equations the dispersion relation of the DAW is measured, which is found to be very close agreement with the damped DAW, although the system is strongly coupled.*

Keywords: *DAW, DIAW, MHD, Dispersion, Debye Length.*

1. INTRODUCTION

Recently for the strong revival of research and development, in the communication engineering, several practical applications of plasma physics have been carried out. To get the better implementation of plasma devices such as MHD generation, plasma propulsion, gas laser arc jets etc, it is necessary to more study about the wave propagation in different plasma media. Therefore, in the present paper attempt has been made to study about the characteristics of wave propagation in weakly coupled dusty plasma medium. For this purpose a d. c discharge is driven between the anode disk and the chamber of walls. The dust particles are accumulated from a dusty tray placed below the anode region. The dust is found to form dust density waves with a certain wavelength and frequency. When the dust acoustic waves have driven in a plasma crystal by a sinusoidal voltage, a wire closed to crystals, the propagation of the waves can be observed. Also the corresponding wavelength and damping length can be calculated. The details of entire investigation are given in different sections of this paper.

2. PROBLEM FORMULATION

Let us consider the n_{d0} is the equilibrium dust density and m_d is the mass of dust particles. If the dust acoustic wave is very low frequent wave with frequencies of the order of the dust plasma frequency ω_{pd}, which is given as [4-5].

$$\omega_{pd} = \left(\frac{Z_d^2 e^2 n_{d0}}{\in_0 m_d} \right)^{\frac{1}{2}} \quad (1)$$

Where $\in_0$ = permittivity of the medium
e = relative dust concentration
Z_d = dust charge

Since the dust mass is very high with compare to electrons, the dust plasma frequency ω_{pd} is much less than the ion plasma ω_{pi} and electron plasma (ω_{pe}) frequency, hence equation (1) can be written as:

$$\omega_{pd} = \left(\frac{Z_d^2 e^2 n_{d0}}{\in_0 m_d} \right)^{\frac{1}{2}} \ll \omega_{pi}\omega_{pe} \quad (2)$$

The DAW is driven by electrons and ions and the inertia is provided by the massive dust particles. Thus DAW is a complete analog to the ion acoustic wave. Hence dust particle taken the role of ions .Now to derive DAW equation, the equation of continuity, momentum equation and Poission's equation for dust particles are used, which are given as:

$$\frac{\partial n_d}{\partial t} + \frac{\partial}{\partial x}(n_d v_d) = 0 \quad (3)$$

$$\frac{\partial v_d}{\partial t} + v_d \frac{\partial v_d}{\partial x} + \gamma_d \frac{k_B T_d}{m_d n_d} \frac{\partial n_d}{\partial x} = \frac{Z_d e}{m_d} \frac{\partial \phi}{\partial x} - \beta_E v_d = 0 \quad (4)$$

And

$$\frac{\partial^2 \phi}{\partial x^2} = -\frac{e}{\in_0}(n_i - n_e - n_d Z_d) \quad (5)$$

It is clear from the above equations that the momentum includes the friction with the neutral gas and Poissions equation includes all three charged species electron, ions and dust. To get the further solution of the equations (3),

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(4) and (5), the electron and ion densities are considered as fluctuating quantities. Hence from the Boltzmann distribution law, one has

$$n_e = n_{e0} \exp\left(\frac{e\phi}{k_B T_e}\right) \tag{6}$$

And

$$n_1 = n_{i0} \exp\left(-\frac{e\phi}{k_B T_e}\right) \tag{7}$$

where n_{e0} and n_{i0} denotes the equilibrium values of the electron and ion density. The undisturbed densities are considered quasi neutral i.e. $n_{i0} = n_{e0} + z_d n_{d0}$.

Hence the dispersion relation of the dust acoustic wave is given as[6]

$$\omega^2 + i\beta_E\omega = \left\{\gamma_d \frac{k_B T_d}{m_d} + \in z_d^2 \frac{k_B T_d}{m_d} \frac{1}{\left[1+\frac{T_i}{T_e}(1-\in z_d q^2\lambda_{di}^2\right]}\right\} \tag{8}$$

Where q is the wave number and $\in = \frac{n_{d0}}{n_{i0}}$ = relative dust density.

For cold dust $T_d = 0$ and cold ion $T_i << T_e$

Hence the dispersion relation for dust acoustic wave can be simplified to:

$$\omega^2 + i\beta_E\omega = \frac{\omega_{pd}^2 q^2 \lambda_{di}^2}{1+q^2\lambda_{di}^2} \tag{9}$$

Where β_E = Friction coefficient, λ_{di} = ion debye length and ω = wave frequency having real values only. The wave vector is treated as complex value such as:

$q = q_r + iq_i$ with $q_r = \frac{2\pi}{\lambda}$ and $q_1 = \frac{1}{L}$ (L = damping length of the system)

Now it is noticed that the dispersion relation for DAW, in case of large wave number ($q^2\lambda_{di}^2 >> 1$), is not acoustic because the wave is not propagating and oscillating at the dust plasma frequency ω_{pd}. Only for small wave number ($q^2\lambda_{di}^2 << 1$) the wave is acoustic.

$$w = qc_{DAW} \text{ with } c_{DAW} = \left(\frac{k_B T_i}{m_d} \in z_d^2\right)^{\frac{1}{2}} \tag{10}$$

On the other hand incase of dust ion acoustic wave, the dust particles are considered immobile, since the wave frequencies are of the order of ion plasma frequency $\omega_{pi} >> \omega_{pd}$.

The influence of the dust particles, the free electron density is reduced due to attachment of some electrons to the dust particles. Hence the dispersion relation for DIAW can be written as:

$$\omega^2 = \frac{\omega_{pi}^2 q^2 \lambda_{de}^2}{1+q^2\lambda_{de}^2} = \frac{n_{i0}}{n_{e0}} \frac{k_B T_e}{m_i} \frac{q^2}{q^2\lambda_{de}^2} \tag{11}$$

hence with increase dust charge density or reduced the electron density, the speed of the DIAW will be increases.

3. PROBLEM SOLUTION

In order to study the behavior of wave propagation in weakly coupled dust plasma the computational works were done using equations (8), (9) and (11) respectively for $\beta_E = 0.1\ \omega_{pd}$ and $0.5\ \omega_{pd}$, $\frac{\omega}{\omega_{pd}}$ = 0.0.2, 0.4, 0.6, 0.8, 1.0 and $q\lambda_d$ = 0, 0.5, 1.0, 1.5, 2.0, 2.5. The data thus obtain are plotted in the form of graphs Figs 1, 2, 3 and 4.

4. CONCLUSION AND FUTURE WORK

The examination of behavior of waves in weakly coupled dusty plasma reveals that the wave motion is influenced by friction DAW dispersion (Figure 1), for small values of β_E, the real part of wave vector behaves, similarly to the case of damping and close to $\omega = \omega_{pd}$, the wave vector turns over and decreases dramatically towards zero.

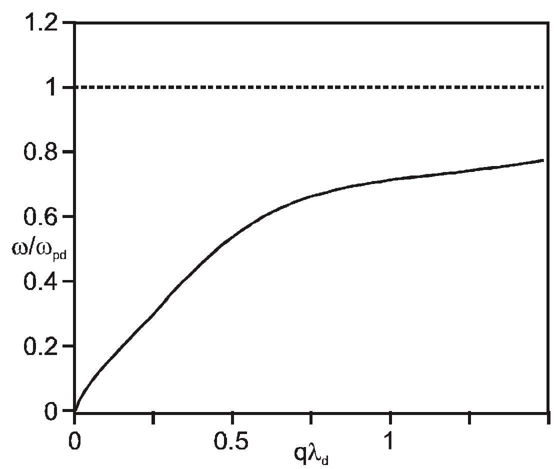

Figure 1: Dispersion Relation of the Dust Acoustic Wave without Damping

In this range, the imaginary part of the wave vector jumps from the lower values. From Figures 2 and 3, it is found that in case of large friction constant β_E, the wave speed $\frac{\omega}{q}$ increases and no. of wave vector is decreases. Moreover the real and imaginary part of the wave vector are strongly damped over the entire range. It is also observed that wave speed is directly proportional to the temperature of higher species (ion) Ti and inversely proportional to the mass of dust particles.

From Figure (4), it is also corroborated with fact that with increasing dust charge density and reducing electron density the speed of DIAW will increase in comparison to the pure acoustic wave. It may therefore be concluded that dispersion relation has close agreement with damped DAW.

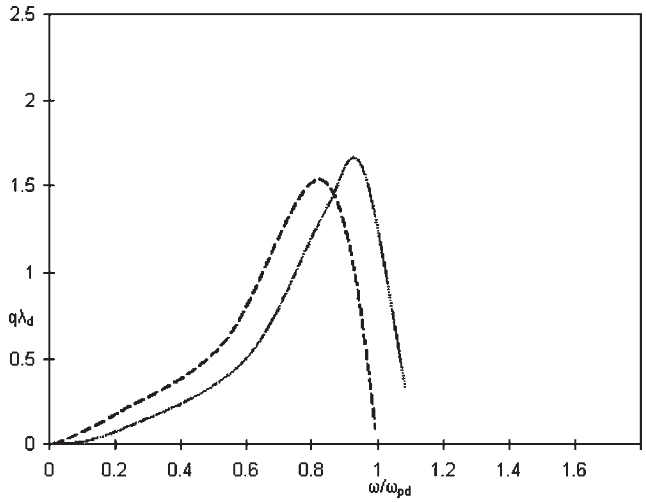

Figure 2: Dispersion Relation with Small Friction Coefficient $\beta_E = 0.1\ \beta_{pd}$

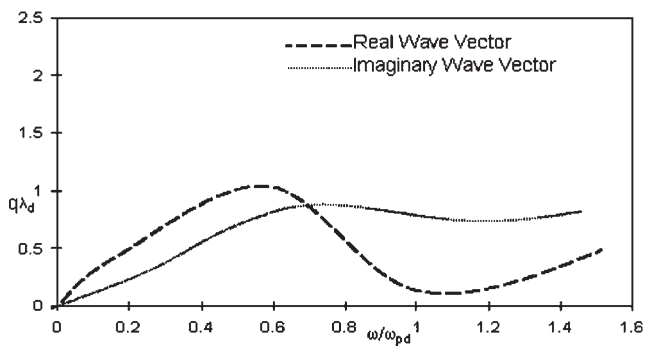

Figure 3: Dispersion Relation with High Friction Coefficient $\beta_E = 0.5\omega_{pd}$

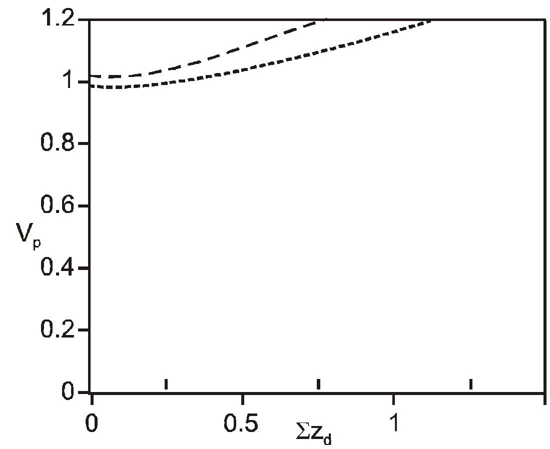

Figure 4: Variation of Phase Velocity V_p with Increasing Dust Charge Density $\sum z_d$

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