ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Growth Rate of Helicon Wave in Ferroelectric Semiconducting Plasmas

Moolchandra Rajpoot*, Sanjay Dixit,**

Post Graduate Department of Physics, Govt Motilal Vigyan Mahavidayalaya Bhopal (Madhya Pradesh)-462008 India

Manuscript Info

Manuscript History:

Received: 15 September 2015
Final Accepted: 22 October 2015
Published Online: November 2015

Key words:

HDM (Hydrodynamic Model), CMT (Coupled Mode Theory), SDDC (Strain Dependent Dielectric Constant) and HW (Helicon Wave) etc.

****Corresponding Author***

Moolchandra Rajpoot

Abstract

A detailed analytical investigation is made of the growth rate of helicon wave in ferroelectric semiconducting plasma in ferroelectric material with strain dependent dielectric constant. A geometrical configuration is made of decay of a high power helicon wave and an acoustic wave in magnetized ferroelectric semiconducting material. The Growth rate of Helicon waves in ferroelectric semiconducting plasma obtain by using a hydrodynamic model of semiconducting plasmas and coupled mode theory of waves. It is found that the Growth rate of helicon waves in ferroelectric semiconductor crystal is appreciably high.

The dispersion relation is obtained by using hydrodynamic model of homogeneous, ferroelectric one-component electron semiconducting plasma and the threshold value of pump electric field and the growth rate of unstable mode is calculated. The growth rate analysis have been applied to $BaTiO_3$ semiconducting crystal at 77K dully irradiated by a high power helicon wave for numerical estimation. The laser wave intensities are used in the range of $10^{12} to\ 10^{14} Wm^{-2}$ is assumed that the damage threshold is less in BaTiO3 crystal. The Growth rate is found to be of the order of $10^{14} s^{-1}$.

INTRODUCTION

The study of the Growth rate of Helicon Waves in piezoelectric semiconducting plasmas have been studied by many scientists [1-3]. Nonlinear interactios in piezoelectric materials are one of the most active fields in solid state plasmas because of its vast potentialities in semiconductor diagnostics. The application of an alternating electric field will introduce significant modifications of the transverse phonon-helicon wave interactions. Recently some investigations of this type have been carried out. Hsieh [4] has shown that the Helicon wave can be amplified in a heavily doped $BaTiO_3$ crystal subjected to parallel static electric and magnetic fields because of the relatively strong electro-mechanical coupling in a piezoelectric semiconductor crystal, Genkin [5] has analyzed the nonlinear electromagnet-acoustic effect manifested by the appearance of a nonlinear polarization in a subjected simultaneously to an external electro-magnetic field and an acoustic wave. An infinite number of new resonances due to the interaction between transverse acoustic waves and helicons in the presence of a strong high-frequency electric field have been studied by Pavlovich and Epshtein [6]. They have inferred that at these resonances (i.e. when Ω and k of acoustic waves are equal to that of helicons) instabilities can occur in the absence of a static electric field. Paverman and Tskhalkaya [7] have studied the parametric excitation of helicon waves in magneto-active plasma in the presence of a weakly modulated high-frequency electric field. The explosive instability in solid state plasma has been studied by Bulgakov et al. [8]. Ghosh and Agarwal [9, 10] have reported excitation of acoustic-helicon wave by parametric interaction in presence of a plane polarized laser beam in magneto-active piezoelectric semiconducting crystal plasmas. Recently, Lee [11] have studied the interaction of a right- hand circularly polarized high-frequency electromagnetic pump wave with an ions wave and a circularly polarized wave propagating parallel to the applied magnetic field in gaseous plasma and assumed the pump field to be weak and the collision frequency small.

The process of interaction between circularly polarized coherent transverse phonons and slow electro kinetic waves in the Centro symmetric crystal placed in a longitudinal magnetic field and possessing strong strain dependence of the dielectric constant caused by the electrostriction is considered. The cut-off system of equations for the process of nonlinear four-wave interaction in crystal with a quadratic electrostriction corresponding to direct energy conversion from helicon to acoustic wave is derived. The solution is sought for numerically in the vicinity of a synchronism point determined by the intersection of Helicon and phonon dispersion curves at different values of semiconductor plasma parameters. The results show the possibility of effective phonon parametric amplification in semiconductor crystal with the electro induced elastic anisotropy Lee [11]. The helicon waves are known to be used for measuring the magnitude of magnetic fields studied by Nishikawa [12], as their attenuation strongly depends on the cyclotron frequency value. The resonance nature of the phonon-helicon interaction considered in this paper offers some possibilities for measuring the magnetic fields by making use of the AW as a physical quantity, which is very sensitive to the magnitude of the cyclotron frequency.

2. THEORETICAL FORMULATION:

We have used the hydrodynamic model of homogenous one-component (electron) ferroelectric semiconducting plasma under the geometrical configuration. The time varying electric field amplitude E_0 of the pump wave produces an electrostrictive strain in the medium which is accompanied by an acoustic wave. This acoustic wave then modulates the space-charge density causing an energy exchange between the acoustic wave and the electromagnetic wave whose frequency is nearly equal to the acoustic frequency Ω and consequently, from the frequency matching condition ($\Omega_0 = \Omega_1 + \Omega$)one gets $\Omega_0 \approx 2\Omega$.

It's first order equation momentum transfer equations in which $v_0$and v are the oscillatory electron fluid velocities due to the electric field amplitudes of the pump and scattered waves, respectively. T is the electron temperature which we approximate to be equal to the lattice temperature, and k_B is the Boltzmann constant.

$$\frac{\partial n}{\partial t} + (v_0.\nabla)n + n_0(\nabla.v) = 0, \quad (1)$$

$$\frac{\partial E}{\partial z} = \frac{en}{\varepsilon_0} - \frac{\varepsilon_0 g E_0}{\varepsilon_0}\frac{\partial^2 u}{\partial z^2}, \quad (2)$$

Equation (2) is the passion equation incorporating the ferroelectric effect.

$$\nabla \times E = -\frac{\partial B}{\partial t}, \quad (3)$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}, \quad (4)$$

$$D = \varepsilon E + \varepsilon_0 g E_0 \frac{\partial u}{\partial z}. \quad (5)$$

Equations (3-5) are the Maxwell equations.These equations are appropriate for nondegenerate semiconductors. The other basic equations used in the present analysis are

$$\frac{\partial v_0}{\partial t} + (v_0.\nabla)v_0 + \nu v_0 = \frac{e}{m}(\mathrm{E}_0 + v_0 \times B_S + v_0 \times B_0), \quad (6)$$

This is zero order equation momentum transfer equations in which $v_0$and v are the oscillatory electron fluid velocities due to the electric field amplitudes of the pump and scattered waves, respectively.$B_0 = k_0 \times E_0/\Omega_0$ is the continuity equation in which n_0 and n are the unperturbed and perturbed electron densities, respectively.

$$\frac{\partial v}{\partial t} + (v_0.\nabla)v + \nu v = \frac{e}{m}(\mathrm{E} + v_0 \times B + v \times B_S) - \frac{k_B T}{m n_0}\nabla n, \quad (7)$$

We assume that the low-frequency perturbations are proportional to $exp[i(\Omega t - kz)]$. In equation (6, 7) we have assumed a scalar effective mass for electrons.

We considered that the acoustic wave generated internally is a pure shear wave propagating along the z-axis, which is the cubic axis (001) of the crystal. The lattice displacement u is then along x-and y-axes (transverse sound wave) which are the cubic axes (1I0) and (110), respectively, of the crystal. We have chosen a cubic ferroelectric semiconducting crystal belonging to class $\bar{4}$3m have only one SDDC, viz., $\varepsilon_0 g E_0$ and consequently, the equations of motion of the lattice become

$$\varrho \frac{\partial^2}{\partial t^2} = C\frac{\partial^2 u}{\partial z^2} + \varepsilon_0 g E_0 \frac{\partial E_x}{\partial z} \quad (8)$$

$$\varrho \frac{\partial^2}{\partial t^2} = C\frac{\partial^2 u}{\partial z^2} - \varepsilon_0 g E_0 \frac{\partial E_y}{\partial z} \quad (9)$$

Where ϱ the density of the crystal is, C is the appropriate elastic stiffness constant, and $\varepsilon_0 g E_0$ is the strain dependent dielectric constant.

The following procedure adopted by Guha et al. [13] and using equation (1-9) in the collisions dominated regime, $\nu \gg \Omega, k.\upsilon_0, k_0.\upsilon_0$, one obtains

$$\frac{\partial^2 n}{\partial t^2} + \nu\frac{\partial n}{\partial t} + k^2 \upsilon_{th}^2 n + \left[\frac{\mp\Omega_P^2\Omega_c\bar{\Omega}}{\Omega(\bar{\Omega}-i\nu \mp\Omega_c)} - \frac{\Omega_P^4\bar{\Omega}^2}{\Omega(k^2C_L^2-\Omega^2)(\bar{\Omega}-i\nu \mp\Omega_c)}\right] n + \left[\frac{n_0 e\varepsilon_0 g E_0}{m\varepsilon_0}\frac{k^2\Omega\bar{\Omega}}{k^2C_L^2 \pm\Omega^2}\right] u_\mp = i(k+k_0)\bar{E}_0 n, \qquad (10)$$

In which $\bar{E}_0 = \frac{e}{m}\frac{\bar{\Omega}_0}{\Omega_0}E_{0\pm} - \Omega_c \upsilon_{0\mp}$, $\bar{\Omega} = \Omega - k.\upsilon_0$, $\Omega_P = (n_0 e^2/m\varepsilon_0\varepsilon_L)^{1/2}$, is the electron plasma frequency, $\Omega_c = eB_S/m$ the electron cyclotron frequency, $C_L = (\mu_0\varepsilon_0\varepsilon_L)^{-1/2}$ the electromagnetic wave velocity in the crystalwith lattice dielectric constantε_L, $\upsilon_{th} = (k_B T/m)^{1/2}$ is the electron thermal velocity.

In obtaining equation (10) we have taken $u_\pm = u_x \pm iu_y, \upsilon_\pm = \upsilon_x \pm i\upsilon_y$, $B_\pm = B_x \pm iB_y$, and $E_\pm = E_x \pm iE_y$, where + and – signs correspond to the right and left hand circularly polarizations, respectively, and used the following equations:

$$\upsilon_\pm = -\left(\frac{ie\bar{\Omega}}{m\Omega}\right)(\bar{\Omega} - i\nu \mp \Omega_c)^{-1},$$

$$i\left(\frac{k^2}{\mu_0\Omega} - \varepsilon\Omega\right)E_\pm = n_0 e\upsilon_\pm - k\Omega\varepsilon_0 g E_0 u_\mp . \qquad (11)$$

Equation (10) is derived from equation (6, 11) is obtained from equation (3, 4). Physically, the high-frequency pump wave generates the low-frequency acoustic wave in the medium and they give rise to the high- and low-frequency components of the carrier density fluctuations (denoted by n_f and n_s) oscillating at frequencies $\Omega_1(= \Omega_0 \pm \Omega)$ and Ω of the generated electromagnetic and acoustic waves, respectively.

Remembering the above discussion, one gets from equation (5)

$$\frac{\partial^2 n_f}{\partial t^2} + \nu\frac{\partial n_f}{\partial t} + \Omega_R^2 n_f = i(k+k_0)\bar{E}_0 n_s, \qquad (12)$$

and

$$\left[\Omega_R^2 + i\Omega\nu + \frac{\Omega_P^4\bar{\Omega}^2}{\Omega(k^2C_L^2-\Omega^2)(\bar{\Omega}-i\nu\mp\Omega_c)} + \frac{\Omega_P^2\Omega\bar{\Omega}k^2C_t^2JK^2}{(k^2C_L^2-\Omega^2)(\Omega^2-k^2C_t^2-k^2C_t^2K^2)}\right] n_s = i(k+k_0)\bar{E}_0 n_f, \quad (13)$$

where$\Omega_R^2 = k^2\upsilon_{th}^2 + \frac{\Omega_P^2\bar{\Omega}}{\Omega}$, $C_t^2 = c/\varrho$ is the sound velocity in the lattice, $K^2 = \varepsilon_0^2 g^2 E_0^2/\varepsilon C$ is the dimensionless electromechanical coupling coefficientn_f have components at frequencies $\Omega_0 \pm \Omega$ higher-order components $\Omega_0 \pm n\Omega$ ($n > 1$) are negligible because they are non-resonant in contrast to $\Omega_0 \pm \Omega$ since $\Omega \ll \Omega_0 \approx \Omega_P$. Equation (12) can be written for two components of n_f as

$$n_f = i(k+k_0)\bar{E}_0 n_s\left[\left\{\Omega_R^2 - (\Omega_0+\Omega)^2 + i(\Omega_0+\Omega)\nu\right\}^{-1} + \left\{\Omega_R^2 - (\Omega_0-\Omega)^2 + i(\Omega_0-\Omega)\nu\right\}^{-1}\right].$$
(14)

Assuming $\Omega_0 \approx \Omega_R(\approx \Omega_P)$ and $\Omega \ll \Omega_0$, (14) becomes

$$n_f = -\frac{i(k+k_0)\bar{E}_0 n_s}{\Omega_R^2}\left[\frac{\Omega_R}{\Omega+\delta-i\nu} - \frac{\Omega_R}{\Omega-\delta-i\nu}\right], \qquad (15)$$

where $\delta = \Omega_0 - \Omega_R$.

Using (13) and (15), we get the dispersion relation as

$$\left(\Omega^2 - k^2C_t^2 - k^2C_t^2K^2\right)\left[k^2C_L^2 - \Omega^2 + \frac{\Omega_P^2\bar{\Omega}}{\bar{\Omega}-i\nu\pm\Omega_c} - \frac{2\delta(k+k_0)^2\bar{E}_0^2(k^2C_L^2-\Omega^2)}{\Omega_R^3\{(\Omega-i\nu)^2-\delta^2\}}\right] = \Omega^2k^2C_t^2k^2 \qquad (16)$$

Equation (16) shows that the two modes, i.e. acoustic and helicon, represented by first and second brackets of the left-hand side are coupled to each other via the ferroelectric property of the crystal. This general dispersion relation can be used to investigate the possibility of parametric conversion of high-power helicon laser wave into a frequency-shifted helicon wave and a generated acoustic wave in a dense ($\Omega_R \approx \Omega_0$), magnetoactive ($\Omega_c \approx \Omega_R$), cubic ferroelectric semiconducting plasma over wide range of the system parameters, with $\Omega < \nu$, and$\Omega > \nu$, provided that other assumptions mentioned in Section 1 are valid.

3. GROWTH RATE AND THRESHOLD FIELD:

In the slow wave limit, we take the quasi-state approximation ($k^2C_L^2 \gg \Omega^2$)and obtain the dispersion relation in simplified form given as

$$\left(\Omega^2 - k^2C_t^2\right)\left[k^2C_L^2 - \Omega^2 + \frac{\Omega_P^2\bar{\Omega}}{\bar{\Omega}-i\nu\pm\Omega_c}\right] = Ak^2C_L^2\left[1 - \frac{2\delta k^2\bar{E}_0^2}{\Omega_R^3(\nu^2+\delta^2)}\right], \qquad (17)$$

where $A = k^2C_t^2K^2$.From equation(17), in the absence of ferroelectric coupling coefficient $\varepsilon_0 g E_0 = 0$ ($K^0 = 0$),

$$\Omega^2 = k^2C_t^2, \qquad (18)$$

One obtains the usual equation for sound propagation in an elastic medium; and the usual equation for helicon mode.

$$k^2C_L^2 + \frac{\Omega_P^2\bar{\Omega}}{\bar{\Omega}-i\nu\pm\Omega_c} = 0, \qquad (19)$$

Equation (18) describes a damped sound mode, the damping arising due to coupling with electrons. Thus one can infer that the excitation of sound wave is possible only in the presence of the high-power oscillatory field. Hence, in order to study parametric excitation of the acoustic-helicon wave, we proceed with equation (16) where $\varepsilon_0 g E_0 \neq 0$ and $E_0 \neq 0$.
We now address ourselves to the principal point of this paper, the question of parametric excitation of the acousto-helicon wave in the presence of a high-power helicon field. The dispersion relation represented by e equation (17) is now solved for complex $\Omega(=\Omega_r + i\Omega_i)$ with real positive values of $\Omega_r \approx kC_t \, and \, \Omega_i \ll \Omega_z$ in agreement with Steele and Vural [2]. Thus separating the real and imaginary parts of equation (17) with only upper sing which is for the right-hand circularly polarised wave), one obtains

$$\Omega_r^2 - \Omega_i^2 - k^2 C_t^2 = A k^2 C_L^2 G \left[k^2 C_L^2 + \frac{\Omega_P^2 \bar{\Omega}(\bar{\Omega} \pm \Omega_c)}{(\bar{\Omega} \pm \Omega_c)^2 + \nu^2} \right]^{-1} \quad (20)$$

And $$2\Omega_r \Omega_i = -A k^2 C_L^2 G \left[\frac{\Omega_P^2 \bar{\Omega} \nu}{(\bar{\Omega} \pm \Omega_c)^2 + \nu^2} \right]^{-1} \quad (21)$$

in which $G = 1 - \frac{2\delta (k+k_0)^2 \bar{E}_0^2}{\Omega_R^3 (\nu^2 + \delta^2)}$

In the collision-dominated regime $\nu \gg \bar{\Omega}$ and at high magnetic field $\Omega_c > \nu$, one gets from (21)

$$\Omega_i = -\frac{K^2}{2\gamma} \frac{\Omega_c^2}{\Omega_P^2} \frac{k^2 C_L^2}{\nu} G, \quad (22)$$

in which $\gamma = 1 - (\upsilon_0 / C_t)$. Since υ_0, the oscillatory electron fluid velocity is much larger than C_t (υ_0 can be determined from equation (9) we always get, $\gamma < 0$. Hence, the mode can become unstable ($\Omega_i < 0$) only when $G < 0$. Now $G < 0$ can be achieved if $\delta > 0$, i.e.

$$\Omega_0 > \Omega_R \quad (23)$$

And

$$\left| \frac{2\delta (k+k_0)^2 \bar{E}_0^2}{\Omega_R^3 (\delta^2 + \nu^2)} \right| > 1. \quad (24)$$

Our next object is to obtain the threshold value of E_0 necessary for the onset of instability which can be obtained by equating Ω_i to zero in equation (22). For $\gamma \neq 0$, this can be fulfilled only when G=0 and consequently, one obtains the threshold electric field as

$$(E_{0x})_{th} = \left\{ \frac{m}{e(k+k_0)} \right\} \left\{ \frac{\Omega_0 - \Omega_c}{2\Omega_0 - \Omega_c} \right\} \left\{ \frac{\Omega_R^3 (\delta^2 + \nu^2)}{2\delta} \right\}^{1/2}. \quad (25)$$

For a value of E_0 greater than $(E_{0x})_{th}$ we obtain instability of the mode with a finite growth rate given by

$$|\Omega_i| = \frac{E^2}{\gamma} \frac{\Omega_c^2}{\Omega_P^2} \frac{k^2 C_L^2}{\nu} \frac{\delta (k+k_0)^2}{\Omega_R^3 (\delta^2 + \nu^2)} \left[\frac{e}{m} \left\{ 2 + \frac{\Omega_c}{(\Omega_0 - \Omega_c)} \right\} \right]^2 \quad (26)$$

4. RESULT AND DISCUSSION:

The analytical results obtained are applied to a semiconductor like $BaTiO_3$. The physical constants taken are m=0.014m_0, $\varepsilon_0 g E_0$ =0.054 cm^{-2}, $\varrho = 5.8 \times 10^3 \text{kgm}^{-3}, \varepsilon_L = 17.8, \nu = 3.5 \times 10^{11} s^{-1}$ [14]. The results are plotted in Fig.1 to 5. Fig.**1** shows the variation of growth rate $|\Omega_i|$ with electric field amplitude E_0. The growth rate increases as E_0 increases at $\Omega_c = 1.5 \times 10^{14} s^{-1}$ and $k = 2 \times 10^6 \text{m}^{-1}$. The nature of dependence of $|\Omega_i|$ as well as (E_{0th}) on wave number are plotted in Fig.**2** and Fig.3. where Fig.**2** shows the variation of threshold electric field amplitude with wave number k at $\Omega_c = 1.5 \times 10^{14} s^{-1}$ and $E_0 = 10^7 Vm^{-1}$. Fig.2 indicates that the threshold electric field decreases rapidly with increasing k and Fig.3 shows that as k increases, the growth rate also increases sharply. But we cannot go to a large k as our analysis is limited by the hydrodynamical approximation ($kl \ll 1$). For larger, one we should follow quantum-mechanical approach. Fig.4 deals with the relation between E_{0th} and Ω_c at $k = 2 \times 10^7 \text{m}^{-1}$ and Fig. 5 shows that the variation of $|\Omega_i|$ and Ω_c at $k = 2 \times 10^6 m^{-1}$and $E_0 = 1 \times 10^6 Vm^{-1}$. The nature of variation of E_{0th} and $|\Omega_i|$ with Ω_c is the same as that with k. The collision frequency ν increases the threshold electric field, as higher damping has to overcome in order to obtain the growth of the excited modes. Higher carrier concentration decreases the growth rate and enhances the threshold electric field amplitude. It is also possible to achieve lower threshold and higher growth rate by increasing the pump frequency. It is interesting to note the mass dependence of the threshold electric field amplitude and growth rate.
The electric field amplitude considered in the present investigation can be expressed in terms of the pump intensityI_0 by using the relation $I_0 = c_0 \varepsilon_0 \varepsilon_L |E_0|^2 / 2\eta$, where$\eta$ is the refracted index of the crystal (= 3.9 for $BaTiO_3$) and c_0 is the velocity of light in vacuum. The results reported in this paper are made for E_0 in the range of $10^7$to$2 \times 10^8 \text{m}^{-1}$, the corresponding range of I_0 using the above relation becomes $6.06 \times 10^9 to \ 2.42 \times 10^{12} Wm^{-2}$. Such value of the threshold field can be obtained by using a high-power helicon which is experimentally feasible [15]. At power intensities corresponding to the value of the pump amplitude necessary in studying the phenomenon of parametric

instability, laser damage of nonlinear crystal is troublesome [16] and was neglected by Ghosh [17] and Ghosh Sen P. K., and Guha S., [18] while studying Brillouin instability and parametric decay in n-BaTiO3 irradiated by a pulsed $10.6\ \mu m$ CO_2 laser with pumpamplitude$E_0 \approx 10^7 Vm^{-1}$. We have also assumed that the pump intensities employed here are well below the damage threshold of the crystal. On the other hand, the damage threshold can be increased by reducing the pulse duration [16, 18].

The results of this paper suggest that one can excite the growth rate of helicon wave in semiconducting plasmas where the parameters of the plasma can be varied over a wide range of values without much difficulty.

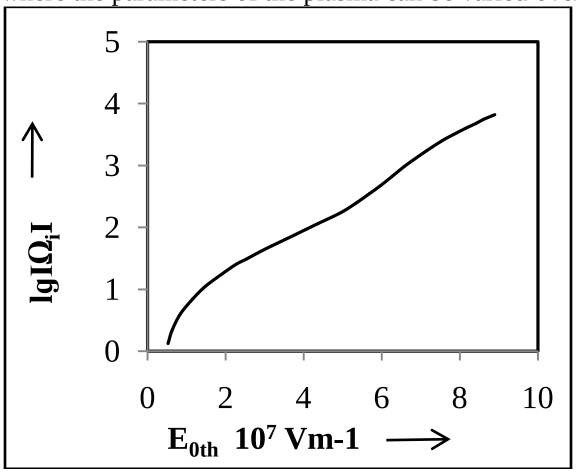

Fig.1: Shows that the Dependence of growth rate $|\Omega_i|$ of the Helicon wave at the pump electric field amplitude E_{0th} at k= $2x10^7$ m^{-1} and Ω_c= $1.5x10^{16}$ sec^{-1}.

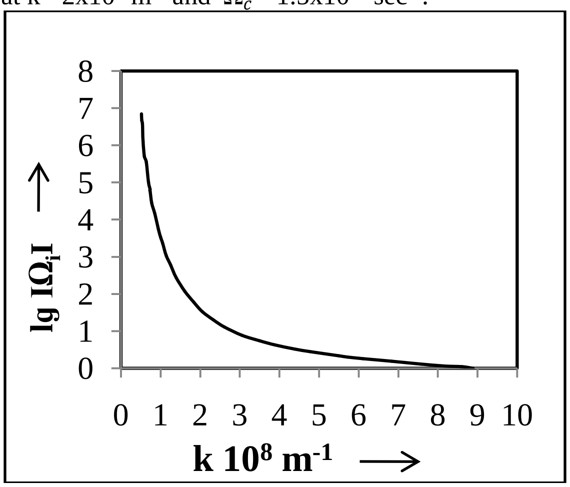

Fig.2: Shows that the Dependence of growth rate $|\Omega_i|$ the wave number k at Ω_c= $1.5x10^{16}$$sec^{-2}$and Variation of growth rate $|\Omega_i|$ with k at E_0 = 10^7 Vm^{-1} and Ω_c= $1.5x10^{16}$ sec^{-1}.

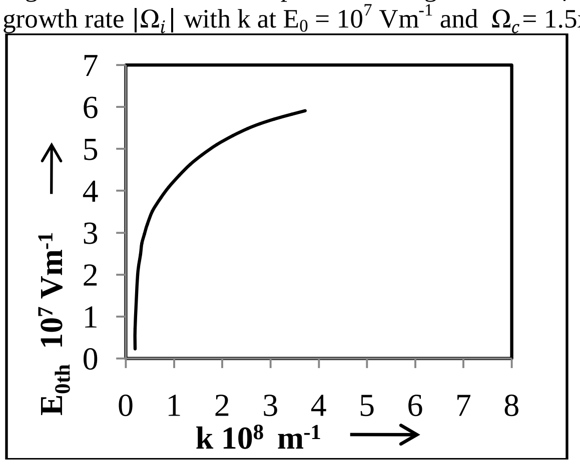

Fig.3: Shows the Dependence of threshold electric E_{0th} on the wave number k at $\Omega_c = 1.5x10^{16} sec^{-2}$ and Variation of growth rate $|\Omega_i|$ with k at $E_0 = 10^7$ Vm^{-1} and $\Omega_c = 1.5x10^{16}$ sec^{-1}.

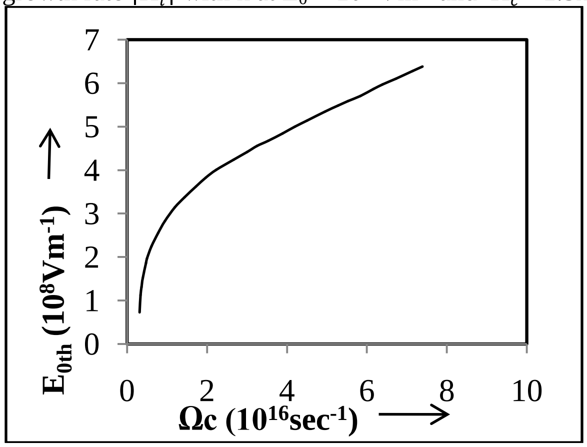

Fig.4: Shows that the Dependence of threshold electric amplitude E_{0th} Ω_c at k $2x10^8$ m^{-1} and Variation of growth rate $|\Omega_i|$ with Ω_c at $E_0 = 10^7$ Vm^{-1} and $k = 2x10^7 m^{-1}$.

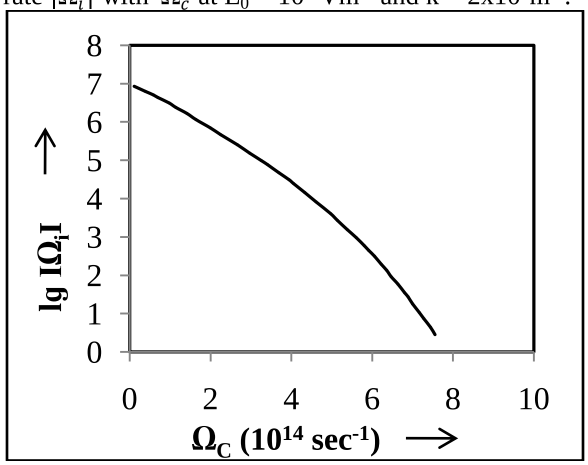

Fig.5: Shows that the Dependence of threshold electric amplitude E_{0th} Ω_c at k $2x10^8$ m^{-1} and Variation of growth rate $|\Omega_i|$ with Ω_c at $E_0 = 10^7$ Vm^{-1} and $k = 2x10^7 m^{-1}$.

ACKNOWLEDGEMENTS

The financial support from Madhya Pradesh Council of Science & Technology Madhya Pradesh Bhopal (India) under the research project entitled "A Study of Nonlinear Wave Interactions in Ferroelectric Material" is gratefully acknowledged. The authors are very much thankful to Principal Govt. Motilal Vigyan Mahavidayalaya, Bhopal (Madhya Pradesh)- 462008 (India).

REFERENCE:

[1] Dixit S., and Ghosh S., "Parametric decay of an electrostatic Pump wavein semiconducting plasmas" Acustica **P 56**(1984).

[2] Stele, M. C., and Vural, B., "Wave interactions in solid state plasma", McGraw Hill Publ. Co., New York **P. 154,** (1969).

[3] Ghosh S., and Dixit S., Phys. Stat. sol. (b) **121**, 661 (1984).

[4] H. C.Hsieh, J. app. Phys. **45**, 489 (1974).

[5] Genkin G. M., Soviet Phy.- Semicond. **7**,708 (1973).

[6] Pavlovich V. V., and Epshtien E. M., Soviet Phys.- Semicond.**7**, 246 (1973).

[7] Paverman V. S., and Tskhalkaya D. D., Soviet Phys. – Tech. Phys. **19**, 1929 (1975).

[8]Bulgakov, A. A.,Khakina S. I., and Yakcaenko V. M., Soviet Phys. Solid State **17**, 1747 (1976).

[9] Ghosh S., and Agarwal V. K., Phys. Stat. Sol. (b) **102,** K107 (1981).

[10] Ghosh S., and Agarwal V. K., Acustica **52,** 31 (1982).

[11] Lee K. F., Phys. Fluids **17,** 1343(1974).
[12] Nishikawa K., J. Phys. Soc. Japan **24,** 916 (1968).
[13] Guha S., Sen P. K., and Ghosh S., Phys. Stat. Sol. (a) **52**, 407 (1979).
[14] Dixit S., Ghosh S., and Phys. Stat. sol. (b) **127**, 245 (1985).
[15] Dixit S., Ghosh S., and Phys. Stat. sol. (b) **124**, 395 (1984).
[16] Ghosh S., and Dixit S., Phys. Stat. sol. (b) **130**, 260 (1985).
[17] Ghosh S., J. Appl. Phys. **52,** 4667 (1981).
[18] Ghosh S., Sen P. K., and Guha S., Physics Lett. **71A** 149 (1979). A