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RESEARCH ARTICLE

Comparision of Nonlinear Interactions in Piezoelectric and Ferroelectric Materials.

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Abstract

In the present work a comprehensive analytical investigation is made of the parametric decomposition of high-power helicon wave into another helicon and an acoustic wave in a longitudinally magnetized inhomogeous semiconducting plasmas for belonging to the class $4\bar{3}m$ and in $BaTiO_3$. The dispersion relation is obtained by using a hydrodynamic model of an homogeneous, piezoelectric, one-component (electron) semiconducting plasma. The threshold value of pump electric field and the growth rate of unstable mode well above the threshold are also discussed in the present study. This analysis is applied to a specific semiconductor, n-InSb at 77K and $BaTiO_3$ with strain dependent dielectric constant (SDDC). The laser wave intensities used are in the range of 10^9 to10^{12} Wm^{-2} which is assumed to be less than the damage threshold of the InSb crystal. The growth rate which is being found in this study is 10^{10} s^{-1}. In non liner wave propagation by the analyses of interaction depending on a particular physical situation is of great importance. It is a fact that the study of matter wave interaction provides a tremendous insight that is very much helpful to analyses the fundamental properties and characteristics of the medium.

Introduction:-

The analysis of Laser, the sources of high-intensity radiation in the micro-wave and infrared optical spectra range, has caused significant increase of both theoretical and experimental investigation of nonlinear interaction of high intensity electromagnetic field with matter. the work in parametric achievement of strong radiation on different direction media have been carried out first for gaseous plasmas in connection with the problem of plasma acceleration by radiation, Which needed to be solved on the way to the controlled thermonuclear fusion (1). It appears from the available literature that no logical attempt has been made so far to investigate the most suitable conditions to get maximum amplified acoustic flux in the solid medium using minimum external power. An important problem in nonlinear acoustics is amplification or attenuation of waves in piezoelectric semiconductors because of immediate relevance to problems of acoustic gain or loss. Of all the techniques, parametric interaction is powerful enough to treat these nonlinearities. Motivated by the intense report the results of the analytical investigations of parametric conversion of electromagnetic waves into an acoustic wave in magnetized piezoelectric semiconducting plasma, under a general configuration and discuss the possibilities of obtaining maximum growth of the unstable acoustic mode in the crystal. In piezoelectric semiconducting plasma, the presence of a time varying electric field produces time varying electrostrictive strain in the medium and thus drives an acoustic wave in it; consequently, the phenomenon of parametric conversion occurs due to the interaction of an electromagnetic wave with the generated acoustic wave in the medium. The present paper such an attempt by choosing a general configuration of the pump wave, propagation vector, and the magnretostatic field which covers the two important geometries, viz., the faraday and the Voigt ones as well. We have considered one component (electron) of cubic ferroelectric semiconducting plasma subjected to a large magnetostatic field $\mathbf{B_0}$ in xz plane making an arbitrary angle with respected to propagation vectors of scattered electromagnetic and general acoustic wave. Two theoretically model compare given explanation in methodology.

Methodology:-

We have focus our concentration towards the non-linear wave interaction in semiconductor plasma. The most systematically investigated of these interactions is the parametric instability so called for the reason that of an comparison with the parametric amplifiers. The consequent properties distinguish the parametric interactions.

(1) The impel and the energized oscillations have to persuade a wave vector (K) and frequency (Ω) selection rule described as

$\Omega_o = \Omega_s + \Omega_i$ and $K_0 = K_s + K_i$

The frequency and wave vector relations reproduce the energy and momentum conservation relations. The instability occurs only when the pump amplitude exceeds a certain critical threshold. The frequency of the amplified oscillations can be indomitable by pump frequency rather than by the natural frequency of the system. We will use the hydrodynamic model of non degenerating semiconductor plasma combining the equations of motions of the charged fluid with Maxwell's equations. We obtain the dispersion relation for unlike wave in terms of frequency (Ω) and wave vector (K). The electro kinetic branches of the dispersion relation are examined; the promulgation characteristics and the possibilities of instabilities are investigated in the present work.

Theoretical formulation for piezoelectric semiconductor plasma:-

Here we used the equation of Elasticity for describing the motion of lattice in SDDC crystal become

$$\varrho \frac{\partial^2 u}{\partial t^2} = C_{44} \frac{\partial^2 u}{\partial z^2} - e_{14} \frac{\partial E}{\partial z}, \quad (1)$$

$$\frac{\partial v_0}{\partial t} = \frac{e}{m}(E_0 + v_0 \times B_0) - \nu v_0, \quad (2)$$

$$\frac{\partial v_1}{\partial t} + (v_0.\nabla) v_1 = \frac{e}{m}(E_1 + v_1 \times B_0) - \nu v_1 - \frac{k_B T}{m n_0} \nabla . n_1, \quad (3)$$

$$\frac{\partial n_1}{\partial t} + (v_0.\nabla) n_1 + n_0(\nabla . v_1) = 0, \quad (4)$$

$$\nabla \times E_1 = -\frac{\partial B_1}{\partial t}, \quad (5)$$

$$\nabla \times H_1 = J_1 + \frac{\partial D_1}{\partial t}, \quad (6)$$

$$D_1 = \varepsilon E_1 + e_{14} \frac{\partial u}{\partial z}. \quad (7)$$

$$\nabla \times \nabla \times E_1 = -\mu_1 \frac{\partial J_1}{\partial t} - \frac{1}{C_L^2} \frac{\partial^2 E_1}{\partial t^2} - \mu_0 \frac{\partial^2}{\partial t^2}\left(e_{14} \frac{\partial u}{\partial z}\right), \quad (8)$$

Where the perturbed current density J_1 is given by

$$J_1 = e(n_0 v_1 + n_1 v_0). \quad (9)$$

Here, μ_0 is the absolute permeability, $C_L \left[= (\varepsilon_0 \varepsilon_L \mu_0)^{\frac{1}{2}}\right]$ is the velocity of the light inside the crystal having dielectric constant $\varepsilon_L, \varepsilon_0$ the permittivity of free space.

$$\Delta . E_1 = \frac{n_1 e}{\varepsilon} - \frac{e_{14}}{\varepsilon} \nabla^2 u; \quad (10)$$

And consequently, one finds

$$n_{1s} = \frac{\varepsilon}{e} \frac{\Omega^2 - k^2 C_t^2 - \frac{e_{14}^2}{\varrho \varepsilon}}{\Omega^2 - k^2 C_t^2} \nabla . E_1, \quad (11)$$

Where $C_t = \left(C_{44}/\varrho\right)^{\frac{1}{2}}$ is the transverse acoustic velocity in the crystal and $\varepsilon = \varepsilon_0 \varepsilon_L$. the fast component n_{1f} can be expressed in terms of n_{1s} by using (2)to (5)and (10) as

$$n_{1f} = -\left[\frac{2ik\delta \overline{E}}{\Omega_0(\nu^2 + \delta^2)}\right] n_{1s}, \quad (12)$$

In which $\delta = \Omega_0 - \overline{\Omega}_R, \overline{\Omega}_R^2 = \Omega_R^2 \left\{1 - \frac{\Omega_c^2}{\Omega_c^2 - \nu^2}\right\}, \Omega_R^2 = \Omega_p^2 + k^2 v_{th}^2, \Omega_p^2 = \frac{n_0 e^2}{m\varepsilon}, \quad v_{th}^2 = \frac{k_B T}{m},$

$\Omega_c = \frac{eB_0}{m}, \overline{E} = -\Omega_{cx} v_{0y}, \Omega_{cx} = \Omega_c \sin\theta.$

In deriving (12), we have restricted ourselves to the range $\overline{\Omega}_R \approx \Omega_0$ and followed the usual procedure (2). Using eqation (1) and assuming the proportionality of the pump as $exp(i\Omega_0 t)$, the components of v_0 are obtained as.

$$v_{0x} = \frac{\Omega_{cz} v_{0y}}{(i\Omega_0 + \nu).}, \quad (13)$$

$$v_{0y} = \frac{e}{m}\left[\frac{(i\Omega_0 + \nu)}{\{(i\Omega_0 + \nu)^2 + \Omega_c^2\}}\right] E_0, \quad (14)$$

$$v_{0z} = -\frac{\Omega_{cx} \Omega_{0y}}{(i\Omega_0 + \nu)}, \quad (15)$$

In which $\Omega_{cz} = \Omega_c \cos\theta$ and $\Omega_c^2 = \Omega_{cx}^2 + \Omega_{cz}^2$. similarly, the components of $v_1(= v_{1f} + v_{1s})$ are derived from eq.(3) and given by

$$v_{1x} = \frac{e}{m\{(\bar{\Omega} - iv)^2 - \Omega_c^2\}}\left[-i\frac{\{(\bar{\Omega}-iv)^2 - \Omega_{cx}^2\}}{(\bar{\Omega} - iv)}E_{1x} - \Omega_{cz}E_{1y} + \frac{i\Omega_{cx}\Omega_{cz}b}{(\bar{\Omega} - iv)}E_{1z} + \frac{\Omega_{cx}\Omega_{cz}}{(\bar{\Omega} - iv)}.\frac{k^3v_{th}^2}{\Omega_p^2}\frac{e_{14}}{\varepsilon}u\right], \quad (16)$$

$$v_{1y} = \frac{e}{m\{(\bar{\Omega}-iv)^2 - \Omega_c^2\}}.\left[\Omega_{cz}E_{1x} - i(\bar{\Omega} + iv)E_{1y} - \Omega_{cx}bE_{1z} + i\Omega_{cx}.\frac{k^3v_{th}^2}{\Omega_p^2}\frac{e_{14}}{\varepsilon}u\right] \quad (17)$$

and

$$v_{1z} = \frac{-e}{m\{(\bar{\Omega} - iv)^2 - \Omega_c^2\}}.\left[\frac{-i\Omega_{cx}\Omega_{cz}}{(\bar{\Omega} - iv)}E_{1x} - \Omega_{cx}E_{1y} + \frac{ib\{(\bar{\Omega} - iv)^2 - \Omega_{cz}^2\}}{(\bar{\Omega} - iv)}E_{1z} - \frac{i\{(\bar{\Omega} - iv)^2 - \overline{\Omega_{cz}^2}\}}{(\bar{\Omega} + iv)}\frac{k^3v_{th}^2}{\Omega_p^2}\frac{e_{14}}{\varepsilon}u\right], \quad (18)$$

Where $\bar{\Omega} = \Omega - k.v_0$, $b = 1 + \frac{k^2v_{th}^2}{\Omega_p^2}$. Using eqs. (6) and (7) one gets u in terms of $\mathbf{E_1}$ as

$$u = \frac{J_z}{k\Omega e_{14}} - \frac{i}{k\Omega e_{14}}\left[\frac{k_1^2}{\Omega_1\mu_0} - \varepsilon\Omega_1\right]E_{1x}. \quad (19)$$

One finds the components of $\mathbf{J}_1$ along the three axes by using eq. (9), (11) to (19) as:

$$J_{1x} = \frac{\varepsilon\Omega_p^2}{\{(\bar{\Omega} - iv)^2 - \Omega_c^2\}}\left[\frac{-i\{(\bar{\Omega} - iv)^2 - \Omega_{cx}^2\}}{(\bar{\Omega} - iv)}E_{1x} - \Omega_{cz}E_{1y} + \frac{i\Omega_{cx}\Omega_{cz}b}{(\bar{\Omega} - iv)}E_{1z}\right], \quad (20)$$

$$J_{1y} = \frac{-i\varepsilon\Omega_p^2}{(\bar{\Omega} - iv)^2 - \Omega_c^2}\left[i\Omega_{cz}E_{1x} + (\bar{\Omega} - iv)E_{1y} - i\Omega_{cx}bE_{1z}\right], \quad (21)$$

$$J_{1z} = \frac{-\varepsilon\Omega_p^2}{(1-Q)\{(\bar{\Omega} - iv)^2 - \Omega_c^2\}}\left[\frac{-i\Omega_{cx}\Omega_{cz}}{\bar{\Omega} - iv}E_{1x} - \Omega_{cx}E_{1y} + i\left\{\frac{b(\bar{\Omega}-iv)^2 - \Omega_{cz}^2}{\bar{\Omega} - iv} + \frac{Q(k_1^2C_L^2 - \Omega_1^2)}{\Omega_1\Omega_p^2}\left\{(\bar{\Omega} - iv)^2 - \Omega_c^2\right\}\right\}E_{1z}\right], \quad (22)$$

Where we have assumed $E_{1x} \gg \frac{\Omega_{cx}\Omega_{cz}}{(\bar{\Omega} - iv)}\frac{k^3v_{th}^2}{\Omega_p^2}\frac{e_{14}}{\varepsilon}u$, $E_{1y} \gg \Omega_{cx}\frac{k^3v_{th}^2}{\Omega_p^2}\frac{e_{14}}{\varepsilon}u$,

$E_{1z} \gg \frac{\{(\bar{\Omega}-iv)^2 - \Omega_{cz}^2\}}{(\bar{\Omega} + iv)}\frac{k^3v_{th}^2}{\Omega_p^2}\frac{e_{14}}{\varepsilon}u$, And $Q = \frac{v_{0z}\varrho\varepsilon}{k\Omega e_{14}}\left\{\Omega^2 - k^2c_t^2 - \frac{e_{14}^2k^2}{\varrho\varepsilon}\right\}.\left\{1 - \frac{2i\delta k\bar{E}}{\Omega_0(v^2+\delta^2)}\right\}$.

From (8) the wave equation for the parametrically excited waves with frequency $\Omega_1(\approx \Omega_0 \; as \; \Omega \ll \Omega_0)$ and wave number $k_1(\approx k)$ is obtained by assuming the space and time dependence as $exp[i(\Omega_1 t - k_1 z)]$,

$$ik_1^2E_{1x} + jk_1^2E_{1y} + i\Omega_1\mu_0J_1 - \frac{\Omega_1^2}{C_L^2}E_1 = -\mu_0\frac{\partial^2}{\partial t^2}\left(e_{14}\frac{\partial u}{\partial z}\right), \quad (23)$$

Where **i** and **j** denote the unit wave vectors along x- and y-axes.

The general dispersion relation for the parametric conversion can now be obtained by substituting the components of $\mathbf{J}_1$ from eqation (20) to (22) in the wave equation (23). After some algebraic simplification, one gets

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = 0 \quad (24)$$

Where $a_{11} = k^2C_L^2 - \Omega_1^2 + \frac{\Omega_1\Omega_p^2\{(\bar{\Omega}-iv)^2 - \Omega_{cx}^2\}}{(\bar{\Omega}-iv)\{(\bar{\Omega}-iv)^2 - \Omega_c^2\}}$, $a_{12} = \frac{-i\Omega_1\Omega_p^2\Omega_{cz}}{\{(\bar{\Omega}-iv)^2 - \Omega_c^2\}} = -a_{21}$,

$a_{13} = \frac{-\Omega_1\Omega_p^2\Omega_{cx}\Omega_{cz}b}{(\bar{\Omega}-iv)\{(\bar{\Omega}-iv)^2 - \Omega_c^2\}}$, $a_{22} = k_1^2C_L^2 - \Omega_1^2 + \frac{\Omega_1\Omega_p^2(\bar{\Omega}-iv)}{(\bar{\Omega}-iv)^2 - \Omega_c^2}$, $a_{23} = \frac{-i\Omega_1\Omega_p^2\Omega_{cx}b}{\{(\bar{\Omega}-iv)^2 - \Omega_c^2\}}$,

$a_{31} = \frac{-\Omega_1\Omega_p^2\Omega_{cx}\Omega_{cz}}{(1-Q)(\bar{\Omega} - iv)\{(\bar{\Omega}-iv)^2 - \Omega_c^2\}}$, $a_{32} = \frac{i\Omega_1\Omega_p^2\Omega_{cz}}{(1-Q)\{(\bar{\Omega}-iv)^2 - \Omega_c^2\}}$, and

$$a_{33} = \frac{\Omega_1\Omega_p^2b\{(\bar{\Omega}-iv)^2 - \Omega_{cz}^2\}}{(1-Q)(\bar{\Omega} - iv)\{(\bar{\Omega}-iv)^2 - \Omega_c^2\}} + \frac{Q(k_1^2C_L^2 - \Omega_1^2)}{(1-Q)} - \Omega_1^2\left[1 - \frac{\mu_0k_1^2C_L^2e_{14}^2}{(\Omega^2 - k^2C_t^2)}\right] \quad (25)$$

Eq.(24)shows that the three modes represented by $a_{11} = 0$, $a_{22} = 0$ and $a_{33} = 0$ are coupled to each other via the finite magneto static field B_0.

Isotropic Semiconducting Plasma:-

$$(\Omega^2 - k^2C_t^2)[-\Omega_1(\bar{\Omega} - iv) + \Omega_R^2] = -\bar{\Omega}_1D(\bar{\Omega} - iv) \quad (26)$$

in which $D = k^2C_L^2\mu_0e_{14}^2/\varrho$,

Magnetoactive semiconducting plasma:

Faraday geometry:-

$(\boldsymbol{k}, \boldsymbol{k_1} \parallel \boldsymbol{B_0} \perp \boldsymbol{E_0})$

For this case, we get the dispersion relation (24) as

$$a_{33}(a_{11}a_{22} - a_{21}a_{12}) = 0 \quad (27)$$

From (26) one can infer that $a_{33} = 0$ yields results similar to those obtained for isotropic semiconducting plasma, which are non interesting. However, the equation $a_{11}a_{22} - a_{21}a_{12} = 0$ corresponds to two transverse electromagnetic waves in a system consisting of electron plasma and acoustic phonon and coupled to each other through a finite magnetostatic field.

Voigt geometry $\boldsymbol{k, k_1 \perp B_0 \perp E_0}$:- when a large magnetostatic field is applied such that $k, k_1 \perp B_0 \perp E_0$, (24) yields

$$a_{11}(a_{22}a_{33} - a_{23}a_{32}) = 0 \tag{28}$$

$a_{11} = 0$ represents a transverse electromagnetic wave propagating in a semiconducting plasma while the term inside the bracket, when equated to zero, refer to the parametric coupling of a high- frequency electromagnetic pump wave to a scattered electromagnetic wave and a produced acoustic wave in a system comprising the electron plasma.

Thus $a_{22}a_{33} = a_{23}a_{32}$ gives

$$\left[k_1^2 C_L^2 - \Omega_1^2 + \frac{\Omega_1 \Omega_p^2(\overline{\Omega} - i\nu)}{(\overline{\Omega} - i\nu)^2 - \Omega_c^2}\right]\left[-\Omega_1^2\left\{1 - \frac{\mu_0 k^2 C_L^2 e_{14}^2}{\varrho(\Omega^2 - k^2 C_t^2)}\right\} + \frac{Q(k_1^2 C_L^2 - \Omega_1^2)}{(1-Q)} + \frac{\Omega_1 \Omega_R^2(\overline{\Omega} - i\nu)}{(1-Q)\left\{(\overline{\Omega} - i\nu)^2 - \Omega_c^2\right\}}\right] = \frac{\Omega_1^2 \Omega_P^2 \Omega_R^2 \Omega_c^2}{(1-Q)\left\{(\overline{\Omega} - i\nu)^2 - \Omega_c^2\right\}^2}, \tag{29}$$

Where Ω_c stands for Ω_{cx}.

Equation (28) can be further simplified by assuming $k_1^2 C_L^2 \approx \Omega_1^2$, $\Omega_r > kv_0$, and $\Omega_i \ll \nu(where\, \Omega = \Omega_r + i\Omega_i)$,whence we get

$$(\Omega^2 - k^2 C_t^2)[\Omega_R^2 - \Omega_1(1-Q)(\Omega_r - i\nu)] = -\Omega_1 D(1-Q)(\Omega_r - i\nu), \tag{30}$$

It can observe from above equation that the acoustic and the electromagnetic modes are coupled via the piezoelectric properties of the crystal. To explore the possibility of instability, we solve (29) for complex $\Omega(= \Omega_r + i\Omega_i)$ with real positive values of the wave number k such that $\Omega_r = kC_t$, $\Omega_i \ll \Omega_r$ and we assume $\Omega_r \gg k.v_0$. Equating the imaginary parts of (29), one can have

$$\Omega_i = \frac{(1-Q)\Omega_1 D\nu}{2\Omega_r(\Omega_R^2 - \Omega_1\Omega_r)}, \tag{31}$$

In obtaining (30) we have neglected 1 in comparison with Q in the right- hand side of (29). The threshold value of the electric field amplitude of the pump under Voigt geometry is obtained by making $\Omega_i = 0$ in (30), which yields Q = 1.

Thus one gets

$$(E_{0th}) = \frac{m}{e\Omega_c}[\Omega_0^2 - (\nu^2 + \Omega_c^2)]\left(\frac{v_s C_t}{k}\right)^{\frac{1}{2}}, \tag{32}$$

The subscript V stand for the parameters under Voigt configuration. In obtaining (31) we have assumed $\Omega_0(\approx \Omega_c) \gg \nu$. It can now be noticed from (30) that the condition of instability ($\Omega_i < 0$) become Q >1 when $\Omega_R^2 > \Omega_1\Omega_r$ and the condition is reversed (i.e. Q < 1) when $\Omega_R^2 < \Omega_1\Omega_r$. But in the second case the precondition ($E_0 \neq 0$) for parametric interaction is violated. Thus to get parametric interaction we have to adjust the carrier concentration to achieve the condition $\Omega_R^2 > \Omega_1\Omega_r$, which gives a threshold value of carrier concentration as

$$n_{0th} = \frac{m\varepsilon_0\varepsilon_L}{e^2}(\Omega_1\Omega_r - k^2 v_{th}^2), \tag{33}$$

Thus the growth rate of the produced acoustic wave well above the threshold pump amplitude in a piezoelectric semiconducting plasma under Voigt geometry is obtained as

$$|\Omega_i|_\nu = \left(\frac{e}{m}\right)^2 \frac{\Omega_c^2 \Omega_1 k^2 C_L^2 \mu_0 e_{14}^2}{2\varrho C_t^2(\Omega_R^2 - \Omega_1\Omega_r)\{\Omega_0^2 - (\nu^2 + \Omega_c^2)\}^2} E_0^2, \tag{34}$$

Where it is presumed that at such an electric field amplitude of the pump Q >1 and $\Omega_R^2 > \Omega_1\Omega_r$. One can conclude that in Voigt configuration, the growth rate well above the threshold is finite only when $B_0 \neq 0$ and $E_0 \neq 0$ because the term $(v_0 \times B_0)_z$ leading to nonlinear coupling of the three interacting waves is finite only when $B_0 \neq 0$ and $B_0 \neq 0$.

General geometry:-

When the magnetostatic field B_0 is applied at an arbitrary angle θ such that $0^0 < \theta < 90^0$, one gets the most general dispersion relation from (24), after some mathematical simplification, as

$$(\Omega^2 - k^2 C_t^2)[\Omega_R^2\{(\Omega_r^2 - \Omega_c^2)^2 - 2\Omega_{cx}^2\Omega_{cz}^2\} - \Omega_1(1-Q)(\Omega_r - i\nu)(\Omega_r^2 - \Omega_c^2)^2] = -(1-Q)D\Omega_1(\Omega_r - i\nu)(\Omega_r^2 - \Omega_c^2)^2, \tag{35}$$

Where it is presumed that $k^2 C_L^2 \approx \Omega_1^2$, $\Omega_i \ll \nu$ and $\Omega_r > k.v_0$. a solution of (34) complex $\Omega(= \Omega_r + i\Omega_i)$, With real positive values of k by assuming $\Omega_r > k.C_t$ and $\Omega_r \gg \Omega_i$ yield the following expression for the growth rate Ω_i:

$$(\Omega_i)_G = [(1-Q)\Omega_1 D\nu(\Omega_r^2 - \Omega_c^2)^2] \times \left[2\Omega_r[\Omega_R^2\{(\Omega_r^2 - \Omega_c^2)^2 - 2\Omega_{cx}^2\Omega_{cz}^2\} - \Omega_1\Omega_r(\Omega_r^2 - \Omega_c^2)^2]\right]^{-1} \tag{36}$$

where subscript G stands for parameters under common geometry. $\Omega_i < 0$, have been measured as solutions in place of the unstable acoustic mode propagating with a phase velocity $\upsilon_p (= \Omega_r/k)$ and a growth rate $|\Omega_i|$. The threshold ($\Omega_i = 0$) electric field amplitude obligatory for the onset of parametric excitation of acoustic mode is obtained from (35) by putting Q = 1, as

$$(E_{0th})_G = \frac{m}{e}\frac{\Omega_0^2-(\nu^2-\Omega_c^2)}{\Omega_{cx}}\left(\frac{\nu C_t}{k}\right)^{\frac{1}{2}}, \tag{37}$$

The growth rate well above the threshold is obtained as

$$|\Omega_i|_G = \left(\frac{e}{m}\right)^2 [\Omega_1\Omega_{cx}^2 k^2 C_L^2 \mu_0 e_{14}^2(\Omega_r^2 - \Omega_c^2)E_0^2] \times \left[2C_t^2 \varrho\{(\Omega_0^2 - \Omega_c^2 + \nu^2)\}^2[\Omega_R^2\{(\Omega_r^2 - \Omega_c^2)^2 - 2\Omega_{cx}^2\Omega_{cz}^2\} - \Omega_1\Omega_r(\Omega_r^2 - \Omega_c^2)^2]\right]^{-1}. \tag{38}$$

In obtaining wq. (37) we have assumed that $Q > 1$,

$\Omega_R^2[(\Omega_r^2 - \Omega_c^2)^2 - 2\Omega_{cx}^2\Omega_{cz}^2] > \Omega_1\Omega_r(\Omega_r^2 - \Omega_c^2)^2$,

which gives the threshold value of the carrier concentration as-

$$n_{0th} = \frac{m\varepsilon_0\varepsilon_L}{e^2}\left[\frac{\Omega_1\Omega_r}{1-\left\{2\Omega_{cx}^2\Omega_{cz}^2/(\Omega_r^2-\Omega_c^2)^2\right\}} - k^2\upsilon_{th}^2\right], \tag{39}$$

It can be inferred from (32) and (38) that in the general geometry the threshold value of carrier concentration is larger than that in the voigt geometry.

Theoretical formulation for strain dependent dielectric constant:-

Using earlier theory to developed these hypothesis important changes. The equation of Elasticity theory recitation the motion of lattice in SDDC crystal become

$$\varrho\frac{\partial^2 u}{\partial t^2} = C\frac{\partial^2 u}{\partial z^2} - \varepsilon_0 g E_0\frac{\partial E}{\partial z},$$

$$D_1 = \varepsilon_0 E + \varepsilon_0 g s E,$$

$$\nabla\times\nabla\times E_1 = -\mu_0\frac{\partial J_1}{\partial t} = \frac{1}{C_L^2}\frac{\partial^2 E_1}{\partial t^2} - \mu_0\frac{\partial^2(\varepsilon_0 g s E)}{\partial t^2}\frac{\partial u}{\partial z}$$

$$J_1 = e(n_0\upsilon_1 + n_1\upsilon_0).$$

$$\nabla.E_1 = \frac{en_1}{\varepsilon_0} - \frac{\varepsilon_0 g E_0}{\varepsilon_0}\nabla^2,$$

$$n_1 = \frac{\varepsilon_0}{e}\left[\frac{\Omega^2 - k^2\upsilon_s^2 - \frac{\varepsilon_0^2 g^2 E^2}{\varrho\varepsilon_0}k^2}{\Omega^2 - k^2\upsilon_s^2}\right]\nabla.E_1, \text{ and}$$

$$n_{1f} = -\left[\frac{2ik\delta\bar{E}}{\Omega_0(\nu^2+\delta^2)}\right]n_{1f}$$

In which $\Omega_{cz} = \Omega_c\sin\theta$ and $\Omega_c^2 = \Omega_{cx}^2 + \Omega_{cz}^2$. similarly, the components of $\upsilon_1 (= \upsilon_{1f} + \upsilon_{1s})$ are derived from eq. and given by

$$\upsilon_{1x} = \frac{e}{m\left\{(\bar{\Omega}-i\nu)^2-\Omega_c^2\right\}}\left[-i\frac{\left\{(\bar{\Omega}-i\nu)^2-\Omega_{cx}^2\right\}}{(\bar{\Omega}+i\nu)}E_{1x} - \Omega_{cz}E_{1y} + \frac{i\Omega_{cx}\Omega_{cz}b}{(\bar{\Omega}+i\nu)}E_{1z} + \frac{\Omega_{cx}\Omega_{cz}}{(\bar{\Omega}+i\nu)}.\frac{k^3\upsilon_{th}^2}{\Omega_p^2}\frac{\varepsilon_0 g E_0}{\varepsilon_0}u\right]$$

$$\upsilon_{1y} = \frac{e}{m\left\{(\bar{\Omega}-i\nu)^2-\Omega_c^2\right\}}.\left[\Omega_{cz}E_{1x} - i(\bar{\Omega}+i\nu)E_{1y} - \Omega_{cx}bE_{1z} + i\Omega_{cx}.\frac{k^3\upsilon_{th}^2}{\Omega_p^2}\frac{\varepsilon_0 g E_0}{\varepsilon_0}u\right], \text{and}$$

$$\upsilon_{1z} = \frac{-e}{m\left\{(\bar{\Omega}-i\nu)^2-\Omega_c^2\right\}}.\left[\frac{-i\Omega_{cz}\Omega_{cx}}{(\bar{\Omega}+i\nu)}E_{1x} - \Omega_{cx}E_{1y} + \frac{ib\left\{(\bar{\Omega}-i\nu)^2-\Omega_{cz}^2\right\}}{(\bar{\Omega}+i\nu)}E_{1z} - \frac{i\left\{(\bar{\Omega}-i\nu)^2-\Omega_{cz}^2\right\}}{(\bar{\Omega}+i\nu)}\frac{k^3\upsilon_{th}^2}{\Omega_p^2}\frac{\varepsilon_0 g E_0}{\varepsilon_0}u\right],$$

$$u = \frac{J_z}{k\Omega\varepsilon_0 g E_0} - \frac{i}{k\Omega\varepsilon_0 E_0}\left[\frac{k_1^2}{\Omega_1\mu_0} - \varepsilon_0\Omega_1\right]E_{1x}$$

$$J_{1x} = \frac{\varepsilon_0\Omega_p^2}{\left\{(\bar{\Omega}-i\nu)^2-\Omega_c^2\right\}}.\left[\frac{-i\left\{(\bar{\Omega}-i\nu)^2-\Omega_{cx}^2\right\}}{(\bar{\Omega}-i\nu)}E_{1x} - \Omega_{cz}E_{1y} + \frac{i\Omega_{cx}\Omega_{cz}b}{(\bar{\Omega}-i\nu)}E_{1z}\right], \tag{20}$$

$$J_{1y} = \frac{-i\varepsilon_0\Omega_p^2}{\left\{(\bar{\Omega}-i\nu)^2-\Omega_c^2\right\}}.\left[i\Omega_{cz}E_{1x} + (\bar{\Omega}-i\nu)E_{1y} - i\Omega_{cx}bE_{1z}\right], \tag{21}$$

and

$$J_{1z} = \frac{-\varepsilon_0\Omega_p^2}{(1-Q)\left\{(\bar{\Omega}-i\nu)^2-\Omega_c^2\right\}}.\left[\frac{-i\Omega_{cx}\Omega_{cz}}{(\bar{\Omega}-i\nu)}E_{1x} - \Omega_{cx}E_{1y} + \frac{i\left\{b(\bar{\Omega}-i\nu)^2-\Omega_{cz}^2\right\}}{(\bar{\Omega}+i\nu)}E_{1z} + \frac{Q(k_1^2C_L^2-\Omega_1^2)\left\{(\bar{\Omega}-i\nu)^2-\Omega_{cz}^2\right\}}{\Omega_1\Omega_p^2}E_{1z}\right], \tag{22}$$

Where we have assumed that

$$E_{1x} \gg \frac{\Omega_{cx}\Omega_{cz}}{(\bar{\Omega}-i\nu)}\frac{k^3\upsilon_{th}^2}{\Omega_p^2}\frac{\varepsilon_0 g E_0}{\varepsilon_0}u,\ E_{1y} \gg \Omega_{cx}\frac{k^3\upsilon_{th}^2}{\Omega_p^2}\frac{\varepsilon_0 g E_0}{\varepsilon_0}u,\ E_{1z} \gg \frac{\left\{(\bar{\Omega}-i\nu)^2-\Omega_{cz}^2\right\}}{(\bar{\Omega}+i\nu)}\frac{k^3\upsilon_{th}^2}{\Omega_p^2}\frac{\varepsilon_0 g E_0}{\varepsilon_0}u, \quad \text{and}$$

$$Q = \frac{\upsilon_{0z}\varrho\varepsilon_0}{k\Omega\varepsilon_0^2 g^2 E_0^2}\left\{\Omega^2 - k^2\upsilon_s^2 - \frac{\varepsilon_0^2 g^2 E^2 k^2}{\varrho\varepsilon_0}\right\}.\left\{1 - \frac{2i\delta k\overline{E}}{\Omega_0(\nu^2+\delta^2)}\right\}.$$

From (8) the wave equation for the parametrically excited waves with frequency $\Omega_1(\approx \Omega_0 as\, \Omega \ll \Omega_0)$ and wave number $k_1(\approx k)$ is obtained by assuming the space and time dependence as $exp[i(\Omega_1 t - k_1 z)]$,

$\hat{\imath}k_1^2 E_{1x} + \hat{\jmath}k_1^2 E_{1y} + i\Omega_1\mu_0 J_1 - \frac{\Omega_1^2}{C_L^2}E_1 = -\mu_0\frac{\partial^2}{\partial t^2}\left(\varepsilon_0 g E_0\frac{\partial u}{\partial z}\right)$ obtains:

$$a_{33} = \frac{\Omega_1\Omega_p^2 b\left\{\left(\overline{\Omega}-i\nu\right)^2 - \Omega_{cz}^2\right\}}{(1-Q)(\overline{\Omega}-i\nu)\left\{\left(\overline{\Omega}-i\nu\right)^2-\Omega_c^2\right\}} + \frac{Q\left(k_1^2 C_L^2 - \Omega_1^2\right)}{(1-Q)} - \Omega_1^2\left[1 - \frac{\mu_0 k_1^2 C_L^2\varepsilon_0^2 g^2 E_0^2}{(\Omega^2 - k^2\upsilon_s^2)}\ ,\right] \quad (24)$$

Eq.(24)shows that the three modes represented by $a_{11} = 0$, $a_{22} = 0$ and $a_{33} = 0$ are coupled to each other via the finite magneto static field B_0.

Isotropic Semiconducting Plasma:-

$$(\Omega^2 - k^2\upsilon_s^2)\left[-\Omega_1\left(\overline{\Omega}-i\nu\right) + \Omega_R^2\right] = -\Omega_1 D\left(\overline{\Omega} - i\nu\right) \quad (25)$$

In which $D = \frac{k^2 C_L^2\mu_0\varepsilon_0^2 g^2 E_0^2}{\varrho}$,

$$(E_{0th}) = \frac{m}{e\Omega_c}\left[(\nu^2 + \Omega_c^2) - \Omega_0^2\right]\left(\frac{\upsilon_s\Omega_0}{k}\right)^{\frac{1}{2}}$$

$$|\Omega_i|_\nu = \left(\frac{e}{m}\right)^2\frac{\Omega_c^2\Omega_1 k^2 C_L^2\mu_0\varepsilon_0^2 g^2 E_0^2}{2\varrho\upsilon_s^2(\Omega_R^2 - \Omega_1\Omega_r)\left\{(\nu^2+\Omega_c^2)-\Omega_0^2\right\}^2}E_0^2$$

$$(\Omega^2 - k^2\upsilon_s^2)[\Omega_R^2\{(\Omega_r^2 - \Omega_c^2)^2 - 2\Omega_{cx}^2\Omega_{cz}^2\} - \Omega_1(1-Q)(\Omega_r - i\nu)(\Omega_r^2 - \Omega_c^2)^2] = -(1-Q)D\Omega_1(\Omega_r - i\nu)(\Omega_r^2 - \Omega_c^2)^2 \quad (26)$$

$$(\Omega_i)_G = [(1-Q)\Omega_1 D\nu(\Omega_r - i\nu)(\Omega_r^2 - \Omega_c^2)^2].\left[2\Omega_r[\Omega_R^2\{(\Omega_r^2 - \Omega_c^2)^2 - 2\Omega_{cx}^2\Omega_{cz}^2\} - \Omega_1\Omega_r(\Omega_r^2 - \Omega_c^2)^2]\right]^{-1} \quad (27)$$

The growth rate well above the threshold is obtained as

$$|\Omega_i|_G = \left(\frac{e}{m}\right)^2[\Omega_1\Omega_{cx}^2 k^2 C_L^2\,\mu_0\varepsilon_0^2 g^2 E_0^2(\Omega_r^2 - \Omega_c^2)E_0^2].\left[2\upsilon_s^2\varrho\{(\Omega_c^2 + \nu^2) - \Omega_0^2\}^2[\Omega_R^2\{(\Omega_r^2 - \Omega_c^2)^2 - 2\Omega_{cx}^2\Omega_{cz}^2\} - \Omega_1\Omega_r(\Omega_r^2 - \Omega_c^2)^2]\right]^{-1} \quad (28)$$

In obtaining wq. (37) we have assumed that $Q > 1$,

$\Omega_R^2[(\Omega_r^2 - \Omega_c^2)^2 - 2\Omega_{cx}^2\Omega_{cz}^2] > \Omega_1\Omega_r(\Omega_r^2 - \Omega_c^2)^2$

which gives the threshold value of the carrier concentration as-

$$n_{0th} = \frac{m\varepsilon_0\varepsilon_L}{e^2}\left[\left[\frac{\Omega_1\Omega_r}{1-\left\{2\Omega_{cx}^2\Omega_{cz}^2/(\Omega_r^2-\Omega_c^2)^2\right\}}\right] - k^2\upsilon_{th}^2\right] \quad (29)$$

Result Discussion and conclusion:-

Results thus obtained are being compared between two theoretical model with the help of graphs:

(a) Depending of growth of rate of the excited model on the pump electric field amplitude two different graph firs is for piezoelectric semiconductor plasma and ferroelectric semiconducting plasmass with strain dependent dielelctric materials (SDDC).

(b)The dependent of the growth rate on the wave number k at angle 45 variation of the threshold pump amplitude with k at angle 45.

(c) Dependence of the growth rate on magnetostatics field at 45 angle and k variation of E_{0th} with Ω_c.

(d) Dependence of the growth rate on the angle theta for E_0 and Ω_c.

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