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Crystallographic Independent Parametric Instability Of Laser Beams In Material With Strain Dependent Constant By Doping Rh^{+4} in $BaTiO_3$ Matrix

[1]Shivani saxena, [2]Sanjay Dixit, [3]Sanjay Srivastava

Abstract— in this present article, the parametric excitation of acoustic wave along the crystallographic direction in strain dependent dielectric constant of doped $BaTiO_3$ matrix was analyzed by the hydrodynamic model of plasma. The coupled mode theory was used to calculate the threshold electric field and growth of acoustic wave along the certain direction of the crystallographic plane of the material. These analyses are investigated in electron- phonon collision dominated regime of the material. $BaTiO_3$ itself show high dielectric constant due to temperature dependent crystallographic phase transformation. By introducing the dopant in the crystallographic plane, the resultant structure of $BaTiO_3$ shows slightly modification in dielectric constant as well as stiffness of the material, which is responsible for changing the acoustic velocity in the different crystallographic plane. With the help numerical calculation, the anomalous growth can be obtained in high dielectric constant along the different crystallographic plane. But their results show no changing of parametric instability of laser beam along the crystallographic plane because of the retention of centrosymmetric structure in doped $BaTiO_3$.

Index Terms— Crystallographic plane, Centro symmetric structure, plasma, acoustic wave

1 Introduction

The medium for charge carriers in different types of the solids is characterized by their high value of dielectric constant, which makes it possible to ionize atoms easily and realize the plasma state even at very low temperature. Plasmon excitation at the surface is one of the most relevant processes with the interaction of swift charged particles with the solid samples. These ions are tightly connected with the lattice of the materials. In this case, the particles moving with the velocity greater than $v>v_0$ (where v_0 is the Bohr orbital velocity of an electron in a hydrogen atom in the ground state) transfer the certain amount of energy to the electron subsystem. These oscillatory charge particles movies freely over the entire surface with violating the neutrality conditions by applying the electric field. Thus the dielectric constant of the medium is one of the most important parameters for the study of the substances. The materials with high dielectric constant are more efficient in the field of study of solid state plasmas.

In the recent past years, there has been a tremendous surge of research activities in nonlinear effects in plasmas because it is realized that the linear approximation becomes inadequate especially to explain the fundamental features of the plasma instabilities. Among them the nonlinear wave instabilities in plasmas are of particular interest due to their high practical aspect. Current instabilities in plasma represent the increase of the amplitude of some oscillations at the expense of other or at the expense of the energy sources drift flux to waves in the plasma and form certain types of waves to other. The absolute instability is a spontaneous, unlimited growth in a time of a fluctuation at a fixed point of the system (the perturbation is spatially limited but not limited time). It is possible to call such a system to a generator of vibrations. With the convective instability, the transport of a perturbation to a different spatial point is responsible for the limitation of its increase in time at a given point. Under these conditions, there is an energy flux that grows as the coordinates increases, and this kind of instability corresponds to the amplification of the wave. The attenuation due to energy losses accompanying the wave propagation can be regarded as the negative amplification. The electric field E of an electromagnetic wave slightly affects the dielectric constant of the medium;

$$\varepsilon = \varepsilon_o + \Delta\varepsilon \ ,$$

$$\Delta\varepsilon = \varepsilon_2 E^2 > 0$$

And also in the refractive index, $n = \sqrt{\varepsilon} \approx n_0 + n_2 E^2 \ n_0 = \sqrt{\varepsilon_0} \ n_2 = \varepsilon_2 / 2\sqrt{\varepsilon_0}$; E^2 is taken to be an average over the period. Absorption, reflectance and transmittance of the electromagnetic waves have a wide application in the different filed by the interaction between of electromagnetic waves and low temperature exiting plasma, and the study of reflection, absorption, and transmission of electromagnetic waves in un-magnetized, magnetized, non-uniform, and uniform plasma have been gained importance for the intensive research of wave instabilities in solid state plasmas, by the interactions between electromagnetic waves and low-temperature plasma [1]. Tang et al studied the absorption, reflection and transmittance of electromagnetic waves in a nonuniform plasma slab immersed in uniform magnetic field [2]. Laroussi and Roth [3] studied the ray tracing technique to deal with the problem of electromagnetic wave interaction with a non-uniform plasma slab in the different materials. Their model is based on the neglecting the multi reflection of the wave from the uniform plasma slab. Gurel et al [4] studied the interaction of electromagnetic waves by using the sinusoidal to determine new reflection, absorption and transmission characteristics in an inhomogeneous plasma slab. Since then a number of researchers have been concentrated to observe the experimentally excitations of various collective modes in solids. Several of these plasma instabilities can now be considered as probable tool useful for the designing of new devices. The major practical interest in semiconductor-plasma instabilities are due to the existence of the different geometries of the applied electric and magnetic fields and the electro kinetic-wave propagation in the crystal as the physical conditions to maximize the growth rate of the propagating wave [5, 6]. The propagation characteristics of the electro-kinetic wave in a system are investigated from the dispersion relation. Chaudhary [7] et al., reported the reflection and transmittance by using the quantum hydrodynamic model in un-magnetized extrinsic semiconductor. They have found the quantum effect through Bohm potential which significantly modifies the dispersion and absorption characteristics of the electrokinetic wave spectrum by supposing the streaming carrier's flow in un- magnetized extrinsic semiconductor.

In nonlinear wave propagation, the analysis of interaction depending on a particular physical situation is of great importance. As a consequence of nonlinear interactions between matter and wave, the phenomenon arises such as parametric, modulation and stimulated scatterings. The most fundamental interaction is the Parametric Interaction. The understandings of these phenomena have led to their successful application in the field like laser technology, laser spectroscopy, optical communication, photo physics, Photochemistry, Material Processing, etc. It is well known fact that the study of matter wave interaction provides a tremendous insight that is helpful in analyzing the basic properties of the medium. Ginzburg and Zheleznyakov [8] reported in deep for the method of emission and the effect of that by using coupled mode theory for the chain analysis of the nonlinear interaction with plasma material .The systematic development of nonlinear wave interactions of kinetic treatment was done by Chandran [9]. Haas [10] et al, reported the multistream model for spinless electrons in relativistic quantum plasma by using the suitable fluid-like version of the Klein-Gordon-Maxwell system. They reported the Fermi-Dirac equilibrium and the study of relativistic effects for quantum ion-acoustic wave propagation by using relativistic quantum kinetic models. The agglomeration is done by the ion implantation in the semiconductor material. So the presence of this colloid as well as the charged moving particle will convert the medium in the multi-component medium of the semiconductor plasma. It is known fact that the study of wave propagation through a medium always provides the information about the properties of the host material, therefore such ion-implanted semiconductor that resembles a dusty plasma system become promising medium to study

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wave propagation phenomena during the last decade.

Ghosh and Agrawal [11, 12] studied the parametric excitation of ultrasonic and Helicon waves by a laser beam. Ghosh and Dixit [13-15] gave parametric decay of the high power Helicon wave in semiconductor plasma and parametric instability in laser beam and stimulated Raman scattering and Raman Instability by Helicon. The quantum effect on parametric amplification characteristics was also used to study the propagation of the wave in plasma media [16]. They have employed the Quantum Hydrodynamic model (QHD) for the electron dynamics in the semiconductor plasma and predicted the parametric interaction of a laser radiation in the unmagnetized piezoelectric semiconductor plasma. It was found that the Bohm potential in the electron dynamics enhances the gain coefficient of parametrically generated modes whereas reduces the threshold pump intensity.

The present work is aimed to analyze the parametric instabilities of a laser beams in substituting $BaTiO_3$ with high dielectric constant and their results are compared with unsubstituted $BaTiO_3$. By substitution of certain positive ions like Rh^{+4} or Ce (III), they affect the lattice of the $BaTiO_3$ but the density of the material is unchanged with the embedded positive ions. $BaTiO_3$ itself is piezoelectric material and possess the pervoskite structure. Centrosymmetric crystal exhibits possess high dielectric constant ($\varepsilon \approx 10^3$) by reducing their symmetry centre in an external electric field. It gives the strong electrochemical coupling which is propotional to the square of field. The elastic anistrpoy and piezoelectric effect induced from the electric field and electron –phonon interaction are casued by strain dependence of dielectric constant (SDDC) due to electrostriction. By substitution of the rare earth elements in pervoskite structure, the lattices slightly expand and possess slightly higher dielectric constant than that from the $BaTiO_3$ and their results shows that slightly stronger amplification of acoustic waves occurred in SDDC materials than in piezoelectric. And the parametric instability is free from the crystallographic axis for the propagation of the acoustic wave.

2 Theory and Methodology

We have considered the parametric instability from the propagation of the electromagnetic wave insides the ferroelectric tetragonal and rhombohedral $BaTiO_3$ with space groups P4mm and R3mand the paraelectric cubic (Pm3m) and antiferrodistortive tetragonal phases (I4/mcm) of $SrTiO_3$ (ST). The variable such as atomic displacements, macroscopic strain, and electric field are used to calculate the phonon spectra, elastic, piezoelectric and dielectric tensors, which are related to the second derivatives of the total energy. The second order derivate of total energy with respect to electric filed and strain gives the idea about the dielectric susceptibility and elastic constants, respectively, while the piezoelectric tensor is mixed of the second derivative of total energy with respect to strain and electric field. A light wave propagating in crystals is the phenomenon of the superposition of two waves, mutually perpendicular polarized, with different wave vectors. The excitation of the acoustic wave is due to application of the high frequency Laser beam. This laser beam with the sinusoidal nature of the electric field $E_0 \cos(\Omega_0 t)$ is applied parallel to the wave vector (along the x-axis) [17-18]. The dipole approximation has been treated for the development of uniform field of the Laser beam in which we have assumed that the wavelength of the excited acoustic wave is very small compared to the scale length of the applied electromagnetic field variations (i.e., $k_0 \ll k$ thus $k_0 \approx 0$). For the numerical calculation, we have taken $\Omega_0 \left(\approx \Omega_p\right) \gg \nu$. The basic equations used in the present analysis are as follows:-

$$\frac{\partial \upsilon_0}{\partial t} + \nu \upsilon_0 = \frac{e}{m} E_0 \cos\left(\Omega_0 t\right) \qquad (1)$$

$$\frac{\partial \upsilon_1}{\partial t} + \left(\upsilon_0 \frac{\partial}{\partial x}\right)\upsilon_1 + \nu \upsilon_1 = \frac{e}{m} E_1 - \frac{k_B T \partial n_1}{m n_0 \partial x} \qquad (2)$$

$$\frac{\partial n_1}{\partial t}+\left(\upsilon_0\frac{\partial}{\partial x}\right)n_1+n_0\left(\frac{\partial}{dx}\upsilon_1\right)=0, \qquad (3)$$

$$\frac{\partial E_1}{\partial x}=\frac{en_1}{\in_0}-\frac{gE_0\in_0}{\in_0}\frac{\partial^2 u}{\partial x^2}, \qquad (4)$$

$$\frac{\partial^2 u}{\partial t^2}=C\frac{\partial^2 u}{\partial\ x^2}-\varepsilon_o gE_o\frac{\partial^2 E_1}{\partial\ x} \qquad (5)$$

Equation (1) represents the zeroth-order equation for the motion, electrons and shows that the electrons will oscillate under the influence of the high-frequency electric field $E_0\cos(\Omega_0 t)$. Equations (2) and (3) are the first-order momentum transfer and continuity equations for electrons, respectively, k_B is the Boltzmann constant, and T the temperature. The space-charge field E_1 is determined by the Poisson relation (4), where the second term on the right-hand side gives the SDDC contribution to the polarization, n_1 is the electron density perturbation. Equation (5) is the equation of elasticity theory describing the motion of the lattice in the strain dependent dielectric constant (SDDC) crystal; u is the lattice displacement and ρ the mass density of the crystal.

We assume that the acoustic wave has an angular frequency Ω and wave number k such that $\Omega << \Omega_0$ and the low-frequency perturbations are proportional to exp $\left[i(\Omega t-kx)\right]$. The transverse acoustic wave is propagating in such a direction of the crystal that it produces a longitudinal electric field. Using (4) and (5) one obtains

$$\left[\Omega^2-k^2\upsilon_S^2-\frac{\in_0^2\ g^2E_0^2k^2}{\rho\in_0}\right]u=\frac{\in_0\ g\ \ E_0 e}{\rho\in_0}n_1 \qquad (6)$$

Where $\upsilon_s=(C/\rho)^{1/2}$ is the transverse acoustic velocity in the crystal? and differentiating (6) with respect to time and using (4) and (5), in the collision-dominated regime $(r >> k\upsilon_o\Omega)$ one obtains

$$\frac{\partial^2 n_1}{\partial t^2}+v\frac{\partial\ n_1}{\partial t}+\Omega_E^2 n_1+\frac{en_1}{m}gE_o k^2 u=ikn_1 E \qquad (7)$$

Where $\Omega_R^2=\Omega_P^2+k^2(k_B T/m)$, Ω_p being the electron-plasma frequency in the lattice given by $\Omega_p=(e^2 n_o/m\varepsilon_o)^{1/2}$ and $\bar{E}=(e/m)E_o\cos(\Omega_o t)$ and ν is the electron-electron collision frequency and given by the following expression: $v=5\times10^{-6}\frac{n_o\ln\Lambda}{T_e^{3/2}}$ sec^{-1}, where T_e is electron temperature. Equation (10) can now be resolved into two components (fast and slow) by writing $n_1=n_f+n_s$ (subscripts f and s represent the fast and the slow components, respectively). Hence we obtained

$$\frac{\partial^2 n_f}{\partial\ t^2}+v\frac{\partial\ n_f}{\partial t}+\Omega_R^2 n_f=ikn_s\bar{E} \qquad (8)$$

and'

$$v\frac{\partial\ n_s}{\partial\ t^2}+\Omega_R^2 n_s+\frac{en_o}{m}gE_o k^2 u=ikn_f\bar{E} \qquad (9)$$

The piezoelectric component of the electron-phonon interaction is responsible for the propogation acoustic wave inside the semiconducting material. At the same time, it starts to couple with TO-phonon via anharmonic channel. This copling is cused the excitation of coherent ultrasonic which gives the periodic modulation of the electromagnetic waves in semiconductor structure by dynamical Bragg scattering phenomena. In Bragg scattering, the two values of the wave vector k_1 and k_2 of the incident wave and the two-values of the vector $k_1^{'}$ and $k_2^{'}$ the light scattered at a given angle is used to determine the four different wave vectors of the phonons, q_{ij}, which satisfy the following condition

$$q_{ij}=k_i^{'}-k_j \quad \text{(i,j=1,2)} \qquad (10)$$

Christoffel’s equation relates acoustic velocities to crystallographic direction and the elastic moduli [19]

$$\det\left|\Gamma_{ik} - \rho \upsilon^2 \delta_{ik}\right| = 0 \quad (11)$$

Where ρ is the density of the considered material, v is the speed of the sound velocity, and δ_{ik} is d delta function (i.e., when $i \neq k$ $\delta_{ik} = 0$). The Kelvin-Christoffel stiffness Γ_{ik} is

$$\begin{aligned}
\Gamma_{11} &= n_1^2 C_{11} + n_2^2 C_{66} + n_3^2 C_{55}, \\
\Gamma_{22} &= n_1^2 C_{66} + n_2^2 C_{22} + n_3^2 C_{44}, \\
\Gamma_{33} &= n_1^2 C_{55} + n_2^2 C_{44} + n_3^2 C_{33} \\
\Gamma_{23} &= n_2 n_3 \left(C_{23} + C_{44}\right), \quad \Gamma_{13} = n_1 n_3 \left(C_{13} + C_{55}\right), \\
\Gamma_{12} &= n_1 n_2 \left(C_{12} + C_{66}\right),
\end{aligned} \quad (12)$$

Where the n_i and C_{ij} are the direction cosines of measured phonons and elastic moduli respectively. To which, the first term is according to the Hook's relationship and the second term are due to the presence of strain in the material, where C is defined the elastic stiffness constant. The excitation of the acoustic wave is due to application of the high frequency Laser beam. By using the hydrodynamic model of a homogeneous one-component material, we evaluate the coupling between conduction electron and acoustic wave in strain dependent dielectric constant. The strain dependent dielectric constant of the materials is given by the following expression:

$$\varepsilon = \varepsilon_0 \left(1 + gS\right) \quad (13)$$

Where ε_0 is the dielectric constant when the strain S is zero and g is coupling constant. Here Electric displacement is given by:

$$D = \varepsilon_0 E + gSE \quad (14)$$

The shape of the dynamic structure factor can be analyzed within the framework of the generalized hydrodynamic model. The shape of the dynamic structure factor can be expressed by the following relation:

$$I_{pp}(\omega) = \frac{I_0}{\omega} \frac{M''(\omega)}{\left[\omega^2 \rho / q^2 - M'(\omega)\right]^2 + \left[M''(\omega)\right]^2} \quad (15)$$

Where q is related to the wave number of the incident light k_i and to the refractive index of the medium $n = \sqrt{\varepsilon}$ by the relationship q=2nki, ρ, q is the mass density, and $M(\omega) = M'(\omega) - iM''(\omega)$ the longitudinal acoustic (LA) modulus. The two limiting cases are considered for characterizing the limiting values of the longitudinal modulus i.e., very low frequency or high temperature (relaxed case) and very high frequency or low temperature (unrelaxed case). We assume that the acoustic wave is characterized by the angular frequency Ω and wave number k such that $\Omega \leq \Omega_0$ and the low frequency perturbation is directly given by the $\exp\left[i\left(\Omega t - kx\right)\right]$. The transverse wave propagating along the different crystallographic plane of the crystal which produce the longitudinal electric filed are given by the following differential equation

$$\left[\Omega^2 - k^2 \upsilon_s^2 - \frac{\varepsilon_0^2 g^2 E_0^2 k^2}{\rho \varepsilon_0}\right] u = \frac{\varepsilon_0 g E_0 e}{\rho \varepsilon_0} n_1 \quad (16)$$

And $\upsilon_s = \sqrt{\frac{C}{\rho}}$ is the acoustic velocity in the crystal. According to crystallographic, the wave is propagating either along the transverse direction or longitudinal direction. The calculating threshold value of the high-frequency oscillatory electric field E_{0th} is raised from the given equation:

$$E_{oth} = \frac{m}{ek}\left[\frac{\Omega_R^3 (v^2 + \delta^2)}{2\delta}\right]^{1/2} \quad (17)$$

To obtain the initial growth rate $\left|\Omega_i\right|$ well above the threshold and the phase velocity $\upsilon_\psi \left(= \Omega_r / k\right)$ of the unstable mode, we get

$$\Omega_i = \pm\left[\frac{\upsilon_S^2\Omega_R^3 vm^2}{\sqrt{2}e^2E_0^2}\right]^{½} \qquad (18)$$

3 Results and Discussion

The analytical investigations of the parametric instabilities due to different electric field from the Laser beam are applied to an SDDC crystal like PZT (taken as $BaTiO_3$). For the investigation of this result, numerical estimation has been carried by considering the following physical parameter: the effective mass of electron m=0.0145m_o, where m_o is the free mass of the electron and theoretical density of 6.07 g/cm^3 [20] is calculated from the molar weight of the nominal composition and from the unit cell volume calculated from the refined PXRD data (obtained from conventionally sintered Pz26); the dielectric constant used in this expression [21] is ε=varied according to axis and effect of the dopant Rh^{+4} and the refractive index taken as $\eta = \sqrt{\varepsilon}$; the effective carrier concentration [22] varies from lower temperature to the higher temperature, but generally taken to be 2-4 x10^{24}. For numerical calculation of the above analysis, the wave is irradiated on a specific case of centro- symmetric crystal with 10.6 μm CO_2 laser. The basic parameter is wave number k_0=5.92x10^5 m^{-1}, and the frequency Ω_0 =1.78x$10^{14}$$sec^{-1}$. The effect, phonon anharmonicity in acoustic wave propagation deals with the resonantly enhanced acousto-optical susceptibilities, refers to an operating acoustic intensity I_{ac} varies 1 – 100 kW/cm^{-2} and the acoustic frequency varies from ν_{ac}~ 0.1– 1 GHz. The Bragg diffraction of far-infrared polaritons can be used to interpret the propagation of THz field by controlling AW (acoustic wave) through pumping by AW [23]. Thus we can analyze the data in terms of the phonon anharmonicity which create an acoustically induced Bragg grating. The parametric interaction and resultant instability in SDDC with high dielectric constant depends upon the wave propagation inside the considered material. As we know, when a plane wave propagates in a piezoelectric material, the equation of motion can be expressed from the following relationship:

$$\rho V_q^2 u_i = \Gamma_{ijkl} q_j q_l u_k \qquad (19)$$

Where V_q is the velocity of the acoustic phonon propagating with wave vector q, which can be determined from the Brillouin scattering frequency shift, u_i is the polarization of the wave. In expression (36), piezoelectrically stiffened elastic modulus is given by

$$\Gamma_{ijkl} = C_{ijkl}^E + \left[\frac{\left(e_{rij}q_r\right)\left(e_{skl}q_s\right)}{\left(\varepsilon_{mn}^S l_m l_n\right)}\right] C_{ijkl}^E \qquad (20)$$

C_{ijkl} is the elastic constant in constant electric field, e_{rij} is the piezoelectric stress , and ε_{mn}^s is the permittivity at the constant strain, whereas l_m and l_n are the directional cosine of the wave propagation direction, i.e., the cosine of the angles between the wave propagation direction and three coordinate axes. The collinear effect was totally considered in explaining the piezoelectricity and the polarization rotation are computed from strain, electric field, and the polarization in parallel along (111) to (001) and with the field direction (001) showed very large piezoelectric response from the development of the new piezoelectric strain. This effect has been observed at the phase boundary between rhombohedral and tetragonal phases in $BaTiO_3$. This is due to monoclinic phase, which can be understood as an intermediate state between the rhombohedral (polarization (111)) and tetragonal (polarization (001)) .The tetragonal symmetry in PZT is found in the composition of 50/50, there is a total 11 independent electrostatic constant: six elastic (C_{ijkl}) constant, three piezoelectric constant (e_{rij}) and two dielectric constants (ε_{mn}^s). Table 1 represent the six independent elastic constants for the rhombohedral group 3m: C_{11}^E, C_{33}^E, C_{12}^E, C_{13}^E, C_{44}^E C_{66}^E, e_{15}, e_{31}, e_{33} ε_{11}^s and ε_{33}^s in Voigt notation, respectively. The wave vector and the mode of the designations of the phone used for the determination of the dielectric, piezoelectric, and elastic constant are tabulated in Table 1. The phonon velocity, Vq is related to the Brillouin shift, $V_q = \Delta\upsilon_B / k_q$ by the equation

$$V_q = \frac{\Delta\upsilon_B}{k_q} = \frac{c\Delta\upsilon_B}{2\upsilon_0 n \sin(\theta/2)} = \sqrt{\frac{stiffness}{\rho}} \quad (21)$$

Where υ_0 is the frequency of the incident light, n is the refractive index of the scattering material used in the experiment, k_q is the phonon wave vector involved in the scattering process and θ is the scattering angle between the incident frequency and scattering frequency. These constant is directly evaluated by measuring an LA and two TA phonon velocities along [100], [001] and [101] by using backscattering and 90° scattering respectively. From the above relationship, the Brillouin frequency shift in a different direction (100), (010), and (001) are used to evaluate the phonon velocity and the velocity anisotropy. The velocity of the compression mode (LA) change according to the direction of propagation and the velocities of the first shear mode (TA1) and the second shear mode (TA2) mode shows the maximum propagation in the direction (010) and the particles showing the perpendicular displacement. The TA1 and TA2 modes show the maximum velocity in [101] and minimum in [101], which indicates the presence of a "soft acoustic mode" in [101] of the Rh : $BaTiO_3$ single crystal. Thus the dielectric constants of Rh: $BaTiO_3$, ε_{11}^s and ε_{33}^s are taken to be 1.98×10^{-8} F / m and 5.2×10^{-10} F / m respectively which is considered from high frequency Brillouin scattering. All the result used for the numerical analysis of the modulation or demodulation of the wave is tabulated in table 2. It can be seen from the table, there is no difference between the elastic constant of $BaTiO_3$ and Rh: $BaTiO_3$ and between $BaTiO_3$ and Ce: $BaTiO_3$.

From the results, it suggests that the substitution of Rh^{+4} occupy the same position at Ti^{+4} ion sites of $BaTiO_3$ and almost it has no impact on the modification of the crystal structure or even the lattice parameter of $BaTiO_3$. However, there is apparently difference obtained in e_{13} between $BaTiO_3$ and Rh: $BaTiO_3$ which indicates that the Rh-atoms doing only affects the electronic structure and the nature of the materials. It shows the better photo refractive properties and better source of the electron. For the study of parametric instabilities, three different materials are selected, which is mentioned above.

Table1: Relation between acoustic phonon velocities with elastic, piezoelectric, and dielectric constant along [001] poled direction in R: $BaTiO_3$. This parameter is determined through the Brillouin scattering geometries (ρ=6. 07 g / cm³). [24]

Direction	Mode	Parameter	Scattering geometries
	LA	$\rho V_q^2 = C_{11}^E$	Backscattering
	TA1	$\rho V_q^2 = C_{66}^E$	Backscattering
[100]	TA2	$\rho V_q^2 = C_{44}^E + \frac{e_{15}^2}{\varepsilon_{11}^s}$	Platelet geometry
	LA	$\rho V_q^2 = C_{33}^E + \frac{e_{15}^2}{\varepsilon^s}$	Backscattering
[001]	TA1	$\rho V_q^2 = C_{44}^E$	Backscattering
	TA2	$\rho V_q^2 = C_{44}^E$	Backscattering
	LA	$\rho V_q^2 = \left(C_{11}^E + C_{12}^E + 2C_{66}^E\right)/2$	90° scattering
[101]	TA1	$\rho V_q^2 = C_{44}^E + \frac{e_{15}^2}{\varepsilon^s}$	90° scattering

Table 2: Elastic Coefficients (G Pa) and piezoelectric coefficients (cm⁻²)

	$\rho V_L^2[100] = C_{33}^E + \frac{e_{33}^2}{\varepsilon_{33}^s}$			$\rho V_{T2}^2[100] = C_{44}^E + \frac{e_{15}^2}{\varepsilon_{11}^s}$		
	ρV_L^2	C_{33}^E	$e_{33}^2/\varepsilon_{33}^s$	ρV_{T2}^2	C_{44}^E	$e_{15}^2/\varepsilon_{11}^s$
Present Rh:$BaTiO_3$	196	175	21	114	58	56
Ding et al, for Ce:$BaTiO_3$	245	189	56	125	54	71
Li et al, for $BaTiO_3$	230	160	70.2	117	56.2	60.8
Shaefer et al., for $BaTiO_3$	153.0	147.9	5.1	125.5	54.9	70.6

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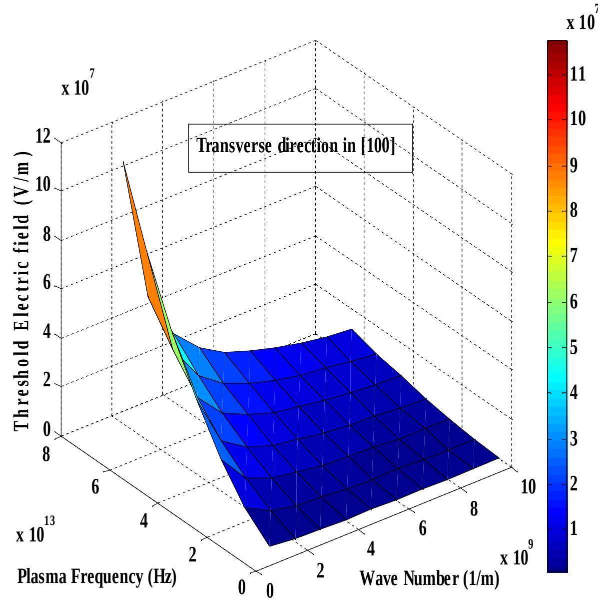
The crystal is irradiated with a pulsed CO2 laser. The parametric instabilities arise from the acoustic velocity propagated in the different direction. Due to the propagation of the wave, the variation of the threshold electric field and growth rate are observed differences in different material due to acoustic velocity, propagated in different directions. Figure 1 a and b show the change in threshold electric field with wave number and the plasma frequency along the different direction of propagation in Rh: BaTiO3 and BaTiO3. It can be seen from the figure that the threshold electric field decrease with increase the k as well as plasma frequency.



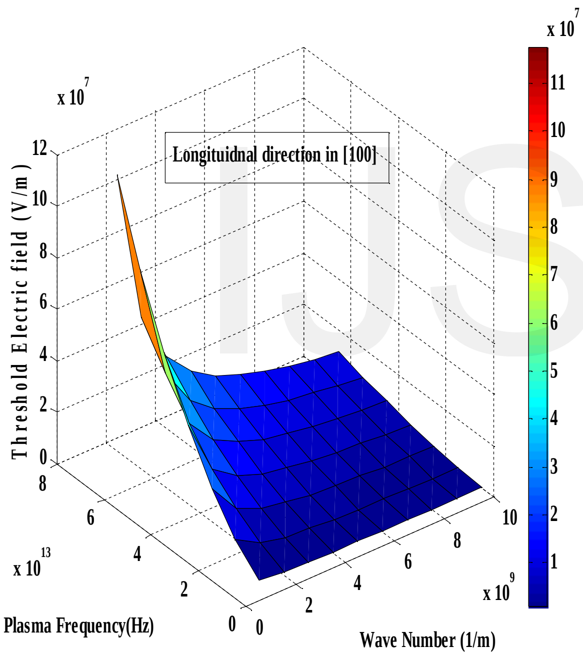
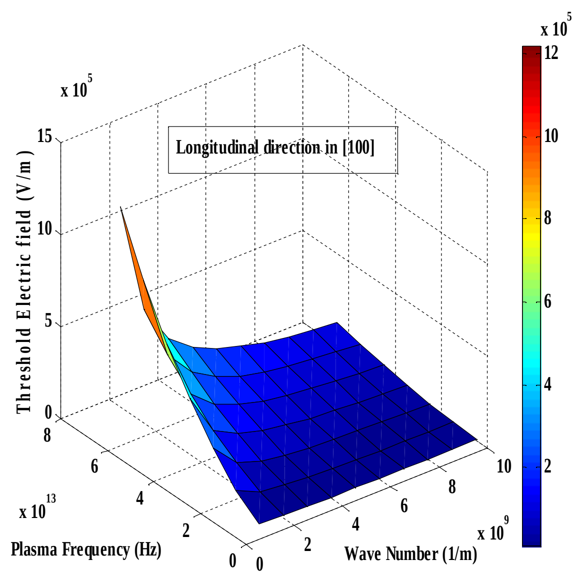


Figure 1: Variation of the threshold electric field E_{oth} with wave number and plasma frequency for (a) Rh: $BaTiO_3$ in longitudinal direction in [100] (b) Rh: $BaTiO_3$ in Transverse direction in [100]



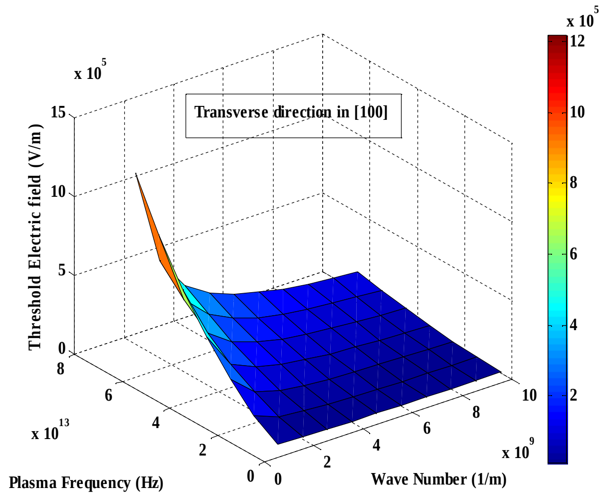
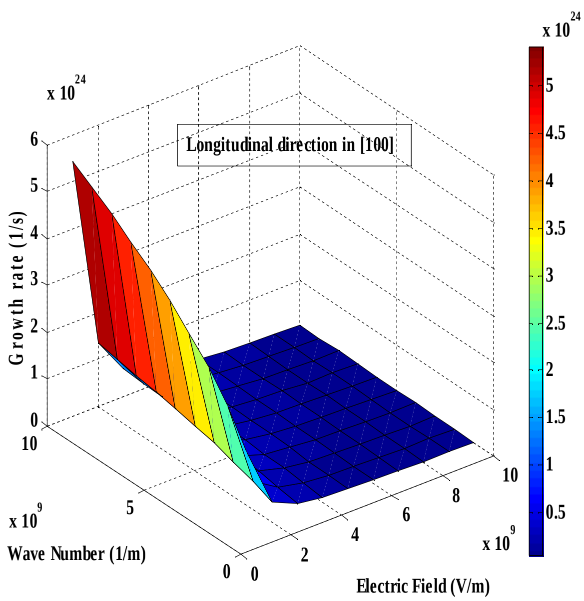


Figure 2: Variation of the threshold electric field E_{oth} with wave number and plasma frequency for (a) $BaTiO_3$ in longitudinal direction [100] (b) $BaTiO_3$

This investigation was carried out at 300 K. The only difference between these materials is the presence of the excess number of charged particles, i.e., hole and electron respectively. From the observed figure, it is shown that as the wave number increase in the experiment the threshold electric field decreases, while in term of the observed pattern, it is found that for a lower value of the wave number indicates the large decrement of the threshold electric filed $\frac{dE}{dk}$, and becomes smaller for large value of k. It is also evident from the figure that the Rh: $BaTiO_3$ show large amplitude of the threshold electric filed that $BaTiO_3$. The decapitation rate of the $\frac{dE}{dk}$ in Rh: $BaTiO_3$ is 100 times more than the decapitation rate of the $\frac{dE}{dk}$ in $BaTiO_3$. The threshold electric field across the longitudinal direction: $\rho V_L^2[100] = C_{33}^E + \frac{e_{33}^2}{\varepsilon_{33}^s}$ is slightly much more as compared to the threshold electric field across the transverse direction: $\rho V_{T2}^2[100] = C_{44}^E + \frac{e_{15}^2}{\varepsilon_{11}^s}$.The acoustic velocities obviously change with crystallographic direction which depend upon the crystal structure and phase transformation as can be seen in Table 2. The shear velocity calculated from $V_L[100] = \sqrt{\frac{C_{33}^E + \frac{e_{33}^2}{\varepsilon_{33}^s}}{\rho}} = 5.6824\times10^3 m/\sec$ and from $V_L[100] = \sqrt{\frac{C_{44}^E}{\rho}} = 5.369386\times10^3 m/\sec$ is slightly enhanced due to incorporation of extra terms $\frac{e_{33}^2}{\varepsilon_{33}^s}$ and also slightly improved the threshold electric field in both the phase. In transverse direction, the acoustic velocity is given by $V_T[100] = \sqrt{\frac{C_{44}^E + \frac{e_{15}^2}{\varepsilon_{11}^s}}{\rho}} = 6.15558\times10^4 m/\sec$. The transverse velocity is slightly enhanced by again introducing the extra term $\frac{e_{15}^2}{\varepsilon_{11}^s}$. These extra terms slightly modifies the threshold electric filed and growth rate. The electric field dependence growth rate is shown in figure 2 and b. Hera as shown in figure 2, it is found that the growth rate $|\Omega_i|$ directly increases with an increase the electric field in both the crystals. The decrement is found very large up to $E_0 \cong 2.5\times10^9 Vm^{-1}$. In the range $E_0 \cong 2.5\times10^9 Vm^{-1}$, the growth rate $|\Omega_i|$ decreases very slowly or becomes independent from the applied electric field (E_0). The large amplification coefficient is observed in doped with Rh^{+4}: in $BaTiO_3$ matrix. From the analysis of the results, it is found that large growth is observed in Rh^{+4} $BaTiO_3$, roughly 10 times from the $BaTiO_3$. Figure 3 a and b also represents the variation of the growth rate with wave number of Rh: $BaTiO_3$ in the different crystallographic plane. Figure 4 a and b shows growth rate with wave number of Ba-

TiO_3 along different crystallographic plane. This show steeply decreases of growth rate with wave number up to 3.1 x10^9 V / m. In Rh: $BaTiO_3$, it shows 10 times more growth as $BaTiO_3$. The major impact is due to only large difference in high dielectric constant. But beyond that, it shows the independent relation of k with the decease of the growth rate. The difference in magnitude is explained by this difference in acoustic damping. It is due to the interaction of the electromagnetic wave with piezoelectric plasma. In these limits the acoustic damping is described by $M''(\omega \to 0) \to \omega\eta_0$ and $M''(\omega \to \infty) \to \omega\eta_\infty$ where $\eta_\infty = \eta_\infty + \Delta\eta$ is the longitudinal viscosity and η_∞ is the limiting longitudinal viscosity. The presence of very high frequency relaxation processes in solids and it is phenomenological described by the Voigt model of visco elasticity, corresponding to a longitudinal modulus written as $M''(\omega \to \infty) \to M_\infty + i\omega\eta_\infty$. To change the crystallographic direction form longitudinal to transverse direction, it shows slight variation in transverse viscosity. The overall impact of viscosity does not change the growth of parametric instability from the absorption of the electromagnetic wave



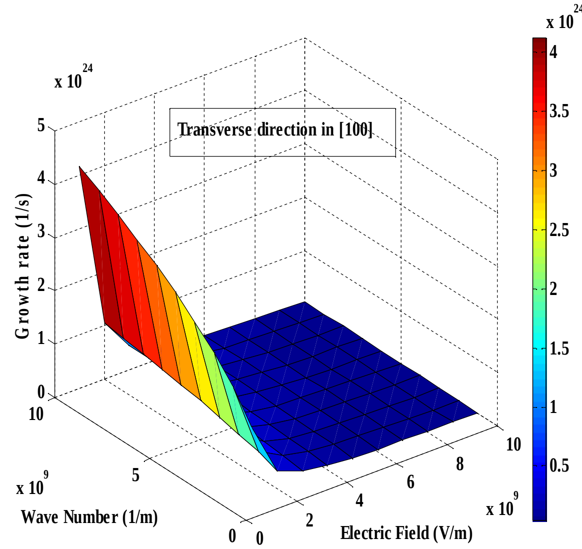
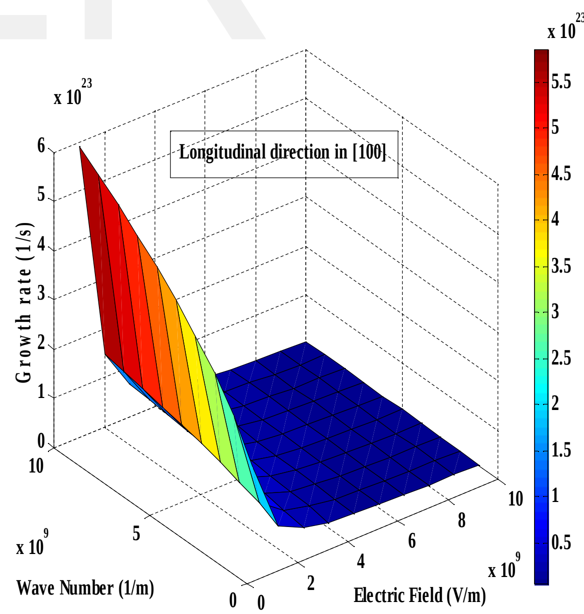


Figure 3: Variation of the growth rate $|\Omega_i|$ with wave number and electric field for (a) Rh: $BaTiO_3$ in longitudinal direction in [100] (b) Rh: $BaTiO_3$ in Transverse direction in [100]



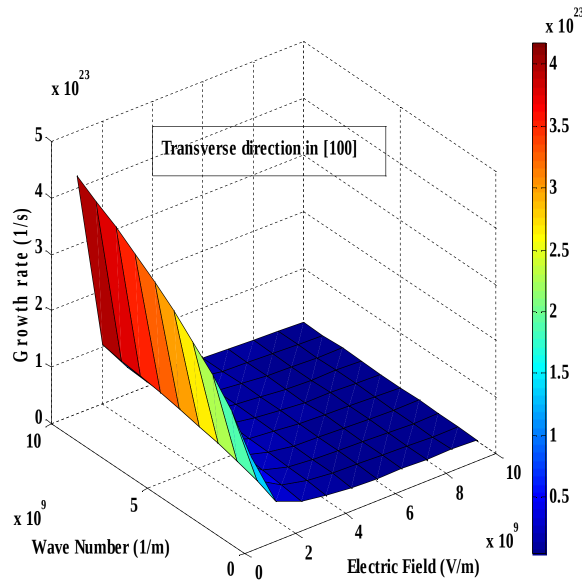


Figure 4: Variation of the growth rate $|\Omega_i|$ with wave number and electric field for (a) $BaTiO_3$ in the longitudinal direction in [100] (b) $BaTiO_3$ in Transverse direction in [100].

4 Conclusion

1. From the above discussion, the parametric instability of the plasma wave by the acoustic wave can be easily achieved by using the high dielectric material. This type of the dielectric property is found in strain dependent dielectric material which is developed by the change in crystal structure by expanding the entire lattice through doping in the parent structure.
2. By introducing the Rh^{+4} in $BaTiO_3$ matrix, it changes the dielectric constant, and they also affect the threshold electric filed and growth. The results show a considerable growth rate in Rh: $BaTiO_3$ by optimizing the parameter like electric field and wave number. It shows 10 times more growth than $BaTiO_3$ because of the high dielectric constant.
3. The threshold electric filed and growth due to high dielectric material decrease with increase the wave number as well as electric field. They show the optimum value at the specific wave number and electric field.
4. From the obtained numerical results, the growth rate is found same in all directions. The propagation of the acoustic wave along any direction of prorogation doesn't disturb the threshold electric field. Even the sign of the electric field is not changed with charge the direction of propagation of acoustic wave inside the material.
5. This property is very useful to design the optoelectric device like optical resonator, oscillators, etc. because of retention of the crystal symmetry of the material after doped with Rh^{+4}.

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Authors Biblography

	**Author1-Shivani Saxena** She completed her M.Sc in physics in the year 2006 from Barkatullah university Bhopal. Now she is persuing Ph.D in plasma physics under the guidance of Dr sanjay Dixit from Barkatullah University.She has worked in a reputed engineering college as a Lecturer.Her field of interest is plasma physics. Email:sxn_shvn@yahoo.co.in
	**Author2-Dr Sanjay Dixit** He was born in the year 1961.He did his M.Sc in 1983 from school of studies in physics Ujjain,and then Phd in plasma physics in the year 1987 from vikram university Ujjain.Initially he worked in school of studies in physics as research fellow and then as research associate.He has been working as assistant professor in Govt MVM college Bhopal since 1987.He has been nominated as Life Fellow by the Indian Physical Society Calcutta in 1987. Email:sanjay_007dixit@rocketmail.com
	**Author3-Dr. Sanjay Srivastava** S. Srivastava was born in Banaras (U.P.), India, in 1975. He received the M. Tech. Degree in 1999 from Materials Science and Technology and the Ph.D degree in 2006, both in Metallurgical Engineering from IIT BHU, Banaras. He is currently working as an Associate Prof. (MSME), MANIT Bhopal. His research interests include composite material, Photonic of the superconducting material and Microwave engineering. He is a life time member of tribological society of India and MRSI. Email:s.srivastava.msme@gmail.com