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Stimulated Brillouin Scattering in Direct gap Semiconductors: Band structure Engineering and Density of State Mass

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Abstract— Based on the hydrodynamical model and band structure effects an analytical investigation of steady state gain coefficient of the Brillouin scattered stokes mode resulting from the nonlinear interaction of an intense pumping light beam with acoustical phonons of direct gap semiconductors. The origin of nonlinear interaction lies in the third order susceptibility arising from the induced current density and density fluctuation generated within the medium. We also describe the procedure that how the steady state Brillouin gain is determined through the effective Brillouin susceptibility derived with the help of coupled mode theory of plasmas. The effect of temperature and band structure has been introduced through an empirical formula relating maximum plasma density with band structure and temperature [1]. The formula is derived using phenomenological model for the plasma thermodiffusion. The numerical estimations are made for III-V (InSb and GaAs) and II-VI (CdS) compound semiconductors duly irradiated by 10 nanosecond pulsed10.6 μm CO_2 laser. The inclusion of band structure and temperature effects adds new dimensions to the problem under study. It is found that the maximum plasma density increases with the amplitude of laser field for all the three compound semiconductors due to enhancement of density of states mass. Thus the magnitude of the plasma density affects the effective Brillouin gain via plasma frequency. The transmitted intensity is found to be highest in CdS and in InSb it becomes lowest. Hence CdS is most efficient among the three. The study establishes that the crystals having higher density of states mass of electrons and holes are the automatic choice for the fabrication of Brillouin cells.

Index Terms— Stimulated Brillouin scattering, Density of states mass, Susceptibility, Direct band gap semiconductors Minimum 7 keywords are mandatory, Keywords should closely reflect the topic and should optimally characterize the paper. Use about four key words or phrases in alphabetical order, separated by commas.

1 Introduction

Stimulated emission has been observed in many direct gap semiconductors [1-5]. Stimulated Brillouin scattering is frequently encountered when narrow band optical signals are amplified in fiber amplifier. The Brillouin gain spectrum may be strongly “smeared out” by various effects such as transverse variations of acoustic phase velocity [6] or longitudinal temperature variation [7], accordingly, the peak gain may be strongly reduced; leading to a substantially higher SBS threshold’s mechanism by employing high power laser systems for improvement in energy excitation, pulse compression [8,9].

Origin of SBS lies in the third order optical susceptibilities of different media used for the fabrication of optoelectronic devices [10]. It is an effect caused by the third order nonlinearity of a medium, specifically by the part of non-linearity which is related to acoustic phonon.In this phenomenon, the maximum intensity is observed along the backward scattering direction [11]. The competition between forward and backward scattered modes was studied by Berger [12]. The SBS instabilities have been observed experimentally in the near quarter critical density region of CO_2 [13]. Using density matrix formulation many workers [viz; 14] have reported the gain characteristics of SBS in noncentrosymmetric crystals. The study of SBS is quite an interesting field of research, due to its manifold technological applications in the area of modern optics such as amplifier isolation, pre pulse suppression, pulse squeezing, laser induced fusion, real time Holography and optical phase conjugation (OPC). SBS is regarded to be of definite advantage because of its high conversion efficiency. SBS is regarded to be of definite advantage because of its high conversion efficiency. The Brillouin nonlinearity can also produce efficient four wave mixing and yield reflection coefficients approaching 10^6, due to its purity and high efficiency.

SBS has been mostly studied in media such as liquids and plasma [15] in which electrostrictive phenomena are being taken as the origin of this process. A competition between forward and backward Brillouin scattering of the finite size laser beam has been discussed in a two dimensional plasma of plane geometry by Amin and Capjacjk [16]. Recently, Kong [17] have proposed a new phase control technique of SBS wave and demonstrated it experimentally. In all the above reports no body have made a detailed study of SBS in direct gap semiconductors and its dependence over plasma density which is a function of the temperature and band structure of the crystal.

Authors have found that Forchel et al. [18] have developed an empirical formula for the plasma density in direct gap semiconductors as a function of temperature and band structure using a phenomenological model for plasma thermo diffusion. They found a good agreement with experimental results from InP and with literature data from different III-V and II-VI compound semiconductors.

Motivated by the above discussion, in the present paper, authors aim to study the effect of temperature and band structure through the plasma density on Stimulated Brillouin scattering in direct gap semiconductor plasma.

The direct gap electrostrictive n-type semiconductor crystals such as InSb, GaAs and CdS are considered as Brillouin samples which are subjected to a pump wave. Further, the pump photo energy $\hbar\omega_0$ is taken well below the band gap energy $\hbar\omega_g$ of the samples. The choice allows the optical properties of sample to be considerably influenced by free carriers and to remain unaffected by the photo induced inter band transition mechanisms. The third order nonlinear optical susceptibility $\chi^{(3)}$ responsible for the occurrence of SBS process has been obtained following coupled mode scheme under hydrodynamic regime. Numerical estimates have been made for n-type InSb, GaAs and CdS crystal at 77K duly irradiated by few nano-second pulsed 10.6μm CO_2 laser.

2 THEORITICAL FORMULATION

This section deals with the theoretical formulation of the third order nonlinear optical susceptibility $\chi^{(3)}$ for stokes component of the scattered electromagnetic wave in doped semiconductors. We have considered the well known hydrodynamical model of homogenous one component plasma (electron) under thermal equilibrium. In order to study the effective Brillouin susceptibility arising due to nonlinear susceptibility $\chi^{(3)}$ and the electrostrictive polarization, the spatially uniform pump electric field strength $E_0 = E_0 \exp(ik_0x - i\omega_0 t)$ is applied parallel to the wave vector k (along the x axis). As the crystal is assumed to be centrosymmetric, the effect of any pseudopotential can be neglected for analytical simplicity. We have employed the coupled mode scheme to obtain the nonlinear polarization arising due to electrostrictive strain.

The basic equations considered for the analysis are:

$$\frac{\partial u(x,t)}{\partial t^2} - \frac{C}{\rho}\frac{\partial^2 u(x,t)}{\partial t^2} + 2\Gamma_a \frac{\partial u(x,t)}{\partial t} = \frac{\gamma}{2\rho}\frac{\partial}{\partial x}(E_0 E_1^*) \quad (1)$$

$$\frac{\partial \vartheta_0}{\partial t} + \nu\vartheta_0 = \frac{e}{m}E_0 \quad (2)$$

$$\frac{\partial v_1}{\partial t} + \nu\vartheta_1 + v_0\frac{\partial \vartheta_1}{\partial x} = \frac{e}{m}E_1 \quad (3)$$

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

$$P_{es} = -\gamma E_0 \frac{\partial u^*}{\partial x} \quad (5)$$

$$\frac{\partial E_1}{\partial x} = \frac{n_1 e}{\varepsilon} + \frac{\gamma}{\varepsilon}E_0\frac{\partial u^*}{\partial x} \quad (6)$$

The Equation (1) represents the equation of motion of generated acoustic wave in centrosymmetric medium, where $u(x,t) = u\exp\{i(k_a x - \omega_a t)\}$ is the lattice displacement. ρ, Γ_a, γ and C are the material density, phenomenological damping constant, electrostriction coefficient and elastic constant of the medium, respectively. E_1 is the space charge electric field. Right hand side of the equation (1) defines the effect of electrostriction. Equations (2) and (3) describe the zeroth and first order electron momentum transfer equations in which m and ν represent the effective mass and phenomenological momentum transfer collision frequency of electrons. Conservation of charge is represented by the continuity equation (4) in which n_0 and n_1 are the equilibrium and perturbed electron densities, respectively. Equation (5) describes that the acoustic wave generated due to electrostrictive strain, modulates the dielectric constant and give rise to a non linear induced eletrostrictive polarization P_{es}. At a frequency that is large compared to the frequencies of motion of electrons in the medium, the polarization of the medium is considered neglecting the interaction of the electron with each other and with the atomic nuclei. The space charge field E_1 is determined from Poisson's equation (6) in which last term on R.H.S. represents the contribution of electrostrictive polarization where $\varepsilon = \varepsilon_0\varepsilon_1$; ε_1 is the lattice dielectric constant and ε_0 is its absolute permittivity.

2.1 Hot Carrier Effect

The fundamental requirement to insite SBS is, the applied pump field must be well above certain amplitude known as threshold amplitude. When this high intensity pump field interacts with a high mobility semiconductor, carriers acquire momentum and energy from the pump and consequently carriers acquire a temperature (T_e) some what higher than that of the lattice temperature (T_0). In steady state, the carrier temperature T_e can be readily obtained from energy balance equations as follows. The power absorbed per carrier from pump electric field is obtained from equation (2) as

$$\frac{e}{2}\mathrm{Re}(\nu_0 E_0^*) = \frac{\nu e^2 E_0 E_0^*}{2m(\nu^2 + \omega_0^2)} \quad (7)$$

Where "∗" denotes the complex conjugate of the quantity and "Re" denotes the real part.

Following conwell [19] the power dissipation per electron (carrier) in collisions with the polar optical phonon (POP) may be expressed as

$$\langle p\rangle_{pop} = \left(\frac{2K_B\theta_D}{m\pi}\right)^{1/2} eE_{PO}x_e^{1/2}K_0\left(\frac{x_e}{2}\right)\exp\left(\frac{x_e}{2}\right)\frac{\exp(x_0 - x_e) - 1}{\exp(x_0) - 1} \quad (8)$$

where $x_{0,e} = \frac{\hbar\omega_1}{K_B T_{0,e}}$ in which $\hbar\omega_1$ is the energy of POP given by $\hbar\omega_1 = K_B\theta_D$ and θ_D is the Debye temperature of the me-

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dium $E_{PO} = \frac{mc\hbar\omega_0}{\hbar^2}\left(\frac{1}{\varepsilon_\infty} - \frac{1}{\varepsilon_L}\right)$ is the field of POP scattering potential in which ε_1 and ε_∞ are the static and high frequency dielectric permittivities of the medium, respectively, $K_0\left(\frac{x_e}{2}\right)$ is the zeroth-order Bessel function of first kind.

In steady state, the power absorbed per carrier from the pump electric field is just equal to the power dissipation per carrier in collision with POP scattering. Therefore, for moderate heating of carrier (i.e. $T_e \approx T_0$) by pump electric field, using equations (7) and (8), we yield

$$\frac{T_e}{T_0} = 1 + \frac{e^2\nu}{2m}\frac{\tau E_0 E_0^*}{\left(\nu^2 + \omega_0^2\right)} \qquad (9)$$

where $\tau^{-1} = \left(\frac{2K_B\theta_D}{m\pi}\right)^{1/2} eE_{PO}x_0 K_0\left(\frac{x_0}{2}\right)\frac{x_0^{1/2}\exp\left(\frac{x_0}{2}\right)}{\exp(x_0)-1}$

This heating of carriers modifies the momentum transfer collision frequency (MTCF) due to acoustic phonon scattering as

$$\nu = \nu_0\left(\frac{T_e}{T_0}\right)^{1/2} \qquad (10)$$

in which ν_0 is the MTCF of carrier in absence of pump electric field.

2.2 Density of State Mass Criteria

Forchel et al. [18] have investigated systematically the relation of the maximum plasma density in a direct gap semiconductor as a function of band structure and temperature. For a one component plasma, they have shown analytically that n increases with the density of states mass m_d and the temperature as $(m_d T)^{3/2}$. For the ambipolar diffusion of electron hole plasma the relation

$$n = 4.2\times10^{22}\left(\frac{m_{de}m_{dh}}{m_{de}+m_{dh}}\right)T^{3/2}m^{-3} \qquad (11)$$

is reported to be a good approximation numerically. Physically this relation means that the density maximum is related to a constant degeneracy of the plasma; it occurs for effective degeneracy's close to two, for which the plasma transport is significantly, affected by both, temperature and density gradients. They have reported that experimentally observed band structure dependence of the reduced densities in direct gap semiconductors is same as the band structure variation of the non equilibrium electron hole plasma observed in the indirect gap materials. They have discussed that for all direct and indirect gap materials. The induced plasma densities are in good agreement with their productions using the thermo-diffusion.

2.3 Third Order Susceptibility

A carrier density perturbation is produced within the Brillouin active medium due to electrostrictive force. In highly doped semiconductor, these density perturbations in terms of coupled fields can be obtained by the standard approach Using equations (1) to (6) and neglecting the Doppler shift under the assumption that $\omega_0 >> \nu > \vec{k}_0\vec{v}_0$, one obtains

$$\frac{\partial^2 n_1}{\partial t^2} + \nu\frac{\partial n_1}{\partial t} + \omega_p{}^2 n_1 + \frac{ik\gamma E_0 e n_0 u^*}{m\varepsilon} = -\overline{E}\,\frac{\partial n_1}{\partial x} \qquad (12)$$

where $\omega_p = \left[\frac{ne^2}{m\varepsilon}\right]^{1/2}$ is carrier plasma frequency of the medium.

The perturbed electron concentration n_1 will have two components due to the electrostrictive interaction within the medium. It may be recognized as slow (n_s) and fast (n_f) components, respectively. The slow component n_s is associated with low frequency acoustic wave ω_a and varies as $\exp[i(k_a x - \omega_a t)]$, whereas the fast component n_f oscillates at high frequency $(\omega_0 \pm \omega_a)$ of electromagnetic wave and varies as $\exp[i(k_0 \pm k_a)x - (\omega_0 \pm \omega_a)t]$. The higher order terms with frequency $\omega_0 \pm p\omega_a$ (p=2, 3, 4) being off resonant are neglected by assuming the interaction path as sufficiently long and only the first order Stoke's component (p=1) has been considered.

In the Stimulated Brillouin process, the phase matching conditions, which are follows:

$$\hbar\omega_0 = \hbar\omega_1 + \hbar\omega_a \qquad (13a)$$
$$\hbar\vec{k} = \vec{k}_1 + \hbar\vec{k}_a \qquad (13b)$$

These are known as the energy and momentum conservation relations. Here we have considered only the Stoke's component of the scattered electromagnetic wave for which phase matching condition becomes $\omega_1 = \omega_0 - \omega_a$ and $k_1 = k_0 - k_a$.

We could neglect the nonuniformity of the high frequency electric field under dipole approximation when the excited acoustic and Stoke's waves have wavelengths, which are small compared to the scale length of the electromagnetic field variation and it has been assumed $|k_a|\ (\approx k) \rangle\rangle\ |k_0|$ without any loss of generality.

We may obtain the following coupled wave equations under rotating wave approximation (RWA) [20] as

$$\frac{\partial^2 n_{1s}}{\partial t^2} + \nu\frac{\partial n_1}{\partial t} + n_{1s}\omega_p = -E_0\frac{e}{m}\frac{\partial n_{1f}{}^*}{\partial x} \qquad (14a)$$

$$\frac{\partial^2 n_{1f}}{\partial t^2} + \nu \frac{\partial n_{1f}}{\partial t} + n_{1f}\omega_p^{\ 2} - \frac{n_0 \gamma k^2 u^*}{\varepsilon}\frac{e}{m}E_0 = \frac{-e}{m}E_0 \frac{\partial n_{1s^*}}{\partial x} \quad (14b)$$

In the above equations, the subscripts "s" and 'f' stands for slow and fast components, respectively.

It may be inferred from equations (14) that the generated slow and fast components of density perturbation are coupled to each other via the pump electric field. Hence, it is obvious that the presence of pump electric field is the fundamental necessity for SBS to occur. From equations (14), one may obtain

$$n_{1s} = \frac{ikn_0\gamma u}{\varepsilon}\left[1 - \frac{(\delta_1^{\ 2} + i\omega_1\nu)(\delta_1^{\ 2} - i\omega_a\nu)}{k^2 E_0^{\ 2} e^2 / m^2}\right]^{-1} \quad (15)$$

It is evident from equation (15) the above that n_{1s} depends upon the magnitude of the pump intensity $I = \left(\frac{1}{2}\right)\eta\varepsilon_0\varepsilon|E_0|^2$ with η, ε_0 and c being the background refractive index of the crystal, absolute permittivity and velocity of light. The density perturbation thus produced affects the propagation characteristics of the generated wave where, $\delta_1^{\ 2} = \omega_P^{\ 2} - \omega_0^{\ 2}$ and $\delta_2^{\ 2} = \omega_p^{\ 2} - \omega_a^{\ 2}$; and the other symbols have their usual meanings. .

Now the Stoke's component of the induced nonlinear current density may be obtained from the relation.

$$J_{NL}(\omega_1) = n_{1s}^{\bullet} e \nu_0 \quad (16)$$

Which yields

$$J_{NL}(\omega_1) = \frac{i\omega_p^{\ 2}\varepsilon E_{1x}(\omega_1)}{\omega_0^{\ 2}} - \frac{i\gamma^2 k^2 \omega_p^{\ 2}\omega_0^{\ 2}|E_0|^2}{2\rho\omega_0(\omega_0)^2\Delta_a^2}\left[1 + \frac{(\delta_1^{\ 2} - i\omega_1\nu)(\delta_2^{\ 2} + i\omega_a\nu)}{k^2 E_0^{\ 2} e^2 / m^2}\right]^{-1} \quad (17)$$

Where $\Delta^2{}_a = (\omega_a^{\ 2} - k^2 v_a^{\ 2} + 2i\Gamma_a\omega_a)$

The induced nonlinear polarization $p_{cd}(\omega_s)$ may be treated as the time integral of the induced nonlinear current density $J_{NL}(\omega_s)$ i.e.

$$P_{cd}(\omega_1) = \int J_{NL}(\omega_1)dt \quad (18)$$

Using equations (17), the induced nonlinear polarization $P_{cd}(\omega_1)$ is obtained as

$$P_{cd}(\omega_1) = \frac{\gamma^2 k^2 \omega_p^{\ 2}\omega_0^{\ 2}(\omega_1)}{2\rho\omega_0\omega_1(\omega_0)^2\Delta_a^2}\left[1 + \frac{(\delta^2{}_1 - i\omega_1\nu)(\delta_2^{\ 2} + i\omega_a\nu)}{k^2 E_0^{\ 2} e^2 / m^2}\right]^{-1} E_0 E_0^* E_1 \quad (19)$$

The threshold pump amplitude for the onset of SBS may be obtained by setting $P_{cd}(\omega_1) = 0$ in equation (19) as

$$|E_{0th}| = \frac{m}{ek}\left[(\delta_1^{\ 2} - i\omega_1\nu)(\delta_2^{\ 2} + i\omega_a\nu)\right]^{1/2} \quad (20)$$

Hence the interaction between the pump and centrosymmetric crystal will be dominated by the SBS phenomena at a pump power level well above the threshold field. From equation (20), we may infer that E_{0th} strongly depends on material parameters, wave number.

Besides the induced polarization at Stoke's mode $P_{cd}(\omega_1)$, the system should also possess an electrostrictive polarization $P_{es}(\omega_1)$ arising due to the interaction of the pump wave with the acoustic wave generated in the medium. This is due to the fact because the scattering of light from the acoustic mode affords a convenient mean to control the frequency, intensity and direction of optical beam. This type of control makes possible a large number of applications involving the transmission, display and processing of information. This electrostrictive polarization is obtained from equations (1) and (5) as,

$$P_{es}(\omega_1) = \frac{k^2\gamma^2 E_0 E_0^* E_1(\omega_1)}{2\rho(\Delta^2{}_a)} \quad (21)$$

Thus, the total induced polarization at the Stoke's component in a Brillouin active medium is given by

$$P(\omega_1) = p_{cd}(\omega_1) + p_{es}(\omega_1)$$

$$= \frac{\varepsilon_0\gamma^2 k^2}{2\rho\varepsilon_0(\Delta^2{}_a)}\left[1 + \frac{\omega_p^{\ 2}}{\omega_0\omega_1}\right] \quad (22)$$

The effective polarization induced by the intense pump in a centrosymmetric semiconductor may be expressed as

$$P(\omega_1) = \varepsilon_0\chi_B^{(3)} E_0 E_0^* E_1(\omega_1) \quad (23)$$

It is well known fact that SBS is a third-order nonlinear phenomenon and therefore component of $P_{cd}(\omega_1)$ which depends upon $|E_0|^2 E_1$ yields Brillouin susceptibility. Using equation (15- 22). We obtain

$$(\chi_B)_{Cd} = \frac{\gamma^2 k^2 \omega_P^{\ 2}}{2\rho\varepsilon_0(\Delta^2{}_a)\omega_0\omega_1} \quad (24)$$

Hence the susceptibility due to induced polarisation is given by

$$(\chi_B)_{es} = \frac{\gamma^2 k^2}{2\rho\varepsilon_0\left(\Delta^2{}_a\right)} \tag{25}$$

Thus from equations equations (24) and (25), one may obtained third order susceptibilities as

$$\chi_{B,eff} = \chi_{B,Cd} + \chi_{B,es}$$

2.3 Steady State Brillouin Gain

In order to investigate the steady state Brillouin gain of the Stoke's component in the presence of the pump amplitude well above the threshold pump field, we use the following relation

$$g(\omega_1) = \frac{-k}{2\varepsilon_1}(\chi_{B,eff})_{img}|E_0|^2 \tag{27}$$

Now this relation may be used for computing the effect of band structure dependent plasma density on the growth rate of Brillouin scattered mode in Brillouin active centrosymmetric semiconductor crystal to study the effect of band structure dependent plasma density.

2.5 Transmitted intensity of the Brillouin scattered mode

If the sample length is 10 and 10^2 orders greater than the pump wavelength, following Simoda [28] one can easily use the expression for effective induced polarisation deduced for an infinite medium, to express the transmitted electric field amplitude E_T in a crystal cell of length L

$$E_T = -\frac{ik_s L}{\varepsilon}\left(P(\omega_1)\right)(\omega_s) \tag{28}$$

Using (28) one may write down the expression for the transmitted intensity I_T as

$$I_T = \frac{1}{2}\eta\varepsilon_0 c|E_T|^2 \tag{29}$$

The input pump intensity Iin is given by

$$I_{in} = \frac{1}{2}\eta\varepsilon_0 c|E_0|^2 \tag{30}$$

The efficiency of the Brillouin cell is given by

$$\beta = \frac{I_T}{I_{in}} \tag{31}$$

Equations (29) and (31) may be used to find out the transmitted intensity and efficiency of the Brillouin cell made of a centrosymmetric crystal.

3 Result and Discussion

This section aims to make a detailed numerical appreciation of the analytical investigation made in above section. The semiconductor bulk crystals used for this purpose are CdS, (Hexagonal) and GaAs, InSb (tetrahedral) respectively. Thus stimulation for the selection of these crystals for the SBS analysis stems from the extensive technological applications. We have considered the irradiation of these crystals by a pulsed 10.6 µm CO_2 laser. The other relevant parameters at room temperature used are; For InSb $\eta = 3.9$, $m_{de} = 4.2\times10^{22} m_0 m^{-3}$, $m_{dh} = 7.3\times10^{24} m_0 m^{-3}$, $\rho = 6.8\times10^3 kgm^{-3}$, $\Gamma_a = 2\times10^{10} s^{-1}$, $v_a = 4.8\times10^3 ms^{-1}$, For GaAs $m_{de} = 4.7\times10^{23} m_0 m^{-3}$, $m_{dh} = 9.8\times10^{24} m_0 m^{-3}$; For CdS $m_{de} = 1.5\times10^{25} m_0 m^{-3}$, $m_{dh} = 1.2\times10^{25} m_0 m^{-3}$. These crystals are assumed to be irradiated by a pulsed $10.6\mu m\ CO_2$ laser.

Fig.1 depicts the qualitative behaviour of the variation of maximum possible plasma density (n) with carrier temperature T_e/T_0 for the three direct gap semiconductors under study. In all the three cases maximum possible plasma density increases with temperature. It is found to be highest in CdS of the order of ($\approx 10^{21}\ m^{-3}$) and lowest in InSb $\left(\approx 10^{18}\ m^{-3}\right)$ crystals. Hence one can conclude that higher the density of state mass higher is the maximum possible plasma density and hence the transmitted intensity is also maximum.

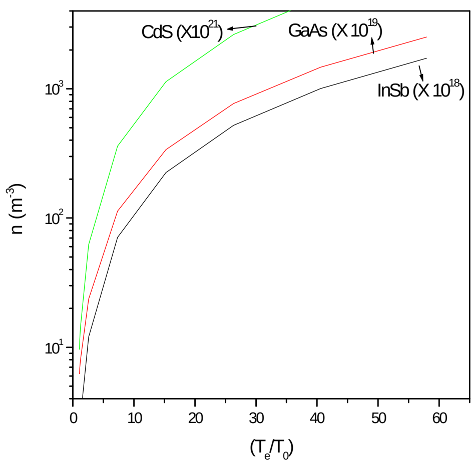

Fig. 1 Variation of maximum plasma density (n) with electron to lattice temperature (T_e/T_0).

In this section we spotlight on the numerical analysis of the transmitted intensity associated with the Brillouin process with pump field E_0.The pump field should be well above the threshold value (i.e. $|E_0| > |E_{th}|$) to achieve the significant modulated signal. Fig. 2 shows the behaviour of transmitted intensity, obtained from Eq. (29) with respect to E_0. The nature of variation of transmitted intensity with pump amplitude is almost similar for all the three semiconductors. Initially for lower pump amplitudes transmitted intensity increases slowly, and then increases rapidly. It is clear from this figure that at $E_0 \geq 10\times10^8 Vm^{-1}$ transmitted intensity increases very rapidly and becomes highest $\approx 7\times10^{11} Wm^{-1}$ for CdS. Again CdS established its suitability as material giving highest amplitude of transmitted intensity and lowest transmitted intensity is achieved for InSb semiconductor. From this Fig. 2 One

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may conclude that the transmitted intensity of the Brillouin scattered wave strongly depend on the density of state mass of the carriers of the crystals through plasma frequency.

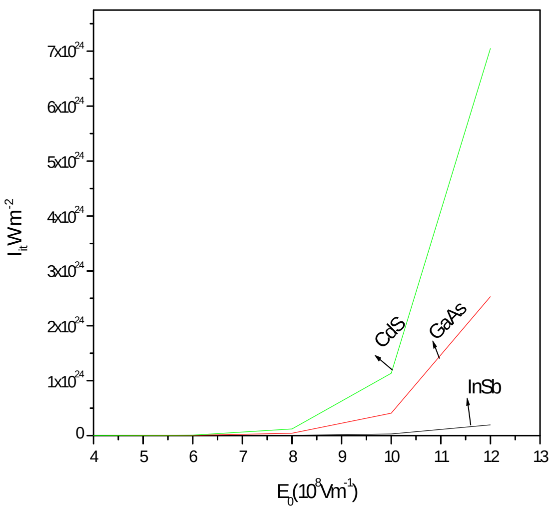

Fig. 2 Variation of Transmitted intensity I_T with pump amplitude E_0 at $k=10^7\ m^{-1}$

Fig. 3 shows the dependence of cell efficiency on pump amplitude. We illustrate that the nature of dependence of cell efficiency β on pump amplitude E_0 for the three direct gap semiconductors. In all the three cases, β increases with increase in pump amplitude E_0. It is found that β increases slowly with the increase in pump amplitude upto $E_0 \le 10\times10^7 Vm^{-1}$ and then for $E_0 \rangle\ 10\times10^7 Vm^{-1}$ it increases explosively, the results are well in agreement with Dubey and Ghosh [21]. Thus to achieve larger efficiency it is always to use high pump amplitude and also higher value of density of states mass. The cell efficiency is found to be highest for CdS $(\approx 6\times10^{16})$ and is lowest for Insb ($\beta \langle 10^{16}$) semiconductor crystal.

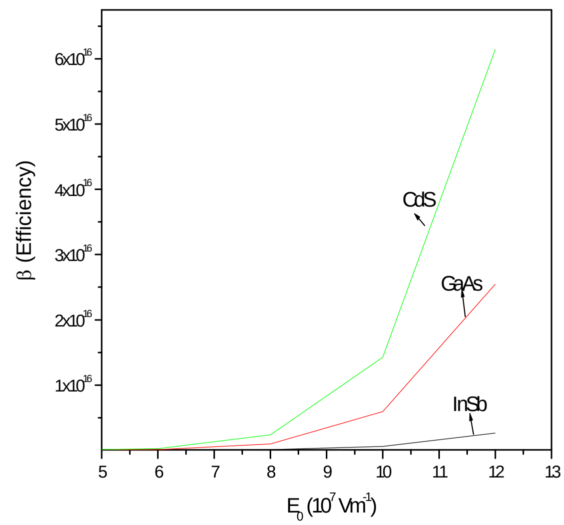

Fig. 3 Variation of Efficiency β with pump field E_0 at $k=10^7\ m^{-1}$

Using material parameters as mentioned earlier, we have estimated Brillouin cell efficiency incorporating the band structure dependence of electron hole plasma density. Figure 4, depicts a typical variation of Brillouin cell efficiency with wave vector k at ($E_0 > E_{0th}$). From the figure given below, it is clear that cell efficiency increases with the increment in wave vector k, and it achieves the maximum value at $k \approx 4.5\times10^7\ m^{-1}$. Again in agreement with the above results the cell efficiency is found to be highest for CdS crystal having higher density of state mass and is lowest for InSb having lower density of state mass. .

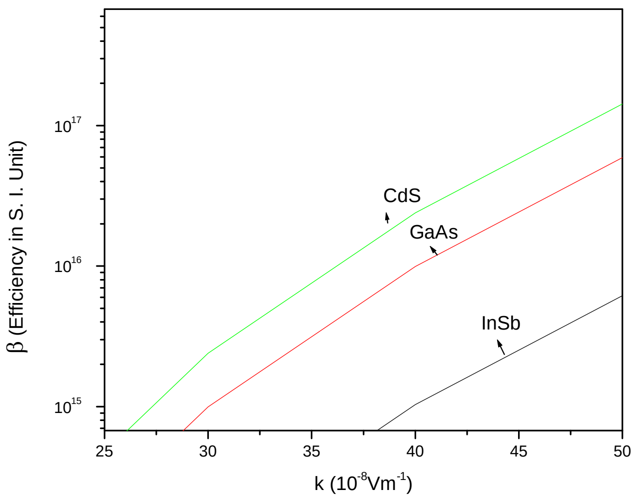

Fig. 4 Variation of Cell Efficiency β with wave vector k at $E_0 = 10^8\ V\,m^{-1}$

From above discussion, we conclude that density of state mass play noteworthy job for deciding cell efficiency. The above study reveals that the large cell efficiency can be easily achieved for the crystal having higher value of transmitted intensities and high density of state mass. The present theoretical study provides a model most appropriate for the finite laboratory solid state plasma and an experimental study based on this work would provide new means for construction of Brillouin cell and for characterization and diagnostics of semiconductors.

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