International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 6 Ver I || June 2018 || PP 77-83

Parametric Dispersion of Acoustic Wave in a Laser Irradiated Semiconductor Plasma: Quantum Effects

S. Ghosh, Swati Dubey and Kamal Jain
[1]*School of Studies in Physics, Vikram University, Ujjain, M.P.- 456001, India*
Corresponding Author: Kamal Jain

Abstract: *Quantum hydrodynamic model for one component plasma along with coupled mode theory is used to study dispersion characteristics of acoustic wave in a laser irradiated semiconductor plasma medium. Dispersion effects are explored in this paper through second order susceptibility of the medium which is a measure of the strength of second order nonlinear interaction. Dispersion characteristics are found to be effectively modified through quantum effects. It is found that doping concentration and pump field amplitude could be used to tune the dispersion characteristics of acoustic wave. Positive and negative magnitudes of real part of second order susceptibility are favourable for self-focusing and defocusing of laser light. It can be envisaged that a practical demonstration of the above kind of parametric dispersion may lead to the possibility of observation of group velocity dispersion in semiconductor plasma medium by considering a small degree of phase mismatch.*

Keywords- *Laser plasma interaction, Dispersion characteristics, Quantum effect, Nonlinear optical effect, Second order nonlinear optical susceptibility.*

Date of Submission: 18-05-2018 Date of acceptance: 04-06-2018

I. Introduction

Earlier studies find classical treatment sufficient to describe the behavior of semiconductor plasma. However under some extreme conditions quantum treatment has been established to be beneficial. Quantum electron gas in metals, semiconductors and laser produced plasmas are some initial metaphors of the most immediate quantum plasma. Different approaches based on semi-classical quantum mechanical methods were adopted in the pioneering fundamental works [1-6]. In cases of metals, semiconductors and laser produced plasmas, when temperature is low and density is quite high, the thermal de-Broglie wavelength of carrier may become comparable to the inter-particle distance [7-11]. Consequently prevailed situation makes quantum effects more significant because of the overlapping of wave functions of neighbouring particles. Classical hydrodynamic model can be converted into a quantum hydrodynamic model by incorporating an appropriate quantum correction term. This quantum correction adds new aspects in the collective behavior of plasma having purely quantum origin.

The plasma density in a semiconductor spans over many orders of magnitude. This versatility makes semiconductor plasma more advantageous than any other plasma medium to study the collective behaviour. The coherent interactions of waves and particles in plasmas have been the subject of extensive studies in nonlinear optics for the last three decades [12-13]. Many research papers have been devoted to the nonlinear interactions of waves in infinite homogeneous plasma [14-15]. These nonlinear effects are crucial when studying plasma instabilities and turbulence. The second order susceptibility of crystalline sample has been a glamorous topic because of its relevance to many technological applications. In case of second order polarization the problem of retardation is closely related to that of phase matching. However, most of these studies considered energy and momentum conservation relation fulfilled as far as propagation characteristics of the waves are concerned [16-18]. These conservation laws are termed as phase matching conditions. Phase matching techniques involve precise control of the indices at the three frequencies involved in mixing process. Infact phase matching techniques are the methods for restoring the proper phasing of the dipoles. Many techniques achieve phase matching condition through quasi-phase matching [19-20], birefringent [21] or metamaterials [22-24]. The advent of artificially engineered metamaterials has unlocked extensive opportunities for nonlinear optics offering novel approaches for phase matching. In case of quasi phase matching, in which the nonlinear properties are made to vary periodically, the efficient frequency conversion can be achieved by reversing the sign of nonlinear coefficient. Quasi phase matching can easily be achieved by periodically poled crystal; but this type of crystals are limited in nature. Alternatively, in birefringent phase matching, the refractive index difference due to dispersion is balanced by the index relation between the ordinary and extraordinary wave in a birefringent medium, through appropriately chosen propagation direction in the crystal. The birefringent phase matching, thus naturally requires that the difference between extraordinary and ordinary refractive indices for the pump and signal frequencies must be larger than that due to dispersion.

However, in case of a cubic semiconductor plasma medium, none of the above said techniques is found applicable to manage the phase mismatch situation. In view of dispersion caused by free electrons of a doped semiconductor specimen, it would be stimulating to consider a small tolerable phase mismatch and investigate its effect on the dispersion characteristics of the medium. Interdependence of wave vector mismatch between different waves propagating in the nonlinear medium and dispersion effects caused due to doping of medium will certainly affect the susceptibility dispersion.

Hence motivated by the above state of art, we have analytically probed the second order dispersion characteristics of semiconductor quantum plasma medium. Dispersion characteristics are explored in this paper through real part of second order susceptibility of the plasma medium which is a measure of the strength of second order nonlinear interaction. Modifications induced by the quantum effects in the dispersion characteristics of semiconductor plasma medium and comparative study of classical and quantum plasma media have been undertaken. Study of dispersion characteristics of acoustic wave is the main focus of present theoretical investigations. Numerical estimations are made for n-CdS crystal duly irradiated by CO_2 laser.

This paper organized as follows: section II deals with the description of quantum hydrodynamic (QHD) model and relevant basic equations governing the dynamics of laser irradiated semiconductor plasma medium. Section III contains numerical and graphical analysis of the problem. In section IV important conclusions have been drawn.

II. Theoretical Formulation

This section is devoted to the theoretical formulation of nonlinear polarization and second order susceptibility in one component compound semiconductor plasma. We consider the case of three wave mixing where the frequency combination $\omega_1 = \omega_0 - \omega_a$ is created in a nearly cubic diatomic crystal. Wave vector is a material dependent function of frequency due to the dispersion in the index of refraction. In case of non-phase match wave vectors ($\Delta k \neq 0$), propagation characteristics of the waves considers a nonzero phase mismatch factor $\Delta k = k_0 - k_1 - k_a$. k_0, k_1 and k_a are the wave vectors of pump, signal and idler waves, respectively.

The QHD model is used to describe carrier dynamics of one component quantum plasma by including of quantum pressure term and quantum Bohm potential. The quantum statistics is included in the model through the equation of state which takes into account the Fermionic character of the electrons. Following field geometry is considered in the present problem:-

(1) Pump electric field is considered along x direction as $\vec{E}_0 = \hat{x} E_0 \exp i(k_0 x - \omega_0 t)$.

(2) External magnetostatic field B_0 is applied across the direction of pump E_0 and wave vector k_0.

The nonlinear response to this three wave parametric interaction is mathematically modelled with the help of analytical treatment of Guha et al [25] and quantum hydrodynamic model of Manfredi [26] and following basic equations are used:

$$\frac{\partial \vec{\vartheta}_0}{\partial t} + \vec{\vartheta}_0\left(\nabla \vec{\vartheta}_0\right) + \upsilon \vec{\vartheta}_0 = \frac{e}{m}\left(\vec{E}_0 + \vec{\vartheta}_0 \times \vec{B}_0\right) \tag{1}$$

$$\frac{\partial \vec{\vartheta}_1}{\partial t} + \vec{\vartheta}_0\left(\nabla \vec{\vartheta}_1\right) + \vec{\vartheta}_1\left(\nabla \vec{\vartheta}_0\right) + \upsilon \vec{\vartheta}_1 = \frac{e}{m}\left(\vec{E}_1 + \vec{\vartheta}_1 \times \vec{B}_0\right) - \frac{ik_1 V_F^2 n_1}{n_0}\left[1 + \Gamma \mathrm{H}^2\right] \tag{2}$$

Zeroth order momentum transfer equation (eq. (1)) shows that carrier will oscillate under the influence of a pump electric field. Equation (2) represents equation of motion of QHD model under the influence of external magnetostatic field. Last term of equation (2) reveals that quantum mechanical effects move in two distinct ways: the first is statistical in the sense that the equilibrium distribution is the Fermi distribution and the second is quantum dynamical arising from the energy associated with the finite momentum transfer of an electron interacting with plasma oscillation. Non-dimensional quantum parameter $H = \frac{\hbar \omega_p}{2k_B T_F}$ measures the relevance of quantum effects being proportional to quantum diffraction. $V_F = \frac{2k_B T_F}{m}$, is Fermi velocity of electrons at Fermi temperature T_F, k_B is the Boltzmann constant, and $\Gamma = \frac{k_1^2 V_F^2}{4\omega_p^2}$ is a quantum parameter.

Conservation of charge is represented by the continuity equation (equation (3) given below) in which n_0 and n_1 are the unperturbed and perturbed electron densities.

$$\frac{\partial n_1}{\partial t} + n_0\left(\frac{\partial \vartheta_1}{\partial x}\right) + n_1\left(\frac{\partial \vartheta_0}{\partial x}\right) + \vartheta_0\left(\frac{\partial n_1}{\partial x}\right) = 0 \quad (3)$$

$$\frac{\partial E_1}{\partial x} + \frac{\beta}{\varepsilon}\left(\frac{\partial^2 u}{\partial x^2}\right) = \frac{n_1 e}{\varepsilon} \quad (4)$$

$$\rho\left(\frac{\partial^2 u}{\partial t^2}\right) + 2\gamma_s \rho\left(\frac{\partial u}{\partial t}\right) + \beta\left(\frac{\partial E_1}{\partial x}\right) = C\left(\frac{\partial^2 u}{\partial x^2}\right) \quad (5)$$

The induced space charge field E_1 due to nonlinear interaction is determined from Poisson's equation (4) in which β is piezoelectric constant of semiconductor medium. Equation (5) describes the lattice vibration in a piezoelectric semiconducting medium with material density ρ and elastic constant C. γ and η are the damping constant and refractive index of the medium respectively.

The components of oscillatory electron fluid velocity ϑ_0 in the presence of a pump and the electromagnetic fields are obtained from equation (1) as

$$\vartheta_{0x} = \frac{-ie\omega_0 E_0}{\left(\omega_c^2 - \omega_0^2\right)} \text{ and } \vartheta_{0y} = \frac{-e\omega_c E_0}{m\left(\omega_c^2 - \omega_0^2\right)} \quad (6)$$

Using standard approach [25], we shall differentiate equation (3) and then simplify it with the help of equations (1) and (2) to get

$$\frac{\partial^2 n_1}{\partial t^2} + \upsilon\left(\frac{\partial n_1}{\partial t}\right) + \varpi_p^2 n_1 + \frac{n_0 e\beta}{m\varepsilon}\left(\frac{\partial^2 u}{\partial x^2}\right)R + \left(k_1^2 + k_1 k_0\right)\left[\frac{e n_0 E_1 \overline{E}}{m\left(\omega_c^2 - \omega_1^2\right)}\right] = -i\left(k_0 + k_1\right)n_1 \overline{E} \quad (7)$$

Where $R = \left[\frac{\omega_1^2}{\omega_c^2 - \omega_1^2}\right]$ and $\varpi_p^2 = \omega_p^2 R + k_1^2 V_F^2 \left[\frac{\left(\omega_1^2 + i\omega_1\omega_c\right)}{\left(\omega_c^2 - \omega_1^2\right)}\right]\left(1 + \Gamma \mathrm{H}^2\right)$ is the dispersive electron plasma waves in a magnetized quantum plasma medium. This term signifies contribution of magnetic field and quantum correction term to the plasma frequency.

Using rotating wave approximation, following coupled equations for slow and fast components of density perturbation are obtained from equation (7) as

$$\frac{\partial^2 n_{1s}}{\partial t^2} + \upsilon\left(\frac{\partial n_{1s}}{\partial t}\right) + \varpi_p^2 n_{1s} + \frac{n_0 e\beta}{m\varepsilon}\left(\frac{\partial^2 u}{\partial t^2}\right)R = -i\left(k_0 + k_1\right)n_{1f}^* \overline{E} \quad (8a)$$

$$\frac{\partial^2 n_{1f}}{\partial t^2} + \upsilon\left(\frac{\partial n_{1f}}{\partial t}\right) + \varpi_p^2 n_{1f} + \left(k_1^2 + k_1 k_0\right)\left[\frac{e n_0 E_1 \overline{E}}{\omega_c^2 - \omega_1^2}\right] = -i\left(k_0 + k_1\right)n_{1s}^* \overline{E} \quad (8b)$$

Subscripts s and f stand for slow and fast components, respectively and * represent complex conjugate of the quantity. It is evident from above equations that slow and fast components of density perturbations are coupled to each other via the pump field.

The usage of equations (5) and (8a, 8b) and mathematical simplification allows one to calculate the slow component of the density perturbation as

$$n_{1s}^* = \frac{-n_0 e\beta^2 k_a^2 k_1 R E_1^*}{2m\varepsilon\rho\gamma_s\omega_a}\left[(\delta_1^2 + i\upsilon\omega_a) - \frac{\left(k_0 + k_1\right)^2\left|\overline{E}\right|^2}{\left(\delta_2^2 - i\upsilon\omega_1\right)}\right]^{-1} \quad (9)$$

where $\delta_1^2 = (\varpi_p^2 - \omega_a^2)$ and $\delta_2^2 = (\varpi_p^2 - \omega_1^2)$

We confined ourselves to the Stokes component of the induced current density that is oscillating at the acoustic wave frequency and is expressed as

$$J_1 = n_{1s}^* e \vartheta_{0x} \quad (10)$$

Substituting n_{1s}^{*} from equation (9) and for the component of oscillatory electron fluid velocity ϑ_{0x} (equation 6) in equation (9), we get

$$J_1 = \frac{iAe\varepsilon\omega_p^2\omega_0 k_1 R E_0 E_1^*}{2m\gamma_s\omega_a\left(\omega_c^2-\omega_0^2\right)}\left[\left(\delta_1^2+i\upsilon\omega_a\right)-\frac{\left(k_0+k_1\right)^2\left|\overline{E}\right|^2}{\left(\delta_2^2-i\upsilon\omega_1\right)}\right]^{-1} \quad (11)$$

where $A = K^2 k_a^2 \vartheta_a^2$, $K^2 = \dfrac{\beta^2}{\varepsilon C}$, $\vartheta_a^2 = \dfrac{C}{\rho}$ and $\varepsilon = \varepsilon_0\varepsilon_1$

The time integral of J_1 yields the nonlinear-induced polarization at the Stokes frequency that may be derived using equation (11) as

$$P_1 = \int J_1 dt = \frac{Ae\varepsilon\omega_p^2\omega_0\omega_1 k_1 R E_0 E_1^*}{2m\gamma_s\omega_1\omega_a\left(\omega_c^2-\omega_0^2\right)}\left[\left(\delta_1^2+i\upsilon\omega_a\right)-\frac{\left(k_0+k_1\right)^2\left|\overline{E}\right|^2}{\left(\delta_2^2-i\upsilon\omega_1\right)}\right]^{-1} \quad (12)$$

The second order optical susceptibility can be obtained by defining the nonlinear polarization at frequency (ω_1) as

$$P_1 = \varepsilon_0 \chi^{(2)} E_0 E_1^*$$

which yields

$$\chi^{(2)} = \frac{Ae\varepsilon_1\omega_p^2\omega_0\omega_1 k_1 R}{2m\gamma_s\omega_1\omega_a\left(\omega_c^2-\omega_0^2\right)}\left[\left(\delta_1^2+i\upsilon\omega_a\right)-\frac{\left(k_0+k_1\right)^2\left|\overline{E}\right|^2}{\left(\delta_2^2-i\upsilon\omega_1\right)}\right]^{-1} = \mathrm{Re}\,\chi^{(2)} + \mathrm{Im}\,\chi^{(2)} \quad (13)$$

Now rationalizing equation (13) one may get the real and imaginary parts of second order susceptibility. It is well known that pure electric dipole susceptibilities are real in the non-dissipative case [27]. Present work focusses on the dispersion characteristics of acoustic wave which could be investigated through the real $\chi^{(2)}$ in equation (13). Dispersion characteristics of acoustic wave are effectively modified in quantum semiconductor plasma through $\delta_1^2 = (\varpi_p^2 - \omega_a^2)$, $\delta_2^2 = (\varpi_p^2 - \omega_1^2)$ and contribution of phase mismatch appears through second term in square bracket of eq. (13).

III. Results And Discussion

Theoretical formulation presented in the former section abides the fact that one may observe second-order nonlinearity by employing the QHD model and explore electron dynamics and dispersion characteristics in the semiconductor plasma. The numerical estimations have been made for n-type CdS assumed to be duly irradiated by pulsed 10.6 µm CO_2 lasers at 77K. The physical parameters used are $m = 0.107 m_0$, $\varepsilon_1 = 9.35$, $\vartheta_a = 1.8\times10^3 ms^{-1}$, $\beta = 0.21 Cm^{-2}$, $\rho = 4.82\times10^3 kgm^{-3}$, $\omega_a = 2\times10^{11} s^{-1}$, $\omega_0 = 1.78\times10^{14} s^{-1}$, $\upsilon = 5\times10^{13} s^{-1}$, $T_F = 77K$.

Being one of the principal objectives of the present analysis, the nature of the parametric dispersion via real part of the second order optical susceptibility $\mathrm{Re}\left(\chi^2\right)$ has been analyzed in the figures 1-4. Signature of distinct anomalous parametric dispersion in quantum plasma is quite significant when variation of $\mathrm{Re}\left(\chi^2\right)$ with respect to n_0 and E_0 are examined in figures 1 and 2. It appears that $\chi^{(2)}$ can both be positive and negative under the anomalous dispersion regime at carrier density around $n_0 = 4\times10^{24} m^{-3}$.

Figure 1 depicts variation of $\mathrm{Re}\left(\chi^2\right)$as a function of E_0 for quantum and classical plasma media. In quantum plasma medium, one can notice that there exists a distinct anomalous parametric dispersion regime with positive and negative values; but dispersion in classical plasma exhibits only positive magnitudes of real part of $\chi^{(2)}$. Inclusion of quantum corrections leads to initial decrements in real $\chi^{(2)}$ upto $3.5\times10^7 Vm^{-1}$ afterwards a rapid increase is observed leading to a maximum at $4\times10^7 Vm^{-1}$. Beyond $E_0 = 4\times10^7 Vm^{-1}$ Re (χ^2) decreases leisurely for the quantum plasma as well as in classical plasma.

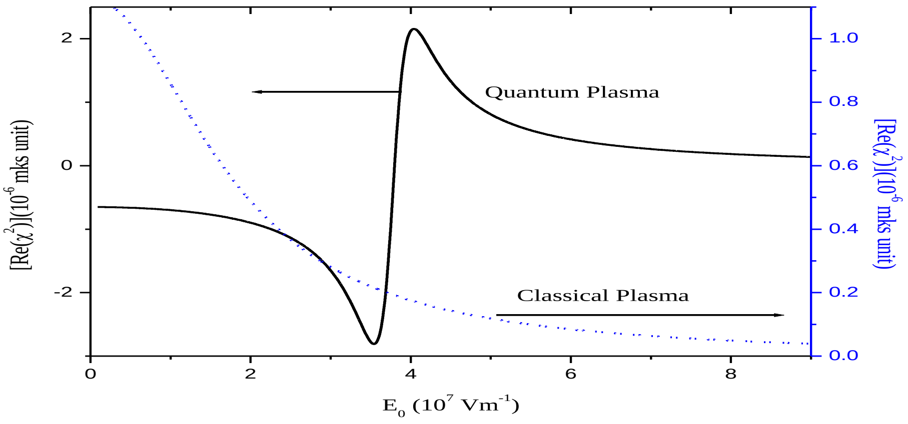

Fig. 1 Variation of the $\mathrm{Re}(\chi^2)$ versus pump amplitude E0 at $n_0 = 4\times10^{24} m^{-3}$ and $\Delta k = 6\times10^6 m^{-1}$.

The nature of parametric dispersion arising due to the real part of the second order optical susceptibility, (equation 13) for quantum and classical plasma media has been displayed in figure 2 with respect to carrier concentration n_0. For the quantum plasma medium initial negative magnitude of Re(χ^2) first decreases with n_0 reaches a minimum value at around $n_0 = 3\times10^{24} m^{-3}$. A slight shift from this doping concentration increases Re(χ^2) abruptly leading towards maximum magnitude of Re(χ^2) at around $n_0 = 4\times10^{24} m^{-3}$. On the other hand for classical plasma medium positive magnitudes of Re(χ^2) increases with increasing carrier concentration.

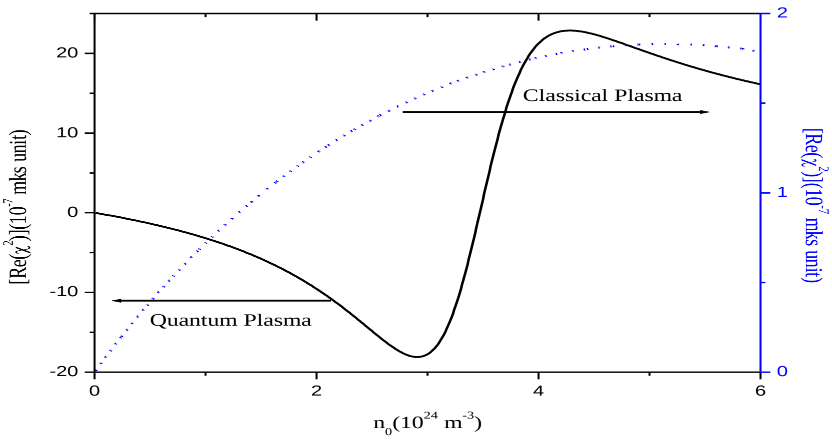

Fig.2 Variation of the $\mathrm{Re}(\chi^2)$ versus carrier concentration n_0 at $E_0 = 3.8\times10^7 Vm^{-1}$ and $\Delta k = 6\times10^6 m^{-1}$.

Parametric dispersion characteristics of classical and quantum semiconductor plasmas with respect to phase mismatch factor has been explored in figure 3. Quite distinct behavior is obtained when Δk is increased in both the media. Initially for small Δk, i.e. in the vicinity of linear phase matched direction Re (χ^2) is maximum for classical plasma and minimum for quantum plasma. However as soon as Δk is increased, Re (χ^2) decreases in classical plasma medium in contrast to increasing magnitude in quantum medium. At higher Δk values the curves exhibit maximum Re (χ^2) for quantum plasma and minimum Re (χ^2) for classical plasma. However considered range of phase mismatch factor resulted into negative magnitude of Re (χ^2) for quantum plasma and positive magnitudes of Re (χ^2) for classical plasma.

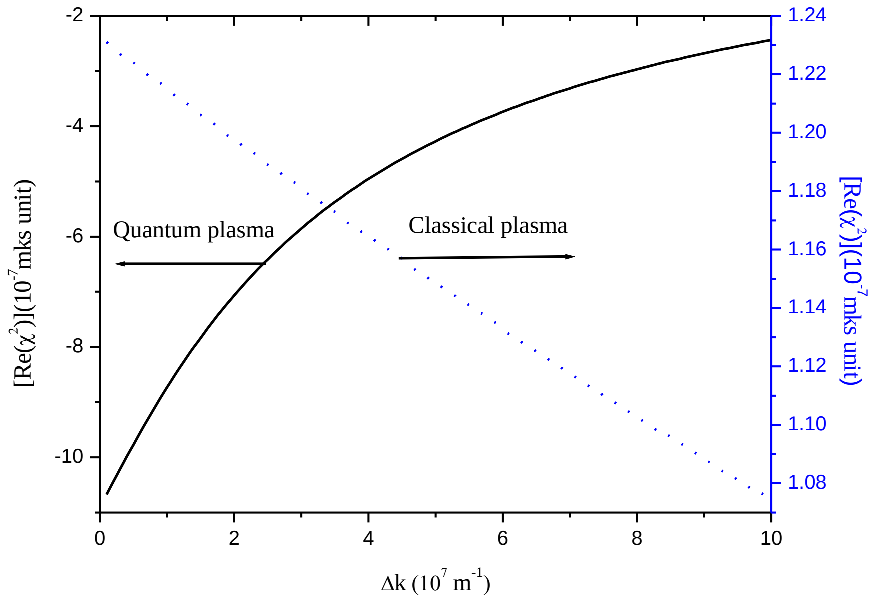

Fig. 3 Variation of the $\mathrm{Re}(\chi^2)$ versus momentum mismatch Δk, at $n_0 = 4\times10^{24} m^{-3}$ and $E_0 = 3.8\times10^7 Vm^{-1}$.

Let us now consider a laser irradiated quantum semiconductor plasma and examine the effect of quantum diffraction parameter on Re (χ^2). Figure 4 examines this behavior with B_0 as a parameter. Identical curves are obtained for both the cases. Initially Re (χ^2) slightly traces two distinct paths leading towards minima at H=5.20 and H= 5.01 for with and without magnetic field respectively. Further increase in H leads to an abrupt increase in Re (χ^2), which subsequently achieves positive values and attains maxima for the both cases. Finally with increasing diffraction parameter fall in Re (χ^2) is observed. Cross over at H=5.60 signifies same magnitude of Re (χ^2) irrespective of presence or absence of external magnetic field.

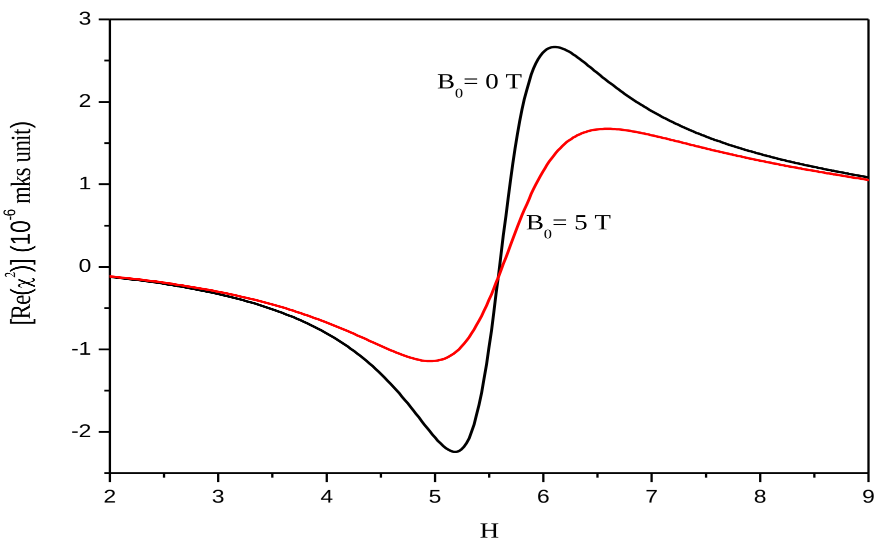

Fig. 4 Variation of the $\mathrm{Re}(\chi^2)$versus quantum parameter H, magnetic field as a parameter $n_0 = 4\times10^{24} m^{-3}$, $E_0 = 3.8\times10^7 Vm^{-1}$ and $\Delta k = 6\times10^6 m^{-1}$.

IV. Conclusion

In the present paper, using electromagnetic treatment the nonlinear susceptibility dispersion via second order optical susceptibility has been studied in piezoelectric II-VI doped semiconductor crystal like n-CdS in the classical and quantum plasmas with non-phasematched condition. The following important conclusions may be drawn:-

1. Dispersion characteristics are found to be effectively modified in quantum plasma through carrier concentration.
2. Enhancement of parametric dispersion could be easily achieved by a proper selection of pump amplitude, doping profile and appropriate phase mismatch.
3. Second order susceptibility is found to be effectively modified by the quantum corrections and hence dispersion characteristics of scattered wave in parametric scattering gets novel character.
4. Positive and negative values of $\mathrm{Re}\left(\chi^2\right)$ may be utilized for frequency conversion methods and self -focusing and defocusing applications.
5. Inclusion of quantum mechanical effects are found to effectively modify the parametric dispersion characteristics. It can be envisaged that a real-world demo of the above kind of parametric dispersion may lead to the possibility of observation of group velocity dispersion in semiconductor plasma medium.

Acknowledgments

Financial assistance from the University Grant Commission, New Delhi, India, under Maulana Azad Minority Fellowship scheme is gratefully acknowledged.

References

[1]. D. Bohm, and D. Pines, A Collective Description of Electron Interactions: III. Coulomb Interactions in a Degenerate Electron Gas, Phys. Rev., 92, 1953, 609.

[2]. D. Pines, A Collective Description of Electron Interactions: IV. Electron Interaction in Metals, Phys. Rev., 92, 1953, 626.

[3]. D. Pines, Quantum Plasma Physics: Classical and Quantum Plasmas, J. Nucl. Energy, Part C 2, 1961, 5.

[4]. Yu. L. Klimontovich, and V.P. Silin, On the spectra of systems of interacting particles, (in Russian) Zh. Eksp. Teor. Fiz., 23, 1952, 151.

[5]. Yu. L. Klimontovich and V.P. Silin, The spectra of systems of interacting particles, In: Plasma Physics ed. by J. Drummond (New York, McGraw-Hill, 1961).

[6]. P. Nozieres, and D. Pines, The Theory of Quantum Liquids (Benjamin, New York, 1966).

[7]. P. K. Shukla, and S. Ali, Dust acoustic waves in quantum plasmas, Phys. of Plasma, 12, 2005, 114502.

[8]. M.D. Ventra, Electrical Transport in Nanoscale Systems (New York, Cambridge, 2008).

[9]. A. Jungel, Transport Equations for Semiconductor Devices(Berlin-Heidelberg, Springer, 2009)

[10]. S. Mola, G. Manfredi, and M. R. Fexi, Expansion of a quantum electron gas, J. Plasma Phys. 50, 1993, 145.

[11]. M. Bonitz, Impossibility of plasma instabilities in isotropic quantum plasmas, Phys. Plasmas, 1, 1994, 832.

[12]. S. Dubey and S. Ghosh, Nonlinear absorption and refractive index of a Raman Scattered mode in magneto active centrosymmetric semiconductor plasmas, Physica B, 210, 1995, 95-103.

[13]. G. Sharma, and S. Ghosh, Nonlinear interactions in magnetized piezoelectric semiconductor plasmas, The Eur. Phys. J., D, 11(2), 2000, 301-307.

[14]. V. M. Tsytovich, Nonlinear effects on Plasmas, (New York, Plenum, 1970).

[15]. J. weiland H. wilhelmson, Coherent nonlinear interaction of plasmas (New York, Pergamon, 1977).

[16]. S. Ghosh, S.Dubey, and R. Vanshpal, Quantum effect on parametric amplification characteristics in piezoelectric semiconductors, Phys. Lett. A, 375, 2010, 43-47.

[17]. Ch. Uzma, I. Zeba, H. Shah, and M. Salimullah, Stimulated Brillouin scattering of laser radiation in a piezoelectric semiconductor: Quantum effect, J Appl. Phys., 105, 2009, 013307-1-013307-5.

[18]. A. Paliwal, S. Dubey and S. Ghosh, Absolute instability of polaron mode in semiconductor magnetoplasma, Solid state communication, 269, 2018, 71-75.

[19]. A. Bahabad, M. M. Murnane, and H. C. Kapteyn, Quasi-phase-matching of momentum and energy in nonlinear optical processes, Nat. Photonics 4, 2010, 570–575.

[20]. A. Rose and D. R. Smith, Broadly tunable quasi-phase-matching in nonlinear metamaterials, Phys. Rev. A, 84, 2011, 013823.

[21]. L.A. Golovan, V. Yu. Timoshenko, and A.B. Fedotov, et. al., Phase matching of second-harmonic generation in birefringent porous silicon, Appl. Phys. B, 73, 2001, 31–34.

[22]. M. W. Klein, C. Enkrich, M. Wegener, and S. Linden, Second-harmonic generation from magnetic metamaterials, Science, 313, 2006, 502-504.

[23]. E. Poutrina, D. Huang, and D. R. Smith, Analysis of nonlinear electromagnetic metamaterials, New J. Phys.,12, 2010, 093010.

[24]. A. Rose, S. Larouche, D. Huang, E. Poutrina, and D. R. Smith, Nonlinear parameter retrieval from three- and four-wave mixing in metamaterials, Phys. Rev. E, 82, 2010, 036608.

[25]. S. Guha, P.K. Sen, and S. Ghosh, Parametric instability of acoustic waves in transversely magnetised piezoelectric semiconductors, Phys. Stat. Sol. (a), 52, 1979, 407.

[26]. G. Manfredi, How to model quantum plasmas, Fields Inst. Commun., 46, 2005, 263.

[27]. P. S. Pershan, In Progress in Optics,ed. E. Wolf, 5:85 114(NewYork, Inter science, Amsterdam: NorthHolland, 1966).

Kamal Jain "Parametric Dispersion of Acoustic Wave in a Laser Irradiated Semiconductor Plasma: Quantum Effects "International Journal of Engineering Science Invention (IJESI), vol. 07, no. 06, 2018, pp 77-83