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Original Research Article

Dielectric response and mode evolution in quantum-corrected GaAs plasma with two stream instability

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ABSTRACT
A generalized dielectric response function for two stream instability (convective only) is obtained in n-type gallium arsenide semiconductor plasma using a quantum hydrodynamic model. In the presence of a non-dimensional quantum parameter-H, we examine the phase and amplification profiles of two stream instabilities with an externally applied electric field ranging from 2600 to 4000 kV m-1. During this range, a sizable portion of the satellite valley's electron population approaches that of the central valley. Two new modes are created when quantum corrections are present in the plasma medium; one of these modes is amplifying and moves forward. Additionally, it alters the spectral signature of four classical plasma modes that already exist. By calculating the real part of the longitudinal electrokinetic power flow density, the existence of two stream instability is also demonstrated analytically.

1. Introduction

A well-known phenomenon in plasma physics is the two stream instability found in several valley semiconductors, such as gallium arsenide (GaAs), silicon (Si), and germanium (Ge). Over the past 50 years, numerous experiments have been proposed to investigate this phenomenon under various physical settings [1–3]. On very solid theoretical basis, the existence of two stream instability has also been investigated [4–6]. Two distinct electron streams are produced by the field-induced transferred electron mechanism, which is caused by the available electron densities in various valleys of the conduction band of several valley semiconductors (such as GaAs). When the drift velocity of streaming electrons approaches but is marginally greater than the phase velocity of the wave associated with it, instability resulting from the interaction of these two streams may manifest in plasma. Two stream instability's special characteristics are being used more and more in a number of significant areas of plasma research. For example, the presence of two stream instability in plasma media due to an electron transferred mechanism reduces the negative impact of high collision frequencies in solid state devices and amplifies the space charge wave linked to the instability under favorable physical conditions.

Because of the peculiarities of its band structure, physicists have been quite interested in several valley semiconductors. Due to the relative simplicity of its band structure, GaAs has been the subject of extensive research in recent years among all numerous valley semiconductors [7, 8]. Studying GaAs's direct bandgap, inter-valley carrier transport, high mobility, and many other characteristics has shown that it is best suited for a wide range of applications, including photonics and microwave production. Since it produces a large number of electrons in both the core and satellite valleys, and since these electrons drift with varying velocities, creating a two stream system in the GaAs crystal, the application of an electric field to GaAs has always been an intriguing area of study.

The implications of this subfield in a variety of physics environments, including intense laser-solid interaction [9, 10], dense astrophysical and cosmological environments [11], micro-plasma systems [12], nano-electronic devices [13], semiconductor devices [14], etc., have piqued the interest of plasma physicists in the last few decades. In this field of study, low-temperature plasma media with high carrier densities are taken into consideration, and it is assumed that the plasma particles exhibit quantum mechanical behavior. The deBroglie wavelength of charged particles becomes comparable to the plasma system's size under such physical circumstances. The quantum hydrodynamic model (QHD), an encompassing model, is used to analyze quantum effects in plasma. The consequences of quantum statistics and quantum diffraction in plasma are addressed by the QHD model. Many workers integrate both of these effects in a non-dimensional quantum parameter-H. The ratio of plasma energy to the Fermi energy of plasma particles is known as the quantum parameter-H. The literature contains the most recent information on how the quantum parameter-H affects various collective modes and related instabilities in plasmas [15–18].

At the classical level, a lot of work has been done to look at the various facets of two stream instability, including theoretical and experimental research. The problem of two stream instability has been handled quantum mechanically in a relatively small number of research works. The two streams are thought to be caused by drifting electron-hole plasma in the majority of these articles [19, 20]. However, under the quantum regime, the situation of two electron streams traveling at different drift velocities has not been examined. Therefore, we have chosen to analyze the two electron stream instability of longitudinal waves in n-type GaAs semiconductor quantum plasma in the current study. A comparable topic has been explored under classical approximations by Guha and Sen [21]. They included the proper polar optical phonon scattering mechanism in their investigation. The nature of the real part of longitudinal electrokinetic power flow density has been used to establish the existence of two stream instability. The real fraction of the longitudinal electrokinetic power flow density, which should be negative for the amplifying mode, was determined by analyzing the impact of the non-dimensional quantum parameter-H on the dispersion equation of two stream instability. In order to determine the magnitudes of different system characteristics, we have also included the polar optical phonon scattering mechanism in our investigation. The results reported here are Guha and Sen's [21] quantum adjusted results. While we obtained two amplifying modes at the classical level—one forward and one backward propagating mode—they only achieved one forward amplifying mode. We discovered two novel modes in two stream instability phenomena in the presence of quantum effects, one of which is an amplifying mode that moves forward.

2. Theoretical formulations

In our analysis, we consider n-type GaAs semiconductor quantum plasma consisting of two streams of electron with same charge ($-q$) and different masses m_j. The instability caused by the interaction of these two different streams of electrons having different drift velocity v_{0j}, is governed by the equation of continuity and equation of motion under QHD model. Here we assume the electron drift velocity, the electrostatic electric field $\vec{E}$ as well as wave vector $\vec{k}$ all are aligned along z-direction, therefore the problem is truly one dimensional and hence the governing equations read as:

$$\frac{\partial n_{1j}}{\partial t}+n_{0j}\frac{\partial \vec{v}_{1j}}{\partial z}+\vec{v}_{0j}\frac{\partial n_{1j}}{\partial z}=0 \tag{1}$$

$$\frac{\partial \vec{v}_{1j}}{\partial t}+\vec{v}_{0j}\frac{\partial \vec{v}_{1j}}{\partial z}+v_j\vec{v}_{1j}=\frac{-q}{m_j}(\vec{E}_1)+\frac{ikV_{Fj}^2 n_{1j}}{n_{0j}}(1+\Gamma_j H_j^2)\ . \tag{2}$$

Here j = 1, 2 represent electron's dynamics in central and satellite valley respectively and subscript 0 and 1 denote the zero and first order quantities. v_j is momentum transfer collision frequency, $V_{Fj}=(2k_BT_F/m_j)^{1/2}$ Fermi velocity with Boltzmann's constant k_B and Fermi temperature T_F, n total carrier concentration and n_{0j} equilibrium carrier density in either of the valley respectively. $H_j=\hbar\omega_{pj}/2k_BT_F$ and $\Gamma_j=k^2V_{Fj}^2/4\omega_{pj}^2$ are the quantum parameters in which $\hbar$ is Planck's constant divided by 2π, $\omega_{pj}=(q^2n_{0j}m_j\varepsilon)$ is plasma frequency with $\varepsilon(=\varepsilon_0\varepsilon_l)$; ε_l being the lattice dielectric constant of semiconductor.

Now under plane wave approximation, we assume that all perturbed quantities vary as: $\exp[i(\sqrt{\omega t-kz})$; where ω and k are wave angular frequency and wave number respectively. Now following one-dimensional QHD model of semiconductor plasma (Eqs. (1) and (2)) and the procedure adopted in [22, 23], the relevant dielectric response function for two stream instability is derived as:

$$\varepsilon(\omega,k)=1-\sum_j\omega_{pj}^2\left[\frac{1+\dfrac{k^2V_{Fj}^2}{\omega_{pl}^2}(1+\Gamma_jH_j^2)}{(\omega-kv_{0j})(\omega-kv_{0j}-iv_j)}\right]=0 \tag{3}$$

It is the generalised form of the dielectric response function in semiconductor quantum plasma. Equation (3) can be rewritten in the following form

$$\varepsilon(\omega,k)=1-\omega_{p1}^2\left[\frac{1+\dfrac{k^2V_{F1}^2}{\omega_{p1}^2}(1+\Gamma_1H_1^2)}{(\omega-kv_{01})(\omega-kv_{01}-iv_1)}\right]-\omega_{p2}^2\left[\frac{1+\dfrac{k^2V_{F2}^2}{\omega_{p2}^2}(1+\Gamma_2H_2^2)}{(\omega-kv_{02})(\omega-kv_{02}-iv_2)}\right]=0\ . \tag{4}$$

For semiconductor plasma with two valleys (central and satellite valleys) in its conduction band, the effective dielectric constant is expressed inferred (Eq. 4). By assuming a drifting Maxwellian as the carrier distribution function and the polar optical phonon scattering mechanism for momentum and energy transfer, the physical parameters of this dielectric response function for central and satellite valley electrons can now be determined [24–28]. This assumption is based on the well-known finding that the primary exchange phenomena in the medium is polar optical phonon scattering for n-GaAs at 300 K (room temperature), as reported by Ehrenreich [29] and Podor and Nador [30]. Therefore, using Stratton's method [24], the electrons' momentum conservation equation [27] is as follows:

$$\left\langle\frac{dP_E}{dt}\right\rangle_{po}=m_jv_{0j}v_j=\frac{2}{3}\frac{qE_{0j}N_lm_jv_{0j}}{(2m_j\pi k_B\theta_D)^{1/2}}x_{ej}^{3/2}e^{x_{ej}/2}[(e^{x_0-x_{ej}}+1)K_{1j}+(e^{x_0-x_{ej}}-1)K_{0j}]\ . \tag{5}$$

Here θ_D is Debye temperature of the crystal. $x_0=\hbar\omega_l/k_BT_0$, $x_{ej}=\hbar\omega_l/k_BT_{ej}$; T_0 and T_{ej} being the lattice temperature and the effective electron temperature in j^{th} valley respectively; $\hbar\omega_l$ is the optical phonon energy where ω_l represents the longitudinal optical phonon frequency; K_{0j} and K_{1j} are the modified Bessel functions of second kind of zeroth and first order respectively in $(x_{ej}/2)$ and can be approximated as [31]

$K_{0j}=-[\ln(x_{ej}/4)+\gamma]$ and $K_{1j}=2/x_{ej}$; $\gamma=0.5772$ is the Euler's constant.

Due to polar optical phonon scattering, the loss of momentum of the carriers occurs which is represented by

$\langle dP_E/dt\rangle_{po}$. $E_{0j} = (1/\varepsilon_\infty - 1/\varepsilon_l)m_j q\hbar\omega_l/\hbar^2$ represents an electric field characterizing the strength of the polar mode scattering, ε_∞ is the optical dielectric constant, $N_l = [\exp(\theta_D/T_0)-1]^{-1}$ is the number of phonons with wave vector $\vec{k}$. From Eq. (5), we obtain v_j as:

$$v_j = \frac{2}{3}\frac{qE_{0j}N_l}{(2\pi m_j k_B\theta_D)^{1/2}} x_{ej}^{3/2} e^{x_{ej}/2}[(e^{x_0-x_{ej}}+1)K_{1j} + (e^{x_0-x_{ej}}-1)K_{0j}] \ . \tag{6}$$

The idea of the carrier temperature (hot carrier) in the crystal becomes crucial because the equilibrium density distribution condition can always be reached at a specific effective carrier temperature [24, 28, 32], particularly when the crystal is heavily doped and subject to an electrostatic field. The electron temperature as a function of static electric field can be calculated using the energy balance condition derived from polar optical phonon scattering, as reported by Stratton [24], provided that the required requirements are met.

$$\left(\frac{E}{E_{0j}}\right)^2 = \frac{2}{3\pi} N_l^2 x_{ej}^2 e^{x_{ej}/2}(e^{x_0-x_{ej}}-1)K_{0j}[(e^{x_0-x_{ej}}+1)K_{1j} + (e^{x_0-x_{ej}}-1)K_{0j}] \ . \tag{7}$$

Either of the two valleys' electron temperatures can be determined using the equation above.

Hilsum's [33, 34] theory that the electron temperature in satellite valleys typically approaches the lattice temperature is therefore taken into consideration when calculating the carrier density in various valleys. The Butcher and Fawcett report [25] also supported this idea. The only factor that affects the total electron distribution in the crystal is the electron temperature in the central valley. In accordance with Hilsum [33], the upper valley's carrier density can be written as follows:

$$n_2 = \frac{n}{\left[1+\left(\frac{m_1}{m_2}\right)^{3/2}\exp\left(\frac{\Delta}{k_B T_{e1}}\right)\right]} \ . \tag{8}$$

where the total carrier concentration is given by $n = n_1 + n_2$ and Δ is the energy gap between the central and satellite valley minima. Hence the carrier density in the lower valley is given by

$$n_1 = n - n_2 \ . \tag{9}$$

We rephrase Eq. (4) as the following polynomial in order to solve it for the study of the convective nature of two stream instability.

$$A_6k^6 + A_5k^5 + A_4k^4 + A_3k^3 + A_2k^2 + A_1k + A_0 = 0 \tag{10}$$

where,

$$A_6 = \left(-v_{02}^2\frac{V_{F1}^4H_1^2}{4\omega_{p1}^2} - v_{01}^2\frac{V_{F2}^4H_2^2}{4\omega_{p2}^2}\right)$$

$$A_5 = \left(v_{02}\frac{V_{F1}^2H_1^2}{4\omega_{p1}^2}(2\omega - iv_2) + v_{01}\frac{V_{F2}^4H_2^2}{4\omega_{p2}^2}(2\omega - iv_1)\right)$$

$$A_4 = \nu_{01}^2\nu_{02}^2 - V_{F1}^2\nu_{02}^2 - V_{F2}^2\nu_{01}^2 + i\omega\nu_2\frac{V_{F1}^4H_1^2}{4\omega_{p1}^2} + i\omega\nu_1\frac{V_{F2}^4H_2^2}{4\omega_{p2}^2} - \omega^2\frac{V_{F1}^4H_1^2}{4\omega_{p1}^2} - \omega^2\frac{V_{F2}^4H_2^2}{4\omega_{p2}^2}$$

$$A_3 = [-\nu_{01}\nu_{02}^2(2\omega - i\nu_1) - \nu_{01}^2\nu_{02}(2\omega - i\nu_2) + \nu_{02}V_{F1}^2(2\omega - i\nu_2) + \nu_{01}V_{F2}^2(2\omega - i\nu_1)]$$

$$A_2 = (4\omega^2 - \nu_1\nu_2)\nu_{01}\nu_{02} + \omega^2(\nu_{01}^2 + \nu_{02}^2) - 2i\omega\nu_{01}\nu_{02}(\nu_1+\nu_2) - i\omega(\nu_1\nu_{02}^2 + \nu_{02}\nu_{01}^2) - \nu_{02}^2\omega_{p1}^2 - \nu_{01}^2\omega_{p2}^2 - \omega^2(V_{F1}^2 + V_{F2}^2) + i\omega(\nu_1V_{F2}^2 + \nu_2V_{F1}^2)$$

$$A_1 = -2\omega^3(\nu_{01}+\nu_{02}) + 2i\omega^2(\nu_2\nu_{01} + \nu_1\nu_{02}) + \omega\nu_1\nu_2(\nu_{01}+\nu_{02}) + i\omega^2(\nu_1\nu_{01} + \nu_2\nu_{02}) + \nu_{02}\omega_{p1}^2(2\omega - i\nu_2) + \nu_{01}\omega_{p2}^2(2\omega - i\nu_1)$$

$$A_0 = \omega^4 - i\omega^3(\nu_1+\nu_2) - \omega^2\nu_1\nu_2 - \omega^2(\omega_{p1}^2 + \omega_{p2}^2) + i\omega(\nu_2\omega_{p1}^2 + \nu_1\omega_{p2}^2)$$

Prior to delving deeply into the dynamics of convective instability, we want to confirm that the system is experiencing convective instability. We now use the relation [22] to determine the real part of the longitudinal electrokinetic power flow density of the wave in order to prove the existence of convective instability.

$$\mathrm{Re}(P_K) = \frac{V_1 J_1^* + V_1^* J_1}{2}. \tag{11}$$

where V_1 is the r.f. electrokinetic potential which for the problem under study is found to be

$$V_1 = -\frac{i v_{0j}\left[1+\frac{k^2 V_{Fj}^2}{\omega_{pj}^2}(1+\Gamma_j H_j^2)\right]E}{(\omega - k v_{0j} - i v_j)}. \tag{12}$$

The r.f. current density becomes

$$J_1 = -\frac{i\varepsilon\omega_{pj}^2\omega\left[1+\frac{k^2 V_{Fj}^2}{\omega_{pj}^2}(1+\Gamma_j H_j^2)\right]E}{(\omega - k v_{0j})(\omega - k v_{0j} - i v_j)}. \tag{13}$$

V_1^* and J_1^* represent the complex conjugate of V_1 and J_1 respectively. Assuming $k(=k_{\mathrm{Re}} + ik_{\mathrm{Im}})$ and ω as real quantity, we obtain the quantum modified real part of the longitudinal electrokinetic power flow density for a two stream instability using Eqs. (11, 12, 13) as:

$$\mathrm{Re}(P_K)_c = \varepsilon\omega_{pj}^2 \nu_{0j}\omega(\omega - k_{\mathrm{Re}}\nu_{0j})\left[\left\{1+\frac{k_{\mathrm{Re}}^2 V_{Fj}^2}{\omega_{pj}^2}(1+\Gamma_{\mathrm{Re}\,j}H_j^2) - \frac{k_{\mathrm{Im}}^2 V_{Fj}^2}{\omega_{pj}^2}(1+\Gamma_{\mathrm{Im}\,j}H_j^2) - 24\Gamma_{\mathrm{Re}\,j}\Gamma_{\mathrm{Im}\,j}H^2\right\}^2 + \frac{4k_{\mathrm{Re}}^2 k_{\mathrm{Im}}^2 V_{Fj}^4}{\omega_{pj}^4}(1+2\Gamma_{\mathrm{Re}\,j}H^2 - 2\Gamma_{\mathrm{Im}\,j}H^2)^2\right]$$
$$\times\left[\left\{(\omega - k_{\mathrm{Re}}\nu_{0j})^2 + k_{\mathrm{Im}}^2\nu_{0j}^2\right\}\left\{(\omega - k_{\mathrm{Re}}\nu_{0j})^2 + (k_{\mathrm{Im}}\nu_{0j} + \nu_j)^2\right\}\right]^{-1} EE^*. \tag{14}$$

where the suffix c denotes convective instability and $\Gamma_{\mathrm{Re}\,j} = \frac{k_{\mathrm{Re}}^2 V_{Fj}^2}{4\omega_{pj}^2}$, $\Gamma_{\mathrm{Im}\,j} = \frac{k_{\mathrm{Im}}^2 V_{Fj}^2}{4\omega_{pj}^2}$.

From this expression it can be inferred that $\mathrm{Re}(P_K)_c$ becomes negative only when the phase velocity of the propagating mode $v_\varphi(=\omega/k_{\mathrm{Re}})$ is less than the drift velocity of the electrons in the central valley ν_{0j}. Hence the convective instability is possible under the physical condition discussed above.

3. Results and discussion

To examine the convective nature of two stream instability, we have solved Eq. (10) numerically for complex $k(=k_{\mathrm{Re}} + ik_{\mathrm{Im}})$ and real ω. For this purpose we consider n-type GaAs as our medium of study. Here we use the possible realistic values of some physical parameters listed below in Table 1.

To investigate numerically the wave spectrum of all possible modes generated due to two stream interactions in n-GaAs, we have applied electrostatic field ranging from 2.6×10^3 to 4×10^3 kV m^{-1}. This range of electrostatic field is quite safe as the damage threshold for n-GaAs is of the order of 4×10^4 kV m^{-1}. Use of above parameters (Table 1) yields the drift velocity of central valley electrons ranging from $1{:}3\times10^5$ to $2{:}3\times10^5$ ms^{-1}. The phase velocities of all six possible modes are obtained in the range 10–10^5 ms^{-1}. Thus in the studied case v_{01} is always found more than phase velocity of the wave. Thus the possibility of convective instability is established.

The signature of the imaginary and real parts of wave vector (k_{Im} and k_{Re}) decides the nature of wave viz., amplifying or attenuating and backward or forward propagating. If the signature is positive ($k_{\mathrm{Im}}, k_{\mathrm{Re}} > 0$) the mode will be forward amplifying mode otherwise backward attenuating mode ($k_{\mathrm{Im}}, k_{\mathrm{Re}} < 0$). The propagation characteristics of all possible modes of two stream instability are illustrated in Figs. 1, 2, 3, 4, 5, 6.

Figure 1 shows that the first mode is backward attenuating mode both in presence ($H \neq 0$) and absence ($H = 0$) of quantum parameter-H. From this figure, we observe that the presence of quantum effects lowers the magnitude of phase velocity of this mode by 4-orders.

Table 1: Material constant of n-GaAs ($T_0 = 300$ K).

Parameters	m_1/m_0	m_2/m_0	ε_l	ε_∞	Δ (eV)	$\hbar\omega_l$ (eV)	θ_D (K)
Values used in the present analysis	0.072 [21]	0.364 [21]	13.5 [21]	11.6 [21]	0.36 [21]	0.036 [21]	420 [21]
Values available in the literature	0.065 [35]	0.35 [35]	12.5 [36]	10.82 [36]	0.29 [37]	0.036 [38]	378 [39]

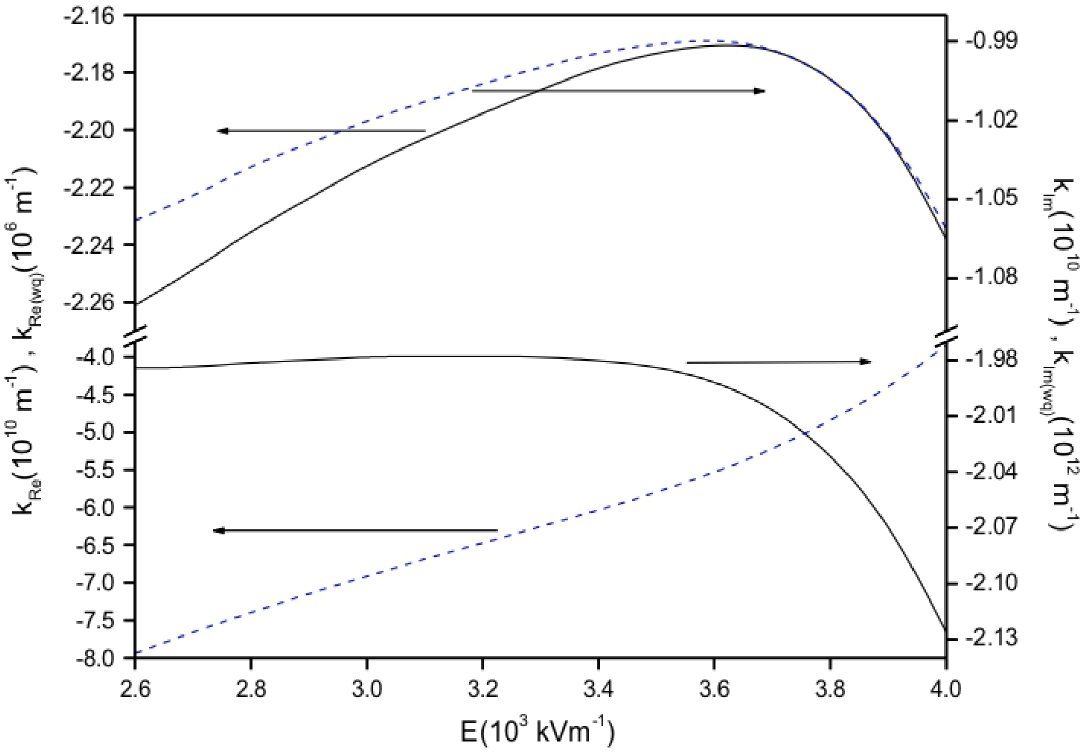

Figure 1: k_{Re}, k_{Im} versus E for I-mode (solid and dashed lines represent curves corresponding to with and without quantum corrections).

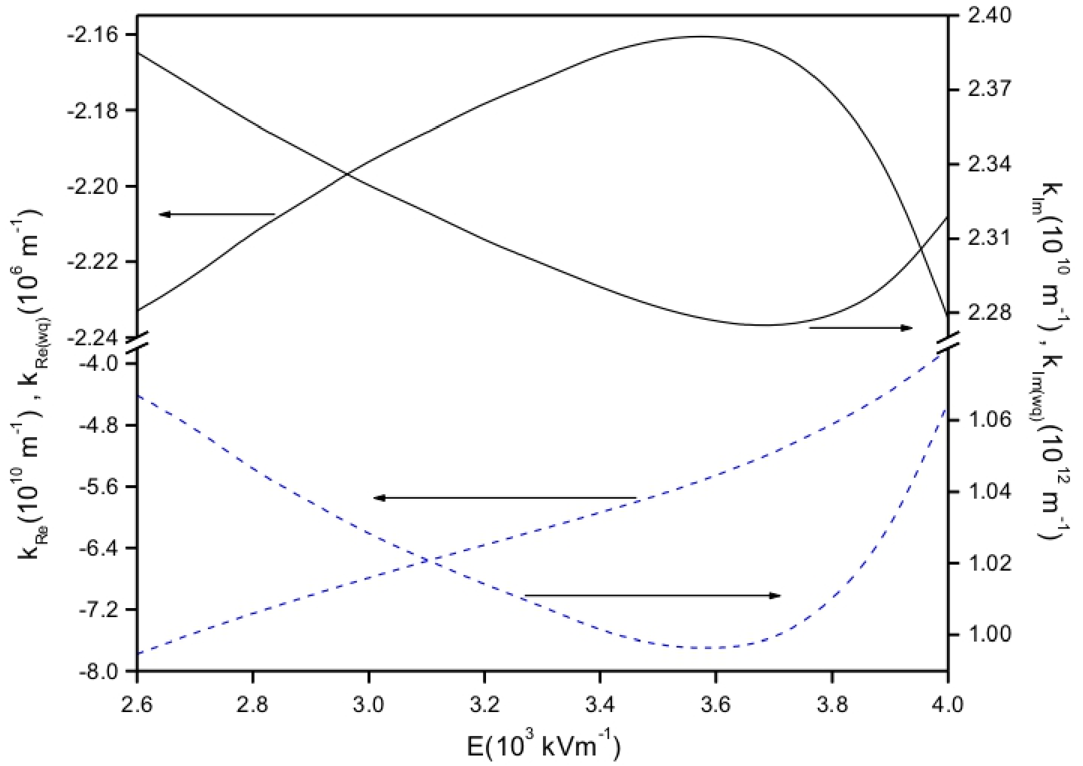

Figure 2: k_{Re}, k_{Im} versus E for II-mode (solid and dashed lines represent curves corresponding to with and without quantum corrections).

Further in classical plasma, the phase velocity increases almost linearly with externally applied electric field E whereas in quantum plasma, it first increases to attain maximal value at $E \approx 3{:}6\times10^3$ kVm^{-1} and then starts reducing with increasing values of E. The magnitude of attenuating constant of this mode is found to be high in classical plasma than in quantum plasma. In quantum plasma, it is nearly independent of E up to $E \approx 3{:}3\times10^3$ kVm^{-1}, afterwards it grows rapidly with E, while in classical plasma, attenuating constant initially decays with E, achieves the minimal value at $E \approx 3{:}6\times10^3$ kVm^{-1} and then it starts increasing with E.

One may infer from Fig. 2 that second mode has backward propagation with amplifying nature under both classical and quantum regimes. In quantum regime, similar to first mode, the phase velocity of this mode also reduces by 4 orders. It may also be inferred from amplification characteristics that the qualitative variation of amplification coefficient (k_{Im}) is identical in both regimes. The magnitude of amplification is found to be a decreasing function of E up to $E < 3{:}6\times10^3$ kVm^{-1} but for $E > 3{:}6\times10^3$ kVm^{-1} it is converted to an increasing function of E. It is noted that the magnitude of amplification is higher in classical plasma by 2-orders than quantum plasma.

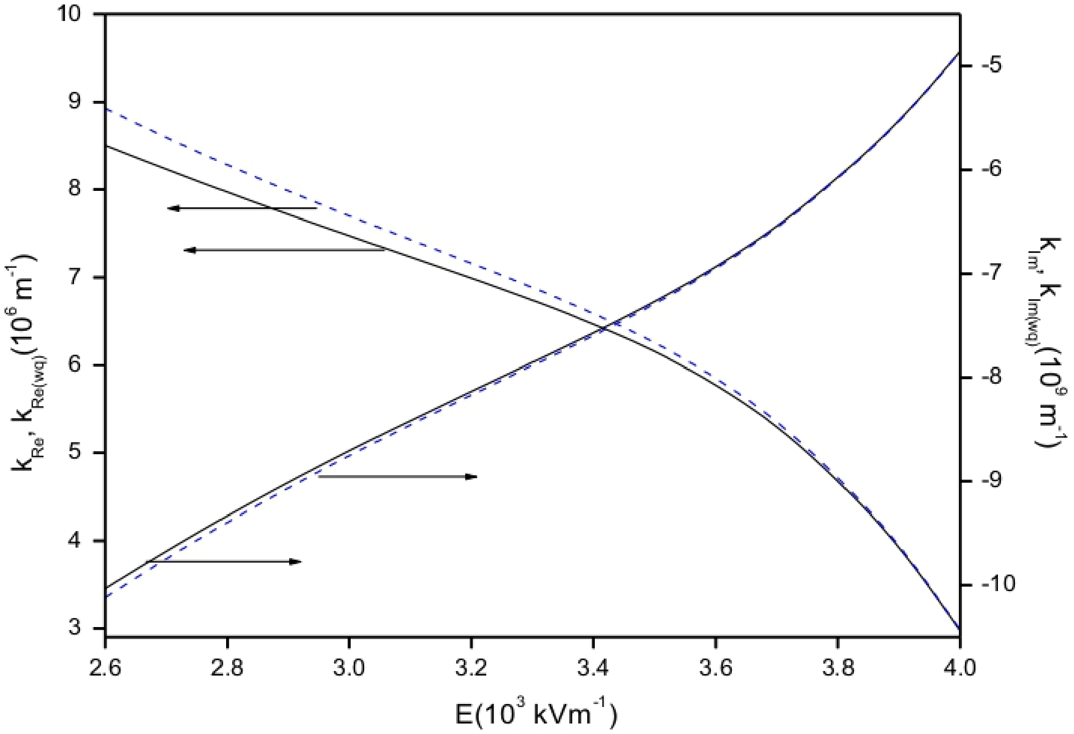

Figure 3: k_{Re}, k_{Im} versus E for III-mode (solid and dashed lines represent curves corresponding to with and without quantum corrections).

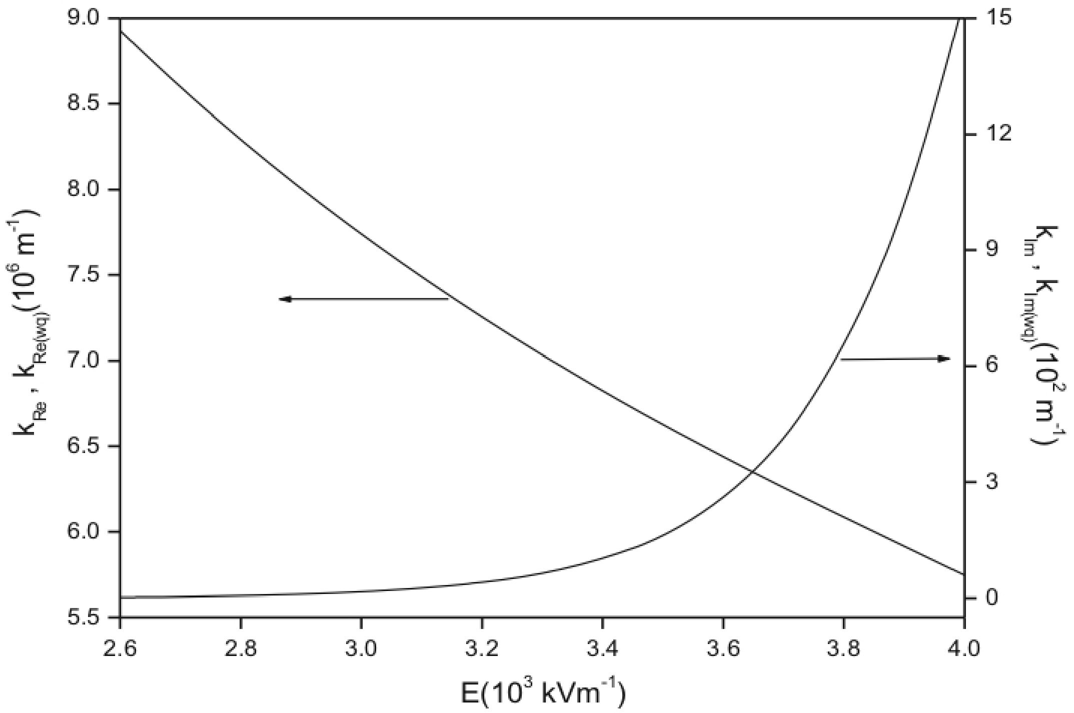

Figure 4: k_{Re}, k_{Im} versus E for IV-mode.

The phase and gain profiles of third mode are displayed in Fig. 3. This mode is forward attenuating in nature. The qualitative variations of phase velocity as well as amplification coefficient do show only marginal deviation in magnitude if one shifted from classical to quantum plasma system. The phase velocity of this propagating mode increases almost linearly with increasing electrostatic field. For $E < 3{:}8\times10^3$ kVm^{-1} one obtains little higher phase velocity in quantum plasma. But for $E > 3{:}8\times10^3$ kVm^{-1} phase velocity becomes independent of quantum correction. The gain profile of this mode depicts that increase in magnitude of E reduces the attenuation rate. Thus the attenuating constant is large for lower values of E and small for higher values. Inclusion of quantum effects reduces the attenuating constant only up to $E \approx 3{:}5\times10^3$ kVm^{-1} and for $E > 3{:}5\times10^3$ kVm^{-1} it becomes ineffective.

Figure 4 depicts the variation of phase and amplification rates of fourth mode. It is seen from this figure that quantum corrections have no impact on the propagation characteristics of fourth mode. The fourth mode has forward amplifying propagation with such a phase velocity which increases as we increase the magnitude of electric field E. The magnitude of amplification coefficient is initially found independent of E up to $E \approx 3{:}0\times10^3$ kVm^{-1} and then it starts increasing with E.

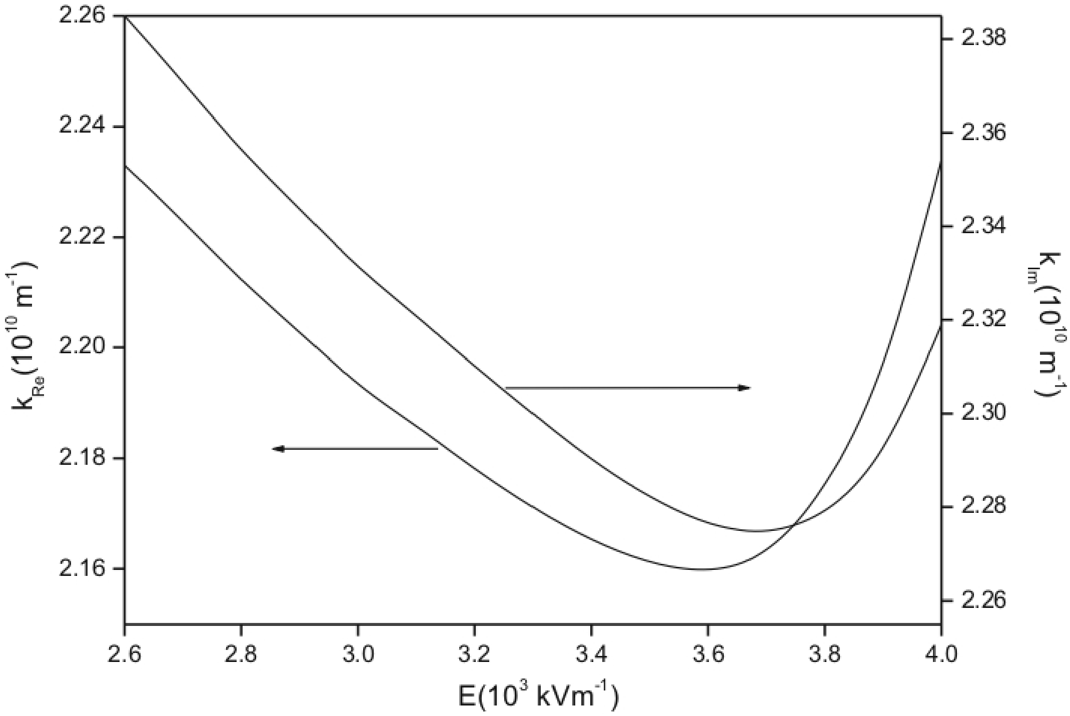

Figure 5: k_{Re}, k_{Im} versus E for V-mode.

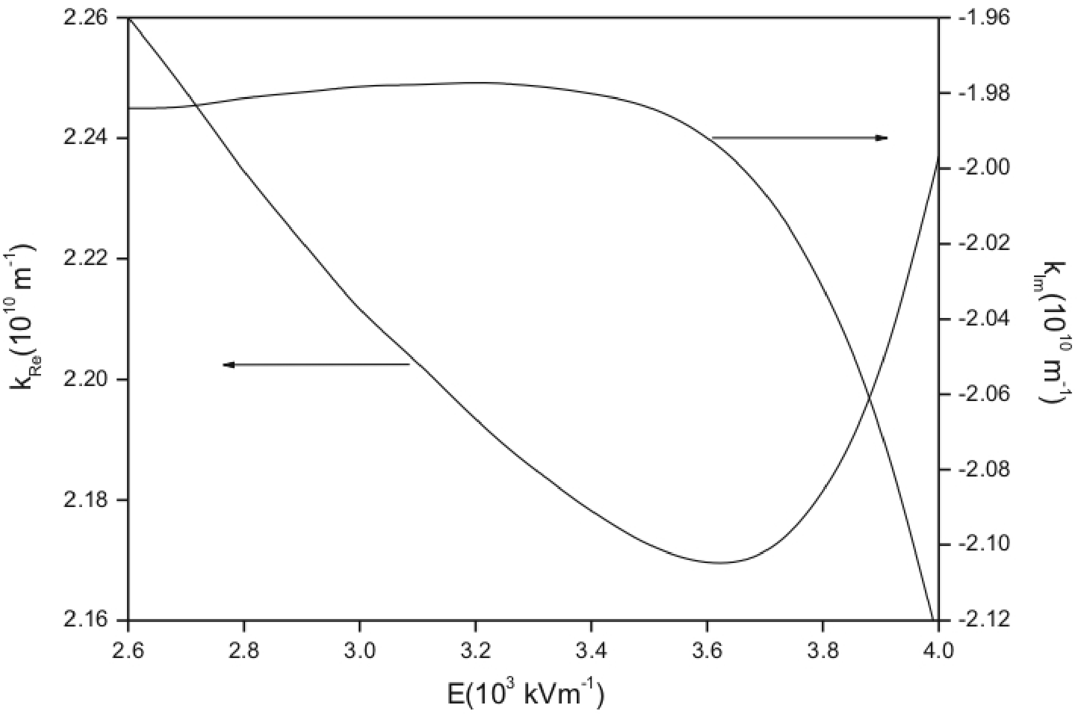

Figure 6: k_{Re}, k_{Im} versus E for VI-mode.

The propagation characteristics of the two novel modes of two stream instability induced due to quantum corrections are illustrated in Figs. 5, 6. The fifth mode is forward amplifying mode while sixth mode has forward propagation with attenuation. The phase velocities of both the novel modes have increasing nature for lower magnitude of applied electric field (only up to $E \approx 3{:}6\times10^3$ kVm^{-1}). For high electric field when $E > 3{:}6\times10^3$ kVm^{-1}, it converts to a function of reducing nature. On the other hand, the magnitude of amplification coefficient of fifth mode decreases up to $E \approx 3{:}6\times10^3$ kVm^{-1} and for $E > 3{:}6\times10^3$ kVm^{-1} it starts increasing rapidly with E; whereas the attenuating constant of sixth mode is initially almost independent of E but for higher magnitude of E, it suddenly starts increasing.

4. Conclusions

The goal of the current analysis is to present how the quantum parameter-H affects two stream instability in n-GaAs semiconductor plasma when an external electric field is introduced. The dispersion relation obtained using the QHD model of plasmas, as stated in Eq. (4), is the primary source of this work's findings. The presentation's findings show that the introduction of quantum effects in the n-type GaAs semiconductor plasma medium causes two new modes to emerge and drastically alters the properties of all the pre-existing modes. The analytical investigation of the real part of longitudinal electrokinetic power flow density under quantum regimes also establishes the existence of two stream instability. Additionally, it is deduced that three of the six potential modes of two stream instability are amplifying in character. It is observed that most modes' phases are lowered by many orders of magnitude when quantum effects are present, allowing them to stay in the medium for longer. These findings are crucial in defining the medium's characteristics. There are numerous significant device potentialities in the investigation of two stream instability in plasma. In order to better understand the physical nature of two stream instability in semiconductor quantum plasma, it is believed that the analysis presented in this study would be useful.

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Authors' contributions

The author read and approved the final manuscript.

Conflicts of interest

The author declares no conflict of interest.

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Data availability

No new data were created.

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