A STUDY OF NONLINEAR WAVES IN SEMICONDUCTOR QUANTUM PLASMA

THESIS

Submitted in fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

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by

NEELAM RANI

Registration No. YMCAUST/PH-03/2011

Under the Supervision of

Dr. Mani Kant Yadav	Dr. Y. K. Mathur
Supervisor	Co Supervisor
Assistant Professor	Professor

Department of Physics

Faculty of Sciences

J. C. Bose University of Science & Technology, YMCA

Sector-6, Mathura Road, Faridabad, Haryana, India

DECEMBER, 2020

DEDICATION

Dedicated

to

My Loving Parents

DECLARATION

I hereby declare that this thesis entitled "**A STUDY OF NONLINEAR WAVES IN SEMICONDUCTOR QUANTUM PLASMA"** by **NEELAM RANI,** being submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in **PHYSICS** under Faculty of Sciences of J. C. Bose University of Science & Technology, YMCA Faridabad, during the academic year 2019, is a bona fide record of my original work carried out under guidance and supervision of **DR. MANI KANT YADAV, ASSISTANT PROFESSOR, DEPARTMENT OF PHYSICS AND DR. Y. K. MATHUR, PROFESSOR, DEPARTMENT OF PHYSICS, PDM UNIVERSITY, BAHADURGARH** and has not been presented elsewhere.

I further declare that the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any other university.

(Neelam Rani)

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CERTIFICATE

This is to certify that this Thesis entitled "**A STUDY OF NONLINEAR WAVES IN SEMICONDUCTOR QUANTUM PLASMA"** by **NEELAM RANI,** submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy in **PHYSICS** under Faculty of Sciences of J. C. Bose University of Science & Technology, YMCA, Faridabad, during the academic year 2020, is a bonafide record of work carried out under our guidance and supervision.

We further declare that to the best of my knowledge, the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any other university.

(Signature of Supervisor)
Dr. Mani Kant Yadav
Assistant Professor
Department of Physics
Faculty of Sciences
J. C. Bose University of Science & Technology,
YMCA, Faridabad
Dated:

(Signature of Co Supervisor)
Dr. Y. K. Mathur
Professor
Department of Physics
Faculty of Physical Sciences
PDM University
Bahadurgarh
Dated:

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(Neelam Rani)

Registration No. YMCAUST/PH-03/2011

ABSTRACT

In this thesis, considered the number of nonlinear wave interaction in semiconductor quantum plasma. In this research, semiconductor quantum plasma was discussed through nonlinear waves and laser beam in self – consistent plasma channel. The propagation characteristics of nonlinear low frequency electrostatic waves in electron-ion quantum plasma are investigated. After reviewing the basic introduction of quantum plasma, the nonlinear phenomenon of electrostatic wave is described. The electrons are degenerate and weakly correlated whereas ions are non-degenerate and strongly correlated. The reductive perturbation technique is employed for weakly nonlinear electrostatic modes. In this study, the ion viscous dissipation affects the weakly nonlinear structures due to ion-ion correlations are observed.

The propagation of ultrasonic waves has studied in semiconductor plasma in the presence of electric field. The measurement of attenuation and velocity of propagating ultrasonic wave is very important property of solid. There was a good agreement between the experimental observations and theoretical predictions. The acoustoelectric effect in a piezoelectric semiconductor has studied. This effect arises from the interaction between the strong electric field associated with acoustic waves and electrons and holes drifting under the influence of an external field. The mathematical formulation and mechanism of propagation of ultrasonic wave in semiconductor in the presence of electric field has explained.

The propagation of Acoustic waves is studied in semiconductor in symmetric pair plasma by derive the Korteweg-de Vries equation. In the present study, the properties of collisionless Vlasov-Poisson model in fluid approximation in context of pair plasmas have discussed. Symmetric pair plasmas have different collective behavior than ordinary asymmetric electron-ion plasmas. In this research, we assume a thermodynamic unequilibrium of pair plasma when temperatures of species are not equal. It is proved that in symmetric pair plasma, but with not equal temperature of species acoustic mode may exist. In the present work , considered the Symmetric pair plasmas, C_{60} and C^{+}_{60}

plasmas having mass opposite charged fullerene is almost equal with two kind of electrons: cold and hot.

The modulational dispersion and amplification in piezoelectric semiconductor plasma is studied by the coupled mode theory and using the hydrodynamic model of a semiconductor plasma. In the present thesis, the analytically investigated in a doped III–V semiconductor, viz. n-InSb, the frequency modulation interaction between copropagating high-frequency electromagnetic beams and acoustic waves and the consequent amplification of the modulated waves. The threshold value of pump electric field ($|E_0|$) and modulational gain coefficient (α_{eff}) are obtained by the nonlinear effective susceptibility χ_{eff}. Modulational Dispersion and Amplification in doped III–V Semiconductors like n-InSb crystal at 77 K duly irradiated by a nanosecond-pulsed 10.6 μm CO_2 laser. The magnitude of χ_{eff} can be increased considerably in a heavily doped medium by increasing the strength of the d.c. magnetic field.

In this research work, investigating the current task is distributing a serious laser beam in a self-made plasma channel. As the intensity of the laser beam increases, the medium displays the neuromuscular electrical conductivity functioning as a result of the mass effectiveness of the effectiveness of the electrons as well as the intensity of the electrons .Based on Wentzel–Kramers–Brillouin and paraxial ray theory, the steady-state solution of an intense, Gaussian electromagnetic beam is studied. The differential equation of the distance with the beam width parameter is derived, including the relativistic effects of self-focusing (SF) and self-channeling ponder motive. Plasma propagation is a radial dynamical force, depending on the width of the beam and σ_p is greater plasma ratio frequency screws. Once the distribution regimes, the beam power beam width is obtained in plane and σ_p is a particular value characterized by standard deviation, oscillation, and diffusion regimes such as SF. The corresponding center parameters are intended for introduction of the plasma density curve, and the laser beam is spatially analyzed to the spatial plasma. Performing this margin can lead to a long distance laser beam guide.

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LIST OF ABBEREVIATIONS

RF: Radio Frequency

MHD: Magnetic Hydrodynamics

QHD: Quantum Hydrodynamics

GQHD: generalized quantum hydrodynamical

QHM: quantum hydrodynamic model

GHM: generalized hydrodynamic model

NLSP: nonlinear semiconductor plasma

UV: ultraviolet radiation

PI: Parametric interaction

EO: Electro-Optical

AO: Acousto-Optical

EM: Electro magnetic

EPO: Electron Plasma Oscillation

FET: Field effect transistor

AM: Amplitude modulation

InP: indium phosphide

GaN: gallium Nitride

SF: Self-focusing

OD: Oscillatory divergence

SD: Steady divergence

KDVB: Korteweg-de Vries Burger

ZK: Zakharov-Kuznetsov

CHAPTER I

INTRODUCTION

INTRODUCTION

1.1 NATURE OF PLASMA

In this thesis, we considered nonlinear wave interaction in semiconductor quantum plasma. In piezoelectric semiconductor, electrical and mechanical effects are coupled. Plasma is described as a fourth state of matter (the others being solid, liquid and gas) and contains approx. 99% of matter in the Universe in its state. It means that we live in 1% of the universe in which plasma does not occur naturally. As the temperature of a material is raised, its state changes from solid to liquid and then to gas. If the temperature is elevated further, an appreciable number of the gas atoms are ionized and become the high temperature gaseous state in which the charge numbers of ions and electrons are almost the same and charge neutrality is satisfied in a macroscopic scale.

The plasma is itself a state of matter in which charged particles such as electrons and atom nuclei has sufficiently high energy to move freely, rather than be bound in atoms as in ordinary matter. It is a form of an electrified gas with the atoms dissociated into positive ions and negative electrons. When the ions and electrons move collectively, these charged particles interact with Coulomb force which is a long range force and decays only in Inverse square of the distance r between the charged particles. The resultant current flows due to the motion of the charged particles and Lorentz interaction. Therefore many charged particles interact with each other by long range forces and various collective movements occur in the gaseous state.

The word *plasma* comes from the Greek and means *something molded.* It was applied for the first time by Tonks and Langmuir, in 1929, to describe the inner region, remote from the boundaries, of a glowing ionized gas produced by electric discharge in a tube, the ionized gas as a whole remaining electrically neutral. The word “plasma” is used in physics to designate the high temperature ionized gaseous state with charge neutrality and collective interaction between the charged particles and waves. Plasma can be produced by raising the temperature of a substance until a reasonably high fractional ionization is obtained. The fractional ionization: for ordinary gas at room temperature by Saha Equation is –

$$\frac{n_i}{n_n} \approx 10^{-122} \qquad \dots (1.1)$$

Where n_i is density of ionized atoms and n_n is density of neutral atoms. As temperature increases then n_i/n_n rises abruptly, and the gas remains in a plasma state. Further increase in temperature makes n_n less than n_i, and the plasma becomes fully ionized. Therefore, plasmas exist in astronomical bodies with temperatures of millions of degrees, but not on the earth. They are not very common in laboratory.

Plasmas can also be generated by ionization processes that raise the degree of ionization much above its thermal equilibrium value. There are many different methods of creating plasmas in the laboratory and depending on the method; the plasma may have a high or low density, high or low temperature, it may be steady or transient, stable or unstable and so on.

The definition of Plasma – The term Plasma denotes quasineutral ionized gas. Plasma is a "quasineutral" gas of charged and neutral particles which exhibits "collective behavior". Quasineutrality means number of positive charges is equal to average of negative charges in sufficiently large volume and large time intervals. Collective behavior" means motions that depend not only on local conditions but on the state of the plasma in remote regions as well. Plasma is a special state of matter is a collective behavior of a system to electromagnetic perturbations. The words "collective behavior of a system" means perturbation of some physical quantity (charge density, electric field strength, magnetic field strength, the particle number density). This perturbation is described by the wavelength which is much greater than average distance between particles in plasma.

$$\lambda << n_0^{\frac{-1}{3}} \qquad \dots (1.2)$$

In a gas of charged particles, plasmas, acoustic waves or any other type of waves appear by neutral particles where inter particle interactions.

Collective behavior: Consider the forces acting on a molecule of, say, ordinary air. Since the molecule is neutral, there is no net electromagnetic force on it, and the force of gravity is negligible. The molecule moves undisturbed until it makes a collision with another molecule, and these collisions control the particle's motion. A macroscopic force applied to a neutral gas, such as from a loudspeaker generating sound waves, is transmitted to the individual atoms by collisions. The situation is totally different in plasma, which has charged particles. As these charges move around, they can generate local concentrations of positive or negative charge, which give rise to electric fields. Motion of charges also generates currents, and hence magnetic fields. These fields affect the motion of other charged particles far away. Therefore, elements of plasma exert a force on one another even a large distance.

Plasma is described as an electrically – charged gas. In an ordinary gas each atom contains an equal number of positive and negative charges. A gas becomes plasma when the addition of heat or other energy causes the negatively charged electrons in the gas atoms to completely split off from the positively charged atomic nuclei (or ions). Those atoms and the resulting electrically charged gas are said to be "ionized." When enough atoms are ionized to significantly affect the electrical characteristics of the gas, it is plasma.

Debye Shielding

The characteristic of the behavior of plasma is its ability to shield out electric potentials that are applied to it and Potential = KT/e.

Suppose we tried to put an electric field inside plasma by inserting two charged balls connected to a battery as shown in fig. 1.1. The balls would attract particles of the opposite charge, and almost immediately a cloud of ions would surround the negative ball and a cloud of electrons would surround the positive ball. If the plasmas were cold and there were no thermal motions, there would be just as many charges in the cloud as in the ball; the shielding would be perfect, and no electric field would be present in the body of the plasma outside of the clouds [1]. On the other hand, if the temperature is finite, those particles that are at the edge of the cloud, where the electric field is weak, have enough thermal energy to escape from the electrostatic potential well. The "edge" of the cloud then occurs at the radius where the potential energy is approximately equal to the thermal energy KT of the particles, and the shielding is not complete. The Debye length (λ_D) is a measure of the shielding distance or thickness of the sheath.

$$\lambda_D \equiv \left(\frac{\varepsilon_0 K T_e}{n e^2} \right)^{\frac{1}{2}} \qquad \ldots (1.3)$$

As the density is increased, λ_D decreases and λ_D increases with increasing KTe.

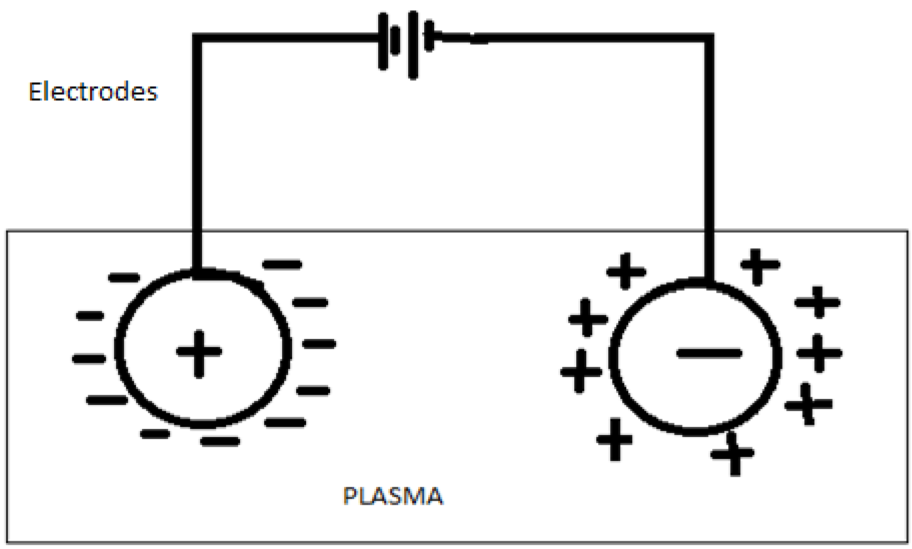

Fig. 1.1 The electric field applied between electrodes inserted into plasma

If the dimensions L of a system are much larger than λ_D, then whenever local concentrations of charge arise or external potentials are introduced into the system, these are shielded out in a distance short compared with L, leaving the bulk of the plasma free of large electric potentials or fields which defines quasineutrality of plasma.

The plasma is "quasineutral"; that is, neutral means $n_i = n_e = n$, where n is a common density called the plasma density. The picture of Debye shielding is valid only if there are enough particles in the charge cloud. Clearly, if there are only one or two particles in the sheath region, Debye shielding would not be a statistically valid concept.

Plasma Parameter: It has given three conditions that an ionized gas must satisfy to be called a plasma.

1. $\lambda_D << L$, the dimensions L of a system are much larger than λ_D.
2. $N_D >>> 1$, Collective behavior requires this condition and the number N_D of particle is debye sphere is -

$$N_D = n\frac{4}{3}\pi\lambda_D^3 = 1.38\times10^6 T^{3/2} / n^{1/2}$$

3. $\omega\tau > 1$, where ω is the frequency of plasma oscillations and τ is the mean time between collisions with neutral atoms.

Quasineutrality: The Debye shielding analysis assumed that the plasma was initially neutral, i.e., that the initial electron and ion densities were equal. We now demonstrate that if the Debye length is a microscopic length, then it is indeed an excellent assumption that plasmas remain extremely close to neutrality, while not being exactly neutral.

It is found that the electrostatic electric field associated with any reasonable configuration is produced by having only a tiny deviation from perfect neutrality. This tendency to be quasi-neutral occurs because a conventional plasma does not have sufficient internal energy to become substantially non-neutral over distances exceeding a Debye length. Consider initially neutral plasma with temperature T and calculate the largest radius sphere that could spontaneously become depleted of electrons due to thermal fluctuations. Let r_{max} be the radius of this presumed sphere. Complete depletion would occur if a random thermal fluctuation caused all the electrons originally in the sphere to vacate the volume of the sphere and move to its surface. The electrons would have to come to rest on the surface of the presumed sphere because if they did not, they would still have available kinetic energy, which could then be used to move out towards an even larger radius, violating the assumption that the sphere was the largest radius sphere that could become fully depleted of electrons [2]. This situation is extremely artificial electrons to be moving radially relative to some origin. In reality, the electrons would be moving in random directions.

When the electrons exit the sphere they leave an equal number of ions. The remnant ions produce a radial electric field, which pulls the electrons back towards the center of the sphere. The energy stored in this system is to calculate the work done by the electrons as they leave the sphere and collect on the surface, but another simpler way is to calculate the energy stored in the electrostatic electric field produced by the ions remaining in the sphere. This electrostatic energy did not exist when the electrons were initially in the sphere and balanced the ion charge and so it must be equivalent to the work done by the electrons on leaving the sphere.

If plasma is weakly ionized then collisions with neutrals must be considered. These collisions differ from collisions between charged particles. All atoms have radii of the order of 10^{-10} m so the typical neutral cross-section is $\sigma_{neutral} \sim 3 \text{ X } 10^{-20}$ m^2. When ions collide with neutrals – the incident ion can capture an electron from the neutral and become neutralized while simultaneously ionizing the original neutral. This process, called charge exchange, is used for producing energetic neutral beams. In this process a high-energy beam of ions is injected into a gas of neutrals, captures electrons, and exits as a high-energy beam of neutrals. Because ions have same mass as neutrals, ions rapidly exchange energy with neutrals and tend to be in thermal equilibrium with the neutrals if the plasma is weakly ionized. As a result, ions are typically cold in weakly ionized plasmas, because the neutrals are in thermal equilibrium with the walls of the container.

1.2 SEMICONDUCTOR QUANTUM PLASMA

The free electrons and holes in semiconductors constitute plasma. The concept of plasma in a solid is used to describe by collective response of quasineutral system consisting of free charge carrier of two signs and ionized impurity of two signs to electromagnetic perturbations. The main difference between the solid state plasma and liquid state plasma is that in solids motion of mobile charges of the plasma under action of external forces with condition of strong interaction with the field of atom and from the lattice and in liquids, in the presence of intense friction resulting from number of collisions with defects and vibrations of the crystalline lattice.

Semiconductor materials have electrons in the conduction band and holes in the valance band that move freely. The behavior of charge carriers in semiconductor crystalline structures is analogous to the behavior of particles in gas plasma. Since the plasma consists of free charge carriers it is a conductor of electricity, and interaction of particles in plasma is governed by the laws of electromagnetism and thermodynamics. Being a conductor of electricity, plasma is a reconfigurable medium with different conductor and dielectric properties. In the semiconductors, electrons and holes exhibit the same collective behavior as in gaseous plasmas and in the metals, electrons under certain condition exhibit the same collective behavior as in gaseous plasma. Thus many of the phenomena such as wave propagation, charge transport etc. which are investigated in gaseous plasmas can also be studied in semiconductors and metal plasmas. These investigations are important in behavior of solid state. These investigations are important from technical point of view because semiconductors have wide applications in field of electronic and optoelectronic device.

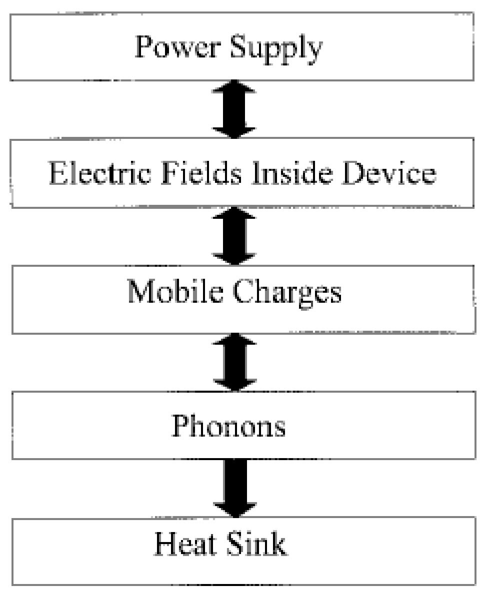

Fig. 1.2 Charged Transport in Semiconductor

Plasmas injected into InSb have been particularly useful in studies of solid state plasma. Because of the lattice effects, the effective collision frequency is much less than one would expect in a solid with n = $l0^{29}$ m^{-s}. The holes in a semiconductor can have a very low effective mass-as little as 0.0 l m_e and therefore have high cyclotron frequencies even in moderate magnetic fields.

Most of the electronic devices are built using semiconductors. The numbers of works have been extended into the study of charge transport in a semiconductor. Energy is exchanged between some external power supply and the internal electric field of the device. This field then accelerates the mobile charge carriers, the electrons and holes. Energy and momentum transfer between the field and these charges. As the charge carriers move though, they also interact with the media through which they move. This is usually modeled by having the charge carrier "emit" or "absorb" a phonon, a quanta of lattice vibrational energy as shown in figure 1.2. The heat energy stored in these phonons then flows out to a heat sink [3].

Plasma processing techniques are one of the important techniques of modern semiconductor fabrication. Low pressure plasmas in particular can achieve high radical density, high selectivity, and anisotropic etch profiles at low temperatures and mild voltages. This gentle processing environment prevents unwanted diffusion and degradation of materials due to heat and lattice damage from ion bombardment. Recent progress in plasma-assisted wafer bonding has demonstrated low temperature, low pressure recipes utilizing O_2 plasma surface treatment for joining dissimilar semiconductor materials, such as silicon (Si) and indium phosphide (InP).

Since the plasma consists of free charge carriers it is a conductor of electricity, and interaction of particles in plasma is governed by the laws of electromagnetism and thermodynamics. Being a conductor of electricity, plasma is a reconfigurable medium with different conductor and dielectric properties. The gaseous plasma is usually manipulated by magnetic fields; gaseous plasma can be confined in magnetic fields to prevent loss of energy to collision with vessel walls. Semiconductor plasma can be generated by optical excitation or current injection.

Plasma is a system consisting of many charged particles and in quantum plasma these particles have quantum mechanical properties, such as for example spin. Quantum properties of individual particles are often negligible on macroscopic scales, but due to collective interaction in the plasma certain phenomena arise that can only be explained by considering the fundamental quantum properties of the particles. A plasma becomes quantum when the quantum nature of its particles significantly affects its macroscopic properties. In classical plasmas, the densities are so low and temperatures so high but in quantum plasmas, the densities are high and temperatures low. Quantum mechanics becomes relevant in plasmas when the de Broglie wavelength of the charge carriers is comparable to the interparticle distance, so that there is a significant overlap of the corresponding wave functions. In quantum semiconductor devices, like high-electron mobility transistors, resonant tunneling diodes or super lattices are treated by quantum effect. In quantum plasmas, the Wigner-Poisson system is used which is equivalent for the Vlasov-Poisson system in classical plasmas.

Quantum hydrodynamics (QHD) is a concept that was developed in by Madelung in 1926 [4, 5]. He transformed the Schrödinger equation for a single particle into the corresponding QHD equations. It was further developed by Bohm in 1953 [6, 7]. The motivation to name this field QHD is that by applying it one finds differential equations with a similar form to the well-known differential equations in classical hydrodynamics, like the continuity equation. Quantum hydrodynamics (QHD) have been a general method applicable to both pure and mixed states of quantum statistical systems widely used. The QHD equations are usually obtained by taking moments of the appropriate kinetic equation like, the Wigner function equation in analogy with the moments of the classical kinetic equation. This leads to the conservation laws for particle number, momentum and energy in terms of macroscopic variables by choosing some suitable closure scheme in an approximate way.

Nonlinearity

A difference between linear and nonlinear laws is whether the properties of superposition holds or break down. As is well known in a linear system the final effect of the combined action of two different causes is simply the superposition of the effect of each cause taken separately. But in a nonlinear system adding two elementary actions to one another can induce new effects reflecting the onset of cooperativity between the constituent elements. This can give rise to unexpected structures and events whose properties can be quite different from those of underlying causes. In semiconductor quantum plasma, we shall be dealing with nonlinearity. We know that in the linear approximation we may find Eigen modes of semiconductor plasma corresponding to propagating waves, where the wave vector and frequency are related through the linear dispersion relation. A variety of basic phenomena of a nonlinear nature has played an essential role in field of solid state plasma physics.

The breakdown of superposition principle in a nonlinear medium leads to interaction between waves of different frequencies. There exist a number of nonlinear interactions which can be classified as modulational interaction of coupled modes. By modulational interactions of coupled modes and consequent amplification of decay channels, one generally refers to as instability of wave propagating in nonlinear dispersive medium such that the steady-state becomes unstable and evolves into a temporally modulated state. The concept of transverse modulational instability originates from a space-time analogy that exists when the dispersion is replaced by diffraction. The well-known instability of a plane wave in a self-focusing Kerr-medium is an example of transverse modulation instability [8].

1.3 OBJECTIVES AND MOTIVATION

Objectives

- To study the interaction of nonlinear low frequency electrostatic modes in quantum plasma
- To calculate the attenuation and velocity of propagating ultrasonic waves in GaN semiconductor as measured by electromechanical coupling coefficient χ.
- To analyze the propagation of the acoustic waves in semiconductor symmetric pair plasma.

- An analytical investigation of the modulational dispersion and amplification in n-type InSb semiconductor plasma.
- To study the nonlinear wave in semiconductor quantum plasma for laser beam in a self consistent plasma channel.

Motivation

The behaviors of nonlinear effects are easily observable in semiconductor plasma. Most of the electronic devices are built with semiconductor due to their compactness, provision of control of material relaxation time and highly advanced fabrication technology. Semiconductor devices are emerged as the most possible application of quantum plasma. The motivation for research on plasma in semiconductor is the practical applications in the modern computer and telecommunication industry. The reason for the rapid development and success in the semiconductor technology is due to the ongoing miniaturization of semiconductor devices and the size of the element of integrated circuits is reducing every year. In such components, quantum phenomena can't be negligible. The electron density in semiconductors is much lower than in metals, even though the miniaturization of electronic components made up of semiconductors is based on the fact that the de Broglie wavelength of charge carriers in these media can be made comparable, to the spatial variation of the doping profiles. Hence, it is now possible to simulate typical quantum effects in semiconductors, like resonant tunneling and negative differential resistivity by using QHD [9]. Recently, various quantum hydrodynamic (QHD) models were used in semiconductor simulations [10].

The plasma wave may be excited due to collective excitations of the carriers in the semiconductor; hence the field semiconductor plasma arises [11]. When electrons in the valence band of a semiconductor are excited to the conduction band by absorbing energy leaving behind vacant electron states called holes, the system can be considered as semiconductor plasma which satisfies the plasma conditions. For modern device physicists dealing with quantum wells, quantum wires, quantum dots, etc. the linear and nonlinear behaviors of waves and instabilities, through the carrier's dynamics in semiconductors, are crucially important. Recently, theoretical observations of nonlinear waves in a number of semiconductors, such as GaAs, GaSb, and GaN inspired us to study and investigate the characteristics of waves in semiconductor quantum plasma.

In quantum plasmas, the Collective interactions between an ensemble of degenerate electrons and positrons/holes give rise to novel waves and structures by Bohm and Pines in 1953 [12]. The basic concept of semiconductor quantum plasma is the de Broglie wavelengths of the plasma particles may be comparable to the Debye length or other scale lengths of the plasma by using magneto hydrodynamic (MHD) model for plasmas, have developed quantum hydrodynamic (QHD) model to study the quantum corrections in plasma characteristics by Haas [13], Manfredi [14] and M. Marklund, P.K. Shukla in 2006 [15]. Plasma-like collective behavior is well studied experimentally and theoretically in solid state physics by Kittel, in 1996, in which metals and semi-conductors support both transverse optical modes, and longitudinal electrostatic modes, such as plasmons and phonons on electron and ion time-scales [16].

Quantum effects are known to play crucial role in nonlinear processes in compact astrophysical objects, such as white-dwarfs, neutron stars and pulsars etc. Recently, the physicists dealing with theory have been attracted towards the quantum mechanical effects in semiconductor plasmas. Motivated by the above, author studied the quantum modifications through Bohm potential in nonlinear wave interaction in semiconductor plasmas and presented this interesting work in the thesis.

1.4 PLAN OF THESIS

The thesis has been allocated with six chapters. The first chapter deals with the introduction of the nonlinear waves in semiconductor quantum plasma medium. Here authors also discussed and explained nature of plasma, the semiconductor quantum plasma medium and the QHD model used.

The second chapter deals with literature review of nonlinear waves in semiconductor quantum plasma.

The third chapter deals with interaction of nonlinear low frequency electrostatic modes in quantum plasma. The electrons are degenerate and weakly correlated whereas ions are non-degenerate and strongly correlated. In this chapter, the dispersion relation have derived and shown the existence of shock wave in dissipation dominated due to ion-ion correlation in weakly nonlinear limit.

Motivated by the utility of nonlinear waves in semiconductor quantum plasma the author in chapter 4 has presented a detailed and systematic study of ultrasonic waves in piezoelectric semiconductor in the presence of electric field and measuring the attenuation and velocity of propagating ultrasonic waves. The propagation of sound in a high-frequency electric field in bulk GaN semiconductor has been studied in this chapter.

Chapter 5 deals with an attempt to investigate the effect of the acoustic waves in semiconductor symmetric pair plasmas. Symmetric pair plasmas, consisting of two species with opposite charge and equal masses is an exciting field. In pure symmetric pair plasma the acoustic structures are impossible and acoustic waves are possible only when impurity of electrons is added.

The phenomenon of modulational instability in a semiconducting medium can be described in terms of electric polarization equations which are cubic function of electric field amplitude. The third order nonlinear susceptibility is in general a complex quantity and is capable of describing the interference between various resonant and non-resonant processes. The third order susceptibility tensor can be conveniently used to explain the modulation process in a Kerr active medium. Due to its vast technological utility in transmission processes, the modulational instability of propagating beams has been studied by a number of authors. Therefore in chapter 6, has presented the characteristics as a result of quantum correction in semiconductor plasma medium.

The seventh chapter deals with nonlinear wave in semiconductor quantum plasma for laser beam in a self consistent plasma channel. In this research, investigating the distributed regimes laser beam on a self-made plasma channel. As the intensity of the laser beam increases, the effect of non-functional effect as well as the electrons is intended to discharge the transmutation of the medium electrical conductor. The disadvantage of numerical predictions is done for laser plasma interaction studies for common factors.

Therefore, author has presented some important aspects of quantum term and effects on nonlinear mechanisms in semiconductor quantum plasma under different physical conditions. It can be concluded from the investigations made in the present thesis that the quantum effects are unavoidable in the case of fully degenerate quantum plasma considered as electrostatic modes. Inclusion of quantum correction term which uses statistical effects via the propagation equation becomes essential while dealing with intense short laser pulse in a self created plasma channel. Thus author hopes that this work shall be able to contribute to the understanding of the mechanism of interaction between nonlinear waves and semiconductor plasmas which may be useful for future generation of integrated circuits as well as for the fabrication of opto-electronic devices. It is also hoped that the reported characteristics may become useful as probe to study the properties of nano structured materials.

CHAPTER II

LITERATURE REVIEW

LITERATURE REVIEW

An attempt has been made to study the work existing in the literature regarding nonlinear waves in semiconducting quantum plasma. During the last forty years, the propagation of nonlinear waves in quantum plasma using quantum hydrodynamic (QHD) has been a very important research topic because they have many physical systems, including many metals, semiconductors and superconductors. Thousands of papers have been published in that area.

In this chapter Researcher has defined the full analysis of topic covered in whole study. It elaborates on methodology, procedures, designing and survey of data. To begin with the research has developed upon the theoretical report of research and different concepts of research.

The propagation of ultrasound is studied in bulk GaN semiconductor in the presence of a strong AC field oscillating at a frequency much higher than that of the ultrasound and analytical expressions have been obtained for the attenuation coefficient (α) and the renormalized velocity (v) of the acoustic wave by **S.Y. Mensah** etal. in 2005 [17]. It is shown that the dependencies of the ultrasonic absorption coefficient of the conduction electrons and the renormalised sound velocity on the field amplitude and the sound frequency have an oscillatory character this can be used to determine the effective mass and mobility of the material.

The propagation of acoustic wave is studied in bulk GaN semiconductor in the presence of a slowly changing AC electric field and a constant electric field and analytical expressions have been obtained for the attenuation coefficient (α) and suggest use of this material as maser by **N.G. Mensah** in 2010 [18].

The parametric dispersion can be achieved by proper selection of doping level and pump field strength in semiconductor plasmas, parametric dispersion can be potential use in the study of squeezed states generation as well as in group velocity dispersion by **M. Singh** etal. in 2008 [19].

M. Singh etal. in 2007, a analytical investigation is made of the Stimulated Brillouin Scattering (SBS) of the Stokes component of the scattered wave in piezoelectric-doped semiconductor plasma subjected to a magnetostatic field by using the aid of hydrodynamic model. The origin of the Stimulated Brillouin Scattering (SBS) process lies in the third-order nonlinear optical susceptibility arising due to the induced nonlinear current density and acoustic perturbations internally generated due to crystal properties such as piezoelectricity and electrostriction. The effective refractive index and absorption coefficient are determined via the effective susceptibility by using coupled mode theory [20].

In quantum plasmas, the existence of a critical point and phase transitions is attributed to an attractive short-range interaction between ions that are shielded by the degenerate electrons. The plasma number density and the ion temperature are the key parameters which determine a critical point and phase transitions at quantum/atomic scales. This results are useful in understanding the existence of solid–liquid phases in the strongly coupled ion state in condensed matter plasmas of astrophysical bodies, interiors of terrestrial and gas giant planets and of inertial confinement schemes for producing limitless fusion energy by using intense laser and relativistic electron and ion beams, as well as in metallic nanostructures and semiconductor devices for industrial applications by **P.K. Shukla** etal. in 2012 [21].

Parametric amplification of an acoustic wave can easily be obtained in an acousto-optic (centrosymmetric) crystal above the threshold pump field $[E_{0th}]$ para by **Nilesh Nimje** etal. in 2011. Although at lower pump amplitudes ($E_0 < [E_{0th}]$ para) the acousto-optical coupling coefficient of the medium causes damping of the acoustic wave, yet it ensures rapid growth above the threshold value via a strong coupling between the acoustic wave and the modified electron plasma wave. In parametric dispersion and amplification, the pump electric field produces a shift in the resonance frequency in the second-order diffusion induced polarization term is important. The parametric dispersion (both positive and negative) can be achieved by a proper selection of doping level and pump field strength. This can be use in the study of squeezed states generation as well as in group velocity dispersion in semiconductor plasmas [22].

The nonlinear equations include the electromagnetic, the electron pressure gradient, as well as the quantum electron tunneling and electron spin forces. They are useful for investigating a number of wave phenomena including linear and nonlinear electromagnetic waves, as well as three dimensional electromagnetic wave turbulence spectra arising from the mode coupling processes in dense magneto plasmas by **Nitin Shukla** etal. in 2009 [23].

S. A. Mikhailov in 2008 consider a propagation of an electromagnetic wave through the structure, and obtain analytic dependencies of the transmission, reflection, absorption and emission coefficients on the frequency of light, drift velocity of two dimensional electrons, and other physical and geometrical parameters of the system. If the drift velocity of two dimensional electrons exceeds a threshold value, current-driven plasma instability is developed in the system, and an incident far infrared radiation is amplified. In structure with a quantum wire grating the threshold velocity of the amplification can be reduced, as compared to metal grating. This is due to enhancement of the grating coupler efficiency because of the resonant interaction of plasma modes in the 2DES and in the grating [24].

At room temperature, in the classical limit (h~0) one of the low-frequency modes is found similar to an experimentally observed one in n-type InSb. The surface modes are modified in the case of high-conductivity semiconductor plasmas where electrons and holes may be degenerate [25]. Even though the particle number density in semiconductors is lower than that in metals, the high-degree of miniaturization of today’s electronic components opens up the possibility that the thermal de Broglie wavelength of charge particles may be comparable to or even larger than the spatial variation of the doping profiles. The investigation of the propagation of electromagnetic surface waves at the e-h plasma-vacuum interface parallel to an applied magnetic field. **A.P. Misra** in 2011 consider the quantum tunneling effect to be associated with the Bohm potential which provides dispersion due to particle's wave-like nature [25].

Zhigang Chen etal. in 2009 apply the finite-difference time-domain (FDTD) method to examine various electromagnetic effects in the plasma etch chamber and investigate strategies for improved chamber design. These effects include the standing wave effects and asymmetric field distributions that can be caused by asymmetric RF power feed configurations. The finite-difference time-domain (FDTD) method is formulated in both cylindrical and Cartesian coordinate systems to facilitate modeling of rotationally symmetric chamber and asymmetric RF feed structures. The electric field distribution generated by various RF feed configurations is studied at different very high frequencies [26].

S.K. El-Labany etal. in 2010 described the quantum hydrodynamic model (QHD) for quantum ion-acoustic wave in electron–ion (ei) plasmas. The quantum hydrodynamic model consists of a set of equations describing the transport of charge, momentum and energy in a charge particle system interacting through a self electrostatic potential. The deBroglie wavelength associated with the particles is comparable to dimension of the system in quantum effect. The quantum hydrodynamic model generalizes the fluid model for plasmas with the inclusion of quantum correction term also known as Bohm potential. The Bohm potential term describes negative differential resistance in resonant tunneling diodes. Negative differential resistance is based on resonant tunneling which is a quantum phenomenon and it does not occur in classical transport model [27].

The dispersion relation is derived using the electron and positron densities response arising from the balance between the quantum Bohm and electrostatic forces and from the electron and positron continuity and Poisson equations by **W.M. Moslem** etal. in 2007. In the local approximation regime, the dispersion relation admits both oscillatory and purely growing instabilities those depend on the quantum parameters as well as the density, velocity and magnetic field in homogeneities [28].

Sagdeev potential approach is describe the nonlinear quantum ion acoustic waves by **S. Mahmood** etal. in 2008 . The nonlinear ion acoustic wave density dips structures are formed in the subsonic region. It is found that only the width of the nonlinear ion acoustic wave structure is broadened and the wave amplitude remains the same by the increase in value of quantum parameter H. However, the wave amplitude is increased with the decrease in the Mach number. The results obtained by nonlinear ion acoustic waves in unmagnetized ei quantum plasmas are different from unmagnetized ei classical plasmas in which solitary density humps structures are formed in the supersonic region (M>1) . However in the case of arbitrary amplitude quantum ion acoustic wave in unmagnetized ei plasmas, the authors have not found any disappearance of soliton solution at any value of quantum parameter *H* [29].

The optical parametric amplification (OPA) is analytically investigated in an unmagnetised n-type piezoelectric semiconductor. **S. Ghosh** etal. in 2010 have considered the origin of nonlinear interaction lies in the second order susceptibility arising from the nonlinear induced current density by using the quantum hydrodynamic model. By the quantum effects on optical parametric amplification has been explored with the determination of threshold electric field required for the onset of optical parametric amplification process and parametric gain coefficient [30]. The large parametric gain constant at lower pump electric field can be achievable in unmagnetised n-type piezoelectric semiconductor.

The general dielectric tensor and dispersion equation for quantum plasmas were derived by **Haijun Ren** etal. in 2008 by using the quantum hydrodynamic equations. Dispersion relations of one-, two-stream and beam-plasma instabilities in uniform quantum magnetized plasmas are derived through the new dielectric tensor ε. It means that there are no quantum effects or thermal effects on magneto electric waves. The magnetic field which is parallel to the fluid velocity does not work on stream instabilities while two-stream instability is altered by quantum effects and thermal effects [31].

S. S. Bulanov in 2004, simplify the analysis of electron-positron pair production inside the hollow waveguide and in the focus region and the main results obtained in the long wave approximation $\left(\frac{2\pi c}{w}\right)^3 n \gg 1$ will not change substantially by the technique of the Lorentz transformation into the reference frame, moving with the wave group velocity [32]. The calculation of the probability in the reference frame moving with the group velocity of the wave by using the properties of the dispersion equation for the electromagnetic wave in plasma.

The nonlinear coupling between two electromagnetic waves in plasmas can be described by a system of coupled nonlinear Schrodinger equations that model nonlinear interactions between localized light and Langmuir or ion-acoustic waves. The laser beams can give rise to fast plasma waves by higher-order nonlinearities, or by the beat wave excitation at frequencies different from the electron plasma frequency at strongly relativistic intensities. Particle-in-cell simulations show that large-amplitude electron plasma waves can be excited by colliding laser pulses or by two co-propagating electromagnetic pulses where a long trailing pulse is modulated efficiently by the periodic plasma wake behind the heading short laser pulse [33]. The effect on parametric instabilities of a partially incoherent pump wave was investigated both theoretically and experimentally by **Lennart Stenflo** etal. in 2007.

The plasma number density is extremely high in classical plasmas and low temperature in quantum plasmas. The quantum plasmas are composed of electrons, positrons and holes, which are degenerate. Positrons (holes) have the same (slightly different) mass as electrons, but opposite charge. The degenerate charged particles (electrons, positrons, holes) follow the Fermi-Dirac statistics. In quantum plasmas, there are new forces associated with quantum statistical electron and positron pressures, electron and positron tunneling through the Bohm potential and electron and positron angular momentum spin. These quantum forces provides possibility of very high-frequency dispersive electrostatic and electromagnetic waves having extremely short wavelengths by **P K Shukla** et al. in 2009 [34]. The number densities of degenerate electrons and positrons are extremely high, and the plasma particles obey Fermi-Dirac statistics in quantum plasmas.

P K Shukla et al. in 2009 have provided the theoretical knowledge of nonlinear physics of non-relativistic quantum plasmas and two mechanisms for the generation of magnetic fields in quantum plasmas. In quantum magneto plasmas, spontaneously generated magnetic fields can affect the linear and nonlinear propagation of both the electrostatic and electromagnetic waves. The quantum corrections produce dispersion at short scales for the electrostatic upper-hybrid, lower-hybrid, and ion-cyclotron waves [34].

The fundamental equations of microscopic quantum hydrodynamics are derived from the many-particle microscopic Schrödinger equation with a spin–spin and Coulomb modified Hamiltonian by **M. Iv. Trukhanova** in 2013. The extended vorticity evolution equation for the quantum spinning plasma is derived by using this approach. The effects of the new spin forces and spin–spin interaction contributions on the motion of fermions, the evolution of the magnetic moment density, and vorticity generations are presented. The influence of the intrinsic spin of electrons on whistler mode turbulence is investigated [35]. Using quantum kinetic theory or some effective theory, the collective electron angular momentum spin effects in spinning quantum plasmas can be investigated. The method of quantum hydrodynamics allows one to obtain a description of the collective effects in magnetized quantum plasmas in terms of functions in physical space. The fermion model was developed. The author explores a new quantum hydrodynamics method of the generation wave in the plasma. A quantum mechanics description for systems of *N* interacting spinning particles is based upon the many-particle Schrödinger equation that specifies a wave function in a 3*N*-dimensional configuration space. As wave processes, processes of information transfer and other spin transport processes occur in 3D physical space, it becomes necessary to turn to a mathematical method of physically observable values that are determined in a 3D physical space and this problem has been solved with the creation of a many-particle quantum hydrodynamics (MPQHD) method.

The dynamics of the circularly polarized electromagnetic waves and electron plasma oscillations is governed by the two coupled nonlinear Schrödinger equations and Poisson's equation. The modulational instability of an intense circularly polarized electromagnetic pump wave against electron plasma oscillations, leading to the formation and trapping of localized circularly polarized electromagnetic wave pipes in the electron density hole that is associated with a positive potential distribution in dense plasma associated with nonlinear equations by **P K Shukla** et al. in 2007 [36]. The nonlinearities admit the electron mass increase in electromagnetic fields and the modification of electron number density by the relativistic pondermotive force. Relativistic nonlinear effects in classical plasma are important, because it provide the possibility of the compression and localization of intense electromagnetic waves. The modulational instability of the circularly polarized electromagnetic due to the quantum diffraction effect is controlled by the parameter *H*. This simulation results show that the parameter *H* plays a crucial role in the formation of localized intense circularly polarized electromagnetic pulses, which are trapped in a quantum electron hole at nanoscales.

The gain characteristics of acousto-electric interaction in piezoelectric semiconductor plasma, in presence of quantum parameter H and magnetostatic field have examined by **S. ghosh** etal. in 2016. Using macroscopic model of piezoelectricity and quantum hydrodynamic model, author have derived dispersion relation and gain coefficient of acoustic wave in terms of quantum parameter H and magnetic field. It has been observed that the presence of quantum parameter H and magnetic field together play a crucial role in the modification of this interaction. This results show that application of magnetic field enhances the magnitude of gain whereas quantum effects, through quantum parameter H, reduce the gain of acoustic wave but they do not affect the wave nature from attenuation to amplification. It has been also found that the presence of magnetic field shifts the maximum gain point towards lower drift velocity. Hence the gain profile of acoustic wave is very sensitive to change in magnitude of magnetic field and quantum parameter H [37].

In semiconductor quantum plasma, the role of quantum correction through non-dimensional quantum parameter-H and magnetic field on convective instability of longitudinal electro kinetic wave in magnetised has been investigated by **Apurva Muley** etal. in 2015 [38]. It is found that the quantum parameter H together with magnetic field significantly modify the dispersion relation of longitudinal electro kinetic wave. The derived general dispersion relation in absence of quantum parameter H and magnetic field reduces to the usual dispersion relation of electron plasma wave. The analytical and numerical analysis depicts that out of six possible modes, four modes are found to be growing in nature and two modes are decaying in nature whose decay constant reduces on enhancing the magnitude of quantum parameter H. It concludes that from the phase characteristics of these modes that three modes have co-propagating nature and remaining three modes have contra-propagating nature. In most of the cases, phase velocity of these modes increases in magnitude with increasing quantum parameter H.

The diffusion- induced nonlinear current density and the consequent second-order effective susceptibility are obtained under off-resonant laser irradiation by using the hydrodynamic model of semiconductor plasma. This analysis deals with the qualitative behavior of the anomalous parametric dispersion and the gain profile with respect to the excess doping concentration and pump electric field [39]. This analysis suggests that a proper selection of doping level and pump field may lead to either positive or negative enhanced parametric dispersion, which can be of great use in the generation of sequeezed states. It is found that gain maximizes at moderate doping concentration level, which may drastically reduce the fabrication cost of parametric amplifier based on this interaction by **N. Yadav** etal. in 2006.

The nonlinear wave structure of electron-acoustic waves is investigated in a three component unmagnetized dense quantum plasma consisting of two distinct groups of electrons (one inertial cold electron and other inertialess hot electron) and immobile ions. The dynamics of electron acoustic waves is derived by employing one dimensional quantum hydrodynamic model and reductive perturbation technique of a Korteweg–de-Vries equation [40]. Both compressive and rarefactive solitons along with periodical potential structures are found to exist for various ranges of dimensionless quantum parameter H. On the profiles of the amplitude and the width of electron -acoustic solitary waves, the quantum mechanical effects are also examined numerically by authors. It is observed that both the amplitude and the width of electron-acoustic solitary waves are significantly affected by the parameter H by **O. P. Sah** etal. in 2009.

The quantum Vlasov equation as a differential equation of the Wigner function directly from the electromagnetic Schrödinger equation and apply it to the plasma waves propagating in the direction parallel to the ambient magnetic field. The upper branches of the L and R waves in the plot of (ω, k) space have dispersion relations similar to those of their respective classical waves, with only minor corrections. The lower R-wave branch also has a dispersion relation similar to that of the classical whistler wave for a small wave number k. However, the dispersion curve encounters a region of anomalous dispersion, exhibiting a negative group velocity, as k increases. Furthermore, the branch becomes a damping wave as k increases above a certain critical value and eventually the wave becomes ill-defined for larger k values by **C. H. Woo** etal. in 2019 [41].

The propagation of linear and nonlinear ion acoustic waves in a dense electron-ion quantum plasma has found in dense astrophysical objects like white dwarfs, rotating around an axis at an angle θ with the direction of the constant magnetic field $\vec{B} = B_0 \hat{z}$ by **Biswajit Sahu** etal. in 2019. The different approximation techniques like linearization, reductive perturbation, phase portraits, etc. are applied. The linear dispersion relation, obtained as a quadratic equation in the plasma frequency ω^2, reveals interesting features. The Korteweg–de Vries equation has derived by using the reductive perturbation technique whose solutions are solitary waves. The effects of various physical parameters like speed and angle of rotation, strength of the magnetic field, the quantum diffraction term, etc., on the shape of the nonlinear structures, are investigated by authors. It is observed that the different plasma parameters have similar effects on both small and arbitrary amplitude waves—stronger magnetic field, larger quantum effects, and higher speed of rotation decrease their width. As the angle between the rotation axis and magnetic axis decreases, i.e., the rotation is aligned with the direction of the magnetic field, the waves get sharper. Additionally, the energy of the small amplitude solitary wave decreases with an increase in the speed of rotation and stronger quantum effects [42].

The properties of solitary acoustic pulses that propagate in electron-hole quantum semiconductor plasmas have given by **W. M. Moslem** etal. in 2012. The dynamics of nonlinear acoustic pulses is governed by the Korteweg–de Vries equation, which includes the contributions of the electron and hole quantum recoil effects, quantum statistical pressures of the plasma species, as well as exchange and correlation effects. The speed and profiles of solitary acoustic pulses are estimate by typical values for GaAs, GaSb, GaN and InP semiconductors. The nonlinear solitary pulses have provided the intrinsic localization of electrostatic wave energies in semiconductor plasmas [43].

Using the quantum hydrodynamic model for one component plasma along with coupled mode theory, the dispersion characteristics of acoustic wave in a laser irradiated semiconductor plasma medium like n-CdS has studied by **S. Ghosh** etal. in 2018. Dispersion effects are explored by the second order susceptibility of the medium which is a measure of the strength of second order nonlinear interaction. By the quantum effects the dispersion characteristics are found to be effectively modified. 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 used for self-focusing and defocusing of laser light [44]. The modified parametric dispersion characteristics has found by the quantum mechanical effects. This parametric dispersion may lead to the possibility of observation of group velocity dispersion in semiconductor plasma.

The stimulated scattering instabilities of intense linearly polarized electromagnetic waves in relativistic plasma with degenerate electrons have studied by A.

P. Misra etal. in 2018. The authors derived coupled nonlinear equations for low-frequency electron and ion plasma oscillations that are driven by the electromagnetic waves ponderomotive force from a relativistic hydrodynamic model and the Maxwell's equations. The nonlinear dispersion relations are obtained from the coupled nonlinear equations which reveal stimulated Raman scattering, stimulated Brillouin scattering, (and modulational instabilities of electromagnetic waves. The thermal pressure of ions and the relativistic degenerate pressure of electrons significantly modify the characteristics of stimulated Raman scattering, stimulated Brillouin scattering and modulational instabilities [45]. This result can also be useful in the next-generation highly intense laser produced solid density compressed plasma experiments.

CHAPTER III

INTERACTION OF NONLINEAR LOW FREQUENCY ELECTROSTATICS MODES IN QUANTUM PLASMA

INTERACTION OF NONLINEAR LOW FREQUENCY ELECTROSTATICS MODES IN QUANTUM PLASMA

3.1 INTRODUCTION

In recent years, there has been rapidly growing interest in global properties of quantum plasma in field of modern sciences and technologies in compact of astrophysical objects, such as white-dwarfs, neutron stars and pulsars etc. Actually all plasmas are in some sense are quantum because it consists of charged particles as they obey the laws of quantum mechanics [46]. Although, the density of classical plasma increases or its temperature decreases, it can enter a region where quantum effect starts. Quantum plasmas are obtained in high density matter. Dense plasma can be described as the collective behavior of charged particle in which electrons are degenerate and weakly correlated whereas ions are non-degenerate and strongly correlated [47].

The nonlinear interaction between matter and wave in plasmas is most important topic of plasma physics. For modern device physicists dealing with quantum wells, quantum wires, quantum dots, etc. the linear and nonlinear behaviors of waves and instabilities, through the carrier's dynamics in semiconductors, are crucially important [48]. In quantum plasma fluids, theoretical investigation of nonlinear phenomena associated with electrostatic waves has been carried out by number of authors.

In quantum plasmas, due to inter-fermion distances much lower than its de Broglie wavelength and the influence of the Pauli exclusion rule, many quantum effects such as electron-tunneling, degeneracy pressure and Landau quantization may occur. Quantum plasma exhibits dispersion instead of dissipation which is caused by quantum tunneling effects described by Bohm potential term. Whereas dissipation may arise due to kinematic viscosity and collisions and wave is propagation is governed by interplay between the quantum tunneling and wave particle interactions.

Most of these works are based on quantum hydrodynamic (QHD) model of plasmas. This model is very useful to study the short-scale collective phenomena, such as waves, instabilities, linear and nonlinear interactions in dense plasmas [49–51]. By the quantum hydrodynamics model (QHM), the low frequency electrostatic modes have been investigated in weakly coupled quantum plasma. In dusty plasmas, the low frequency dust acoustic waves in classical strongly correlated plasmas with non-degenerate electrons, ions and charge dust grains have been observed. The nonlinear studies of electrostatic and electromagnetic waves in quantum plasma were based on the generalized quantum hydrodynamical (GQHD) equations [52–54] for nonrelativistic degenerate electron fluids supplemented by Poisson's and Maxwell's equations.

In this chapter, the electrons are degenerate and weakly correlated is described by quantum hydrodynamic model (QHM) whereas ions are non-degenerate and strongly correlated is described by generalized hydrodynamic model (GHM). In this paper, we have derived the dispersion relation for nonlinear electrostatic modes in strongly coupled plasmas by using continuity equations and Poisson's equation. In weakly nonlinear limit, ion-ion correlation effects introduce a viscous dissipation which is responsible for Korteweg-de Vries Burger equation. The dispersion relation is analyzed both theoretically and numerically and this solution shows existence the shock wave in dissipation dominated.

3.2 THEORETICAL FORMULATION

In order to study the weakly nonlinear low frequency electrostatic wave propagation characteristics we take the assumption for solve our problem.

1. The degeneracy parameter for a particle kind a is defined as-

$$\chi_a = \frac{\varepsilon_{F_a}}{T_a} = \frac{1}{2}\left(3\pi^2\right)^{2/3}\left(n_{a0}\lambda_{B_a}^3\right)^{2/3}$$

Where $\varepsilon_{F_a} = \hbar^2\left(3\pi^2 n_{a0}\right)^{2/3}/2m_a$ are the Fermi energy of ground state and $\lambda_{B_a} = \hbar/\sqrt{m_a}T_a$ is thermal de Broglie wavelength of particle kind a.

(i) The electrons are fully degenerate so that the electron Fermi energy (ε_{Fe}) is much larger than electron thermal energy (T_e) and electron degeneracy parameter $\chi_e >> 1$. This implies that

$$n_{e0} >> \frac{1}{3\pi^2}\left(\frac{2m_eT_e}{\hbar^2}\right)^{3/2} = n_{eQ}$$

(ii) The ions are non-degenerate so that ion Fermi energy (ε_{Fi}) is much smaller than ion thermal energy (T_i) and ion degeneracy parameter $\chi_i << 1$. This implies that

$$n_{i0} << \frac{1}{3\pi^2}\left(\frac{2m_iT_i}{\hbar^2}\right)^{3/2} = n_{iQ}$$

2. The electron correlations are neglected as electron-electron correlation effects are negligibly small compared to ion-ion correlation. The electron coupling parameter is

$$\Lambda_e = \left(\frac{1}{n_{e0}\lambda_{Fe}^3}\right)^{2/3} = 1.5Z^{-5/3}\chi_e^{-1}\phi$$

The electron degeneracy parameter $\chi_e >> 1$, $Z \geq 1$ and $\phi = (T_i / T_e) \leq 1$. Where $\lambda_{Fe} = v_{Fe} / \sqrt{3}\omega_{pe}$ is the Thomas-Fermi three dimensional screening length of electrons, $v_{Fe} = \sqrt{\frac{2\varepsilon_{Fe}}{m_e}}$ is the Fermi speed of electrons and $\omega_{pe} = \sqrt{\frac{n_{e0}e^2}{\varepsilon_0 m_e}}$ is the electron plasma frequency. The electron-ion interactions are weak compared to ion-ion correlations and therefore we neglect electron-ion interactions.

3. The ions are strongly correlated, i.e., ion coupling parameter is –

$$\Lambda_i = \left(\frac{1}{n_{i0}\lambda_{Di}^3}\right)^{2/3} = \frac{Z^2e^2}{\varepsilon_0 x_i T_i} >> 1$$

Where $\lambda_{Di} = \sqrt{\varepsilon_0 T_i} /(n_{i0} Z^2 e^2)$ is the ion Debye radius and $x_i = (3/4\pi n_{i0})^{1/3}$ is inter ionic distance. This implies that

$$n_{i0} >> \frac{3}{4\pi}\left(\frac{Z^2 e^2}{\varepsilon_0 T_i}\right)^{-3} = n_{SC}$$

The assumptions 1 and 3 determine highly dense quantum plasma system [(n_{eQ}, n_{SC} << n_{i0} << n_{iQ}]. Our assumptions are valid for a typical hydrogen plasma if plasma number density n_{i0} ~ (10^{28}-10^{32}) m^{-3} and $\phi = (T_i / T_e) = 1$.It means physical plasma system is highly dense, if ion coupling parameter $\Lambda_i >> 1$(strongly coupled) in which electrons form a degenerate quantum fluids with weak interactions whereas ions form a classical fluids with strong interactions.

In order to account for the correlation among ion dynamics, we use viscoelastic approach which is described by general hydrodynamics model [55-56]. We consider generalized momentum equation for ion fluid using the relation $\frac{d}{dt} = \frac{\partial}{\partial t} + u_i.\nabla$ is

$$\left(1 + \tau_m \frac{d}{dt}\right)\left[\rho_i \frac{du_i}{dt} + \nabla P_i - Zen_i \vec{E}\right] = \eta \nabla^2 u_i + \left(\kappa + \frac{\eta}{3}\right)\nabla(\nabla.u_i)$$

… (3.1)

Where τ_m is the viscoelastic relaxation time that accounts the memory function, u_i is ion fluid velocity, $\rho = m_i n_i$ is ion mass density, Pi is ion pressure, η and κ are the shear and bulk coefficients of viscosity.

The general hydrodynamic model also includes ion continuity equation and energy equation. The ion energy equation is not required because ion dynamics is isothermal at strong couplings.

$$\frac{\partial n_i}{\partial t} + \nabla.(n_i u_i) = 0$$

… (3.2)

The gradient ion pressure becomes –

$$\nabla P_i = T_i \mu_i \nabla n_i$$

Where μ_i is the coefficient of isothermal compressibility for ion fluid.

The conservation of momentum equation for electron is –

$$0 = -e\vec{E} - \frac{\nabla P_e}{n_e} + \frac{\hbar^2}{2m_e}\nabla\left(\frac{\nabla^2\sqrt{n_e}}{\sqrt{n_e}}\right) \qquad \ldots (3.3)$$

Where n_e is unperturbed electron number density, P_e is electron pressure and the term $\hbar^2$ arises due to electron tunneling through the Bohm potential. The system of equations is closed by Poisson's equation

$$\nabla.E = \frac{e}{\varepsilon_0}\left(Zn_i - n_e\right) \qquad \ldots (3.4)$$

In strongly coupled quantum plasma, we considered the ion viscous dissipation effects the weakly nonlinear structures in 1-dimensional in the hydrodynamic range ($\omega\tau_m << 1$). To explore the nonlinear structures, it is convenient to write governing equations in dimensionless form. We use following dimensionless variables:

$$\frac{\partial u_i}{\partial t} + u_i\frac{\partial u_i}{\partial x} + \mu_i\frac{\partial \ln n_i}{\partial x} - \vec{E} = \frac{\eta^*}{n_i}\frac{\partial^2 u_i}{\partial x^2} \qquad \ldots (3.5)$$

$$\frac{\partial n_i}{\partial t} + \frac{\partial}{\partial x}\left(n_i u_i\right) = 0 \qquad \ldots (3.6)$$

$$0 = -\vec{E} - \left(\frac{\overline{\lambda}_{Fe}}{\lambda_{Di}}\right)^2 n_e\frac{\partial n_e}{\partial x} + \frac{\overline{H}^2}{2}\left(\frac{\overline{\lambda}_{Fe}}{\lambda_{Di}}\right)^4\frac{\partial}{\partial x}\left(\frac{1}{\sqrt{n_e}}\frac{\partial^2\sqrt{n_e}}{\partial x^2}\right) \qquad \ldots (3.7)$$

$$\frac{\partial\vec{E}}{\partial x} = n_i - n_e \qquad \ldots (3.8)$$

Where $\overline{H} = \frac{H}{3} = \frac{\hbar\omega_{pe}}{2T_{Fe}}$ the quantum diffraction due to 1-dimensional electron tunneling effect and $\overline{\lambda}_{Fe} = \sqrt{3}\lambda_{Fe} = v_{Fe}/\omega_{pe}$ is the Thomas–Fermi 1-dimensional screening length of electrons.

Now, we derive the Korteweg-de Vries equation from (3.5)-(3.8) by employing the reductive perturbation technique and the stretched coordinates –

$\delta = \varepsilon^{1/2}(x - Mt)$ and $\tau = \varepsilon^{3/2} t$ … (3.9)

Where ε is a smallness parameter proportional to the amplitude of the perturbation and M is the mode normalized by the ion thermal speed.

We can expand the variables and $n_{e(i)}$, u_i and E in a power series of ε as -

$$n_{e(i)} = 1 + \varepsilon n_{e(i)}^{(1)} + \varepsilon^2 n_{e(i)}^{(2)} + ... \qquad \text{… (3.10)}$$

$$u_i = 0 + \varepsilon u_i^{(1)} + \varepsilon^2 u_i^{(2)} + ... \qquad \text{… (3.11)}$$

$$\vec{E} = 0 + \varepsilon^{3/2} E^{(1)} + \varepsilon^{5/2} E^{(2)} + ... \qquad \text{… (3.12)}$$

Now, using (3.10)-(3.12) in (3.5) - (3.8) and taking the coefficient of $\varepsilon^{3/2}$ from (3.12) and ε from (3.10) – (3.11), we get -

$$E^{(1)} = \frac{\partial\left(\mu_i n_i^{(1)} - M u_i^{(1)}\right)}{\partial\delta} \qquad \text{… (3.13)}$$

$$u_i^{(1)} = M n_i^{(1)} \qquad \text{… (3.14)}$$

$$E^{(1)} = -\left(\frac{\overline{\lambda}_{Fe}}{\lambda_{Di}}\right)^2 \frac{\partial n_e^{(1)}}{\partial\delta} \qquad \text{… (3.15)}$$

$$n_e^{(1)} = n_i^{(1)} \qquad \text{… (3.16)}$$

Now, using (3.13) – (3.16) we have -

$$M = \sqrt{\mu_i + \left(\frac{\overline{\lambda}_{Fe}}{\lambda_{Di}}\right)^2} \qquad \text{… (3.17)}$$

Now substituting (3.13) - (3.16) into (3.5) - (3.8) and equating the coefficient of from (3.10) – (3.12), we obtains –

$$E^{(2)} = \frac{\partial u_i^{(1)}}{\partial \tau} + u_i^{(1)} \frac{\partial u_i^{(1)}}{\partial \delta} - \mu_i n_i^{(1)} \frac{\partial n_i^{(1)}}{\partial \delta} - \eta^* \frac{\partial^2 u_i^{(1)}}{\partial \delta^2} + \mu_i \frac{\partial n_i^{(2)}}{\partial \delta} - M \frac{\partial u_i^{(2)}}{\partial \delta} \quad \ldots (3.18)$$

$$\frac{\partial n_i^{(1)}}{\partial \tau} + \frac{\partial \left(n_i^{(1)} u_i^{(1)}\right)}{\partial \delta} = M \frac{\partial n_i^{(2)}}{\partial \delta} - \frac{\partial u_i^{(2)}}{\partial \delta} \quad \ldots (3.19)$$

$$E^{(2)} = -\left(\frac{\overline{\lambda}_{Fe}}{\lambda_{Di}}\right)^2 n_e^{(1)} \frac{\partial n_e^{(1)}}{\partial \delta} - \left(\frac{\overline{\lambda}_{Fe}}{\lambda_{Di}}\right)^2 \frac{\partial n_e^{(2)}}{\partial \delta} + \frac{\overline{H}^2}{4} \left(\frac{\overline{\lambda}_{Fe}}{\lambda_{Di}}\right)^4 \frac{\partial^3 n_e^{(1)}}{\partial \delta^3} \quad \ldots (3.20)$$

$$\frac{\partial E^{(1)}}{\partial \delta} = n_i^{(2)} - n_e^{(2)} \quad \ldots (3.21)$$

Now, using above equation and eliminating $n_{e(i)}$, u_i and E we obtain –

$$\psi = \frac{M n_i^{(1)}}{\mu_i + 2\left(\frac{\overline{\lambda}_{Fe}}{\lambda_{Di}}\right)^2} \quad \ldots (3.22)$$

$$\frac{\partial \psi}{\partial \tau} + \psi \frac{\partial \psi}{\partial \delta} + A \frac{\partial^3 \psi}{\partial \delta^3} = \mu \frac{\partial^2 \psi}{\partial \delta^2} \quad \ldots (3.23)$$

Where the coefficients *A* and μ are given by –

$$A = \frac{1}{2M}\left(\frac{\overline{\lambda}_{Fe}}{\lambda_{Di}}\right)^2 \left(1 - \frac{\overline{H}^2}{4}\right)$$
$$\mu = \frac{\eta^*}{2} \quad \ldots (3.24)$$

Equation (3.23) is the Korteweg-de Vries Berger equation of the weakly nonlinear low frequency electrostatic wave in strongly coupled quantum plasma. The solution of Korteweg-de Vries equation is found by transforming the independent variables δ and τ to -

$K = \delta - C_0 \tau, \quad \tau = \tau$ … (3.25)

Where, C_0 is a constant velocity normalized by c.

3.3 NUMERICAL SOLUTION AND DISCUSSION

In order to get the existence of shock structure, it is necessary to apply the boundary condition on wave. The exact solution of KDVB is not possible because this equation is not exactly integral solution. A particular solution of KDVB is possible which exhibits only monotonic shock structure. Actually, a monotonic shock structure is possible only when dissipation dominates and oscillatory shock structure is possible only when dissipation is weak.

The boundary condition is –

$$\psi \to 0, \frac{d\psi}{dK} \to 0, \frac{d^2\psi}{dK^2} \to 0 at K \to \infty$$

Finally equation (4.23) becomes -

$$\frac{d^2\psi}{dK^2} = \left(\frac{C_0}{A}\right)\psi - \left(\frac{1}{2A}\right)\psi^2 + \left(\frac{\mu}{A}\right)\frac{d\psi}{dK} \quad \dots (3.26)$$

Equation (3.26) is well known the damped harmonic oscillator in which ψ describes the generalized coordinate and δ describes the time. Equation (3.26) has two singular points –

(i) $\psi \to 0, \frac{d\psi}{dK} \to 0$

(ii) $\psi \to 2C_0, \frac{d\psi}{dK} \to 0,$

The first point shows the equilibrium downstream state and second point shows the upstream state. If we assume, K= ∞ (δ = ∞), the particle was located at ψ = 0 and if K = -∞ (δ = -∞), the particle at point ψ = $2C_0$. The shock strength is –

Shock strength = ψ (-∞) – ψ (+∞) = $2C_0$.

The Mach number is independent of dispersion -

MA = Nonlinear Wave Velocity / Linear Wave Velocity

$$MA = 1 + \varepsilon\left(\frac{C_0}{M}\right) \qquad \ldots (3.27)$$

In order to find nature of shock structure, the solution of equation (3.26) is obtained by substitute the

$\psi = 2C_0 + \overline{\psi}$, where $2C_0 >> \overline{\psi}$ ---

$$\frac{d^2\overline{\psi}}{dK^2} + \left(\frac{C_0}{A}\right)\overline{\psi} - \left(\frac{\mu}{A}\right)\frac{d\overline{\psi}}{dK} = 0 \qquad \ldots (3.28)$$

The solution of equation (3.28) is proportional to ~ exp (σK), where -

$$\sigma = \frac{\mu}{2A} \pm \sqrt{\left(\frac{\mu^2}{4A^2} - \frac{C_0}{A}\right)} \qquad \ldots (3.29)$$

$$\overline{H} = 0.2$$

The oscillatory shock structure in which dispersion dominates over dissipation by different values of τ as shown in figure 3.1 and this follow the equation (3.29) with the singular point ($2C_0$, 0). It is clear from figure 3.1(d), the oscillatory shock is fully developed at τ = 1200 with singular point $2C_0 = 0.1$ giving shock speed $C_0 = 0.05$, burger coefficient $\mu = 10^{-2}$, dispersion coefficient A = 3.

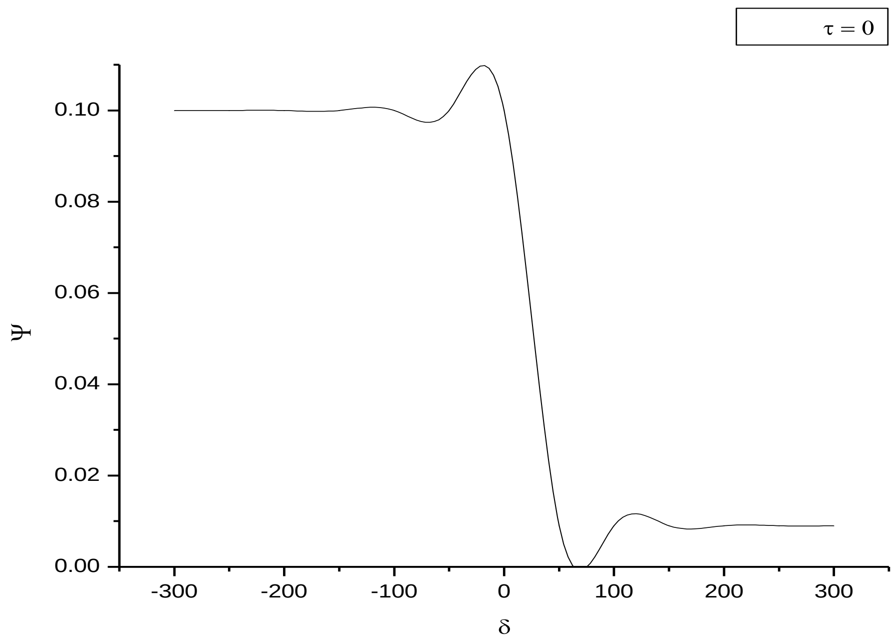

Fig. 3.1(a) Oscillatory shock structure at τ = 0

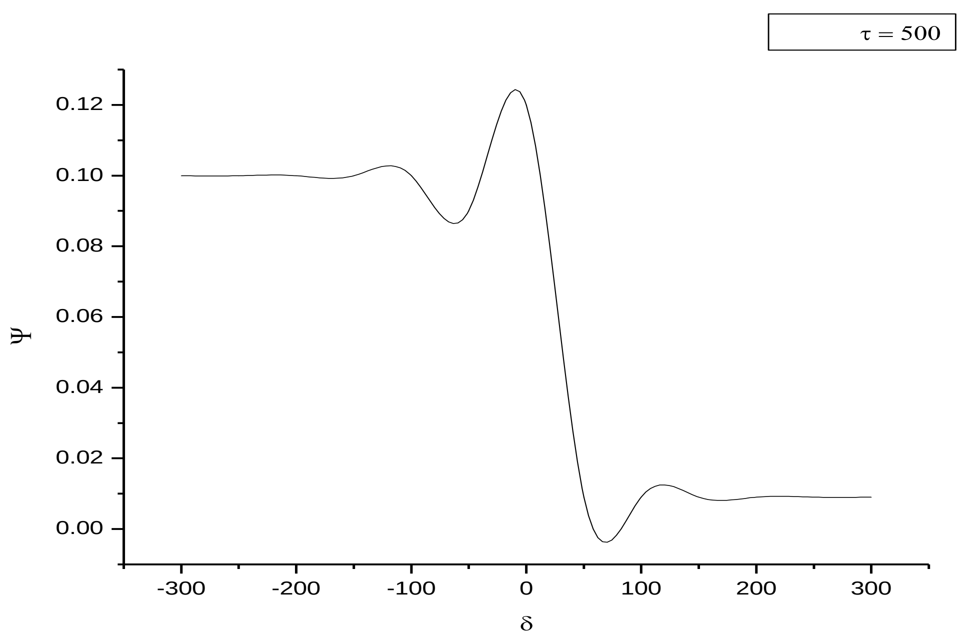

Fig. 3.1(b) Oscillatory shock structure at τ = 500

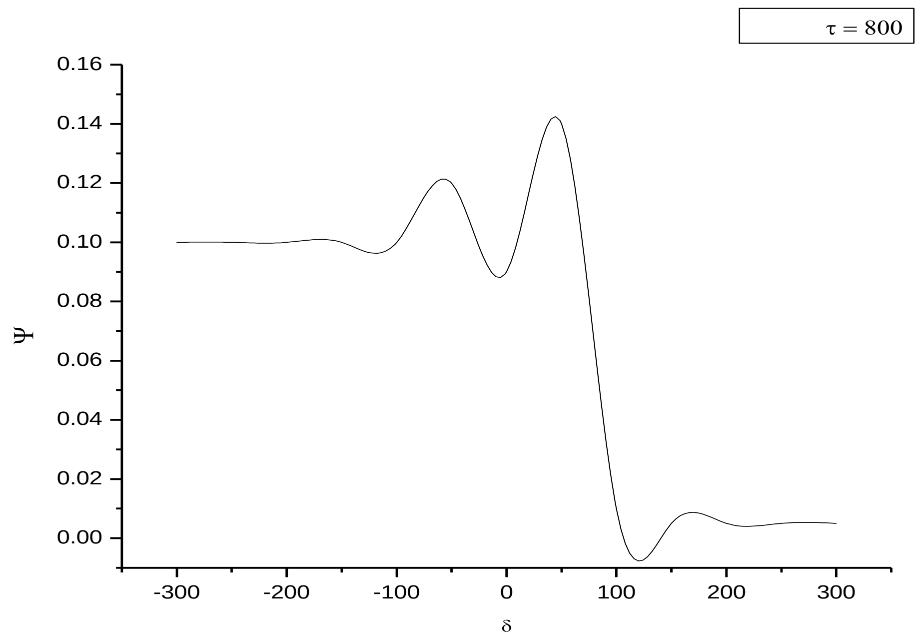

Fig. 3.1(c) Oscillatory shock structure at τ = 800

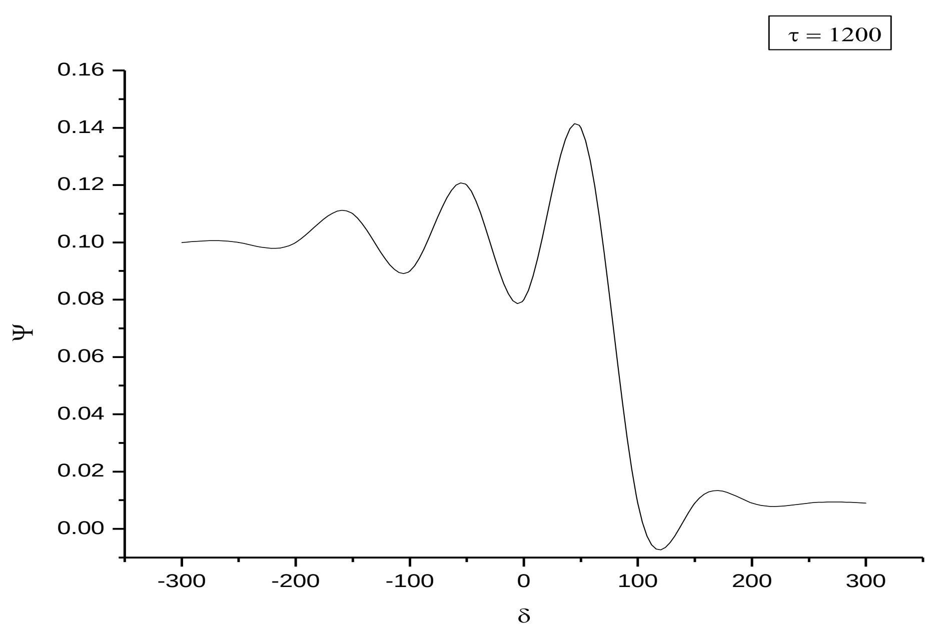

Fig. 3.1(d) Oscillatory shock structure at τ = 1200

$$\psi = C_0\left[1-\tanh\left(\frac{C_0 K}{2\mu}\right)\right] \qquad \text{… (3.30)}$$

$$\overline{H} = 2$$

The monotonic shock structure in which dissipation dominates over dispersion by different values of τ as shown in figure 3.2 and this follow the equation (3.30) with the singular point ($2C_0$, 0). In figure 3.2, the dispersion coefficient A = 0, C_0 is the amplitude and $2\mu/ C_0$ is width of the shock and other values are same as in figure 1. In this range, burger coefficient $\mu = 10^{-2}$, dispersion coefficient A = 1~3 and 0 < H < 2 [57-58], monotonic shock structure is well agree with equation (3.30).

Therefore, the time-dependent numerical solutions, as shown in Figures 3.1 and 3.2 exhibit the evolution of no analytic initial data to the steady-state solutions predicted by the time-independent analysis.

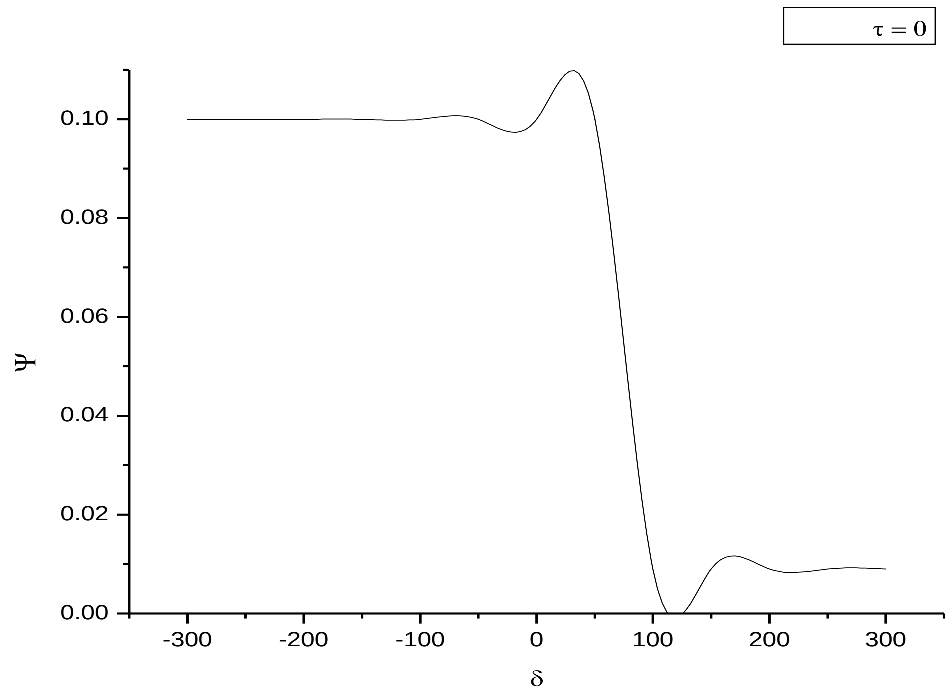

Fig. 3.2(a) Monotonic shock structure at τ = 0

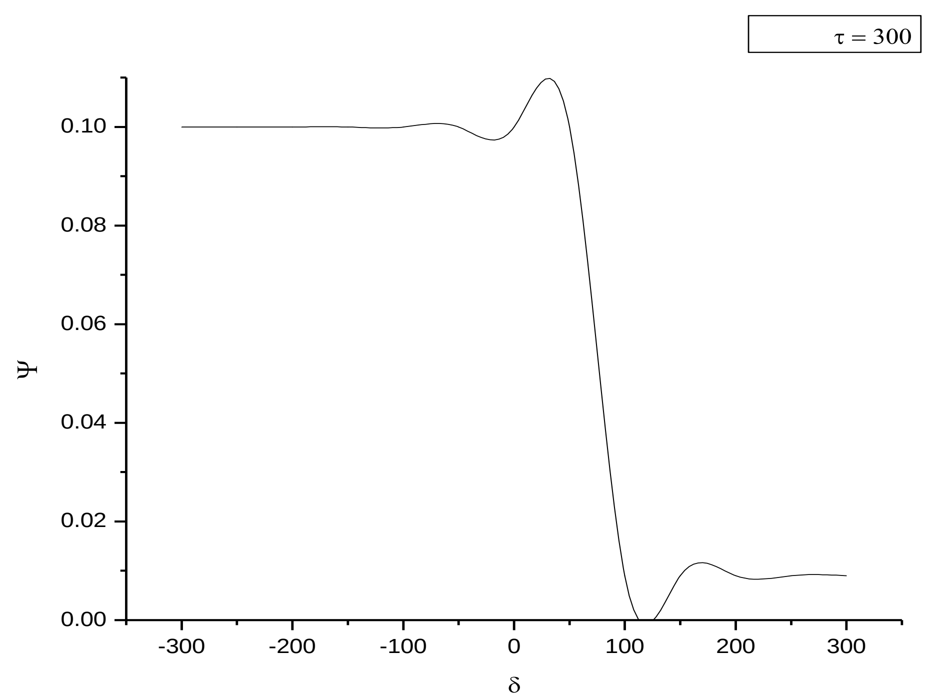

Fig. 3.2(b) Monotonic shock structure at τ = 300

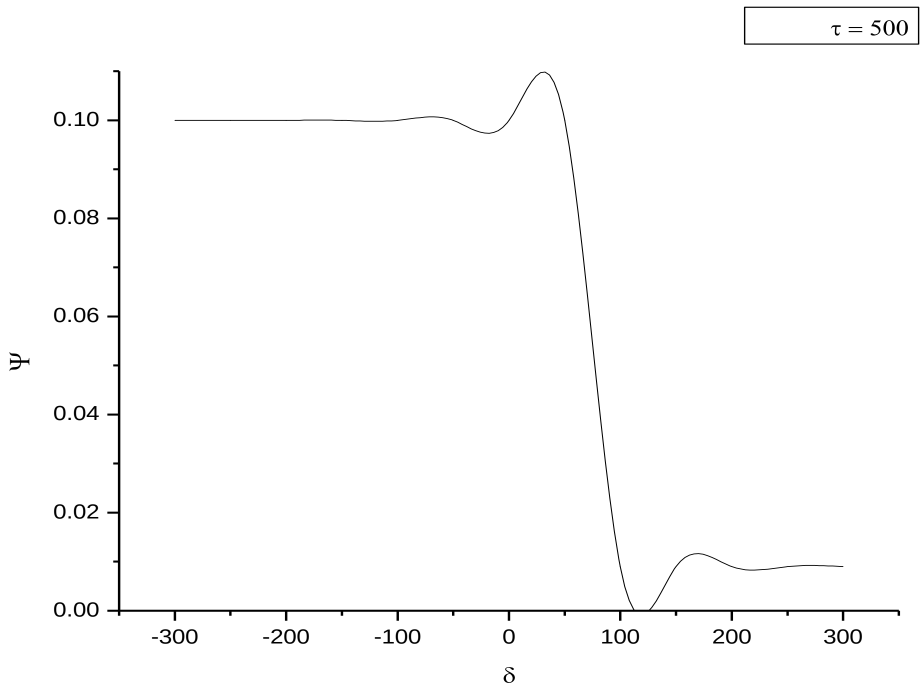

Fig. 3.2(c) Monotonic shock structure at τ = 500

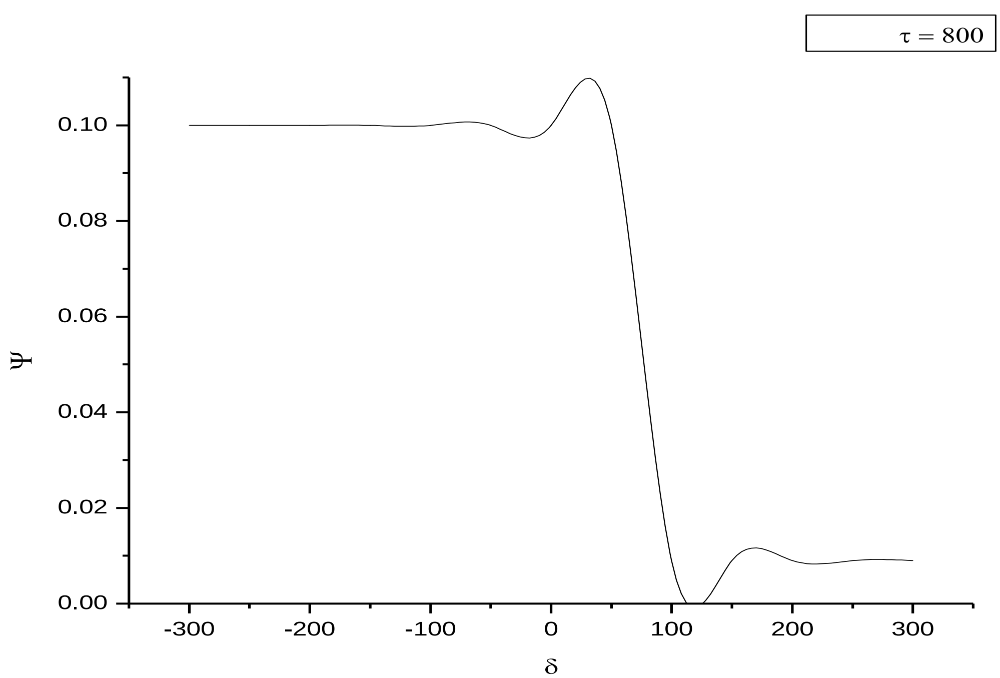

Fig. 3.2(d) Monotonic shock structure at τ = 800

3.4 CONCLUSION

The propagation of nonlinear low frequency electrostatic modes in strongly coupled quantum plasma is investigated. The behavior of strongly coupled quantum plasma is the collective nature, which is most important property of this plasma. This investigation supports the existence of shock wave due to ion-ion correlation in high energy density of strongly coupled quantum plasma. The oscillatory shock structure in which dispersion dominates over dissipation and monotonic shock structure in which dissipation dominates over dispersion by different values of τ are discussed. The quantum forces associated with the quantum statistical pressure and the quantum recoil effect act on the degenerate electron fluid. The monotonic shock structure is observed only for a particular value of the quantum recoil effect. The results may be significant for understanding the scattering process involving intense laser beam in high energy density compressed plasma experimentally. In dissipative plasma, the propagation of small but finite amplitude nonlinear excitations maybe described by Korteweg-de Vries Burger equation.

CHAPTER IV

THE ULTRASONIC WAVES IN PIEZOELECTRIC SEMICONDUCTOR IN THE PRESENCE OF ELECTRIC FIELD

THE ULTRASONIC WAVES IN PIEZOELECTRIC SEMICONDUCTOR IN THE PRESENCE OF ELECTRIC FIELD

4.1 INTRODUCTION

In the previous chapter, we have studied the interaction of nonlinear low frequency electrostatic modes in quantum plasma. The electrons are degenerate and weakly correlated whereas ions are non-degenerate and strongly correlated are presented. The oscillatory shock structure and monotonic shock structure by different values of τ are discussed. We have established the mathematical equations for nature of shock structure.

This Chapter explains the interaction between the electric field associated with ultrasonic waves and electrons and holes drifting with the external field. Ultrasonic waves are elastic waves consisting of frequencies greater than 20 kHz. When crystal is semiconducting the electric field produces current and space charge resulting in energy loss which clearly demonstrates the capabilities of ultrasonic methods in the study of physical properties of solid materials. In this study, measuring the attenuation and velocity of propagating ultrasonic waves is very important. Such measurements permit one to study the influence on the propagation behavior of any such property of solid that is sufficiently well coupled to lattice**.** For example 1. Electron-phonon interaction 2. Thermo-elastic or heating effect 3. Magneto-elastic loss effect in ferromagnetic material 4. Phonon-phonon interaction 5. Acoustoelectric effect, etc. In this chapter, the interaction of acoustic signal with the strong electric field and electrons and holes drifting with the external field will study [17].

Ultrasonic velocity and attenuation are the important parameters required for ultrasonic technique of material characterization. The velocity is related to the elastic constants and density of material. Hence, information about mechanical, anisotropic and elastic properties of a medium can be determined from knowledge of the velocity change. Piezoelectricity is a well-known effect that involves the production of an electrical potential in a substance as the pressure on it changes. This effect has been widely used for fabricating electromechanical sensors, actuators, and energy converters. Piezoelectric materials include dielectrics which have been extensively investigated and semiconductors which have received much less attention so far. A mechanical field in a piezoelectric crystal is usually accompanied by an electric field. When a piezoelectric crystal is also semiconducting, the electric field produces currents and space charge. Piezoelectric materials that are used for fabricating electronic and optoelectronic devices are required to be semiconductors, such as ZnO, GaN, InN, and ZnS.

The number of electronic device is built with semiconductors. In 1953, Parmenter predicted [59] that the acoustic effect occurs only in metal. In 1956, G. Weinreich predicted [60] that the acoustic effect is not present in semiconductors because charge carriers of only one sign. In 1956, again Holstein predicted [61] that the acoustic defect may be present in semiconductors but only for those semiconductors which have complicated band structure. In 1961, Hutson et al. Predicted [62] that when electric drift velocity exceeds that of sound velocity then amplification of the acoustic signal within the applied electric field.

Ultrasound is generally defined as acoustic waves at frequencies larger than ~20 kHz. The upper limit corresponds to phonon frequencies at the edge of the Brillouin zone, which, in most crystalline solids, lies in the THz range. Over the years, steady progress toward generating higher and higher frequencies has been made. Nowadays, piezoelectric thin film resonators generating acoustic waves at frequencies of a few GHz are ubiquitous in wireless communication devices, and frequencies up to 20 GHz have been achieved with this technology.

More recent works are showing very interesting results [63 - 68]. We are, therefore, revisiting a paper written by Epshtein [69] on the propagation of ultrasound in semiconductors under the influence of a high-frequency electric field, elaborating on the calculations and applying the results on bulk gallium Nitride (GaN). In this chapter, we elaborate the calculations on the Gallium Nitride (GaN) semiconducting material in which large band gap and the propagation of ultrasound under the influence of electric field.

4.2 MATHEMATICAL FORMULATION

We following the approach in and consider the situation in which the conditions is $\Omega >> \omega_c \equiv \omega_p \tau$ and $\omega_p \tau << 1$ are fulfilled [69] (Ω is the ac frequency, ω_p is the electronic plasma frequency and τ is the average electronic relaxation time). This means that the electric field penetrates the semiconductor both for $\Omega\tau << 1$and for $\Omega\tau >> 1$ [70].

Here, Maxwell's electromagnetic field theory of electron sound wave interaction is applicable in which sound wave length is larger than electronic mean free path.

The propagation of sound waves in the semiconductor has describe the system of equations -

$$\frac{\partial^2 u}{\partial t^2} - v_o \frac{\partial^2 u}{\partial x^2} = \frac{\beta}{\rho}\frac{\partial E}{\partial x} \qquad \dots (4.1)$$

$$\varepsilon \frac{\partial E}{\partial x} - 4\pi\beta \frac{\partial^2 u}{\partial x^2} = 4\pi e(n - n_o) \qquad \dots (4.2)$$

$$\frac{\partial n}{\partial t} + \frac{\partial (n v)}{\partial x} = 0 \qquad \dots (4.3)$$

$$\frac{\partial v}{\partial t} + v\frac{\partial v}{\partial x} = \frac{e}{m}E - \frac{v}{\tau} - \frac{KT}{mn}\frac{\partial n}{\partial x} \qquad \dots (4.4)$$

where u is the sound wave displacement, **E** is the electric field, n is the electron concentration, n_o is its equilibrium value, v is the average electron velocity caused by the electric field and the sound wave, v_o is the non-renormalized sound velocity, ρ is the crystal density, β is the piezoelectric constant and ε is the dielectric constant of the lattice.

The total electric field **E** consists of the external high-frequency electric field **E**(t) = $E_o e^{at}$ $\sin\Omega t$, and the electric field caused by the sound wave ($a \rightarrow +0$ is a parameter of the adiabatic switching-in of the external field at $t = -\infty$).

In the absence of a sound wave the solutions of the system of eqns. (4.1) to (4.4) in the form-

$$\left.\begin{aligned} &\mathrm{E(x,\ t) = E(t)} \\ &u(x,t) = u \\ &n = n_0 \\ &v = \tilde{v}(t) = \frac{eE_0}{m}\frac{e^{at}\tau}{1+\Omega^2\tau^2}(Sin\Omega t - \Omega\tau\cos\Omega t) \end{aligned}\right\} \quad \ldots (4.5)$$

In the presence of a weak sound the solutions of the system of eqns. (4.1) to (4.4) in the form -

$$\left.\begin{aligned} &E(x,t) = \vec{E}(t) + e^{ikx}E_1(t) \\ &v(x,t) = \vec{v}(t) + e^{ikx}v_1(t) \\ &n(x,t) = n_0 + e^{ikx}n_1(t) \\ &u(x,t) = e^{ikx}u_1(t) \end{aligned}\right\} \quad \ldots (4.6)$$

Here we have linearized by retaining only terms with subscript 1. Eliminating E_1 and v_1 using the equations (4.2) and (4.3) we have -

$$\frac{\partial^2 u}{\partial t^2} - \frac{\partial^2 u}{\partial x^2}v_0(1+\chi) = \frac{4\pi e\beta}{\rho\varepsilon}(n-n_0) \quad \ldots (4.7)$$

$$\frac{\partial^2 u}{\partial t^2} + v_0 k^2(1+\chi)u = \frac{4\pi e\beta}{\varepsilon\rho}e^{ikx}n_1(t) \quad \ldots (4.8)$$

Where $\chi = \dfrac{4\pi\beta^2}{\varepsilon\rho}$ is the electromechanical coupling constant for the material.

$$x = \tilde{x}(t) = \left[\int_{-\infty}^{t}(\tilde{v}(t')dt'\right] \quad \ldots (4.9)$$

We have -

$$\frac{\partial^2 u}{\partial t^2} + v_0 k^2(1+\chi)u = \frac{4\pi e\beta}{\varepsilon\rho}n_1(t)\exp\left[ik\int_{-\infty}^{t}\tilde{v}(t')dt'\right] \quad \ldots (4.10)$$

This can be expressed as -

$$\frac{\partial^2 u}{\partial t^2} + \nu_0 k^2 (1+\chi) u = \frac{4\pi e\beta}{\varepsilon\rho} n_1(t) \exp\left[\frac{ieE_0 k}{m\Omega^2} \frac{\Omega\tau}{\sqrt{1+\Omega^2\tau^2}} \sin\left(\Omega t' + \tan^{-1}\frac{1}{\Omega\tau}\right)\right] \quad \ldots (4.11)$$

Using the well- known expansion is -

$$\exp(iz\sin\varphi) = \sum_{p=-\infty}^{\infty} J_p(z) e^{ip\varphi} \quad \ldots (4.12)$$

Where $J_p(z)$ is the p-th order Bessel function, eqn (4.11) becomes

$$\frac{\partial^2 u}{\partial t^2} + \nu_0 k^2 (1+\chi) u = \frac{4\pi e\beta}{\varepsilon\rho} \nu \sum_{p=-\infty}^{\infty} J_p(a) \exp\left[ip\left(\Omega t + arctg\frac{1}{\Omega\tau}\right)\right] \quad \ldots (4.13)$$

Similarly, using eqns (4.3) and (4.4) and proceeding as above, neglecting second and higher order terms, we obtain

$$\frac{\partial^2 \nu}{\partial t^2} + \frac{1}{\tau}\frac{\partial \nu}{\partial t} + \frac{KT}{m}\left(k^2 + \xi^2\right)\nu = \frac{4\pi e\beta}{\varepsilon m} n_0 k^2 u \exp\left[ik\int_{-\infty}^{\infty} \frac{eE_0}{m} \frac{e^{at}\tau}{1+\Omega^2\tau^2} \left(Sin\Omega t' - \Omega\tau Cos\Omega t'\right) dt'\right]$$

$$\ldots (4.14)$$

Where $\xi = \left(\frac{4\pi^2 n_0}{\varepsilon KT}\right)^{\frac{1}{2}}$ is the screening radius

$$a = \frac{eE_0 k}{m\Omega^2} \frac{\Omega\tau}{\sqrt{1+\Omega^2\tau^2}} \quad \ldots (4.15)$$

is the argument of the Bessel function.

4.3 DISPERSION RELATION

We now average eqns (4.13) and (4.14) over the period of the high-frequency field. Since we are considering only waves with frequencies much smaller than the field frequency, it is sufficient to replace ν and u by their averages, and to retain only terms with p = 0 on the right sides of the equations.

Equations (4.13) and (4.14) then become -

$$\frac{d^2\bar{v}}{dt^2}+\frac{1}{\tau}\frac{d\bar{v}}{dt}\frac{KT}{m}\left(k^2+\xi^2\right)\bar{v}=\frac{4\pi e\beta n_0 k^2}{\varepsilon m}\bar{u}J_0(a) \qquad \ldots (4.16)$$

$$\frac{d^2\bar{u}}{dt^2}+v_0 k^2(1+\chi)\bar{u}=\frac{4\pi e\beta}{\varepsilon\rho}\bar{v}J_0(a) \qquad \ldots (4.17)$$

Assuming the average quantities to be proportional to exp (-iωt) for (ω << Ω). Now eqns (4.16) and (4.17) becomes -

$$-\omega^2\bar{v}-\frac{i\omega\bar{v}}{\tau}+\frac{KT}{m}\left(k^2-\xi^2\right)\bar{v}=\frac{4\pi e n_0 k^2}{\varepsilon m}\bar{u}J_0(a) \qquad \ldots (4.18)$$

$$-\omega^2\bar{u}+\omega_0(1+\chi)\bar{u}=\frac{4\pi e\beta}{\varepsilon\beta}\bar{v}J_0(a) \qquad \ldots (4.19)$$

From eqns (4.18) and (4.19) we express $\bar{v}$ in terms of $\bar{u}$ as

$$\bar{v}=\frac{4\pi e\beta n_0 k^2 J_0(a)}{\omega^2+i\frac{\omega}{\tau}-\frac{KT}{m}\left(k^2+\xi^2\right)} \qquad \ldots (4.20)$$

Where $\omega_0=v_0 k,\qquad \omega_a=\omega_p^2\tau\qquad$ and $\quad \omega_b=\frac{mv_0^2}{KT}\frac{1}{\tau}$

We consider the χ<<1 and obtain for the sound velocity, *v*, and the coefficient of its absorption by electrons α, from the expression

$$\omega=\omega_0\left\{1+\frac{\chi}{2}\left(1-\frac{i\frac{\omega_a}{\omega_0}J_0^2(a)+J_0^2(a)\frac{\omega_a}{\omega_0}\left(\frac{\omega_a}{\omega_0}+\frac{\omega_0}{\omega_b}\right)}{1+\left(\frac{\omega_a}{\omega_0}+\frac{\omega_0}{\omega_b}\right)^2}\right)\right\} \qquad \ldots (4.21)$$

$$v = \frac{\omega}{k} = v_0 \left[1 + \frac{\chi}{2} \left\{ 1 - J_0^2(a) \frac{\frac{\omega_a}{\omega_0}\left(\frac{\omega_a}{\omega_0} + \frac{\omega_0}{\omega_b}\right)}{1 + \left(\frac{\omega_a}{\omega_0} + \frac{\omega_0}{\omega_b}\right)^2} \right\} \right] \qquad \ldots (4.22)$$

Where $v_0 = \frac{\omega_0}{k}$

Also, the attenuation coefficient is given by -

$$\alpha = \frac{2I_m \omega}{v_0} = \frac{\chi \frac{\omega_a}{v_0} J_0^2(a)}{1 + \left(\frac{\omega_a}{\omega_0} + \frac{\omega_0}{\omega_b}\right)^2} = \chi \frac{\omega_c}{v_0} J_0^2(a) \left\{ 1 + \frac{\omega_a^2}{\omega_0^2} \left(1 + \frac{\omega_0^2}{\omega_a \omega_b} \right)^2 \right\}^{-1} \qquad \ldots (4.23)$$

4.4 RESULT AND DISCUSSION

The analysis of propagation of electromagnetic waves in solid state plasma has been a very important research topic over the last fifty years. Every problem involves a complicated field solution and complicated materials / electronic device solution include situations where active electron device will be coupled by passive environment that cannot accurately described by a simple equivalent circuit. In this chapter the attenuation and velocity of propagating ultrasonic waves in GaN semiconductor is measured by electromechanical coupling coefficient χ .

Using the parameters of Ridley [71], O'Clock, Duffy [72] and Shimada etal [73], for calculated the attenuation, velocity of propagating ultrasonic wave in GaN and the electromechanical coupling coefficient χ . It is cleared that under high frequency electric field, the sound absorption coefficient and renormalization of sound velocity are affected with the roots of Bessel function $J_0^2(a)$ which can be used to determine mobility and effective mass of electron.

The argument of Bessel function is $a = \frac{eE_0 k}{m\Omega^2} \frac{\Omega\tau}{\sqrt{1+\Omega^2\tau^2}}$

It can now be written as –

$a = \frac{v_d \omega_0}{v_0 \Omega} \frac{1}{\sqrt{1+\Omega^2\tau^2}}$, where $v_d = \frac{e\tau E_0}{m}$ is the drift velocity of electron oscillating under the influence of high frequency field. For $\Omega\tau \ll 1$ and $\omega_0 \ll \Omega$, a significantly from unity for $v_d \gg v_0$. Taking, $a = \left(\frac{v_d}{v_0}\right)\left(\frac{\omega_0}{\Omega}\right)$ and

$v_0 = \mu E$ and $\mu = e\tau/m$

Where a = 2040 is the first root of Bessel function, we calculated $v_d = 2.7\ X10^7$cm/s is agreement with experimental result in [74, 75] and μ = 1500 cm^2/Vs is agreement with [17] by using E = 3.3 $X10^2$ V/cm, $\omega_0 / \Omega = 0.6$ and $v_0 = 5\ X\ 10^5$ cm.

For large values of the argument a, the Bessel function tends to an asymptotic value giving the expression for the absorption α to be periodic. Measurement of the oscillation amplitude can be used to separate the lattice and the electronic contributions to sound absorption.

Figure 4.1 shows the variation of the attenuation with the ultrasonic frequency [76]. It is clear that at high frequencies attenuation disappears. However, as the drift frequency exceeds the sound frequency, *i.e.* $\gamma \gg 1$, the curves quickly falls before beginning to oscillate at very low velocities where maximum absorption at low frequencies occur. The reason for these behaviors may be explain as follows; the high fields create electronic bunching which initially absorbed more of the sound and slows down the electron motion. However, over time there are debauching and the ultrasonic waves now propagating in the system.

It is cleared that from figure 4.1, under high frequency electric field, the sound absorption coefficient and renormalization of sound velocity are affected with the roots of Bessel function $J_0^2(a)$ which can be used to determine mobility and effective mass of electron is oscillatory. For large values of the argument a, the Bessel function is the asymptotic value and give the expression for the absorption coefficient α which is periodic. For small value of the augment a, the sound absorption tends to zero. An ultrasonic wave traveling in certain directions in a piezoelectric semiconductor such as GaN can be amplified or attenuated by application of a dc electric field. The direct current flowing through the medium in the presence of an ultrasonic wave creates a traveling ac field which interacts with the ultrasonic wave. Amplification occurs when the drift velocity of the electrons exceeds the velocity of sound.

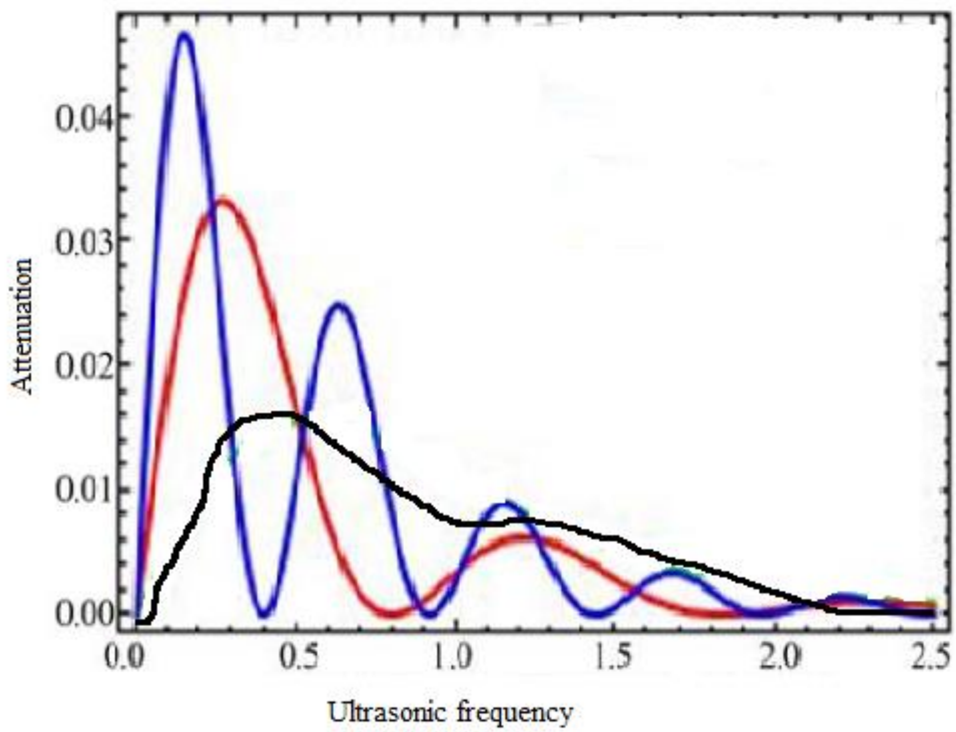

Fig. 4.1 Variation of Attenuation with frequency

The analysis of result show that at low frequency $\omega_c >> \omega_0$ the sound absorption tends to zero and normal velocity approaches unity when a is very small in figure 4.2. As a increases then shift in normalized velocity and at high frequency $\omega_c << \omega_0$, the normalized velocity independent of a in figure 4.2.

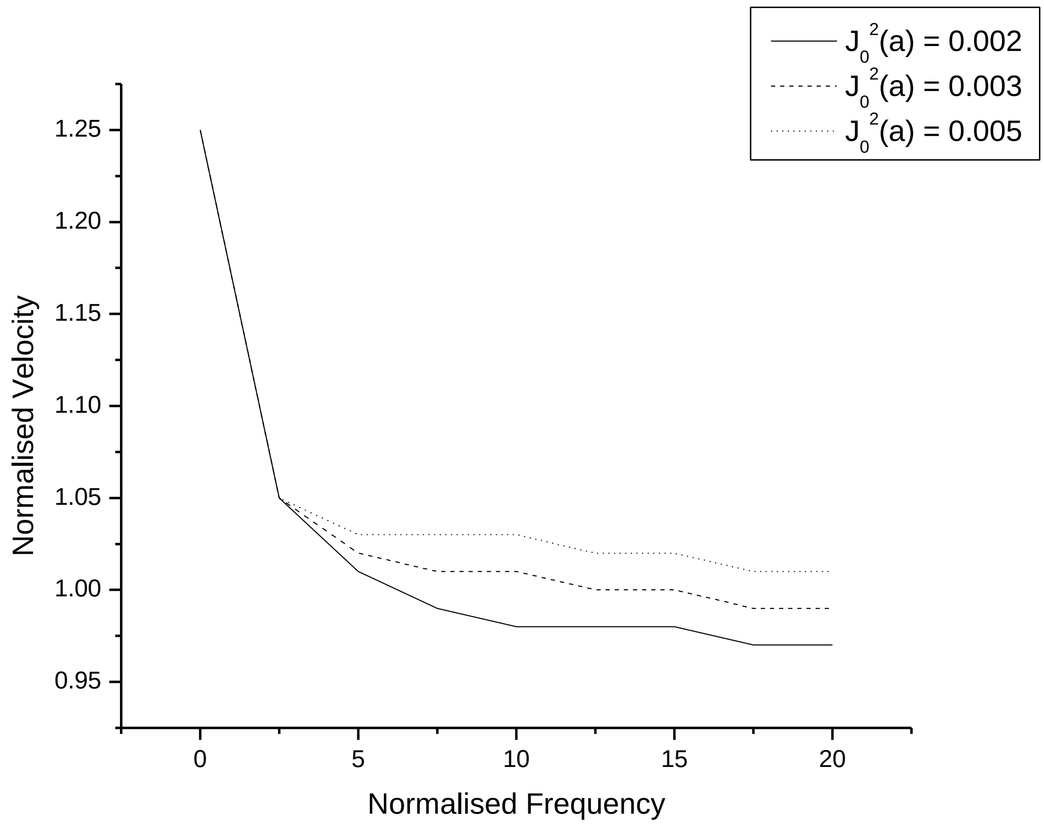

Fig. 4.2 Variation of Normalized Velocity with Normalized Frequency for values of $J_0^2(a)$

Finally, when the high frequency field is switched off the expression becomes equivalent to the absorption of sound in the absence of electric field and utilized the oscillatory nature of the absorption and velocity variation to compute electronic mobility which agrees quite well with reported values. The mobility can be tuned by the applied electric field amplitude. It is possible to have amplification of ultra-sonic waves when drift velocity is larger than the sound velocity.

4.5 CONCLUSION

The propagation of sound in a high-frequency electric field in bulk GaN semiconductor has been studied. It has been shown that the contributions made by electrons to the sound absorption coefficient and to the renormalization of the sound velocity are affected by a factor of $J_0^2(a)$ and is oscillatory. The points of zero absorption associated with the roots of the Bessel function can be used to determine the mobility and effective mass of the electrons. The threshold field $E = 3.3 \times 10^2$ V/cm needed to observe this oscillation in GaN is two orders smaller than that in CdS.

CHAPTER V

THE ACOUSTIC WAVES IN SEMICONDUCTOR SYMMETRIC PAIR PLASMAS

THE ACOUSTIC WAVES IN SEMICONDUCTOR SYMMETRIC PAIR PLASMAS

5.1 INTRODUCTION

In the previous chapter, the propagation of ultrasonic waves in semiconductor plasma in the presence of electric field is studied. The system of equations in semiconductor in presence of sound waves and in absence of sound waves has described. . The Maxwell's electromagnetic field theory of electron sound wave interaction is applicable in which sound wave length is larger than electronic mean free path. The attenuation and velocity of propagating ultrasonic waves in GaN semiconductor is measured by electromechanical coupling coefficient χ .Under high frequency electric field, the sound absorption coefficient and renormalization of sound velocity are affected with the roots of Bessel function $J_0^2(a)$ which is oscillatory and can be used to determine mobility and effective mass of electron. In this chapter, the acoustic waves in semiconductor symmetric pair plasma will study.

The pair plasmas have been an important challenge for many plasma physicists. Symmetric pair plasmas are named plasmas of charged species which have equal particle masses. Electron-hole plasmas ($e-h+$ plasmas) in pure semiconductors also are symmetric pair plasmas if effective masses of electrons and holes are equal. The difference between the electron and ion masses in ordinary electron-ion plasma gives rise to different time-space scales [77] which are used to simplify the analysis of low- and high-frequency modes. Such time-space parity disappears when studying a pure pair plasma which consisting of only positive- and negative-charged particles with an equal mass, because the mobility of the particles in the electromagnetic fields is the same. Begelman et al. in 1984 and Miller & Witta in 1987 play an important role in the physics of electron-positron plasmas of a number of astrophysical situations [78, 79]. Sturrock in 1971 and Michel in 1991 suggested that the creation of electron-positron plasma in pulsars is essentially by energetic collisions between particles which are accelerated as a result of electric and magnetic fields in such systems [80, 81 and 82].

Recently, Oohara and Hatakeyama [83 - 84] have developed a novel method for generation of pair plasma consisting of only negative and positive ions with equal mass by using positive and negative fullerene ions C^{+}_{60} and C^{-}_{60} as the ion source. The pair-ion plasma is expected to be used for the synthesis of dimers directly from carbon allotropes, as well as in nanotechnology. The pair-ion plasma is expected to be used for the synthesis of dimers directly from carbon allotropes, as well as in nanotechnology. The pair plasma plays a significant role in plasma physics due to numerous astrophysical environments such as the pulsar magnetosphere, active galactic nuclei, neutron stars etc., where intense energies create electron, positrons through pair production and annihilation.

In e–p plasmas, electrons and positrons have the same masses but opposite charges. The e–p plasma symmetry is broken in the presence of ions, and both fast and slow time scales can occur in the dynamics of electron–positron–ion (e–p–i) plasmas. Some astrophysical plasma contain ions besides the electrons and positrons, for example, in the magnetar corona the presence of electrons and positrons is due to instability of vacuum in an ultra strong magnetic field. The ions originate from some interior source. There has been a great deal of interest in studying the linear and nonlinear wave motions in both *e–p* and *e–p–i* plasmas. In the next generation, the compressed plasma created by intense laser beams due to their interactions with dense solid materials. However, in dense astrophysical bodies, the plasma contains a very high density of electrons and positrons, which can be regarded as degenerate fluids. The number density of electrons in some compact objects is of the order of 10^{29} cm^{-3}.

A semiclassical approach has been applied to investigate the nonlinear dynamics of solitary structures in electron-positron-ion plasma, where the electrons and positrons are treated as an ideal Fermi gas and the ions are treated as classical fluid due to the fact that in dense quantum plasma the ion Fermi speed is much smaller than that of the electrons. For instance, Dubinov [85] have developed a nonlinear theory of ion-acoustic (IA) waves in ideal plasma with degenerate electrons and classical ions.

On the other hand, a more realistic model of quantum plasma is quantum hydrodynamics (QHD) model which incorporates the quantum statistical pressure as well as the quantum-force tunneling effect for degenerate plasma ingredients. The QHD model alike the classical hydrodynamics includes the ion (electron/positron) continuity, momentum, and Poisson equations. However, unlike classical fluids, quantum plasma, instead of dissipation, exhibits dispersion caused by the quantum tunneling effects associated with the Bohm potential.

More recently, QHD model has been extended to explain the propagations of IA solitary excitations in unmagnetized electron-ion (e-i) and electro-acoustic solitary propagations in two-temperature electron (2Te) plasma. The Korteweg de Vries (KdV) evolution equation is obtained in this chapter.

Symmetric pair plasmas, C^{-}_{60} and C^{+}_{60} plasmas having mass opposite [86] charged fullerene is almost equal have a possibility to investigate the collective behavior of symmetric pair-ion plasma experimentally under controlled conditions. The effective masses of electrons and holes are equal then electron (e-) - hole (e+) plasmas in pure semiconductors also are symmetric pair plasmas [87]. In the astrophysics the Symmetric pair plasmas are the most interesting subject among scientists. In the numerical research, the main difficulty of electron-ion plasmas is the large difference between the two involved time scales. The large differences between the electron and ion masses typically give rise to different scales, in single and multiion plasmas. These differences are removed in case of Symmetric pair plasmas, in which the equal masses and opposite charges destroy the scales.

Symmetric pair plasmas have different collective behavior than ordinary asymmetric electron-ion plasmas. There are number of theoretical considerations gave the proof of acoustic structure such as stationary solitary electrostatic waves in symmetric unmagnitized pair plasmas [88]. There are number of proof which is based on the analysis of solutions of momentum and Poisson equation and continuity equations of species means that the thermodynamic equilibrium is assumed and temperature of species are equal. The lifetime of electron-positron pairs in the plasma is much longer than the characteristic time scales [89, 90 and 91].

This chapter explains the acoustic structure is lies when temperatures of species are not equal in Symmetric pair plasmas and the thermodynamic unequilibrium is assumed [85]. It means the plasma dynamics time scale is less than the ordinary collisional time scale. Acoustic structures are removed when temperatures of species are equal. Symmetric pair plasmas, C^{-}_{60} and C^{+}_{60} plasmas having mass opposite charged fullerene is almost equal have cold and hot electrons and acoustic mode in it. In this chapter we study the properties of collisionless Vlasov-Poisson model in fluid approximation in context of pair plasmas [92, 93].

5.2 MATHEMATICAL FORMULATION

Consider the situation in which the conditions is acoustic waves in a symmetric pair fullerene plasmas such as C^{-}_{60} and C^{+}_{60} with two kind of electrons system such as cold and hot in one-dimensional form is in fluid approximation is –

$$\frac{\partial N_1}{\partial t} + \frac{\partial}{\partial x}(N_1 U_1) = 0 \qquad \dots (5.1)$$

$$\frac{\partial U_1}{\partial t} + U_1 \frac{\partial U_1}{\partial x} = \frac{\partial V}{\partial x} \qquad \dots (5.2)$$

$$\frac{\partial N_2}{\partial t} + \frac{\partial}{\partial x}(N_2 U_2) = 0 \qquad \dots (5.3)$$

$$\frac{\partial U_2}{\partial t} + U_2 \frac{\partial U_2}{\partial x} = -\frac{\partial V}{\partial x} \qquad \dots (5.4)$$

$$\frac{\partial^2 V}{\partial x^2} = N_1 - (1 + a_1 + a_2) N_2 + a_1 e^{\gamma V} + a_2 e^{V} \qquad \dots (5.5)$$

Where, N_1 is the negative and N_2 is the positive fullerene number density normalized by its equilibrium value n_{10} and n_{20}, U_1 is the negative and U_2 is the positive fullerene fluid speed normalized by $c = (k_B T_2/m)^{1/2}$, V is the wave potential electrical field normalized by k_BT_2/e, m is the mass of the fullerene, e is the electronic charge, $\gamma = T_2/T_1$, T_1 is the temperature of hot and T_2 is the temperature of cold electrons, k_B is the Boltzmann constant, a_2 electrons cold and a_1 electrons hot number density normalized by n_{10}. Now, we derive the Korteweg-de Vries equation from (5.1) - (5.5) by employing the reductive perturbation technique and the stretched coordinates $\delta = \varepsilon^{1/2}(x-Mt)$ and $\Gamma = \varepsilon^{3/2} t$, where ε is a smallness parameter measuring the weakness of the dispersion.

We can express (5.1) - (5.5) in terms of δ and ε as –

$$\varepsilon^{3/2}\frac{\partial N_1}{\partial \Gamma} - M\varepsilon^{1/2}\frac{\partial N_1}{\partial \delta} + \varepsilon^{1/2}\frac{\partial}{\partial \delta}\left(N_1 U_1\right) = 0 \quad \dots (5.6)$$

$$\varepsilon^{3/2}\frac{\partial U_1}{\partial \Gamma} - M\varepsilon^{1/2}\frac{\partial U_1}{\partial \delta} + \varepsilon^{1/2}U_1\frac{\partial U_1}{\partial \delta} = \varepsilon^{1/2}\frac{\partial V}{\partial \delta} \quad \dots (5.7)$$

$$\varepsilon^{3/2}\frac{\partial N_2}{\partial \Gamma} - M\varepsilon^{1/2}\frac{\partial N_2}{\partial \delta} + \varepsilon^{1/2}\frac{\partial}{\partial \delta}\left(N_2 U_2\right) = 0 \quad \dots (5.8)$$

$$\varepsilon^{3/2}\frac{\partial U_2}{\partial \Gamma} - M\varepsilon^{1/2}\frac{\partial U_2}{\partial \delta} + \varepsilon^{1/2}U_2\frac{\partial U_2}{\partial \delta} = -\varepsilon^{1/2}\frac{\partial V}{\partial \delta} \quad \dots (5.9)$$

$$\varepsilon\frac{\partial^2 V}{\partial \delta^2} = N_1 - \left(1 + a_1 + a_2\right)N_2 + a_1 e^{\gamma V} + a_2 e^{V} \quad \dots (5.10)$$

We can expand the variables and N_1, U_1, N_2, U_2 and V in a power series of ε as -

$$N_1 = 1 + \varepsilon N_1^{(1)} + \varepsilon^2 N_1^{(2)} + \dots \quad \dots (5.11)$$

$$U_1 = 0 + \varepsilon U_1^{(1)} + \varepsilon^2 U_1^{(2)} + \dots \quad \dots (5.12)$$

$$N_2 = 1 + \varepsilon N_2^{(1)} + \varepsilon^2 N_2^{(2)} + \dots \quad \dots (5.13)$$

$$U_2 = 0 + \varepsilon U_2{}^{(1)} + \varepsilon^2 U_2{}^{(2)} + ... \qquad \ldots (5.14)$$

$$V = 0 + \varepsilon V^{(1)} + \varepsilon^2 V^{(2)} + ... \qquad \ldots (5.15)$$

Electrons number density is treated as parameters.

Now, using (5.11)-(5.15) in (5.6) - (5.10) and taking the coefficient of $\varepsilon^{3/2}$ from (5.6)-(5.9) and ε from (5.10) we get -

$$N_1{}^{(1)} = U_1{}^{(1)} / M \qquad \ldots (5.16)$$

$$U_1{}^{(1)} = -V^{(1)} / M \qquad \ldots (5.17)$$

$$N_2{}^{(1)} = U_2{}^{(1)} / M \qquad \ldots (5.18)$$

$$U_2{}^{(1)} = V^{(1)} / M \qquad \ldots (5.19)$$

$$N_1{}^{(1)} - (a_1 + a_2) N_2{}^{(1)} + a_1 \gamma V^{(1)} + a_2 V^{(2)} = 0 \qquad \ldots (5.20)$$

Now, using (5.16) – (5. 20) we have –

$$N_1{}^{(1)} = -V^{(1)} / M^2 \qquad \ldots (5.21)$$

$$N_2{}^{(2)} = V^{(1)} / M^2 \qquad \ldots (5.22)$$

$$M^2 = \frac{2 + a_1 + a_2}{\gamma a_1 + a_2} \qquad \ldots (5.23)$$

Equation (5.23) is the linear dispersion relation for acoustic waves propagating in our fullerene pair plasma model. Now substituting (5.11) - (5.15) into (5.6) - (5.10) and equating the coefficient of from (5.6) – (5.9) and from (5.10), we obtains -

$$\frac{\partial N_1^{(1)}}{\partial \Gamma} - \frac{\partial N_1^{(2)}}{\partial \delta} + \frac{\partial U_1^{(2)}}{\partial \delta} + \frac{\partial}{\partial \delta}\left[N_1^{(1)} U_1^{(1)}\right] = 0 \qquad \ldots (5.24)$$

$$\frac{\partial U_1^{(1)}}{\partial \Gamma} - M\frac{\partial U_1^{(2)}}{\partial \delta} + U_1^{(1)}\frac{\partial U_1^{(1)}}{\partial \delta} = \frac{\partial V^{(2)}}{\partial \delta} \qquad \ldots (5.25)$$

$$\frac{\partial N_2^{(1)}}{\partial \Gamma} - M\frac{\partial N_2^{(2)}}{\partial \delta} + \frac{\partial U_2^{(2)}}{\partial \delta} + \frac{\partial}{\partial \delta}\left[N_2^{(1)} U_2^{(1)}\right] = 0 \qquad \ldots (5.26)$$

$$\frac{\partial U_2^{(1)}}{\partial \Gamma} - M\frac{\partial U_2^{(2)}}{\partial \delta} + U_2^{(1)}\frac{\partial U_2^{(1)}}{\partial \delta} = -\frac{\partial V^{(2)}}{\partial \delta} \qquad \ldots (5.27)$$

$$\frac{\partial^2 V^{(1)}}{\partial \delta^2} = N_1^{(2)} - (1 + a_1 + a_2)N_2^{(2)} + a_1 \gamma V^{(2)} + \frac{1}{2}a_1\gamma^2\left[V^{(1)}\right]^2 + a_2 V^{(2)} - \frac{1}{2}a_2\left[V^{(1)}\right]^2 \qquad \ldots (5.28)$$

Now, using above equation and eliminating $N_1^{(2)}$, $N_2^{(2)}$, $U_1^{(2)}$, $U_2^{(2)}$ and $V^{(2)}$ we obtain -

$$\frac{\partial V^{(1)}}{\partial \Gamma} + AV^{(1)}\frac{\partial V^{(1)}}{\partial \delta} + B\frac{\partial^3 V^{(1)}}{\partial \delta^3} = 0 \qquad \ldots (5.29)$$

Where the nonlinear coefficient *A* and the dispersion coefficient *B* are given by -

$$A = \frac{1}{2M\left[2 + a_1 + a_2\right]}\left[3(1 + a_1 + a_2) - 3 - M^4\left(\gamma^2 a_1 + a_2\right)\right] \qquad \ldots (5.30)$$

$$B = \frac{M^3}{2(2 + a_1 + a_2)} \qquad \ldots (5.31)$$

Equation (5.29) is the Korteweg-de Vries equation of the acoustic waves the nonlinear propagation in our fullerene pair plasmas with semiconductor. The solution of Korteweg-de Vries equation is found by transforming the independent variables δ and г to

$K = \delta - C_0 г, \quad г = г$ … (5.32)

Where, C_0 is a constant velocity normalized by c.

The boundary condition is –

$$V^{(1)} \to 0, \frac{\partial V^{(1)}}{\partial K} \to 0, \frac{\partial^2 V^{(1)}}{\partial K^2} \to 0 at K \to \pm\infty$$

Therefore, the solution of the Korteweg-de Vries equation is –

$$V^{(1)} = V_m \sec h^2\left(\frac{K}{\Delta}\right) \quad \dots (5.33)$$

Where V_m is the amplitude which is normalized by $k_B T_2/e$ and Δ is the width which is normalized by λ_D is given by –

$$\left.\begin{aligned} V_m &= \frac{3C_0}{A} \\ \Delta &= \sqrt{\frac{4B}{C_0}} \end{aligned}\right\} \quad \dots (5.34)$$

5.3 RESULT AND DISCUSSION

The analysis of propagation acoustic waves in solid state plasma has been a very important research topic. Symmetric pair plasmas, consisting of two species with opposite charge and equal masses is an exciting field where not only unexpected phenomena have been experimentally identified, but also where new theoretic problems have been defined. Electron-hole plasmas in pure semiconductors also are symmetric pair plasmas if effective masses of electrons and holes are equal. Although pair plasmas consisting of electrons and positrons have been experimentally produced, however, because of fast annihilation and the formation of positronium atoms and also low densities in typical electron-positron experiments, the identification of collective modes in such experiments is practically very difficult.

In this chapter, considered acoustic waves in symmetric pair fullerene plasmas with two kinds of electrons: cold and hot. In the present study we discussed the properties of collisionless Vlasov-Poisson model in fluid approximation in context of pair plasmas has in the classical physics. In this chapter, author studied the acoustic-like modes in Symmetric pair plasmas, C^{-}_{60} and C^{+}_{60} plasmas having mass opposite charged fullerene is almost equal have cold and hot electrons. The fullerenes are molecules containing 60 carbon atoms in a very regular geometric arrangement it is hoped that the present paper would be useful for explanation of the intriguing low and high frequency modes in pair plasma, which are out of the scope of the plasma fluid theory and the Boltzmann-Gibbs statistics. Equation (5.29) is the Korteweg-de Vries equation of the acoustic waves the nonlinear propagation in our fullerene pair plasmas with semiconductor is derived in quantum plasma physics. The steady state solution of Korteweg-de Vries equation is obtained.

It is clear that from equation (5.34) as C_0 increases, the width of the solitary wave's decreases. If $A > 0$ then it is clear that from equations (5.30), (5.33) and (5.34) the solitary potential profile is positive, and if $A<0$ then solitary potential profile is negative. It is clear that from equations (5.30), (5.31), (5.33) and (5.34) a number density of electrons a_1 and a_2 decreases then width Δ increases and amplitude V_m increases which means soliton wave disappear. It means that acoustic waves are absent in a pure symmetric pair plasma and acoustic waves are present only when impurity of electrons are added. In this chapter, authors have found the nonlinear coefficient A and the dispersion coefficient B.

5.4 CONCLUSION

The present work deals with the analysis of propagation acoustic waves in solid state plasma. The analysis enables one to draw the following conclusions.

1. Pure symmetric pair plasma the acoustic structures are absent.

2. Equation (5.29) is the Korteweg-de Vries describing the nonlinear propagation of the acoustic waves in our fullerene pair plasmas with electron impurities.
3. The dynamics of the acoustic waves in fullerene pair plasmas with two population of electrons system in one-dimensional form is in fluid approximation.
4. In symmetric pair plasmas, where both species have the same temperature, acoustic mode are impossible, but in that plasmas exists nonlinear amplitude modulation of electrostatic mode. These mode mixed higher harmonics with basic waves and can gives envelope solitons. It is not a pure acoustic mode according to above remarks.

CHAPTER VI

MODULATIONAL DISPERSION AND AMPLIFICATION IN SEMICONDUCTOR PLASMA

MODULATIONAL DISPERSION AND AMPLIFICATION IN SEMICONDUCTOR PLASMA

6.1 INTRODUCTION

In the previous chapter, the acoustic waves in semiconductor symmetric pair plasma have studied. Symmetric pair plasmas are named plasmas of charged species which have equal particle masses. Electron-hole plasmas ($e^{-}h^{+}$ plasmas) in pure semiconductors also are symmetric pair plasmas if effective masses of electrons and holes are equal. The difference between the electron and ion masses in ordinary electron-ion plasma gives rise to different time-space scales which are used to simplify the analysis of low- and high-frequency modes. Symmetric pair plasmas, C^{-}_{60} and C^{+}_{60} plasmas having mass opposite charged fullerene is almost equal have cold and hot electrons and acoustic mode in it. In this chapter, the modulational dispersion and amplification in semiconductor plasma will study.

The phenomena of modulation interaction exhibit a distinctive role in non linear optics. The modulational interaction between propagating laser is Modulational instability and generated acoustic mode is analyzed by using coupled mode theory and nonlinear induced current density. The phenomenon of modulational instability in a semiconducting medium can be described in terms of electric polarization equations which are cubic function of electric field amplitude. The third order nonlinear susceptibility is in general a complex quantity and is capable of describing the interference between various resonant and non-resonant processes.

Modulational instability refers to instability of a wave propagating in nonlinear dispersive media such that the steady state becomes unstable and evolves into a temporally modulated state [94]. The concept of transverse modulational instability originates from a space time analogy that exists when the dispersion is replaced by diffraction [95]. The well-known instability of a plane wave in a self-focusing Kerr medium [96] is an example of transverse modulational instability. There are number of papers published in this area is that modulational instability of a laser beam found in a piezoelectrically active semiconducting medium with a high dielectric constant.

The transmission, display and processing of information is possible by modulation [97]. The fabrication of some optical devices, such as acousto-optic modulators, is based on the interaction of an acoustic wave or low-frequency electromagnetic waves with the incident laser beam. The propagation of the acoustic wave creates a refractive index grating, which in turn diffracts the incident laser beam resulting in the modulation of the incident beam. At small diffraction efficiencies the diffracted light intensity is proportional to the acoustic intensity. This fact is used in acoustic modulation of optical radiation. The information signal is used to modulate the intensity of the acoustic beam. This modulation is then transferred, as intensity modulation, onto the diffracted optical beam [98].The most important application of acousto-optic interactions is the deflection of optical beams. This can be achieved by changing the sound frequency while operating near the Bragg diffraction condition [98].

Most optoelectronics devices for control the relaxation time of material are used the semiconductors [19]. Semiconductors are used in most of the sophisticated, sensitive and ultrafast optoelectronic devices [99] due to their compactness, provision of control of material relaxation time and highly advanced fabrication technology. In nonlinear optical processes, large number of free electrons/holes act as majority charged carriers is doped with semiconductors [100]. Scattering of light beam from free electrons in piezoelectric semiconductors was reported by Guha and Sen [101] and by other workers. Many such investigations are based upon the nonlinear optical response in a semiconductor medium [102, 103].

The mechanisms for the intensity dependent refractive index have been one of the most important subjects for research in nonlinear optics. The nonlinear interactions of waves and particles in plasmas have been the subject of extensive studies in nonlinear optics. The field induced change in the refractive index due to a change in the local optical characteristics of the medium leads to parametric instability, modulational instability, nonlinear focusing, or filamentation of the propagating beams. The electro-optical (EO) and acousto-optical (AO) effects afford a convenient and widely used means of controlling the intensity, frequency, or phase of the propagating radiations. Photo-induced light scattering in photorefractive and AO materials is an area of extensive research due to its potential applications in optoelectronics [98–103]. AO interactions in dielectrics and semiconductors are playing an increasing role in optical modulation and beam steering.

The electro-optic (EO) and acousto-optic (AO) effects afford a convenient and widely used means of controlling intensity and/or phase of the propagating radiation. This modulation is used in an ever-expanding number of applications including the impression of information onto optical pulses, mode-locking, and optical beam deflection. The modulation problems have been studied theoretically by a number of workers due its vast technological potentialities. An important field of study in nonlinear acoustics is amplification/attenuation and frequency mixing of waves in semiconductors (especially III-V semiconductors) because of its immediate relevance to problems of optical communication systems. The study of modulation can be made with respect to amplitude, frequency and phase. Amplitude modulation (AM) is one of the oldest forms of modulation. One of the important problems in communication systems is that of developing an effective method of modulation as well as demodulation of waves.

The periodic variation of the propagation parameter leads to the modulation of an electromagnetic wave passing through plasma. This periodic variation in the propagation parameters, caused by the time varying change in the carrier density and collision frequency of the plasma, may be due to a modulated magnetic field, the modulation of power in an rf discharge or the propagation of an acoustic wave. The phenomenon of modulation of an electromagnetic wave by an acoustic wave is of special interest in the problems of communication of different types. This is due to fact that the scattering of light from sound or low frequency electromagnetic waves affords a convenient means of controlling the frequency, intensity and direction of an optical beam

[94]. This type of modulation makes possible a large number of applications involving the transmission, display and processing of information.

6.2 THEORETICAL FORMULATION

In order to study the transverse modulational amplification in a magnetized piezoelectric semiconductor arising due to nonlinear effective susceptibility χ_{eff}, the hydrodynamic model of semiconductor plasma is considered.

A Spatially uniform pump electric field is applied along the x-axis parallel to propagation vector k and externally applied D.C. magnetic field B_o, is taken along the z-axis normal to E_o and k.

The momentum and energy exchange between these waves can be described by phase-matching condition: $\hbar w_o = \hbar w_s + \hbar w_a$. The phase-matching conditions enable one to consider $k_s + k_a = k$. We could neglect the nonuniforamility of the high-frequency electric field under the dipole approximation when the wavelength of the excited sound wave is very small compared to the scale length of the electromagnetic field variation [104].

A uniform pump electric field $\vec{E} = E_0 e^{-iwt}$ (pump vector k_0=0)

$$\frac{\partial v_0}{\partial t} + \nu v_0 = -\frac{e}{m}\vec{E}_0(t) \qquad \text{… (6.1)}$$

$$\frac{\partial v_1}{\partial t} + \nu v_1 = -\frac{e}{m}\vec{E}_1(t) - \left(v\frac{\partial}{\partial x}\right)v_1 \qquad \text{… (6.2)}$$

$$\frac{\partial n_1}{\partial t} + n_e\frac{\partial v_1}{\partial x} = -v_0\left(\frac{\partial n_1}{\partial x}\right) \qquad \text{… (6.3)}$$

$$\frac{\partial E_a}{\partial x} + \frac{\beta}{\varepsilon}\frac{\partial^2 u}{\partial x^2} = -\frac{n_1 e}{\varepsilon} \qquad \text{… (6.4)}$$

$$\rho\frac{\partial^2 u}{\partial t^2} + 2\gamma\rho\frac{\partial u}{\partial t} + \beta\frac{\partial E_a}{\partial x} = C\frac{\partial^2 u}{\partial t^2} \qquad \text{… (6.5)}$$

Eqs. (6.1) and (6.2) are the zeroeth- and first-order momentum transfer equations in which v_0 and v_1 are, respectively, the zeroeth and first-order oscillatory fluid velocities of the electron of effective mass m and charge e^-, ν being the electron collision frequency. The basic nonlinearity induced in the motion of the charge carriers is due to the convective derivative **(v. Δ).v** depends on the total intensity of illumination and the Lorentz force on the electrons in equation (6.2) [24]. Eq. (6.3) is the continuity equation, where n_0 and n_1 are the initial electron concentrations in the n-type-doped semiconductor and perturbed electron concentration, respectively. In Poisson's equation (6.4), $\mathbf{E_a}$ represents the perturbed electric field component and ε, and β are the dielectric constant and piezoelectric constant of the crystal material, respectively. Equation (6.5) describes the motion of the lattice in the piezoelectric crystal with ρ, u, γ and C being, respectively, the mass density of the crystal, displacement of the lattice, phenomenological damping parameter of acoustic mode and crystal elastic constant. The acoustic perturbation created in the medium under the influence of a strong pump source gives rise to an electron density perturbation at the acoustic frequency, which couples nonlinearly with the pump wave and drives the acoustic wave at modulated frequencies in a modulational instability process.

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$$\frac{\partial^2 n_1}{\partial t^2} + \nu \frac{\partial n_1}{\partial t} + w_p^2 n_1 + \frac{n_e e\beta}{m\varepsilon} \times \frac{\partial^2 u}{\partial x^2} = -\frac{eE_0}{m}\frac{\partial n_1}{\partial x} \qquad \ldots (6.6)$$

Where $\omega_c = eB_0/m$ being the cyclotron frequency and $\omega_p = [(ne_0 / m\varepsilon)^{1/2}]$ is electron plasma frequency. In Eq. (6.6), we have neglected the Doppler shift assuming $\omega_o \gg kv_0$. We consider the cyclotron frequency (ω_c) and electron plasma frequency (ω_p) to be comparable to the incident pump frequency (ω_0) and the pump field amplitude and the magnetic field due to the pump wave (B) **is** neglected.

The modulation process under consideration must fulfill the phase matching conditions –

$$k_0 = k_1 \pm k_s$$
$$w_0 = w_1 \pm w_s$$

Such that $|k| = |k_0 \pm k_s| \approx |k_s| = k$

We considered only the resonant sideband frequencies and higher order terms are neglected. These two equations exhibit the coupling between the high and low-frequency components of the density perturbations n_{1s} and n_{1a} via the pump electric field.

Under rotating-wave approximation, Eq. (6.6) yields the two-coupled equations for n_{1s} and n_{1a} as-

$$n_{1S} = \frac{i n_e e \beta^2 k^3 E_S}{m\varepsilon\rho\left(\omega_S^2 - k^2 v_S^2 + 2i\gamma\omega_S\right)} \times \left[\omega_p^2 - \omega_+^2 - i\nu\omega_+ + ik_S \vec{E}\right]^{-1} \qquad \text{... (6.7(a))}$$

$$n_{1a} = \frac{i n_e e \beta^2 k^3 E_S}{m\varepsilon\rho\left(\omega_S^2 - k^2 v_S^2 + 2i\gamma\omega_S\right)} \times \left[\omega_p^2 - \omega_-^2 - i\nu\omega_- + ik_S \vec{E}\right]^{-1} \qquad \text{… (6.7(b))}$$

Where $\omega_+ = \omega_s + \omega_0$ and $\omega_- = \omega_s - \omega_0$ and $v_s = (C / \rho)^{1/2}$ is the velocity of the acoustic wave in the lattice. It is clear that from equation (6.7) n_{1s} and n_{1a} is depend upon the magnitude of the pump intensity (I). We consider only the Stokes component of the nonlinear current density J (ω) associated with the Stokes mode arising due to the coupling of the nonlinear current densities n_{1s} and n_{1a} expressed as -

$$J(\omega_+) = -n_{1S} e v_0 \qquad \text{… (6.8)}$$

$$J(\omega_-) = -n_{1a} e v_0^* \qquad \text{… (6.9)}$$

The induced polarization at the modulated frequencies $P(\omega_\pm)$ as the time integral of the nonlinear current density $J(\omega_\pm)$ is –

$$P(\omega_\pm) = \int J(\omega_\pm) dt \qquad \text{… (6.10)}$$

The effective nonlinear polarization of the modulated wave is -

$$P_{eff} = P(\omega_+) + P(\omega_-) \qquad \text{… (6.11)}$$

Therefore, total effective polarization is -

$$P_{eff} = \frac{i\omega_p^2 \omega_0 e\varepsilon Ak E_0 E_S}{m\left(\omega_S^2 - k^2 v_S^2 + 2i\omega_S \gamma\right)\left(\omega_0^2 - \omega_c^2\right)} \times \left[\frac{1}{\omega_+}\left(\Delta_1^2 - i\nu\omega_+ + ik\vec{E}\right)^{-1} - \frac{1}{\omega_-}(\Delta_2^2 - i\nu\omega_- + ik\vec{E})^{-1}\right]$$

… (6.12)

Where $\Delta_1^2 = \omega_p^2 - \omega_+^2$, $\Delta_2^2 = \omega_p^2 - \omega_-^2$, $A = \alpha^2 k^2 v_s^2$, $\zeta^2 = \beta^2/\varepsilon C$ and $\Delta = \omega_0 - \omega_p$

$$P_{eff} = \frac{2\omega_p^2 e^2 \varepsilon Ak^2 E_0^2 E_S (\Delta^2 - \nu^2)}{m^2\left(\omega_S^2 - k^2 v_S^2 + 2i\omega_S \gamma\right)\left(\omega_0^2 - \omega_c^2\right)^2} \times \left[\left(\Delta^2 + \nu^2 - \frac{k^2 \vec{E}^2}{\omega_0^2}\right)^2 + \frac{4k^2 \Delta^2 \vec{E}^2}{\omega_0^2}\right]^{-1}$$

… (6.13)

In the presence of pump fields, the transverse components of the oscillatory electron fluid velocity v_0 is –

$$\left.\begin{aligned} v_{ox} &= \frac{\vec{E}}{\nu - i\omega_0} \\ v_{0y} &= \frac{-(e/m)E_0\omega_c}{\omega_0^2 - \omega_c^2} \end{aligned}\right\}$$

… (6.14)

The induced polarization due to nonlinearities at modulated frequencies (ω_+) is defined as -

$$P_{eff} = \varepsilon_0 \chi_{eff} \left|E_0\right|^2 E_S$$

… (6.15)

This gives -

$$\chi_{eff} = \frac{2\omega_p^2 e^2 \varepsilon_1 Ak^2 (\Delta^2 - \nu^2)}{m^2\left(\omega_S^2 - k^2 v_S^2 + 2i\omega_S \gamma\right)\left(\omega_0^2 - \omega_c^2\right)^2} \times \left[\left(\Delta^2 + \nu^2 - \frac{k^2 \vec{E}^2}{\omega_0^2}\right)^2 + \frac{4k^2 \Delta^2 \vec{E}^2}{\omega_0^2}\right]^{-1}$$

… (6.16)

We assume the semiconductor medium to be dispersionless for the acoustic waves. This analysis are made in the highly doped regime –

$\omega_p \approx \omega_0 \approx \omega_\pm$ And $\omega_p >> \nu\ (\omega_s)$

Consequently, the effective nonlinear susceptibility of the semiconductor medium given by Eq. (6.16) reduces to the form

$$\chi_{eff} = \frac{2\omega_p^2 e^2 \varepsilon_1 A k^2 (\Delta^2 - \nu^2)\left(\omega_s^2 - k^2 v_s^2\right)}{m^2\{\left(\omega_S^2 - k^2 v_S^2\right)^2 + 4\omega^2 s \gamma^2\}\left(\omega_0^2 - \omega_c^2\right)^2} \times \left[\left(\Delta^2 + \nu^2 - \frac{k^2 \vec{E}^2}{\omega_0^2}\right)^2 + \frac{4k^2 \Delta^2 \vec{E}^2}{\omega_0^2}\right]^{-1}$$

… (6.17)

In the presence of a transverse magnetostatic field, the effective nonlinear susceptibility equation (6.17) characterizes the steady state optical response of the medium and governs the nonlinear wave propagation through the medium. It is clear that the total crystal susceptibility is affected by the equilibrium carrier concentration through ω_P # 0 and the external d.c. magnetic field through ω_c # 0.

In order to investigate the modulational amplification coefficient α_{eff} in a doped semiconductor, we employ the relation –

$$\alpha_{eff} = \frac{k}{2\varepsilon_1} \chi_{eff} \left|E_0^2\right| \qquad \text{… (6.18)}$$

If α_{eff} is negative, then the nonlinear growth of the modulated signal is possible. Therefore, the nonlinear growth of the modulated signal is possible only if χ_{eff} is negative.

The nonlinear modulational gain of the signal as well as the idler waves can be possible only if α_{eff} is negative for pump electric field $|E_0|>|E_{0th}|$.

In general, to determine the threshold value of the pump amplitude of the modulational amplification is we set P_{eff}=0 and is –

$$\left|E_{0th}\right| = \frac{\Delta m\left(\omega_0^2 - \omega_c^2\right)}{ek\omega_0^2} \qquad \text{… (6.19)}$$

It is cleared from eqn (6.18) even in absence of damping the transverse modulational instability of the signal wave has a nonzero intensity threshold.

Thus, the growth rate of modulated beam is –

$$g = \frac{\omega_p^2 e^2 \varepsilon_1 A k^3 (\Delta^2 - \nu^2)\left(\omega_s^2 - k^2 v_s^2\right) E_0^2}{m^2 \varepsilon_1 \{\left(\omega_S^2 - k^2 v_S^2\right)^2 + 4\omega^2 s \gamma^2\}\left(\omega_0^2 - \omega_c^2\right)^2} \times \left[\left(\Delta^2 + \nu^2 - \frac{k^2 \vec{E}^2}{\omega_0^2}\right)^2 + \frac{4k^2 \Delta^2 \vec{E}^2}{\omega_0^2}\right]^{-1}$$

… (6.20)

6.3 RESULT AND DISCUSSION

Modulational Dispersion and Amplification in doped III–V Semiconductors like n-InSb crystal at 77 K duly irradiated by a nanosecond-pulsed 10.6 μm CO_2 laser. The physical constants of the n-type InSb crystals are –

m = $0.014 m_0$ (m_0 the free electron mass), ε_1=17.9, β= 0.054cm^{-2}, γ = 5x10^{-10} s^{-1}, ρ= 5.8 X 10^3 kgm^{-3} and ν = 4 X 10^{11} s^{-1}.

The expression of the growth rate as obtained from equation (6.20) has predicted by Drake et al. [105].

$$g \propto [ak^2(b|E_0|^2 - ak^2)]^{1/2}$$

It is cleared that from equation (6.20) the gain constant g has dependence on the wave vector k has following –

(i) For lower magnitudes of k (such that ω_s>> kv_s), g increases with k

(ii) For a non dispersive acoustic mode, at ω_s ~kv_s, g is maximum.

(iii) At ω_s << kv_s, then g shows a steep decline with increasing k.

In Figure 6.1 we have plotted the growth rate of the signal as a function of the electron plasma frequency w_P, for the dispersion less regime of the low-frequency acoustic mode ω_c at E_o = 2 x l0^7 Vm$^-$1, ω_c = 0.9ω_0 and k = 2.5 x I0^7 m-^{1}. It is cleared that from this paper the growth rate of the transversely modulated wave increases with a rise in electron density of the medium The nature of the curve is similar to the conclusions arrived at by Salimullah and Singh [106] who considered the modulational interaction of an extraordinary mode subjected to perturbations parallel to the magnetic field. Therefore, higher amplification of waves can be produced by increasing the carrier concentration of the medium by n-type doping in the crystal. However, the doping should not exceed the limit for which plasma frequency ω_p exceeds the pump frequency ω_0 because in this regime the electromagnetic pump wave will be reflected back by medium. Hence, for modulational instability process, the heavily doped semiconductors are necessary.

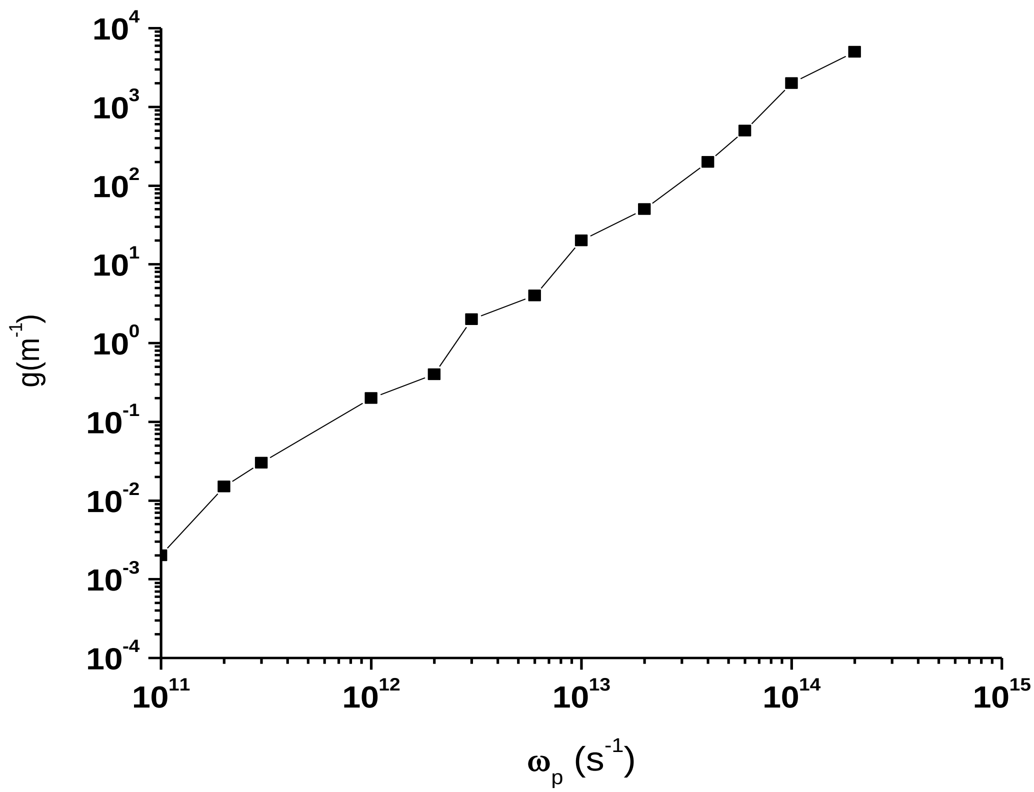

Fig. 6.1 Variation of growth rate with electron plasma frequency

In Figure 6.2 shows that dependence of E_{oth} on cyclotron frequency ω_c. It is clear from figure that threshold field required for inciting the modulational amplification is much less at lower values of the magnetic field. E_{oth} is found to increase till the magnetic field approaches 1 Tesla corresponding to cyclotron frequency $\omega_c = 10^{13}s^{-1}$. However for $\omega_c >$

2×10^{19} s^{-1} encounter a drop in value of required threshold field at $k = 2.5 \times 10^7$ Vm^{-1}. Therefore, the presence of external transverse d.c. magnetic field for which $\omega_c > 2 \times 10^{19}$ s^{-1} effectively reduces the threshold field.

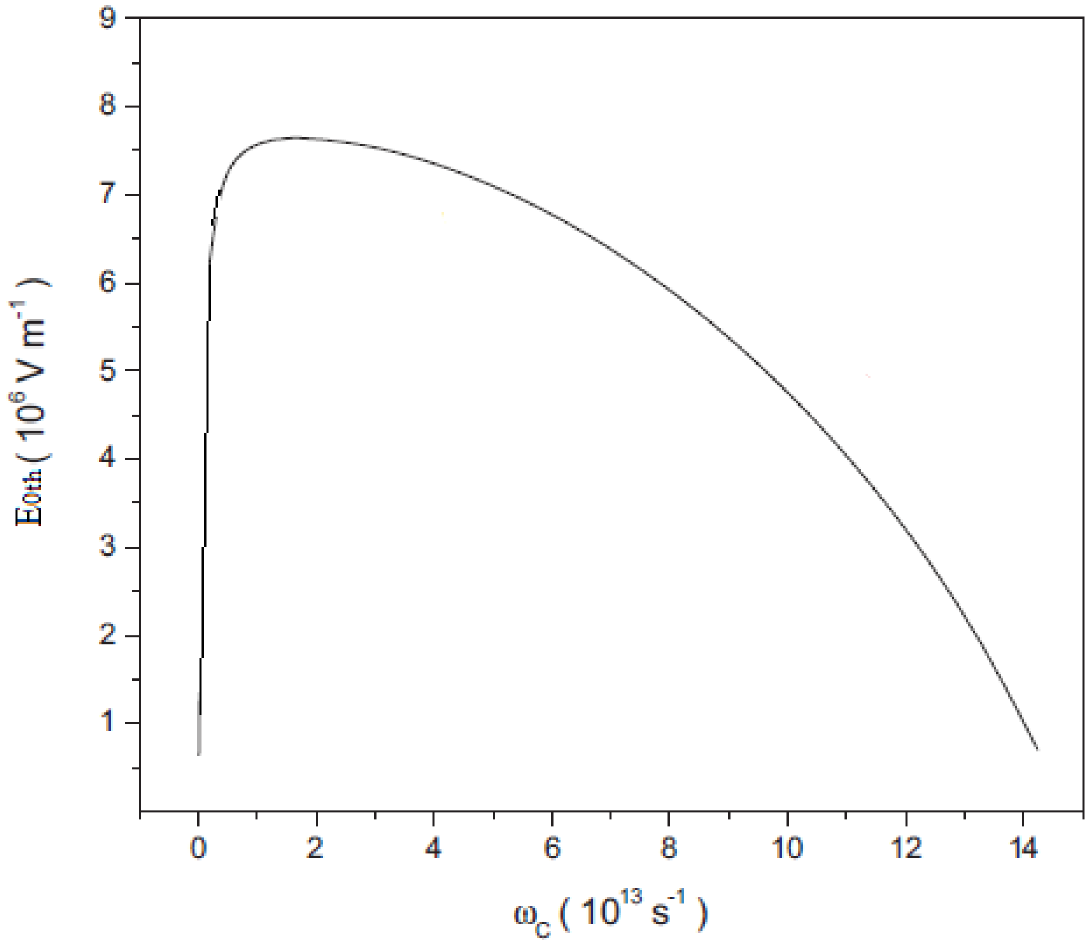

Fig. 6.2 Variation of E_{0th} with Cyclotron Frequency

Figure 6.3 we have plotted E / E_0 with the applied magneto static field (ω_c). It may be clear that when $\omega_c < \omega_0$ the demodulation indices of both the side bands increases with cyclotron frequency. Theses indices are equal when $\omega_c = \omega_0$ and abruptly reduce to zero on further increases the cyclotron frequency $\omega_c > \omega_0$.

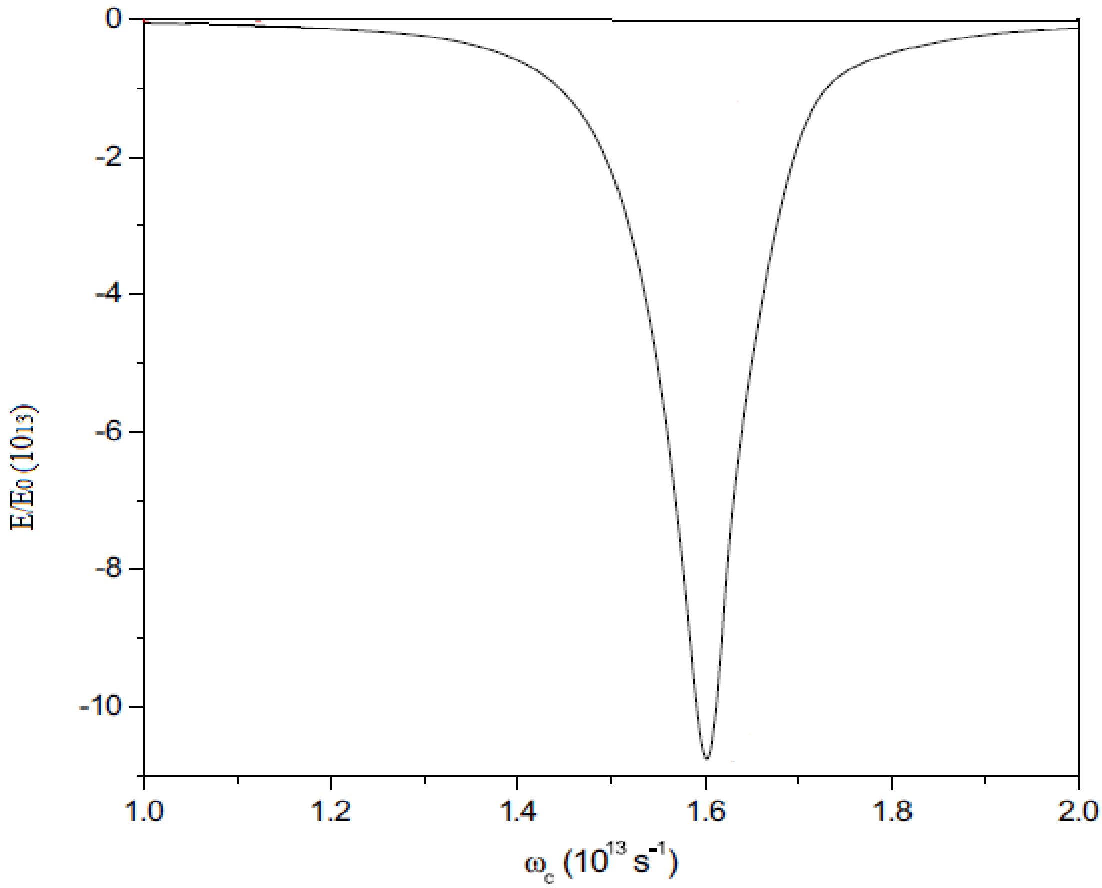

Fig. 6.3 Variation of E/ E_0 with Cyclotron Frequency

Figure 6.4 shows the qualitative behavior of α_{eff} as a function of excess electron concentration n_0. In this case, the magnitude of gain as well as the range of doping concentration at which gain occurs increases with the increase of pump field strength E_0 and shifts towards lower values of doping concentration. This amplification increases sharply with the increase of n_0 and attains a peak value. Curves a-c are for E_0 = 5 X 10^6, 8 X 10^6 and 2 X 10^7 respectively.

The growth rate g is found to increase monotonically with increase in the magnitude of k in this regime. The gain constant increases with a rise in cyclotron frequency ω_c with threshold electric field taking k as a parameter.

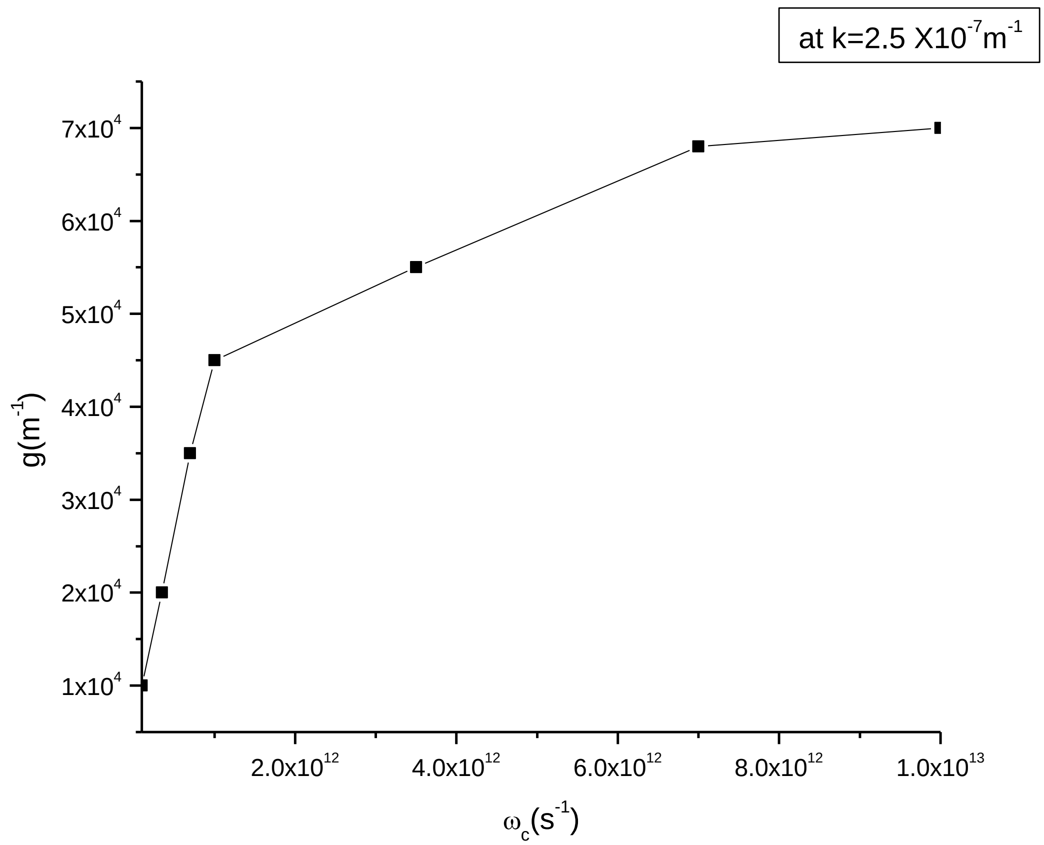

Fig. 6.4 Variation of growth rate g with ω_c (s^{-1})

6.4 CONCLUSION

The present work deals with the higher magnitudes of wave number k and presence of an external d.c. magnetic field are favorable for the modulational amplification of the modulated waves in heavily doped regimes. For a magnetic field of magnitude less than 1T these parameters not only reduce the threshold field required for the phenomenon but also enhance the gain constant.

CHAPTER VII

THE NONLINEAR WAVE IN SEMICONDUCTOR QUANTUM PLASMA FOR LASER BEAM IN A SELF-CONSISTENT PLASMA CHANNEL

THE NONLINEAR WAVE IN SEMICONDUCTOR QUANTUM PLASMA FOR LASER BEAM IN A SELF-CONSISTENT PLASMA CHANNEL

7.1 INTRODUCTION

The previous chapter deals with the analytical investigations of modulational dispersion and amplification in n-InSb semiconductor plasmas. The modulational instability in a semiconducting medium can be described in terms of electric polarization equations which are cubic function of electric field amplitude. The pump electric field produces a shift in the resonance frequency in induced polarization term and it plays an important role in the enhancement of both modulational dispersion and amplification. In this chapter, the nonlinear wave in semiconductor quantum plasma for laser beam in a self consistent plasma channel will study.

Disparity in uniformity under uniform plasma studies on spreading stability for displacement kinetics stops the spread of large constant zones. The discovery basically manages the spread and it has an iconic mode that gives a strong stability to moisture even when it's a divisor. This stability is physiology with displacement of physical appearance charge. Accordingly, for the first time, the non-functional charging-displacement mechanism collapses in two petty attributes. Plasma is the first exceptionally high density (~ 1020 watt / cm3), spreading a state unconditional stability. An Interferometer and shading techniques have been reported to channel development and plasma density mechanics testing research. The observations allow us to define the sample results of self-focus laser beam and the laser production plasma channel properties. Various distribution regimes, such as the conductivity of the electromagnetic wave, are likely to be concentrated / centered plasma parameters and the beam that is read here at different times.

The underlying laser pulse guideline as a plasma of dysfunctional aggression is reported and theoretically studied in the same number as simulations. In many situations laser can create different types of nonlinearities at different time sizes. The work described here involves the effect of integrating an increase in free electrons and the risk of displacement effect in the mass. Accordingly, it is considered here that the Pulse Term ion Plasma is longer and short except electron plasma seasons except for the periods. The succession of Plasma Channel's creation is much easier and it is possible that the intense laser pulse associated with the laser pulse involve it as the way it passes through the plasma. Initially, the laser pulse plasma electrons push a deeper thinking into driving force and evacuate them in the periphery. If the ionic exit the exterior from this diffusion axis, a large external charge will be set up. After the laser pulse is passed, the ions continue to circumcise when they create a self-sustaining plasma channel on its axis. In the current period, self-distracted, more than a decade after observation of the first experiments, the purpose of thinking is the intensity and intentional thinking of the intended mechanism The high intensity of the plasma of the laser pulse controlled power compression holds the first place.

When the self-focus and marginalization effects are in balance, the laser transmits a consistent spot size. Using this simple analogical technique, this is the intensification of a range of laser plasma parameters, such as self-focusing (SF), oscillatory divergence (OD) and steady divergence (SD) are investigated. In the self-careless non-serial media, the laser beam limits the current diagnostic tape's electric vector range to the limitation of electrostatic constant biometrics to date. Such an approach is independent of the beam width, which is a valuation that criticizes the value of criticism. While this approach calculates a point of focus, it should be remembered that the focus is too large for the speculation of the quadratic linearity that the nearest power vector is not correct.

Since the last decade, the study of nonlinear electrostatic and electromagnetic waves in quantum plasma using linear and quantum hydrodynamic (QHD) has come to the attention of highly researchers, because they have many physical systems, including many metals, semiconductors, super There are dense astrophysical environments, nanotechnology, and laser plasma experiments [107 - 111].In these systems with plentiful concentrations, plasma acts as a degenerative fluid, and plasma mechanics of quantum mechanical effects plays an important role [14]. A quantum statistical pressure period can normalize QHD models by adding quantum diffraction period and exchange correlation effect [112 - 114] for fluid models. An uneven wave phenomenon has been demonstrated in quantum plasma, along with quantum effects by studying the nonlinear wave event in these systems [107].

The QHD was used to investigate the quantum ion acoustic waves, and a deformed Korteweg-deVries (KdV) equation was derived by Haas et al. [115]. Due to non-essential effects, both the system is in balance, and the clearing system may have resulted in a shocking buildup of large amounts of inequities in the presence of decay effects. In classical plasma, the KDV equation is well known for the small but limited amplitude of ionic sound wave [116]. In quantum plasma, many authors have studied nonlinear low frequency waves in linear and such ion acoustic waves, drift waves, and so on [115], [117] - [118].

Recently the intensification of the laser beam is analyzed by the different reactions of magnetized [118, 119] and unmagnified plasma [120, 121] with regard to the non-inertial combustion of the nonlinear dielectric material. On the surveys we have made a self-generated plasma channel for serious gauge electromagnetic beam propulsion regimens. When an intense electromagnetic beam is multiplied through a plasma, its deep-minded driving force drives the plasma away from the high field, the beam is a wave guide that rarely pushes the density of the channel. The lower plasma density on the beam axis slows the phase velocity of the wave on-axis, imparting to the phase fronts a curvature that counters diffraction. This effect is also due to mass increases in the relativity of electrons and increases the intensity of plasma frequency reduction near the beam print. The laser beam is powerful enough, and the beam is self-stuck by a density subway or channel dug with enough to prevent the beam from diffracting it out in the plasma. As the intensity of the laser beam increases, the effect of non-functional effect as well as the electrons is intended to discharge the transmutation of the medium electrical conductor.

It has been proved that by adding positrons to the plasma as usual, their collective behavior has changed considerably [120 - 123] plasma [124] smashing [123], [125] in the early universe, the vital role of survival and electron-positron (E-P). Although most of the astronomical environments can be considered by the EP plasma existent senses [126 - 127], the EP plasma combination in nonrelativistic regimes is astronomical plasma in some aspects [125], [128]. Verheest et al. studied through a reductive disturbance analysis, large amplitude in electron-positron plasma studied solitary electromagnetic waves and received a modified Korteweg-de verse (KdV) equation [129]. Using two fluid plasma samples, Kourakis et al. [130] the pair studied parallel wavelength packets in parallel magnetic plasma in pairs. With this approach, Esfandyari-Kalejahi et al. E-P-I is considered nonlinear propagation of amplitude collective electrostatic wave-packets in Plasma [131]. Esfandyari-Kalejahi et al. [132] Studied electrostatic waves which unmagnified collision pair modulation of nonlinear amplitude propagation in plasma. Furthermore, many researchers have examined solder tissue structures in magnetic plasma, which are derived from the Zakharov-Kuznetsov (ZK) equation in various media. For example, Kourakis et al. have studied Magnetic mixed pair-ion plasma molecular electrostatic reactions are equated with linear dissemination analysis and forming their dimensional solutions [133]. The spread of shear Alfven waves in a strongly magnetic e-P-I plasma has been investigated [134], and also in Quantum E-P-I plasma, solitary waves were examined [117], [125]. In the presence of stable ions, in the presence of Mahmood et al., QHD for disseminating nonlinear acoustic wave in dense magnetic e-p plasma, ZK has found the equation and found that the positron concentration decreases the wave dimension increases.

7.2 MATERIALS AND METHOD

In this section is concerned with a comprehensive investigation for propagation regimes of an intense short laser pulse in a self-created plasma channel. Various propagation regimes of electromagnetic wave are possible for various sets of parameters of the plasma and the beam; (a) The beam becomes focused, either immediately or after undergoing some expansion, before it reaches the critical surface m the plasma, the beam creates a self-sustaining channel along its own axis, and it penetrates into the plasma, to a density above the critical value. The depth of this bleaching of the plasma is limited. When the time scale of the order of we need to take into account the dynamics of the ions and to assume nonlinear re reaction forces increases and that the beam begins to defocus, (b) the beam becomes focused to a critical size and then expands rapidly, (c) The beam immediately undergoes defocusing. Based on WKB and paraxial ray theory, the steady state solution of an intense, Gaussian electromagnetic beam is studied for arbitrary large nonlinearity. The nature of propagation of an intense beam in a plasma depends on the power, width of the beam andφ_p, the ratio of plasma to wave frequency. For given values of $\varphi_p \left[= \frac{\omega_p}{\omega}\right] < 1$, the propagation regimes have been obtained m beam power-beam width plane, characterizing the regimes of focus Steady divergence (SD), Oscillatory Divergence (OD) and self-focusing.

7.2.1 Self-channeling of laser beam

To propagate along the direction of Z-direction, the electron density n_0 is a serious gaseous laser beam spread through a cold plasma. The cylindrical coordinate can be expressed with the electric vector power range as follows:

$$E = \hat{x}A(r,z,t)\exp[-i(wt - kz)] \qquad \dots (7.1)$$

Where

$$A|_{z=0}^{2} = A_{00}^{2}g(t)\exp\left(\frac{-r^{2}(z)}{r_{o}^{2}(z)}\right)$$

$$k(z) = \left(\frac{\omega}{c}\right)\varepsilon_{0}^{\frac{1}{2}}(z)$$

$$w_p(z) = \left(\frac{4\pi n_0(z)e^2}{m}\right)^{1/2} \qquad \dots (7.2)$$

If 'e' the electron charge, the mass 'm' and 'c' are velocity of light respectively, the electron plasma frequency ω_p, for t[0] and g(t) = 0 plasma electromagnetic material and selective step-pump function g (t) = 1.

The current work, a plasma channel, is thought to have auxiliary picosecond laser pulse set in plasma of helium gas. It is possible to build a plasma channel through plasma can easily be influenced by the driving force implicating the intense laser pulse. Initially, the laser pulse plasma electrons push a deeper thinking into driving force and evacuate them in the periphery. A large outer charge of the ion is pushed outward from this diffusion axis. After the laser pulse is passed, the ions continue to radiate when creating a plasma channel. The optical profile of the laser beam in the plasma can be attributed to the optical profile inward profile curve wave interface and converts the laser beam to a maximum of the axis.

The laser pulse can be carried in long distances and maintained in a small cross section while this center is strong enough to resist the edge of the pivot. The index of refraction or dielectric function ε can be written as -

$$\varepsilon(r) = [1 - (\frac{\omega_p^2}{\omega^2})(\frac{n_e(r)}{n_o \gamma(r)})] \quad \dots (7.3)$$

Where

ω_p = Plasma frequency for electron density n_0,

'ω' = laser frequency

$n_e(r)$ = radial distribution of electron density

$\gamma(r)$= relativistic factor

This can be seen from the fact that it can be generated by the maximum γ /or n_e oriented profile of a radial. The electron has a laser beam which is due to the massive intensity of the proportion,

$$F_p = e\nabla\emptyset_p \quad \dots (7.4)$$

Where

$$\emptyset_p = -(\frac{mc^2}{e})(\gamma - 1)$$

The ponder motive potential with relativistic Lorentz factor is expressed as

$\gamma = [1 + q^2/2]^{1/2}$ … (7.5)

Where

$$q = (e|A|/m\omega c)$$

Before the laser pulse, think the driving force has axial and radial elements. In this model setting, we ignore the laser pulse plasma and directional asymmetry in this direction asymmetric. However, seriously azimuthally unrestricted incident can be carried out with the constant redirection of profanity profiles and the efficient imprisonment. Radial pondermotive force is pushing the electrons outward in a radial space charge area$E_s = (-\nabla_s)$. Use of position equation-

$\nabla^2 \emptyset_s = 4\pi e(n_e - n_0)$ … (7.6)

For $\omega_p \tau > 1$, that assumes a quasi-steady state with using F_p- eEs = 0 that is $\emptyset_s - \emptyset_p$and using Eqs. (7.5) in (7.7), we get the modified electron density -

$n_e(z) = n_o(z)[1 + \frac{c^2}{w_{p\,(z)}^2}]\nabla^2\gamma(r)$ … (7.7)

In Equation (7.8) where 'r' is greater than 1 for the second term, otherwise n_e = 0, it is valid in those areas, where there is complete electron clearance in

$\left[1 + \left(\frac{C^2}{w_p^2(z)}\right)\nabla^2\gamma(r)\right] < 0$ … (7.8)

The problem set is considered by the state, developed by Plasma Channel time evolution. Changing the pulse shape and amplitude and assuming that the range kaichi standard form spreads without using ansatz

$q^2 = \frac{q_0^2}{f^2}\exp(\frac{-r^2}{r_0^2 f^2})$ … (7.9)

Where

f = dimensionless beam width parameter
$r^2= (x^2+y^2)$ = radial component in cylindrical coordinate system
r_0= initial beam width
$q_{o\cong}$(EA00/mwc) = axial amplitude

$$n_e(z) = n_0[1-\frac{C^2q^2}{\omega_p^2 r_o^2 f^2\gamma}] \times (1-\frac{r^2}{r_o^2 f^2}\frac{1+q^2/4}{\gamma^2}) \qquad \ldots (7.10)$$

Using Eqn. (7.11) in (7.4) and making paraxial approximation under radial direction can be written in the Taylor extension of the dielectric function

$$\varepsilon = \varepsilon_0 - \frac{\varepsilon' r^2}{r_0^2} \qquad \ldots (7.11)$$

Where

$$\varepsilon_0 = 1 - \frac{\frac{\omega^2}{\omega_p}}{\gamma'0}(1-\frac{c^2}{\omega_p^2 r_o^2 f^2}\frac{q_0^2/f^2}{\gamma'0})$$

$$\varepsilon' = 1 - \frac{\frac{\omega^2}{\omega_p}}{\gamma'0}(1+\frac{c^2}{\omega_p^2 r_o^2 f^2}\frac{8+q_0^2/f^2}{\gamma'0})$$

$$\gamma_0^1 = (1+\frac{q_0^2}{2f^2})^{1/2}$$

7.2.2 Propagation equation / regimes

When an intense laser radiation interacts with plasma, the dielectric properties of the laser are produced plasma significantly affected as it passes through it. The modified, effective dielectric constant can in general, be expressed as –

$$\epsilon = \epsilon_0 + \emptyset(EE^*) \qquad \ldots (7.12)$$

Where

$$\varepsilon_0 = \left[1 - \left(\frac{\omega_p^2}{\omega^2}\right)\right]$$

'co' = laser frequency

$\emptyset(EE^*)$= nonlinear term

The dielectric function tries to achieve its saturated value with the power of the laser beam increasing. In the case of the laser beam in the plasma molecule, some interesting features are combined with the absorption of dielectric leads. Consider the intense laser beam distribution of Gaussian intensity in its wave front. Dimensions of power vector e satisfies wave equation -

$$\frac{\sigma^2 E}{\sigma z^2} + \frac{\sigma^2 E}{\sigma r^2} + \frac{1}{r}\frac{\sigma E}{\sigma r} + \frac{\omega^2}{c^2}\epsilon(r,z)E = 0 \qquad \dots (7.13)$$

It is obtained from the Maxwell equation by neglecting∇ (∇.E), which is valid when C$\frac{C^2}{\omega^2}\left|\left(\frac{1}{\varepsilon}\right)\nabla^2\right| \ll 1$, a situation valid for most situations of interest. The solution of equation (7.13) is obtained. In the case of arbitrary non-linearity, the dielectric constant can generally be divided into

$$\varepsilon(r,z) = \varepsilon_0 + \varepsilon_1(r,z) \qquad \dots (7.14)$$

Where ε_1 (r, z) vanishes at r = 0. A first order JWKB solution of the one-dimensional wave equation -

$$\frac{\sigma^2 E_0(z)}{\sigma z^2} + \frac{\omega^2}{c^2}\epsilon_0(z)E_0(z) = 0 \qquad \dots (7.15)$$

$$E_0(Z) = \frac{Const.}{(\varepsilon_0(z))^{1/4}}\exp[-i\frac{\omega}{c}\int_0^2 \sqrt{\epsilon_0}]dz$$

This solution is valid if the two first and second derivatives z of the order $E_0(Z)$ is negligible. We can predict that the solution of equation (7.13) for scalar $E\{r, z$ will have a form that goes into equation (7.16) for r = 0. Thus,

$$E(r,z) = A(r,z)[\frac{\varepsilon_0(0)}{\varepsilon_0(z)}]^{\frac{1}{4}}\exp[i(\omega t - \frac{\omega}{c}\int_0^z \sqrt{\varepsilon_0 dz}] \quad \ldots (7.16)$$

An eikonal function *S(r, z)* may now be introduced through

$$A(r,z) = A_r(r,z)\exp[-i\frac{\omega}{c}\varepsilon_0 S(r,z)] \quad \ldots (7.17)$$

In the paraxial approximation Equation (7.13) and Equation (7.17) lead to the solution corresponding to an initially (z = 0) Gaussian laser beam as -

$$S = \frac{r^2}{2}\beta(z) + \emptyset(z) \quad \ldots (7.18)$$

$$A_r^2 = \frac{A_{00}^2}{f^2(z)}\exp(-\frac{r^2}{r_0^2 f^2(z)}) \quad \ldots (7.19)$$

Where $\beta(z)$ = 1/f df/dz can be identified as the curvature of the wave front. The parameter f(z) is obviously the beam width parameter, which can be defined as -

$$r(z) = r_0 f(z) \quad \ldots (7.20)$$

r_o being the beam width at z = 0. In Equation (7.20) we have written E_0(z = 0) as A_{00}.Obviously, at z= 0 the beam width parameter *f*= 1. Further if the wave front at z = 0 is assumed to be plane $\beta(z)|z = 0\ and\ \left(\frac{df}{dz}\right) = 0$ also vanishes. Thus the boundary conditions on 'f' are –

$$f = 1; \frac{df}{d\varepsilon} = 0\ at\ z = 0 \quad \ldots (7.21)$$

After the first analysis, following the differential equation for the obtained from the equation with the distance of publicity (7.16), (7.17), (7.18), (7.19), (7.20) and (7.21), ray width parameter

$$\frac{1}{f}\frac{d^2 f}{dz^2} = [\frac{c^2}{\omega^2 r_0^4 \varepsilon_o f^4} + \frac{\varepsilon_1}{\varepsilon_0}] \quad \ldots (7.22)$$

Transforming the coordinate's z and the initial beam width r_0 to dimensionless forms;

$$\varepsilon = \left(\frac{Zc}{r_0^2\omega}\right) and\ p_0 = (r_0\omega/c) \quad \ldots (7.23)$$

7.2.3 Critical power curve

Substituting Equations (7.21), (7.22) in (7.23), applying the boundary conditions and simplifying for (d^2f/de^2) to vanish yields

$$p_0^2 = \frac{4\omega^2}{\omega_p^2}\frac{(1+\frac{q_0^2}{2f^2})^2}{q_o^2}\left[1-\frac{c^2}{r_0^2\omega_p^2}\right]\frac{(8+q_0^2)}{(1+\frac{q_0^2}{2f^2})^{1/2}} \qquad \dots (7.24)$$

The dependence of p_o versus q_o according to Equation (7.24) gives the critical power curve. An initial beam width (r_o) is said to be below a certain value that the r_{om} (minimum) may be regardless of any initial power of any self-focused beam. When the initial beam width (ro) is greater than r_{om}, there are two values of critical beam power say *qocr1* (such that *qocr1 < qocr2)* for which the beam propagates in the uniform waveguide mode without any change in beam width. If the initial power q_o of the beam lies between *qocr1* and *qocr2* (with $r_o > r_{om}$) the beam propagates in an oscillatory converging mode with the beamwidth varying between the original and a minimum, this is referred to as self-focusing. For $q_o >$ *qocr2* (when $r_o > r_{om}$) and for some values of power (for $r_o < r_{om}$) the beam propagates in an oscillatory guided diverging mode with the beamwidth varying between the original value and a maximum.

7.3 RESULTS AND DISCUSSION

The critical curve Equation (7.24) is represented by Figure 7.1 for$\delta_r^2\left(=\frac{\omega p}{\omega)^2}\right) = 0.1\ and\ 0.3$. In the parallel line of the two right curves, the 1, 2 and 3 in the parallel areas are categorized into self-focus, oscillation and stem redness respectively, print q_o.

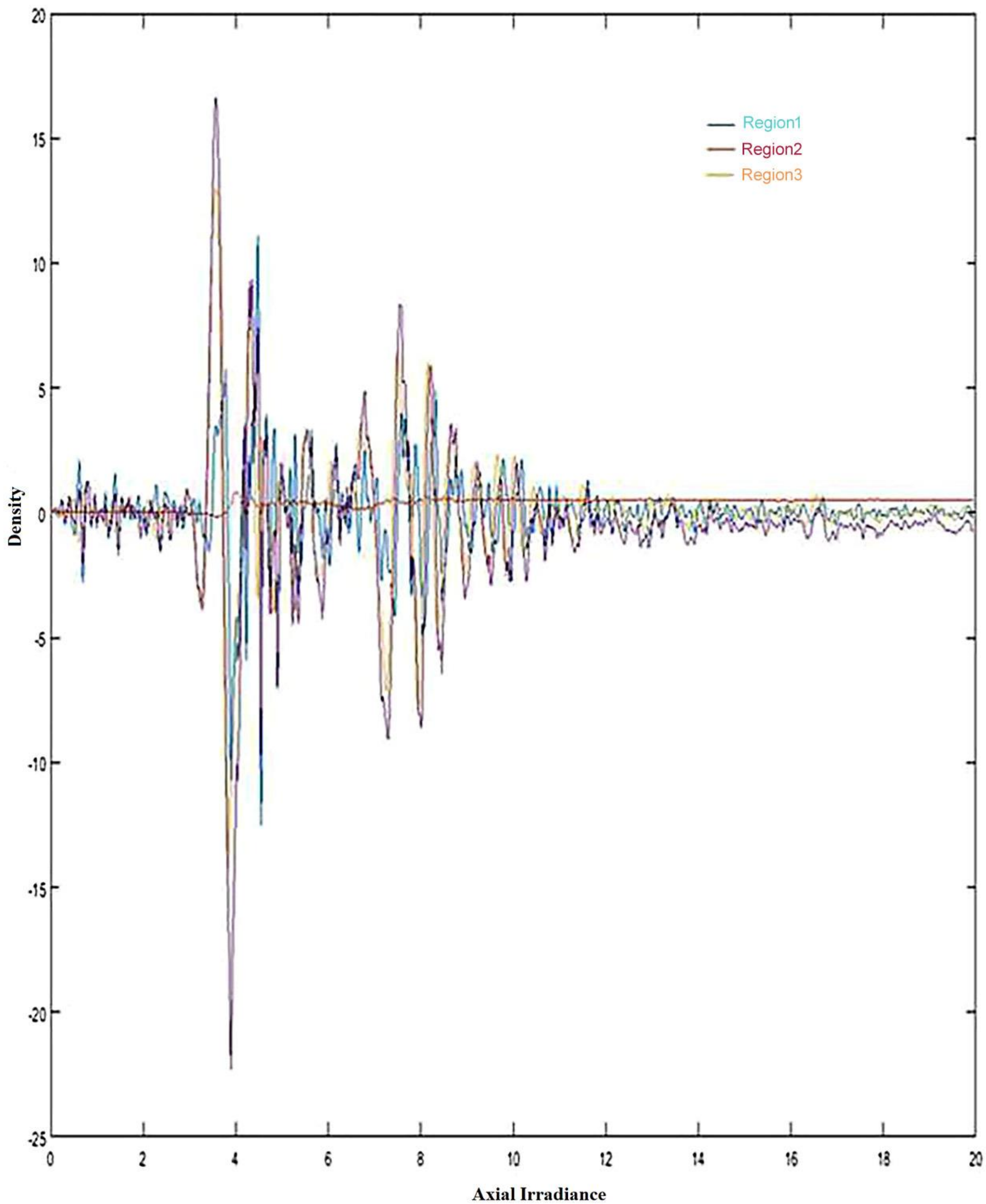

Figure 7.1 Relationship between axial irradiance q_o and inverse of dimensionless beam radius ($\frac{1}{p_o} = c/\omega r_0$) indicating different regimes of propagation for varied density.

.

Beam Width Parameter Variation is explained in different points of view by the spread of distinctions are depicted in Figures 7.2 and 7.3 in different areas (f versus ε).If these points are correctly lying on the critical curve then the beam is self-stuck and it spreads without scattering.

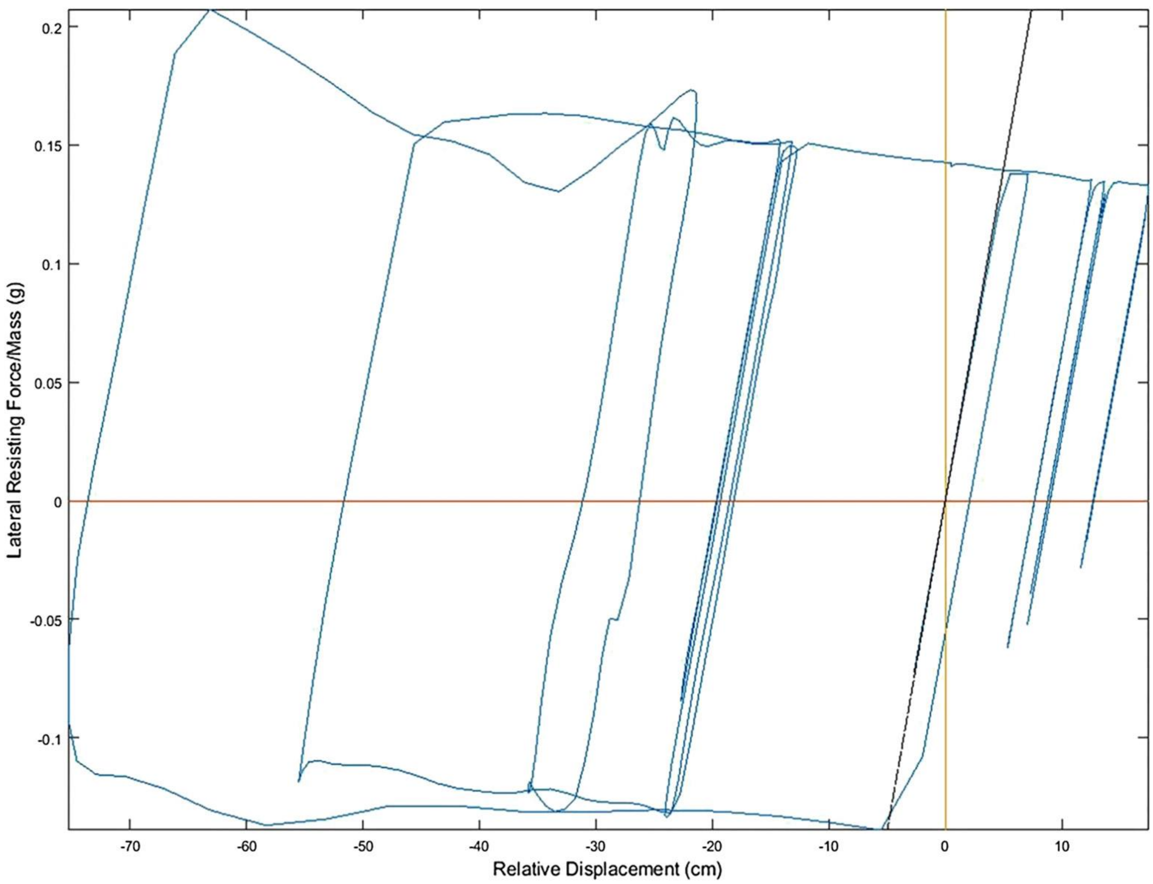

Figure 7.2 Variation of beamwidth parameter (f) with dimensionless distance of propagation (ε) in different regimes for variable laser intensity and density.

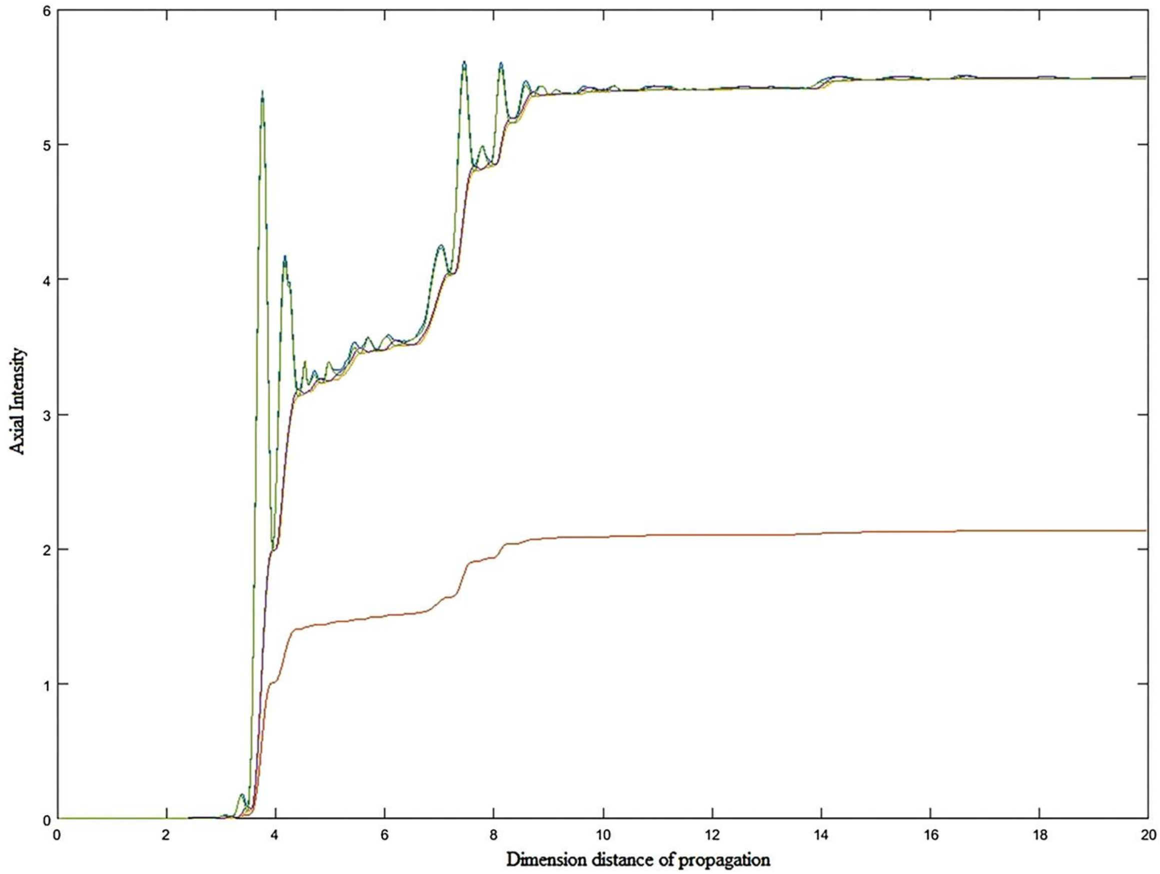

Figure 7.3 Variation of beamwidth parameter (f) with dimensionless distance of propagation (ε) in different regimes for same laser intensity and variable density.

Figure 7.4 depicted that the beam width parameter for lying points on the critical curve depicts diffusion by plasma without much change. Graphical display reflects that the beam is self-stuck and is spreading on a self-motivated plasma channel without much of it or scattering. This incident indicates that a laser power can be trapped in a short channel near the axis of spreading many of the length of several rays less without leaving a large section.

Figure 7.4 (q_o, $1/p_o$) lies in the bottom of the critical curve of the beam (Division 1), that the origin ($d2f\ /d\ \varepsilon$) <0 curve on the same page and points lie on the other side (Region 2 and Region 3), ($d2f$ / de) >0, Hence, the beam width parameter does not lie on the initial complex curve, such as the beam spread or decrease. The corresponding conspiracies statistics 2 and 3 are explained in various points of the different important curve of the electron density and intensity.

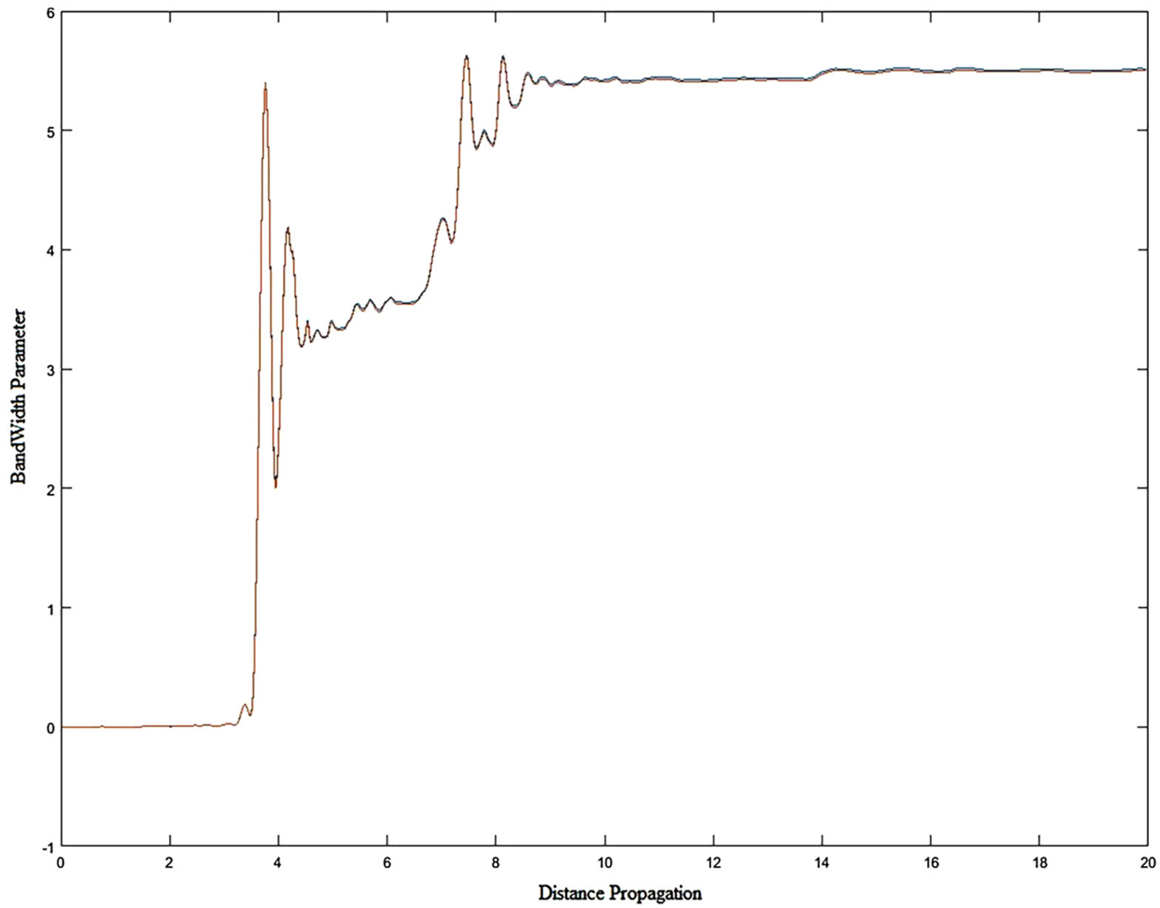

Figure 7.4 Variation of beamwidth parameter (f) with dimensionless distance of propagation ε in self-trapped mode for points lying on critical curve I.

7.4 CONCLUSION

This work is based on differing equations and critical curves, and the characteristics of laser beam and individual distributive regimens are examined in a self-made laser-made plasma channel. Using WKB and paraxial theory, it is very instructive to understand the channel dynamics near the axis for a wide range of normalized parameters applied to intensive plasma under the analytical model. Theory and numerical calculations purpose of the study of the laser is to suggest that the force manages the electron mass and the electron exhaustive proportion increases the plasma self-diverted early stage. To increase the refractive index of the plasma on these two effects axis, focusing on the laser pulse and trapping a large part of the event power propagation in a self-trapped mode.

In the targeted region beyond focus, non-linear refraction begins its weakening, and the spot size of the laser increases, which shows the focusing / defocusing behavior with the propagation distance. To overcome defocusing and get a minimum position size, plasma density ramp functions are used. This is where one needs a laser pulse to propagate several longitude lengths while maintaining an efficient communication with the plasma. It is useful in many applications. The focusing properties are found to depend significantly on density and intensity. The method used here for the treatment of different laser pulse distribution regimes can be applied to the diversity of non-dissipative media with saturating non-linearity.

CHAPTER VIII

CONCLUSION AND FUTURE SCOPE

8.1 CONCLUSION

This work has presented a study of nonlinear waves in semiconductor quantum plasma. We have used the number of different angles to solve this problem. For example we have considered the interaction of nonlinear low frequency electrostatic modes in quantum plasma and the ultrasonic waves in piezoelectric semiconductor in the presence of electric field. We have considered the acoustic waves in semiconductor symmetric pair plasmas and finally we looked at modulation dispersion and amplification in semiconductor plasma and nonlinear wave in semiconductor quantum plasma for laser beam in a self consistent plasma channel.

Plasma is regarded as the fourth state of matter after solid, liquid and gas. It is an ionized gas which contains sufficient charged particles for the overall behavior of the system to be different from an ordinary gas. Plasma occurs naturally in many places such as in ionosphere and in the universe, 99% of the matter is in the form of plasma. Plasma can be categorized in many ways such as thermal, non-thermal, equilibrium and non-equilibrium, etc; Plasma can be produced by various methods depending upon the requirement. These methods include the DC discharge, dielectric barrier discharge, RF discharge which includes helicon discharge and both capacitively coupled and inductively coupled discharges, microwave discharge, etc. Plasma supports a variety of fundamental modes which can be obtained from the cold plasma dielectric tensor.

In chapter 1, studied the basic introduction of nonlinear waves in semiconductor quantum plasma and used number of equation of quantum hydrodynamics (QHD).

In chapter 2, studied the basic literature related to this topic. Authors have studied the number of research paper but some have discussed in this chapter.

The chapter 3 deals with the interaction of nonlinear low frequency electrostatic modes in quantum plasma. The propagation characteristics of nonlinear low frequency electrostatic waves in electron-ion quantum plasma are investigated. The electrons are degenerate and weakly correlated whereas ions are non-degenerate and strongly correlated are presented in this chapter. The most important property of quantum plasma is the collective nature of strongly coupled quantum plasma. This shows the existence of shock wave due to ion-ion correlation in high energy density of strongly coupled quantum plasma. The oscillatory shock structure in which dispersion dominates over dissipation by different values of τ is plotted and the monotonic shock structure in which dissipation dominates over dispersion by different values of τ is plotted. The propagation characteristics of nonlinear low frequency electrostatic modes in quantum plasma can be described by Korteweg-de Vries Burger equation.

The chapter 4 deals with the investigation of the ultrasonic waves in piezoelectric semiconductor in the presence of electric field. In this chapter we considered the Maxwell's electromagnetic field theory of electron sound wave interaction is applicable in which sound wave length is larger than electronic mean free path. This chapter has done the calculations on the Gallium Nitride (GaN) semiconducting material in which large band gap and the propagation of ultrasound under the influence of electric field by the electromechanical coupling coefficient χ. The sound absorption coefficient and renormalization of sound velocity are affected with the roots of Bessel function $J_0^2(a)$ which can be used to determine mobility and effective mass of electron by high frequency electric field. The expression becomes equivalent to the absorption of sound in the absence of electric field when the high frequency field is switched off.

In chapter 5, studied the acoustic waves in semiconductor symmetric pair plasma and considered the situation in which the conditions are acoustic waves in symmetric pair fullerene plasmas such as C^-_{60} and C^+_{60} with two kind of electrons system such as cold and hot in one-dimensional form. The Korteweg-de Vries equation has derived by employing the reductive perturbation technique and the stretched coordinates $\delta = \varepsilon^{1/2}(x\text{-}Mt)$ and $\Gamma = \varepsilon^{3/2} t$, where ε is a smallness parameter measuring the weakness of the dispersion.

Electron-hole plasmas in pure semiconductors also are symmetric pair plasmas if effective masses of electrons and holes are equal. The main difficulty of electron-ion plasmas is the large difference between the two involved time scales. The large differences between the electron and ion masses typically give rise to different scales, in single and multiion plasmas. These differences are removed in case of Symmetric pair plasmas, in which the equal masses and opposite charges destroy the scales.

In this study, discussed the properties of collisionless Vlasov-Poisson model in the fluid approximation in context of pair plasmas and the acoustic-like modes in Symmetric pair plasmas, C^{-}_{60} and C^{+}_{60} plasmas having mass opposite charged fullerene is almost equal have cold and hot electrons. In symmetric pair plasmas, where both species have the same temperature, acoustic mode are impossible, but in that plasmas exists nonlinear amplitude modulation of electrostatic mode. These mode mixed higher harmonics with basic waves and can gives envelope solitons. In pure symmetric pair plasma the acoustic structures are absent. This pair-ion plasma could be useful for the synthesis of C60 dimers and the investigation of linear and nonlinear behaviors of collective modes.

The chapter 6 deals with the investigation of modulational dispersion and amplification in doped semiconductor plasma and considered the transverse modulational amplification in a magnetized piezoelectric semiconductor arising due to nonlinear effective susceptibility χ_{eff}, the hydrodynamic model of semiconductor plasma.

Modulational instability refers to instability of a wave propagating in nonlinear dispersive media such that the steady state becomes unstable and evolves into a temporally modulated state. The modulational amplification coefficient α_{eff} in a doped semiconductor is –

$$\alpha_{eff} = \frac{k}{2\varepsilon_1} \chi_{eff} \left| E_0^2 \right| \qquad \ldots (8.1)$$

If α_{eff} is negative, then the nonlinear growth of the modulated signal is possible. Therefore, the nonlinear growth of the modulated signal is possible only if χ_{eff} is negative. This chapter deals with the analytical investigations of modulational dispersion and amplification in n-InSb semiconductor plasmas. The pump electric field produces a shift in the resonance frequency in induced polarization term and it plays an important role in the enhancement of both modulational dispersion and amplification.

The chapter 7 deals with the distributed a serious laser beam on a self-made plasma channel. The medium displays the neuromuscular electrical conductivity functioning as a result of the mass effectiveness of the effectiveness of the electrons as well as the intensity of the electrons when the intensity of the laser beam increases. The differential equation of the distance with the beam width parameter is derived, including the relativistic effects of self-focusing (SF) and self-channeling ponder motive. Theory and numerical calculations purpose of the study of the laser is to suggest that the force manages the electron mass and the electron exhaustive proportion increases the plasma self-diverted early stage. To increase the refractive index of the plasma on these two effects axis, focusing on the laser pulse and trapping a large part of the event power propagation in a self-trapped mode. It is useful in many applications.

Thus, in this thesis investigated the number of aspects of nonlinear wave interactions in semiconductor quantum plasma.

8.2 APPLICATIONS AND FUTURE SCOPE

The nonlinear waves and plasma interaction has diverse applications in different fields such as nuclear fusion, particle acceleration, heating of ionospheric and laboratory plasmas by radio waves etc. along with controlled fusion applications to ITER (International Thermonuclear Experimental Reactor), frequency upshifting, resonance absorption, laser focusing and defocusing, material processing, generation of X-ray, THz and microwave radiations, higher order harmonic generation, laser filamentation etc. With the inclusion of plasma, the performance of some devices such as backward wave oscillator (BWO), travelling wave tube (TWT) amplifiers, gyrotrons and other microwave tubes have been found to increase and to study the properties of nano structured materials. In this thesis, quantum effects cannot ignore in semiconductor quantum plasma.

Although, many theories are carried out on the semiconductor quantum plasma system, there is still lot of scope for many other theories. Future research can be carried out by the different ways.

1. Semiconductor miniaturization is necessary. This size demands not only dimensional accuracy on the scale of several atoms but also controllability of the etching side wall and selectivity to underlayers. To meet these demands, it is necessary to control the plasma parameters more accurately than ever before.

2. Different plasma techniques have different advantages that may be suitable for certain applications. Semiconductor quantum plasma may have a wider range of applications.

3. There are number of new methods based on the Transverse Magnetic mode analysis for analyzing plasma wave interactions in semiconductor plasma structure.

4. There are number of nonlinear wave interactions in semiconductor quantum plasma structure.

5. Realization of such applications of semiconductor plasma requires studies on the generation and behavior of semiconductor plasma of different substrate materials. Each semiconductor substrate has different dielectric properties, and doping significantly changes the behavior of semiconductor materials. Also there are many semiconductor plasma generation techniques, optical excitation being one of them.

6. Sharing of the research achievements in these interdisciplinary fields would also benefit the scientific community around the world.

Therefore, author recommends further modification in technology before any other uses are considered.

REFERENCES

REFERENCES

[1] Francis F. Chen "Introduction to Plasma Physics and controlled Fusion," *Springer*, book, Second edition 1983.

[2] Robert O. Grondin, Samir M. El-Ghazaly and Stephen Goodnick, "A Review of Global Modeling of Charge Transport in Semiconductors and Full-Wave Electromagnetics," *IEEE Trans. on Microwave Theory Tech.*, Vol. 47, 1999, pp. 817-829.

[3] Paul. M. Bellan. "Fundamentals of Plasma Physics" *Cambridge University Press*, 2006.

[4] E. Madelung, "Eine anschauliche Deutung der Gleichung von Schrödinger," *The Science of Nature (Springer-Verlag)*, Vol. 14, 1926, pp. 1004-1004.

[5] E. Madelung, "Quantentheorie in hydrodynamischer Form," *The Science of Nature (Springer-Verlag)*, Vol. 40, 1927, pp. 322-326.

[6] David Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variables. I," Vol. 85, 1952, pp. 166.

[7] David Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variables. II," Vol. 85, 1952, pp. 180.

[8] G. Sharma and S. Ghosh, "Modulational interactions in magnetized piezoelectric semiconductor plasmas," *The European physical Journal D (Springer)*, vol. 11, 2000 pp. 301-307.

[9] I. Gasser, P.A. Markowich, D. Schmidt, A. Unterreiter, Proceedings of the Workshop on Mathematical Problems in Semiconductor Physics, Rome 1995.

[10] C.L. Gardner, C. Ringhofer, *Transport Theory and Statistical Physics*, Vol. 29, 2000, pp. 563.

[11] S. Rehman, "linear and nonlinear quantum ion acoustic waves in a plasma with positive, negative ion and Fermi electron gas" *Physics of Plasma (American Institute of Physics)*, Vol. 17, 2010, pp. 062303.

[12] Bohm, D., and D. Pines, "A Collective Description of electron interactions; III. Coulomb interactions in a degenerate electron gas" *Physical Review Letters (The American Physical Society)*, Vol. 92, 1953, pp. 609-625.

[13] F. Haas, “Quantum Magnetohydrodynamics” *Physics of Plasmas (American Institute of Physics)*, Vol.12, 2005, pp. 062117.

[14] G. Manfredi, “How to model quantum plasmas” *Field Inst. Commun*., Vol. 46, 2005, pp. 263 - 287.

[15] M. Marklund, P.K. Shukla, “Nonlinear collective effects in photon-photon and photon plasma interactions,” *Reviews of Modern Physics (The American Physical Society)*, Vol.78, 2006, pp.591.

[16] Kittel, C., Introduction to Solid State Physics, Seventh Edition (John Wiley & Sons, Inc., New York), 1996.

[17] S.Y. Mensah, N.G. Mensah, V.W. Elloh, G.K. Banini, “Propagation of ultrasonic waves in bulk gallium nitride (GaN) semiconductor in the presence of high-frequency electric field” *Physica E (Elsevier)* , Vol. 25, 2005, pp.500-506.

[18] N.G. Mensah, “Amplification of acoustic waves in GaN in the presence of slowly changing periodic electric field” *Condensed Matter Physics (Elsevier)*, 2010.

[19] M. Singh, P. Aghamkar, S.K. Bhaker “Parametric dispersion and amplification in semiconductor plasmas: Effects of carrier heating,” *Optics & Laser Technology (Elsevier)*, Vol. 41, 2008, pp. 64-69.

[20] M. Singh, P. Aghamkar, N. Kishore, P.K. Sen “Nonlinear absorption and refractive index of Brillouin scattered mode in piezoelectric semiconductor plasmas by an applied magnetic field,” *Optics & Laser Technology (Elsevier)*, Vol. 40, 2007, pp. 215-240.

[21] P.K. Shukla, K. Avinash “Phase transitions in quantum plasmas,” *Physics Letters A (Elsevier)*, Vol. 376, 2012, pp. 1312-1355.

[22] Nilesh Nimje, Swati Dubey, and S. Ghosh, “Parametric Interaction in Acousto-Optical Semiconductor Plasmas in the Presence of Hot Carriers,” *Chinese Journal of Physics (The Physical society of the Republic of China*), vol. 49, 2011, pp. 901-916.

[23] Nitin Shukla, G. Brodin, M. Marklund, P. K. Shukla and L. Stenflo “Nonlinear electromagnetic wave equations for superdense magnetized plasmas,” *Journal of Plasma Physics (Springer)*, Vol. 41, 2009 pp. 1-5.

[24] S. A. Mikhailov "Plasma instability and amplification of electromagnetic waves in low-dimensional electron systems," Germany, 2008, pp. 1-42.

[25] A. P. Misra "Electromagnetic surface modes in a magnetized quantum electron-hole plasma," *physica (Elsevier)*, Vol. 43, 2011 pp. 1-4.

[26] Zhigang Chen, Shahid Rauf, Kartik Rama swamy and Ken Collins "Electromagnetic Modeling of Plasma Etch Chamber for Semiconductor Microchip Fabrication," *Progress in Electromagnetics Research, PIER*, Vol. 5, 2009, pp. 221-225.

[27] S.K. El-Labany, E.F. El-Shamy, W.F. El-Taibany and P.K. Shukla "Head-on collision of quantum ion-acoustic solitary waves in a dense electron–positron–ion plasma," *Physics Letters A (Elsevier)*, Vol. 374, 2010, pp. 960-964.

[28] W.M. Moslem, S. Ali, P.K. Shukla and B. Eliasson "Three-dimensional electrostatic waves in nonuniform quantum electron–positron magneto plasma," *Physics Letters A (Elsevier)*, Vol. 372, 2008, pp. 3471-3475.

[29] S. Mahmood, A. Mushtaq "Quantum ion acoustic solitary waves in electron–ion plasmas: A Sagdeev potential approach," *Physics Letters A (Elsevier)*, Vol. 372, 2008, pp. 3467-3470.

[30] S. Ghosh, Swati Dubey, R. Vanshpal "Quantum effect on parametric amplification characteristics in piezoelectric semiconductors," *Physics Letters A (Elsevier)*, Vol. 375, 2010, pp. 43-47.

[31] Haijun Ren, Zhengwei Wu, Jintao Cao, Paul K. Chu "Dispersion of multi-stream instability in quantum magnetized hot plasmas," *Physics Letters A (Elsevier)*, Vol. 372, 2008, pp. 2676 - 2683.

[32] S. S. Bulanov "Pair production by a circularly polarized electromagnetic wave in plasma," *Physical Review E (The American Physical Society)*, Vol. 69, 2004, pp. 036408 1-036408 7.

[33] Lennart Stenflo, Bengt Eliasson and Mattias Marklund, "Three-dimensional instability of two nonlinearly coupled electromagnetic waves in a plasma," *Physics of Plasma (American Institute of Physics)*, 2007, pp.1-11.

[34] P K Shukla and B Eliasson "Nonlinear aspects of quantum plasma physics," *Physics-Uspekhi (IOP Science)*, Vol. 53, 2010, pp. 51-92.

[35] M. Iv. Trukhanova “Quantum hydrodynamics approach to the research of quantum effects and vorticity evolution in spin quantum plasmas,” *Progress Theory Experiment Physics, PTEP*, Vol. 86, 2013, pp. 1-12.

[36] P. K. Shukla and B. Eliasson “Nonlinear Interactions between Electromagnetic Waves and Electron Plasma Oscillations in Quantum Plasmas,” *Physical Review letters (The American Physical Society)*, Vol. 99, 2007, pp. 096401 1-096401 4.

[37] S. Ghosh and Apurva Muley “Acousto-Electric Interaction in Magnetised Piezoelectric Semiconductor Quantum Plasma,” *Acta Physica Polonica A*, Vol. 130, 2016, pp. 1401 -1405.

[38] Apurva Muley and S. Ghosh “Effect of quantum parameter-H on longitudinal electro-kinetic wave characteristics in magnitised semiconductor plasma,” *International Journal of engineering sciences & research technology*, Vol. 4, 2015, pp. 88-95.

[39] N. Yadav and S. Ghosh “Diffusion-induced parametric dispersion and amplification in doped semiconductor plasmas,” *Pramana Journal of Physics (Indian Academy of Sciences),* Vol. 68, 2007, pp. 123-128.

[40] O. P. Sah and J. Manta “Nonlinear electron-acoustic waves in quantum plasma,” *Physics of Plasmas (The American institute of Physics),* Vol. 16, 2009, pp. 032304 1-032304 4.

[41] C. H. Woo, M. H. Woo, Cheong R. Choi, and K. W. Min “Parallel propagating electromagnetic waves in magnetized quantum electron plasmas,” *Physics of Plasmas (The American institute of Physics),* Vol. 26, 2019, pp. 042103 1-042103 7.

[42] Biswajit Sahu, Anjana Sinha and Rajkumar Roychoudhury “Ion-acoustic waves in dense magneto-rotating quantum plasma,” *Physics of Plasmas (The American institute of Physics),* Vol. 26, 2019, pp. 072119 1-072119 6.

[43] W. M. Moslem, I. Zeba, and P. K. Shukla “Solitary acoustic pulses in quantum semiconductor plasmas,” *Applied Physics Letters (The American institute of Physics),* Vol. 101, 2012, pp. 032106 1-032106 7.

[44] S. Ghosh, Swati Dubey and Kamal Jain "Parametric Dispersion of Acoustic Wave in a Laser Irradiated Semiconductor Plasma: Quantum Effects," *International Journal of Engineering Science Invention,* Vol. 7, 2018, pp. 77-83.

[45] A. P. Misra, and Debjani Chatterjee, "Stimulated scattering instability in a relativistic plasma," *Physics of Plasmas (The American institute of Physics),* Vol. 25, 2018, pp. 062116 1-062116 7.

[46] A. Agrawal, N.Yadav and S.Ghosh "Diffusion induced modulational instability in semiconductor quantum plasma with strain dependent dielectric constant," *IJESRT*, Vol. 6, 2017, pp. 381-389.

[47] P. K. Shukla and B. Eliasson "Colloquium: Nonlinear collective interactions in quantum plasmas with degenerate electron fluids," *Reviews of modern physics (The American Physical Society),* Vol. 83, 2011, pp. 885 -909.

[48] S. Rehman, "linear and nonlinear quantum ion acoustic waves in a plasma with positive, negative ion and Fermi electron gas," *Physics of Plasma (The American institute of Physics),* Vol. 17, 2010, pp. 062303.

[49] F. Hass, A. Bret, "Nonlinear low frequency collisional quantum buneman instability," *Europhysics Letter (IOP Science),* Vol. 97, 2011, pp. 26001 – 26005.

[50] S. Ghosh, Swati Dubey, R. Vanshpal, "Steady state and transient gain characteristics of the stimulated brillouin scattered mode in quantum semiconductors plasma," *Chinese Journal of Physics*, Vol. 51, 2013, pp. 1251-1269.

[51] M.R. Amin, "Modulation of a quantum positron acoustic wave," *Astrophysics and Space Science (Springer),* Vol. 359, 2015.

[52] H. F. Wilhelm, "Wavemechanical formulation of plasma dynamics in longitudinal electric fields," Zeitschrift für Physik A Hadrons and nuclei *(Springer),* Vol. 241, 1971, pp. 1-8.

[53] C. L. Gardner and C. Ringhofer, "Smooth quantum potential for the hydrodynamic model," *Physical Review E (The American Physical Society),* Vol. **53**, 1996, pp. 157.

[54] G. Manfredi and F. Haas, "Self-consistent fluid model for a quantum electron gas," *Physical Review B (The American Physical Society)*, Vol.64, 2001, pp. 075316.

[55] P. K. Kaw and A. Sen, "Low frequency modes in strongly coupled dusty plasmas," *Physics of Plasmas (The American institute of Physics)*, Vol. 5, 1998, pp. 3552.

[56] M. S. Janaki and N. Chakrabarti,"Shear wave vortex solution in a strongly coupled dusty plasmas," *Physics of Plasmas (The American institute of Physics)*, Vol. 17, 2010, pp. 053704 1 - 053704 3.

[57] V. I. Karpman, "Nonlinear Waves in Dispersive Media,"1st edition, *Pergamon, London, (Elsevier)*, 1975.

[58] A. Jeffery and T. Kakutani, "Weak nonlinear dispersive wave: A discussion centered around the korteweg – De Vries equation," *SIAM Reiew (Society for Industrial and Applied Mathematics)*, Vol.14, 1972, pp. 582 – 643.

[59] R. H. Parmenter "The acoustoelectric effect," *Physical Review Letters (The American Physical Society)*, Vol. 113, 1959, pp. 102.

[60] G. Weinreich, "Acoustodynamics effects in semiconductors" *Physical Review Letter (The American Physical Society)*, Vol. 104, 1956, pp. 321.

[61] T. Holstein, *Westinghouse Reprt.*, Vol.60, 94698-3-M15, 1956.

[62] A.R. Hutson, J.H. Mcfee and D.L. White, "Ultrasonic Amplification in CdS," *Physical Review Letters (The American Physical Society)*, Vol. 7, 1961, pp.237 – 240.

[63] H.N. Spector, *Phyical Review A (The American Physical Society)*, Vol. 134, 1964, pp. 507.

[64] S.Y. Mensah, F.K.A. Allotey and N.G. Mensah, "Nonlinear acoustoelectric effect in a semiconductor super lattice," *Journal of Physics: Condensed Matter*, Vol. 12, 2000, 5225.

[65] S.Y. Mensah, F.K.A. Allotey, S.K. Adjepong, "Acoustoelectric effect in semiconductor superlattice," *Journal of Physics: Condensed Matter*, Vol. 6, 1994, pp. 6783 -6787.

[66] S.Y. Mensah, F.K.A. Allotey, S.K. Adjepong, N.G. Mensah, "Photostimulated attenuation of hypersound in Superlattices and Microstructure," *Superlattices Microstructure*, Vol. 22 (4), 1997, pp. 453 – 457.

[67] S.Y. Mensah, F.K.A. Allotey, N.G. Mensah and V.W. Elloh, "Laser Induced Ampli-fication of Hypersound in Nondegenerate Semiconductor Superlattices," *Superlattices Microstructure*, Vol. 33, 2003, pp. 41 – 52.

[68] A. Govorov, A.V. Kalametseiv, M. Rotter, K.H. Hoffmann and N. Botkin, *Physical Review B (The American Physical Society)*, Vol. 62, 2000, pp. 2659-2668.

[69] E. M. Epshtein, Fiz. Tverd. Tela, 10 2945 (1960) [Sov. Phys. – Solid State, Vol. 10 2325, 1969].

[70] V. L. Ginzburg, "Propagation of Electromagnetic Waves in Plasma," *GIFML Moscow,* 1960 (In Russian).

[71] B. K. Ridley, Quantum Processes in Semiconductors, Chapter 3, Clarendon Press, Oxford 1999, pp. 119.

[72] G. D. O' Clock and M. T. Duffy, "Acoustic surface wave properties of epitaxially grown aluminum nitride and gallium nitride on sapphire," *Apply. Phys. Lett.*, Vol. 23, 1973, pp.55-56.

[73] K. Shimada, T. Sota and K. Suzuki, "First principles study on electronic and elastic properties of BN, AIN and GaN," *Journal of Applied Physics (The American institute of Physics)*, Vol. 84, 1998, pp. 4951.

[74] D. K. Ferry, "High-field transport in wide-band-gap semiconductors," *Physical Review B (The American Physical Society),* Vol.12, 1975, pp. 2361-2362.

[75] J.M. Bhaker, D. K. Ferry, D. D. Koleske and R. J.Shul, *Journal of Applied Physics (The American institute of Physics),* Vol.97, 2005, 063705.

[76] Musah Rabiu , Samuel Y. Mensah, Sulemana S. Abukari , Matthew Amekpewu , Baah Sefa-Ntiri , Anthony Twum "Generation and Propagation of Ultrasonic Waves in Piezoelectric Graphene Nanoribbon" *Open Journal of Acoustics (Scientific Research),* Vol. 3, 2013, pp. 38-42.

[77] W. Misner, K.S. Thorne and J.A. Wheeler, "Gravitation," by W. H. Freeman Company, San Francisco, 1973.

[78] Mitchell C. Begelman, Roger D. Blandford and Martin J. Rees, “Theory of extra Galactic radio Sources,” *Review of Modern Physics (The American Physical Society),* Vol. 56, 1984, pp. 255 - 270.

[79] H.R. Miller and P.J. Witta, *Active Galactic Nuclei (Springer),* Berlin, 1987, pp. 202- 207.

[80] F. Curtis Michel, “Theory of pulsar Magnetospheres,” *Review of Modern Physics (The American Physical Society),* Vol. 54, 1982, pp. 1-66.

[81] F. Curtis Michel, 1991, “Theory of Neutron Star Magnetospheres,” *University of Chicago Press, Chicago. Press,* 1991, pp. 517.

[82] P. A. Sturrock, “A model of pulsars,” *Astrophysical Journal,* Vol. 164, 1971, pp. 529 -539.

[83] Wataru Oohara and R. Hatakeyama, “Pair ion plasma generation using Fullerenes,” *Physical Review Letters (The American Physical Society),* Vol. 91, 2003, 205005.

[84] W. Oohara, D. Date and R. Hatakeyama, “Electrostatic Waves in a Paired Fullerene – Ion Plsma,” *Physical Review Letters (The American Physical Society),* Vol. 95, 2005, 175003.

[85] A.E.Dubinov, I.D.Dubinova, and V.A.Gordienko, “Nonlinear theory of ion sound waves in electron positron ion plasma,” *Journal of Plasma Physics (Springer), Vol.13, 2006, pp.* 082111.

[86] H.Saleem, “Kinetic Theory of acoustic wave in pair ion plasmas,” *Physics of Plasmas (The American Institute of physics),* Vol. 13, 2006, pp.044502.

[87] E.P.Liang, S.C.Wilks and M.Tabak, “Pair production by ultraintense lasers,” *Physical Review Letters (The American Physical Society),* Vol. 81, 1998, pp. 4887–4890.

[88] F.Verheest, “Obliquely propagating large amplitude solitary waves in charge neutral plasmas,” *Nonlinear Processes in Geophysics,* Vol. 12, 2005, pp. 569 – 574.

[89] C.M. Surko, M. Leventhal and A. Passner, “Positron Plasma in the laboratory,” *Physical Review Letters (The American Physical Society),* Vol. 62, 1989, pp. 901 - 910.

[90] C.M. Surko and T. Murphy, “Use of the positron as a plasma particle,” *Physics of Fluids B*, Vol. 2, 1990, pp. 1372 – 1377.

[91] C.M., Surko and R. G. Greaves “Emerging science and technology of antimatter plasmas and trap-based beams,” *Physics of Plasmas (The American Institute of physics)*, Vol. 11, 2004, pp. 2333-2348.

[92] P.K.Shukla, N.N.Rao, M.Y. Yu, and N. L. Tsintsadze, “Relativistic Nonlinear effects in plasmas,” *Physics Reports*, Vol. 138, 1986, pp.1 - 149.

[93] A.Esfandyari-Kalejahi, I.Koukaris and P.K.Shukla, “Oblique modulation of electrostatic modes and envelope excitations in pair-ion and electron-positron plasmas,” *Physics of Plasmas (The American Institute of physics)*, Vol. 13, 2006, pp. 122310.

[94] G. P. Agarwal, *Nonlinear Fibre Optics 5.1.* Academic press, Boston, Massachusetts 1984.

[95] S. A. Akhmanov, V. A. Vyslolukh and A. S. Chirkin, *Phys. Lrsp.*, Vol. 29,1986, pp. 642.

[96] V. I. Bespalov and V. I. Talonov, “Filamentary Structure of Light Beams in Nonlinear Liquids,” *Journal of Experimental and Theoretical Physics Letters,* Vol. 3, 1966, pp. 307.

[97] **A.** NEOGI and S. Ghosh, *Journal of Physics Chew. Solids,* Vol. 53, No. 7, 1992, pp. 941-947.

[98] A. Yariv, *Optical Electronics***,** 3rd edition, 1988, pp. 395-40.

[99] O. Wada, “Femtosecond semiconductor-based optoelectronic devices for optical communication systems,” *Optics Quantum Electron*, Vol. 32, 2000, pp.453–471.

[100] D. A. B. Miller, “Dynamic nonlinear optics in semiconductors: physics and applications,” *Laser Focus*, Vol. 19, 1983, pp.61–69.

[101] S. Guha, P. K. Sen, Modulation instability of a laser beam in a piezoelectric semiconductor, *Journal of Applied Physics* , Vol. 50, 1979, pp.5330–5387.

[102] A. M. Fox, J. J. Baumberg, M. Dabbicco, B. Huttner and J. F. Ryan, “Squeezed light generation in semiconductors,” *Physical Review Letters (The American Physical Society)*, Vol. 74, 1995, pp. 1728 - 1739.

[103] G. M. Sehucan, AM Fox and JF Ryan, “Femtosecond quadrature - Squeezed light generation in CdSe at 1.55 m,” *Optics Letters*, Vol. 23, 1998, pp.712–716.

[104] Chr. Flytzanis, “Third-order optical susceptibilities in IV-IV and III–V semiconductors,” *Physics Letters A (Elsevier)*, Vol. 31, 1970, pp. 273 -274.

[105] J. F. Drake, P. K. Kaw, C. Lee, Y., G. Schmidt , C. S. Liu and M. N. Rosenbluth, “Parametric Instabilities of Electromagnetic Waves in Plasmas,” *Physics Fluids*, Vol. 17, 1974, pp. 778 -780.

[106] Md. Salimullah and T.Singh, *Journal of Physics Chemistry Solids*, Volume 43, 1982, pp. 1087 - 1089.

[107]B. Eliasson and P. K. Shukla, "Nonlinear Aspects of Quantum Plasma Physics: Nanoplasmonics and Nanostructures in Dense Plasmas," *Plasma and Fusion Research*, Vol. 4, 2009, pp. 032.

[108]Y. D. Jung, "Quantum-mechanical effects on electron–electron scattering in dense high-temperature plasmas," *Physics of Plasmas (The American institute of Physics)*, Vol. 8, 2001, pp. 3842.

[109]G. Manfredi and F. Haas, "Self-consistent fluid model for a quantum electron gas," *Physical Review B (The American Physical Society)*, Vol. 64, 2001, pp. 075316.

[110]W. Masood and B. Eliasson, "Electrostatic solitary waves in a quantum plasma with relativistically degenerate electrons," *Physics of Plasmas (The American institute of Physics)*, Vol. 18, 2011, pp. 034503.

[111]A. Abdikian and M. Bagheri, "Electrostatic waves in carbon nanotubes with an axial magnetic field," *Physics of Plasmas (The American institute of Physics)*, Vol. 20, 2013, pp. 102103.

[112]Y. T. Ma, S. H. Mao, and J. K. Xue, "Waves in a bounded quantum plasma with electron exchange-correlation effects," *Physics of Plasmas (The American institute of Physics)*, Vol. 18, 2011, pp. 102108.

[113]A. Abdikian, "The influence of external transverse magnetic field in propagation of electrostatic oscillations in single-walled carbon nanotube," *The European Physical Journal D*, Vol. 70, 2016, pp. 218.

[114] A. Abdikian and Z. Ehsan, "Propagation of electromagnetic waves in quantum plasmas magnetized slab," *Physics Letters A (Elsevier)*, p. in press, 2017.

[115] F. Haas, L. G. Garcia, J. Goedert, and G. Manfredi, "Quantum ionacoustic waves," *Physics of Plasmas (The American institute of Physics)*, Vol. 10, 2003, pp. 3858.

[116] Amar Kakad, Bharati kakad, Ajay Lotekar and G. S. Lakhina, "Role of ion thermal velocity in the formation and dynamics of electrostatic solitary waves in plasmas," *Physics of Plasmas (The American institute of Physics)*, Volume 26, 2019, pp. 042112.

[117] S. Ali, W. Moslem, P. Shukla, and R. Schlickeiser, "Linear and nonlinear ion-acoustic waves in an unmagnetized electron-positron-ion quantum plasma," *Physics of Plasmas (The American institute of Physics)*, Vol. 14, 2007, pp. 082307.

[118] A. Misra, P. Shukla, and C. Bhowmik, "Electron-acoustic solitary waves in dense quantum electron-ion plasmas," *Physics of Plasmas (The American institute of Physics)*, Vol. 14, 2007, pp. 082309.

[119] S. Mahmood and Q. Haque, "Nonlinear electrostatic waves in inhomogeneous dense dusty magnetoplasmas," *Physics Letters A (Elsevier)*, Vol. 374, 2010, pp. 872.

[120] P. K. Shukla, B. Dasgupta, and P. Sakanaka, "Nonlinear magneto hydrodynamics of electron–positron plasmas," *Physics Letters A (Elsevier)*, Vol. 269, 2000, pp. 144.

[121] S. Mahmood, A. Mushtaq, and H. Saleem, "Ion acoustic solitary wave in homogeneous magnetized electron-positron-ion plasmas," *New Journal of Physics*, Vol. 5, 2003, pp. 28.

[122] P. Shukla, B. Eliasson, and L. Stenflo, "Electromagnetic solitary pulses in a magnetized electron-positron plasma," *Physical Review E (The American Physical Society)*, Vol. 84, 2011, pp. 037401.

[123] M. Momeni, "Linear and nonlinear electromagnetic waves in a magnetized quantum electron-positron plasma," *International Journal of Modern Physics C*, Vol. 26, 2015, pp. 1550058.

[124] Rehman, Momin and M. Mishra, “Ion-acoustic Gardner Solitons in electron-positron-ion plasma with two-electron temperature distributions,” *Physics of Plasmas (The American institute of Physics),* Vol.23, 2016, pp.012302.

[125] S. Mahmood, N. Akhtar, and H. Ur-Rehman, "Acoustic solitons in magnetized quantum electron-positron plasmas," *Physica Scripta (IOP Science),* Vol. 83, 2011, pp. 035505.

[126] Hosen, B, Shah, M. G., Hossen, MdRasel and Mamun, A., “Relativistic Ion-Acoustic Solitary Waves in a Magnetized Pair Ion Dense Plasma with Nuclei of Heavy Elements,” *Plasma Physics Reports (Springer)*, Vol. 44. 2018, pp. 976-985.

[127] Iwamoto, S and Takahara, F., “Relativistic Outflow of Electron-Positron Pair Plasma from a Wien Equilibrium State,” *The Astrophysical Journal*, Vol. 565, 2002.

[128] Wang, Jianyong, Zeng, Ying, Liang, Zufeng, Xu, Yani and Zhang, Yuanxiang, “Ion acoustic quasi-soliton in an electron-positron-ion plasma with superthermal electrons and positrons,” *Open Physics*, Vol. 16, 2018, pp.563-567.

[129] F. Verheest and T. Cattaert, "Large amplitude solitary electromagnetic waves in electron-positron plasmas," *Physics of Plasmas (The American institute of Physics),* Vol. 11, 2004, pp.3078.

[130] I. Kourakis, A. EsfandyariKalejahi, M. Mehdipoor, and P. K. Shukla, "Modulated electrostatic modes in pair plasmas: Modulational stability profile and envelope excitations," *Physics of Plasmas (The American institute of Physics),* Vol. 13, 2006, pp.052117.

[131] A. EsfandyariKalejahi, I. Kourakis, M. Mehdipoor, and P. Shukla, "Electrostatic mode envelope excitations in e-p-i plasmas-application in warm pair ion plasmas with a small fraction of stationary ions," *Journal of Physics A: Mathematical and General,* Vol. 39, 2006, pp. 13817.

[132] A. EsfandyariKalejahi, I. Kourakis, and P. Shukla, "Oblique modulation of electrostatic modes and envelope excitations in pair-ion and electronpositron plasmas," *Physics of Plasmas (The American institute of Physics),* Vol. 13, 2006, pp. 122310.

[133] I. Kourakis, W. M. Moslem, U. M. Abdelsalam, R. Sabry, and P. K. Shukla, "Nonlinear dynamics of rotating multi-component pair plasmas and epi plasmas," *Plasma and Fusion Research,* Vol. 4, 2009, pp. 018.

[134] Q. Haque, S. Mahmood, and A. Mushtaq, "Nonlinear electrostatic drift waves in dense electron-positron-ion plasmas," *Physics of Plasmas (The American institute of Physics),* Vol. 15, 2008, pp. 082315.

BRIEF PROFILE OF THE RESEARCH SCHOLAR

Name – Neelam Rani

Research Scholar – J. C. Bose University of Sciences & Technology, YMCA, Faridabad

Registration No. - YMCAUST/PH-03/2011

Subject – Physics

Department – Department of Physics

Faculty of Sciences

Topic – "A Study of nonlinear waves in Semiconductor Quantum Plasma"

Supervisor - Dr. Manikant Yadav

Assistant Professor

Department of Physics

Faculty of Sciences

J. C. Bose University of Science & Technology, YMCA, Faridabad

Co Supervisor - Dr. Y. K. Mathur

Professor

Department of Physics

Faculty of Physical Sciences

PDM University, Bahadurgarh

LIST OF PUBLICATIONS OUT OF THESIS

List of Published Papers

S. No	**Title of the paper**	**Name of Journal where Published**	**No.**	**Volume & Issue**	**Years**	**Pages**
1.	The Study of Ultrasonic Waves in Piezoelectric Semiconductor in the Presence of Electric Field	Research India Publication	1	Volume 9, Issue 1	2014	59 – 64
2.	The Study of Acoustic waves in Semiconductor in Symmetric pair plasmas	International Journal of Electronics, Communication & Soft Computing Science and Engineering		Volume 3, Issue 6	2014	14 – 17
3.	Modulational Dispersion and Amplification in Semiconductor Plasma	American International Journal of Research in Sciences, Technology, Engineering & Mathematics		Volume 15-399	2015	272 – 276

S. No	Title of the paper	Name of Journal where Published	No.	Volume & Issue	Years	Pages
4.	Conventional methods of plasma Etching in semiconductor Manufacturing process	International Journal of Current Research		Volume 7, Issue 10	2015	22036 – 22040
5.	Interaction of Plasma Medium with electromagnetic Waves	International journal of Development Research		Volume 5, Issue 12	2015	6204 – 6208
6.	Propagation characteristics of nonlinear low frequency electrostatic modes in quantum plasma	International journal on Technical and Physical problems of Engineering (Scopus)	4	Volume 11, Issue 41	2019	16 – 21
7.	The Nonlinear waves in semiconductor quantum plasma for laser beam in a self - consistent plasma channel	Physics Letters A (Elsevier)		Volume 384,	2020	1- 7

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II. INTRODUCTION

2.1 NATURE OF PLASMA

In this thesis, we consider nonlinear wave interaction in semiconductor quantum plasma. In piezoelectric semiconductor, electrical and mechanical effects are coupled. Plasma is described as a fourth state of matter (the others being solid, liquid and gas) and contains approx. 99% of matter in the Universe in its state. It means that we live in 1% of the universe in which plasma does not occur naturally. As the temperature of a material is raised, its state changes from solid to liquid and then to gas. If the temperature is elevated further, an appreciable number of the gas atoms are ionized and become the high temperature gaseous state in which the charge numbers of ions and electrons are almost the same and charge neutrality is satisfied in a macroscopic scale.

The plasma is itself a state of matter in which charged particles such as electrons and atom nuclei has sufficiently high energy to move freely, rather than be bound in atoms as in ordinary matter. It is a form of an electrified gas with the atoms dissociated into positive ions and negative electrons. When the ions and electrons move collectively, these charged particles interact with Coulomb force which is a long range force and decays only in Inverse square of the distance r between the charged particles. The resultant current flows due to the motion of the charged particles and Lorentz interaction. Therefore many charged particles interact with each other by long range forces and various collective movements occur in the gaseous state.

The word *plasma* comes from the Greek and means *something molded.* It was applied for the first time by Tonks and Langmuir, in 1929, to describe the inner region, remote from the boundaries, of a glowing ionized gas produced by electric discharge in a tube, the ionized gas as a whole remaining electrically neutral. The word “plasma” is used in physics to designate the high temperature ionized gaseous state with charge neutrality and collective interaction between the charged particles and waves. Plasma can be produced by raising the temperature of a substance until a reasonably high fractional ionization is obtained. The fractional ionization: for ordinary gas at room temperature by Saha Equation is –

$$\frac{n_i}{n_n} \approx 10^{-122} \qquad \ldots (1)$$

Where n_i is density of ionized atoms and n_n is density of neutral atoms. As temperature increases then n_i/n_n rises abruptly, and the gas remains in a plasma state. Further increase in temperature makes n_n less than n_i, and the plasma becomes fully ionized. Therefore, plasmas exist in astronomical bodies with temperatures of millions of degrees, but not on the earth. They are not very common in laboratory.

Plasmas can also be generated by ionization processes that raise the degree of ionization much above its thermal equilibrium value. There are many different methods of creating plasmas in the laboratory and depending on the method; the plasma may have a high or low density, high or low temperature, it may be steady or transient, stable or unstable and so on.

The definition of Plasma – The term Plasma denotes quasineutral ionized gas. Plasma is a "quasineutral" gas of charged and neutral particles which exhibits "collective behavior". Quasineutrality means number of positive charges is equal to average of negative charges in sufficiently large volume and large time intervals. Collective behavior" means motions that depend not only on local conditions but on the state of the plasma in remote regions as well. Plasma is a special state of matter is a collective behavior of a system to electromagnetic perturbations. The words "collective behavior of a system" means perturbation of some physical quantity (charge density, electric field strength, magnetic field strength, the particle number density). This perturbation is described by the wavelength which is much greater than average distance between particles in plasma.

$$\lambda << n_0^{\frac{-1}{3}} \qquad \ldots (2)$$

In a gas of charged particles, plasmas, acoustic waves or any other type of waves appear by neutral particles where inter particle interactions.

Collective behavior: Consider the forces acting on a molecule of, say, ordinary air. Since the molecule is neutral, there is no net electromagnetic force on it, and the force of gravity is negligible. The molecule moves undisturbed until it makes a collision with another molecule, and these collisions control the particle's motion. A macroscopic force applied to a neutral gas, such as from a loudspeaker generating sound waves, is transmitted to the individual atoms by collisions. The situation is totally different in plasma, which has charged particles. As these charges move around, they can generate local concentrations of positive or negative charge, which give rise to electric fields. Motion of charges also generates currents, and hence magnetic fields. These fields affect the motion of other charged particles far away. Therefore, elements of plasma exert a force on one another even a large distance.

Plasma is described as an electrically – charged gas. In an ordinary gas each atom contains an equal number of positive and negative charges. A gas becomes plasma when the addition of heat or other energy causes the negatively charged electrons in the gas atoms to completely split off from the positively charged atomic nuclei (or ions). Those atoms and the resulting electrically charged gas are said to be "ionized." When enough atoms are ionized to significantly affect the electrical characteristics of the gas, it is plasma.

2.2 IDEA OF THE THESIS AND MOTIVATION FOR STUDY

The behaviors of nonlinear effects are easily observable in semiconductor plasma. Most of the electronic devices are built with semiconductor due to their compactness, provision of control of material relaxation time and highly advanced fabrication technology. Semiconductor devices are emerged as the most possible application of quantum plasma. The motivation for research on plasma in semiconductor is the practical applications in the modern computer and telecommunication industry. The reason for the rapid development and success in the semiconductor technology is due to the ongoing miniaturization of semiconductor devices.

In the microelectronics industry, the size of the element of integrated circuits is reducing every year. The microelectronics industry produces much miniaturized components with small characteristic length scale, like tunneling diodes, which have a length of only a few nanometers. In such components, quantum phenomena can't be negligible. The electron density in semiconductors is much lower than in metals, even though the miniaturization of electronic components made up of semiconductors is based on the fact that the de Broglie wavelength of charge carriers in these media can be made comparable, to the spatial variation of the doping profiles. Hence, it is now possible to simulate typical quantum effects in semiconductors, like resonant tunneling and negative differential resistivity by using QHD [1]. Recently, various quantum hydrodynamic (QHD) models were used in semiconductor simulations [2].

The plasma wave may be excited due to collective excitations of the carriers in the semiconductor; hence the field semiconductor plasma arises [3]. When electrons in the valence band of a semiconductor are excited to the conduction band by absorbing energy leaving behind vacant electron states called holes, the system can be considered as semiconductor plasma which satisfies the plasma conditions. For modern device physicists dealing with quantum wells, quantum wires, quantum dots, etc. the linear and nonlinear behaviors of waves and instabilities, through the carrier's dynamics in semiconductors, are crucially important. Recently, theoretical observations of nonlinear waves in a number of semiconductors, such as GaAs, GaSb, and GaN inspired us to study and investigate the characteristics of waves in semiconductor quantum plasma.

In quantum plasmas, the Collective interactions between an ensemble of degenerate electrons and positrons/holes give rise to novel waves and structures by Bohm and Pines in 1953 [4]. The basic concept of semiconductor quantum plasma is the de Broglie wavelengths of the plasma particles may be comparable to the Debye length or other scale lengths of the plasma by using magneto hydrodynamic (MHD) model for plasmas, have developed quantum hydrodynamic (QHD) model to study the quantum corrections in plasma characteristics by Haas [5], Manfredi [6] and M. Marklund, P.K. Shukla in 2006 [7]. Plasma-like collective behavior is well studied experimentally and theoretically in solid state physics by Kittel, in 1996, in which metals and semi-conductors support both transverse optical modes, and longitudinal electrostatic modes, such as plasmons and phonons on electron and ion time-scales [8].

Quantum effects also play crucial role in nonlinear processes in compact astrophysical objects, such as white-dwarfs, neutron stars and pulsars etc. Recently, the physicists dealing with theory have been attracted towards the quantum mechanical effects in semiconductor plasmas. Motivated by the above, author studied the quantum modifications through Bohm potential in nonlinear wave interaction in semiconductor plasmas and presented this interesting work in the thesis.

2.3 PLASMA IN SEMICONDUCTOR

The free electrons and holes in semiconductors constitute plasma. The concept of plasma in a solid is used to describe by collective response of quasineutral system consisting of free charge carrier of two signs and ionized impurity of two signs to electromagnetic perturbations. The main difference between the solid state plasma and liquid state plasma is that in solids motion of mobile charges of the plasma under action of external forces with condition of strong interaction with the field of atom and from the lattice and in liquids, in the presence of intense friction resulting from number of collisions with defects and vibrations of the crystalline lattice.

Semiconductor materials have electrons in the conduction band and holes in the valance band that move freely. The behavior of charge carriers in semiconductor crystalline structures is analogous to the behavior of particles in gas plasma. Since the plasma consists of free charge carriers it is a conductor of electricity, and interaction of particles in plasma is governed by the laws of electromagnetism and thermodynamics. Being a conductor of electricity, plasma is a reconfigurable medium with different conductor and dielectric properties. In the semiconductors, electrons and holes exhibit the same collective behavior as in gaseous plasmas and in the metals, electrons under certain condition exhibit the same collective behavior as in gaseous plasma. Thus many of the phenomena such as wave propagation, charge transport etc. which are investigated in gaseous plasmas can also be studied in semiconductors and metal plasmas. These investigations are important in behavior of solid state. These investigations are important from technical point of view because semiconductors have wide applications in field of electronic and optoelectronic device.

In this chapter, we will cover the applications of plasmas to etching and depositing materials, as well as novel processing modalities such as surface treatments in preparation for wafer bonding. All these processes rely on the inductively coupled plasma reactive ion etcher (ICP-RIE) used in the integrated electronics industry, which we will explain in detail.

III. RESEARCH OBJECTIVES

- To study the plasma etching in semiconductor industry and number of methods of etching.
- To measure the attenuation and velocity of propagating ultrasonic waves in GaN semiconductor is measured by electromechanical coupling coefficient χ.
- To analysis the propagation of the acoustic waves in semiconductor symmetric pair plasma.
- To analytical investigation of the modulational dispersion and amplification in n-type InSb semiconductor plasma.

IV. ORGANIZATION OF PROPOSED THESIS

4.1 INTRODUCTION

The thesis has been allocated with six chapters. The first chapter deals with the introduction of the nonlinear waves in semiconductor quantum plasma medium. Here authors also discussed and explained the quantum plasma medium and the QHD model used. We have also studied the plasma etching in semiconductor industry. There are number of methods of etching have discussed in this chapter. There are two basic methods of etching are –

1. Wet Etching
2. Dry Etching

We have also studied the quasineutrality, nonlinearity and Magnetic hydrodynamics in this chapter.

3.2 REVIEW OF LITERATURE

In chapter 2 we have studied the basic literature related to this topic. We have studied the number of research paper but some have discussed in this chapter.

The propagation of ultrasound is studied in bulk GaN semiconductor in the presence of a strong AC field oscillating at a frequency much higher than that of the ultrasound and analytical expressions have been obtained for the attenuation coefficient (α) by **S.Y. Mensah** etal. in 2005 [9].

The propagation of acoustic wave is studied in bulk GaN semiconductor in the presence of a slowly changing AC electric field and a constant electric field and analytical expressions have been obtained for the attenuation coefficient (α) and suggest use of this material as maser by N.G. Mensah in 2010 [10].

The parametric dispersion can be achieved by proper selection of doping level and pump field strength in semiconductor plasmas, parametric dispersion can be potential use in the study of squeezed states generation as well as in group velocity dispersion by M. Singh etal. in 2008 [11].

3.3 THE ULTRASONIC WAVES IN PIEZOELECTRIC SEMICONDUCTOR IN THE PRESENCE OF ELECTRIC FIELD

In chapter 3 we have made investigation of the ultrasonic waves in piezoelectric semiconductor in the presence of electric field. Ultrasonic waves are elastic waves consisting of frequencies greater than 20 kHz. When crystal is semiconducting the electric field produces current and space charge resulting in energy loss which clearly demonstrates the capabilities of ultrasonic methods in the study of physical properties of solid materials. In this study, measuring the attenuation and velocity of propagating ultrasonic waves is very important. Such measurements permit one to study the influence on the propagation behavior of any such property of solid that is sufficiently well coupled to lattice**.** For example 1. Electron-phonon interaction 2. Thermo-elastic or heating effect 3. Magneto-elastic loss effect in ferromagnetic material 4. Phonon-phonon interaction 5. Acoustoelectric effect, etc. In this chapter, we will study the interaction of acoustic signal with the strong electric field and electrons and holes drifting with the external field [9].

Ultrasound is generally defined as acoustic waves at frequencies larger than ~20 kHz. The upper limit corresponds to phonon frequencies at the edge of the Brillouin zone, which, in most crystalline solids, lies in the THz range. Over the years, steady progress toward generating higher and higher frequencies has been made. Nowadays, piezoelectric thin film resonators generating acoustic waves at frequencies of a few GHz are ubiquitous in wireless communication devices, and frequencies up to 20 GHz have been achieved with this technology.

The number of electronic device is built with semiconductors. In 1953, Parmenter predicted [12] that the acoustic effect occurs only in metal. In 1956, G. Weinreich predicted [13] that the acoustic effect is not present in semiconductors because charge carriers of only one sign. In 1956, again Holstein predicted [14] that the acoustic defect may be present in semiconductors but only for those semiconductors which have complicated band structure. In 1961, Hutson et al. Predicted [15] that when electric drift velocity exceeds that of sound velocity then amplification of the acoustic signal within the applied electric field.

More recent works are showing very interesting results [16 - 21]. We are, therefore, revisiting a paper written by Epshtein [22] on the propagation of ultrasound in semiconductors under the influence of a high-frequency electric field, elaborating on the calculations and applying the results on bulk gallium Nitride (GaN). In this chapter, we elaborate the calculations on the Gallium Nitride (GaN) semiconducting material in which large band gap and the propagation of ultrasound under the influence of electric field.

In this chapter we considered the Maxwell's electromagnetic field theory of electron sound wave interaction is applicable in which sound wave length is larger than electronic mean free path.

The propagation of sound waves in the semiconductor has describe the system of equations -

$$\frac{\partial^2 u}{\partial t^2} - \nu_o \frac{\partial^2 u}{\partial x^2} = \frac{\beta}{\rho}\frac{\partial E}{\partial x} \qquad \dots (3)$$

$$\varepsilon \frac{\partial E}{\partial x} - 4\pi\beta \frac{\partial^2 u}{\partial x^2} = 4\pi e(n - n_o) \qquad \dots (4)$$

$$\frac{\partial n}{\partial t} + \frac{\partial (n\nu)}{\partial x} = 0 \qquad \dots (5)$$

$$\frac{\partial \nu}{\partial t} + \nu \frac{\partial \nu}{\partial x} = \frac{e}{m}E - \frac{\nu}{\tau} - \frac{KT}{mn}\frac{\partial n}{\partial x} \qquad \dots (6)$$

where u is the sound wave displacement, **E** is the electric field, n is the electron concentration, n_o is its equilibrium value, v is the average electron velocity caused by the electric field and the sound wave, ν_o is the non-renormalized sound velocity, ρ is the crystal density, β is the piezoelectric constant and ε is the dielectric constant of the lattice.

In this chapter, we elaborate the calculations on the Gallium Nitride (GaN) semiconducting material in which large band gap and the propagation of ultrasound under the influence of electric field by the electromechanical coupling coefficient χ. The sound absorption coefficient and renormalization of sound velocity are affected with the roots of Bessel function $J_0^2(a)$ which can be used to determine mobility and effective mass of electron by high frequency electric field. The expression becomes equivalent to the absorption of sound in the absence of electric field when the high frequency field is switched off.

Using the parameters of Ridley [23], O'Clock, Duffy [24] and Shimada etal [25] for calculating the attenuation and velocity of propagating ultrasonic wave in GaN, the electromechanical coupling coefficient . It is cleared that under high frequency electric field, the sound absorption coefficient and renormalization of sound velocity are affected with the roots of Bessel function $J_0^2(a)$ which can be used to determine mobility and effective mass of electron.

The argument of Bessel function is $a = \frac{eE_0 k}{m\Omega^2} \frac{\Omega\tau}{\sqrt{1+\Omega^2\tau^2}}$

It can now be written as –

$a = \frac{\nu_d \omega_0}{\nu_0 \Omega} \frac{1}{\sqrt{1+\Omega^2\tau^2}}$, where $\nu_d = \frac{e\tau E_0}{m}$ is the drift velocity of electron oscillating under the influence of high frequency field. For $\Omega\tau \ll 1$ and $\omega_0 \ll \Omega$, a significantly from unity for $\nu_d \gg \nu_0$. Taking $a = \left(\frac{\nu_d}{\nu_0}\right)\left(\frac{\omega_0}{\Omega}\right)$ and $\nu_0 = \mu E$ and $\mu = e\tau/m$

Where a = 2040 is the first root of Bessel function, we calculated $\nu_d = 2.7 \times 10^7$ cm/s is agreement with experimental result in [26, 27] and $\mu = 1500$ cm^2/Vs is agreement with [28] by using E = 3.3 X10^2 V/cm $\omega_0/\Omega = 0.6$ and $\nu_0 = 5 \times 10^5$ cm.

We found the attenuation coefficient by using the dispersion relation is as –

$$\alpha = \frac{2I_m\omega}{\nu_0} = \frac{\chi \frac{\omega_a}{\nu_0} J_0^2(a)}{1+\left(\frac{\omega_a}{\omega_0}+\frac{\omega_0}{\omega_b}\right)^2} = \chi \frac{\omega_c}{\nu_0} J_0^2(a)\left\{1+\frac{\omega_a^2}{\omega_0^2}\left(1+\frac{\omega_0^2}{\omega_a\omega_b}\right)^2\right\}^{-1} \qquad \ldots (14)$$

For large values of the argument a, the Bessel function is the asymptotic value and give the expression for the absorption coefficient α which is periodic. For small value of the augment a, the sound absorption tends to zero. An ultrasonic wave traveling in certain directions in a piezoelectric semiconductor such as GaN can be amplified or attenuated by application of a dc electric field. The direct current flowing through the medium in the presence of an ultrasonic wave creates a traveling ac field which interacts with the ultrasonic wave. Amplification occurs when the drift velocity of the electrons exceeds the velocity of sound.

3.4 THE ACOUSTIC WAVES IN SEMICONDUCTOR SYMMETRIC PAIR PLASMAS

In chapter 4 we have considered the acoustic waves in semiconductor symmetric pair plasma. The pair plasmas have been an important challenge for many plasma physicists. Ordinary plasmas consist of electrons and positive ions, and the mass difference between negative- and positive-charged particles essentially causes temporal and spatial varieties of collective plasma phenomena. Symmetric pair plasmas are named plasmas of opposite charged species which have equal particle masses have been investigated experimentally. The pair plasmas, such as electron-positron plasma represent a new state of matter with unique thermodynamic property drastically different from ordinary plasmas in the relativistic/nonrelativistic regime.

Recently, Oohara and Hatakeyama [29 - 30] have developed a novel method for generation of pair plasma consisting of only negative and positive ions with equal mass by using positive and negative fullerene ions C^{+}_{60} and C^{-}_{60} as the ion source. The pair-ion plasma is expected to be used for the synthesis of dimers directly from carbon allotropes, as well as in nanotechnology. The pair-ion plasma is expected to be used for the synthesis of dimers directly from carbon allotropes, as well as in nanotechnology. The pair plasma plays a significant role in plasma physics due to numerous astrophysical environments such as the pulsar magnetosphere, active galactic nuclei, neutron stars etc., where intense energies create electron, positrons through pair production and annihilation.

Electron-hole plasmas ($e{-}h{+}$ plasmas) in pure semiconductors also are symmetric pair plasmas if effective masses of electrons and holes are equal. The difference between the electron and ion masses in ordinary electron-ion plasma gives rise to different time-space scales [31] which are used to simplify the analysis of low- and high-frequency modes. Such time-space parity disappears when studying a pure pair plasma which consisting of only positive- and negative-charged particles with an equal mass, because the mobility of the particles in the electromagnetic fields is the same. Begelman et al. in 1984 and Miller & Witta in 1987 play an important role in the physics of electron-positron plasmas of a number of astrophysical situations [32, 33]. Sturrock in 1971 and Michel in 1991 suggested that the creation of electron-positron plasma in pulsars is essentially by energetic collisions between particles which are accelerated as a result of electric and magnetic fields in such systems [34, 35 and 36].

We considered the situation in which the conditions is acoustic waves in a symmetric pair fullerene plasmas such as C^-_{60} and C^+_{60} with two kind of electrons system such as cold and hot in one-dimensional form is in fluid approximation is –

$$\frac{\partial N_1}{\partial t} + \frac{\partial}{\partial x}(N_1 U_1) = 0 \qquad \dots (15)$$

$$\frac{\partial U_1}{\partial t} + U_1 \frac{\partial U_1}{\partial x} = \frac{\partial V}{\partial x} \qquad \dots (16)$$

$$\frac{\partial N_2}{\partial t} + \frac{\partial}{\partial x}(N_2 U_2) = 0 \qquad \dots (17)$$

$$\frac{\partial U_2}{\partial t} + U_2 \frac{\partial U_2}{\partial x} = -\frac{\partial V}{\partial x} \qquad \dots (18)$$

$$\frac{\partial^2 V}{\partial x^2} = N_1 - (1 + a_1 + a_2)N_2 + a_1 e^{\gamma V} + a_2 e^{V} \qquad \dots (19)$$

Where, N_1 is the negative and N_2 is the positive fullerene number density normalized by its equilibrium value n_{10} and n_{20}, U_1 is the negative and U_2 is the positive fullerene fluid speed normalized by $c = (k_B T_2/m)^{1/2}$, V is the wave potential electrical field normalized by $k_B T_2/e$, m is the mass of the fullerene, e is the electronic charge, $\gamma = T_2/T_1$, T_1 is the temperature of hot and T_2 is the temperature of cold electrons, k_B is the Boltzmann constant, a_2 electrons cold and a_1 electrons hot number density normalized by n_{10}.

We derived the Korteweg-de Vries equation from (15) - (19) by employing the reductive perturbation technique and the stretched coordinates $\delta = \varepsilon^{1/2}(x - Mt)$ and $\Gamma = \varepsilon^{3/2} t$, where ε is a smallness parameter measuring the weakness of the dispersion. Where the nonlinear coefficient A and the dispersion coefficient B are given by –

$$A = \frac{1}{2M[2 + a_1 + a_2]}\left[3(1 + a_1 + a_2) - 3 - M^4(\gamma^2 a_1 + a_2)\right] \qquad \ldots (20)$$

$$B = \frac{M^3}{2(2 + a_1 + a_2)} \qquad \ldots (21)$$

Therefore, the solution of the Korteweg-de Vries equation is –

$$V^{(1)} = V_m \sec h^2\left(\frac{K}{\Delta}\right) \qquad \ldots (22)$$

Where V_m is the amplitude which is normalized by $k_B T_2/e$ and Δ is the width which is normalized by λ_D is given by –

$$\left.\begin{aligned} V_m &= \frac{3C_0}{A} \\ \Delta &= \sqrt{\frac{4B}{C_0}} \end{aligned}\right\} \qquad \ldots (23)$$

.

In this study we discussed the properties of collisionless Vlasov-Poisson model in the fluid approximation in context of pair plasmas. we have studied the acoustic-like modes in Symmetric pair plasmas, C^-_{60} and C^+_{60} plasmas having mass opposite charged fullerene is almost equal have cold and hot electrons. In symmetric pair plasmas, where both species have the same temperature, acoustic mode are impossible, but in that plasmas exists nonlinear amplitude modulation of electrostatic mode. These mode mixed higher harmonics with basic waves and can gives envelope solitons. In pure symmetric pair plasma the acoustic structures are absent.

It is clear that from equation (23) as C_0 increases, the width of the solitary wave's decreases. If A> 0 then it is clear that from equations (20), (22) and (23) the solitary potential profile is positive, and if A<0 then solitary potential profile is negative. It is clear that from equations (20), (21), (22) and (23) a number density of electrons a_1 and a_2 decreases then width Δ increases and amplitude V_m increases which means soliton wave disappear. It means that acoustic waves are absent in a pure symmetric pair plasma and acoustic waves are present only when impurity of electrons are added. In this chapter, we have found the nonlinear coefficient *A* and the dispersion coefficient *B*.

3.5 MODULATIONAL DISPERSION AND AMPLIFICATION IN SEMICONDUCTOR PLASMA

In chapter 5 we have made investigation of modulational dispersion and amplification in doped semiconductor plasma. The phenomenon of modulational instability in a semiconducting medium can be described in terms of electric polarization equations which are cubic function of electric field amplitude. The third order nonlinear susceptibility is in general a complex quantity and is capable of describing the interference between various resonant and non-resonant processes. The well-known instability of a plane wave in a self-focusing Kerr medium [37] is an example of transverse modulational instability. There are number of papers published in this area is that modulational instability of a propagating beams. [38-42]. Modulational instability refers to instability of a wave propagating in nonlinear dispersive media such that the steady state becomes unstable and evolves into a temporally modulated state [43]. The concept of transverse modulational instability originates from a space time analogy that exists when the dispersion is replaced by diffraction [44].

The transmission, display and processing of information is possible by modulation [45]. The fabrication of some optical devices, such as acousto-optic modulators, is based on the interaction of an acoustic wave or low-frequency electromagnetic waves with the incident laser beam. The propagation of the acoustic wave creates a refractive index grating, which in turn diffracts the incident laser beam resulting in the modulation of the incident beam. At small diffraction efficiencies the diffracted light intensity is proportional to the acoustic intensity. This fact is used in acoustic modulation of optical radiation. The information signal is used to modulate the intensity of the acoustic beam. This modulation is then transferred, as intensity modulation, onto the diffracted optical beam [46].The most important application of acousto-optic interactions is the deflection of optical beams. This can be achieved by changing the sound frequency while operating near the Bragg diffraction condition [46].

A Spatially uniform pump electric field is applied along the x-axis parallel to propagation Avector k and externally applied D.C. magnetic field B_o, is taken along the z-axis normal to E_o and k. A uniform pump electric field $\vec{E} = E_0 e^{-iwt}$ (pump vector k_0=0)

We considered the transverse modulational amplification in a magnetized piezoelectric semiconductor arising due to nonlinear effective susceptibility χ_{eff}, the hydrodynamic model of semiconductor plasma as –

$$\frac{\partial v_0}{\partial t} + v v_0 = -\frac{e}{m}\vec{E}_0(t) \qquad \ldots (24)$$

$$\frac{\partial v_1}{\partial t} + v v_1 = -\frac{e}{m}\vec{E}_1(t) - \left(v\frac{\partial}{\partial x}\right)v_1 \qquad \ldots (25)$$

$$\frac{\partial n_1}{\partial t} + n_e\frac{\partial v_1}{\partial x} = -v_0\left(\frac{\partial n_1}{\partial x}\right) \qquad \ldots (26)$$

$$\frac{\partial E_a}{\partial x} + \frac{\beta}{\varepsilon}\frac{\partial^2 u}{\partial x^2} = -\frac{n_1 e}{\varepsilon} \qquad \ldots (27)$$

$$\rho\frac{\partial^2 u}{\partial t^2} + 2\gamma\rho\frac{\partial u}{\partial t} + \beta\frac{\partial E_a}{\partial x} = C\frac{\partial^2 u}{\partial t^2} \qquad \ldots (28)$$

Eqs. (24) and (28) are the zeroeth- and first-order momentum transfer equations in which v_0 and v_1 are, respectively, the zeroeth and first-order oscillatory fluid velocities of the electron of effective mass m and charge e^-, ν being the electron collision frequency. The basic nonlinearity induced in the motion of the charge carriers is due to the convective derivative **(v. Δ).v** depends on the total intensity of illumination and the Lorentz force on the electrons in equation (25). Eq. (26) is the continuity equation, where n_0 and n_1 are the initial electron concentrations in the n-type-doped semiconductor and perturbed electron concentration, respectively. In Poisson's equation (27), $\mathbf{E_a}$ represents the perturbed electric field component and ε, and β are the dielectric constant and piezoelectric constant of the crystal material, respectively. Equation (28) describes the motion of the lattice in the piezoelectric crystal with ρ, u, γ and C being, respectively, the mass density of the crystal, displacement of the lattice, phenomenological damping parameter of acoustic mode and crystal elastic constant.

The effective nonlinear susceptibility of the semiconductor medium given as –

$$\chi_{eff} = \frac{2w_p^2 e^2 \varepsilon_1 A k^2 (\Delta^2 - \nu^2)\left(w_s^2 - k^2 v_s^2\right)}{m^2 \left\{\left(w_S^2 - k^2 v_S^2\right)^2 + 4w^2{}_s \gamma^2\right\}\left(w_0^2 - w_c^2\right)^2} \times \left[\left(\Delta^2 + \nu^2 - \frac{k^2 \vec{E}^2}{w_0^2}\right)^2 + \frac{4k^2 \Delta^2 \vec{E}^2}{w_0^2}\right]^{-1} \quad \ldots (29)$$

The modulational amplification coefficient α_{eff} in a doped semiconductor is –

$$\alpha_{eff} = \frac{k}{2\varepsilon_1} \chi_{eff} \left|E_0^2\right| \quad \ldots (30)$$

If α_{eff} is negative, then the nonlinear growth of the modulated signal is possible. Therefore, the nonlinear growth of the modulated signal is possible only if χ_{eff} is negative. This chapter deals with the analytical investigations of modulational dispersion and amplification in n-InSb semiconductor plasmas. The pump electric field produces a shift in the resonance frequency in induced polarization term and it plays an important role in the enhancement of both modulational dispersion and amplification.

The growth rate of modulated beam is –

$$g = \frac{w_p^2 e^2 \varepsilon_1 A k^3 (\Delta^2 - \nu^2)\left(w_s^2 - k^2 v_s^2\right) E_0^2}{m^2 \varepsilon_1 \left\{\left(w_S^2 - k^2 v_S^2\right)^2 + 4w^2{}_s \gamma^2\right\}\left(w_0^2 - w_c^2\right)^2} \times \left[\left(\Delta^2 + \nu^2 - \frac{k^2 \vec{E}^2}{w_0^2}\right)^2 + \frac{4k^2 \Delta^2 \vec{E}^2}{w_0^2}\right]^{-1} \quad \ldots (31)$$

The expression of the growth rate as obtained from equation (31) has usual nature as predicted by Drake et al. [47].

$$g \propto [ak^2 (b\left|E_0\right|^2 - ak^2)]^{1/2}$$

The gain constant g has dependence on the wave vector k has following –

(a) For lower magnitudes of k (such that $w_s >> kv_s$), g increases with k.

(b) For a non dispersive acoustic mode, at $w_s \sim kv_s$, g is maximum.

(c) At $W_s << kv_s$, then g shows a steep decline with increasing k.

It is cleared that from this paper the growth rate of the transversely modulated wave increases with a rise in electron density of the medium The nature of the curve is similar to the conclusions arrived at by Salimullah and Singh [48] who considered the modulational interaction of an extraordinary mode subjected to perturbations parallel to the magnetic field.

When the carrier concentration of the medium by n-type doping in the crystal is increases then higher amplification of the waves is obtained. It is condition that the doping should not exceed the limit for which the plasma frequency w_P exceeds the input pump frequency w_0, because, in the regime when $w_P > w_0$, the electromagnetic pump wave will be reflected back by the intervening medium.

The present chapter deals with the analytical investigations of modulational dispersion and amplification in n-InSb semiconductor plasmas. The pump electric field produces a shift in the resonance frequency in induced polarization term and it plays an important role in the enhancement of both modulational dispersion and amplification.

3.6 CONCLUSION

In chapter six, we have given the basic conclusion of study of nonlinear waves in semiconductor quantum Plasma.

Thus we have investigated the number of aspects of nonlinear wave interactions in semiconductor quantum plasma. We have used the number of different angles to solve this \problem. For example we have considered the ultrasonic waves in piezoelectric semiconductor in the presence of electric field. We have considered the acoustic waves in semiconductor symmetric pair plasmas and finally we looked at modulation dispersion and amplification in semiconductor plasma.

V. CONTRIBUTION

The nonlinear wave and plasma interaction has diverse applications in different fields such as nuclear fusion, particle acceleration, heating of ionospheric and laboratory plasmas by radio waves etc. along with controlled fusion applications to ITER (International Thermonuclear Experimental Reactor), frequency upshifting, resonance absorption, laser focusing and defocusing, material processing, generation of X-ray, THz and microwave radiations, higher order harmonic generation, laser filamentation etc. With the inclusion of plasma, the performance of some devices such as backward wave oscillator (BWO), travelling wave tube (TWT) amplifiers, gyrotrons and other microwave tubes have been found to increase.

- We studied the plasma etching in semiconductor industry and number of methods of etching. There are two basic methods of etching are –

1. Wet Etching - It is the oldest method of material removal still in use.
   (a) Sacrificial Layer deposition
   (b) Patterning of layer
   (c) Metal Deposition
   (d) Etch of sacrificial layer to free feature
2. Dry Etching - Dry Etching can be a physical or chemical process (or both)
   (a) Ion Beam Etch - a physical etch process
   (b) Gaseous chemical etch
   (c) Plasma enhanced etch
   (d) Reactive Ion Etch

- We have made investigation of the ultrasonic waves in piezoelectric semiconductor in the presence of electric field.

- We have considered the acoustic waves in semiconductor symmetric pair plasma.

- We have made investigation of modulational dispersion and amplification in doped semiconductor plasma.

VI. SCOPE FOR FURTHER WORK

Although, many theories are carried out on the semiconductor plasma system, there is still lot of scope for many other theories like quantum plasma. Future research can be carried out by the different ways.

8. We want Semiconductor miniaturization. This size demands not only dimensional accuracy on the scale of several atoms but also controllability of the etching side wall and selectivity to underlayers. To meet these demands, it is necessary to control the plasma parameters more accurately than ever before.

9. Different plasma techniques have different advantages that may be suitable for certain applications. Semiconductor plasma may have a wider range of applications.

10. In future, studies focused on reconfiguration schemes may be conducted for various antenna systems and ultra wide band structures.

11. There are number of new methods based on the Transverse Magnetic mode analysis for analyzing plasma wave interactions in semiconductor plasma structure.

12. Realization of such applications of semiconductor plasma requires studies on the generation and behavior of semiconductor plasma of different substrate materials. Each semiconductor substrate has different dielectric properties, and doping significantly changes the behavior of semiconductor materials. Also there are many semiconductor plasma generation techniques, optical excitation being one of them.

REFERENCES

[135] I. Gasser, P.A. Markowich, D. Schmidt, A. Unterreiter, Proceedings of the Workshop on Mathematical Problems in Semiconductor Physics, Rome 1995.

[136] C.L. Gardner, C. Ringhofer, *Transport Theory and Statistical Physics*, Vol. 29, 2000, pp. 563.

[3] S. Rehman, "linear and nonlinear quantum ion acoustic waves in a plasma with positive, negative ion and Fermi electron gas" *Physics of Plasma*, Vol. 17, 2010, pp. 062303.

[4] Bohm, D., and D. Pines, "A Collective Description of electron interactions; III. Coulomb interactions in a degenerate electron gas" *Physical Review*, Vol. 92, 1953, pp. 609-625.

[5] F. Haas, "Quantum Magnetohydrodynamics" *Physics of Plasmas*, Vol.12, 2005, pp. 062117.

[6] G. Manfredi, "How to model quantum plasmas" *Field Inst. Commun.*, Vol. 46, 2005, pp. 263 - 287.

[7] M. Marklund, P.K. Shukla, "Nonlinear collective effects in photon-photon and photon plasma interactions" *Reviews of Modern Physics*, Vol.78, 2006, pp.591.

[8] Kittel, C., Introduction to Solid State Physics, Seventh Edition (John Wiley & Sons, Inc., New York), 1996.

[9] S.Y. Mensah, N.G. Mensah, V.W. Elloh, G.K. Banini, "Propagation of ultrasonic waves in bulk gallium nitride (GaN) semiconductor in the presence of high-frequency electric field" *Physica E (Elsevier)* , Vol. 25, 2005, pp.500-506.

[10] N.G. Mensah, "Amplification of acoustic waves in GaN in the presence of slowly changing periodic electric field" *Condensed Matter Physics (Elsevier)*, 2010.

[11] M. Singh, P. Aghamkar, S.K. Bhaker "Parametric dispersion and amplification in semiconductor plasmas: Effects of carrier heating," *Optics & Laser Technology (Elsevier)*, Vol. 41, 2008 pp. 64-69.

[12] R. H. Parmenter "The acoustoelectric effect" *Phys. Rev. Lett.*, Vol. 113, 1959.

[13] G. Weinreich, "Acoustodynamics effects in semiconductors" *Physics Review Letter*, Vol. 104, 3211956.

[14] T. Holstein, *Westinghouse Reprt.*, Vol.60, 94698-3-M15, 1956.

[15] A.R. Hutson, J.H. Mcfee and D.L. White, "Ultrasonic Amplification in CdS," *Physics Review Letter*, issue 6, Vol. 7, 1961, pp.237 – 240.

[16] H.N. Spector, *Phys. Review A*, Vol. 134, 1964, 507.

[17] S.Y. Mensah, F.K.A. Allotey and N.G. Mensah, "Nonlinear acoustoelectric effect in a semiconductor super lattice," *Journal of Physics: Condensed Matter*, Vol. 12, 2000, 5225.
[18] S.Y. Mensah, F.K.A. Allotey, S.K. Adjepong, "Acoustoelectric effect in semiconductor superlattice," *Journal of Physics: Condensed Matter*, Vol. 6, 1994, pp. 6783 -6787.
[19] S.Y. Mensah, F.K.A. Allotey, S.K. Adjepong, N.G. Mensah, "Photostimulated attenuation of hypersound in Superlattices and Microstructure," *Superlattices Microstructure*, Vol. 22 (4), 1997, pp. 453 – 457.
[20] S.Y. Mensah, F.K.A. Allotey, N.G. Mensah and V.W. Elloh, "Laser Induced Amplification of Hypersound in Nondegenerate Semiconductor Superlattices," *Superlattices Microstructure*, Vol. 33, 2003, pp. 41 – 52.
[21] A. Govorov, A.V. Kalametseiv, M. Rotter, K.H. Hoffmann and N. Botkin, *Physics Review B*, Vol. 62, 2000, pp. 2659- 2668.
[22] E. M. Epshtein, Fiz. Tverd. Tela, 10 2945, 1960 [Sov. Phys. – Solid State, Vol. 10 2325, 1969].
[23] B. K. Ridley Quantum Processes in Semiconductors, Chap. 3, Clarendon Press, Oxford 1999, pp. 119.
[24] G. D. O'Clock and M. T. Duffy, Apply. Phys. Lett. 23, 1973, 55.
[25] K. Shimada, T. Sota and K. Suzuki. J. Appl. Phys. 84, 1998, 4951.
[26] D. K. Ferry, Physics Review B, 12, 1975, 2362.
[27] J.M. Bhaker , D. K. Ferry, D. D. Koleske and R. J.Shul, Journal of Applied Physics , 97,2005, 063705.
[28] S.Y. Mensah, N.G. Mensah and V.W. Elloh,etal. Physica E, 28, 2005, 500.
[29] Wataru Oohara and R. Hatakeyama, "Pair ion plasma generation using Fullerenes," *Physical Review Letter*, Vol. 91, 2003, 205005.
[30] W. Oohara, D. Date and R. Hatakeyama, "Electrostatic Waves in a Paired Fullerene – Ion Plsma," *Physics Review Letter*, Vol. 95, 2005, 175003.
[31] W. Misner, K.S. Thorne and J.A. Wheeler, "Gravitation," by W. H. Freeman Company, San Francisco, 1973.
[32] Mitchell C. Begelman, Roger D. Blandford and Martin J. Rees, "Theory of extra Galactic radio Sources," *Review of Modern Physics*, Vol. 56, 1984, Issue 2, pp. 255 - 270.

[33] H.R. Miller and P.J. Witta, *Active Galactic Nuclei (Springer),* Berlin, 1987, pp. 202-207.

[34] F. Curtis Michel, "Theory of pulsar Magnetospheres," *Review of Modern Physics*, Vol. 54, 1982, pp. 1-66.

[35] F. Curtis Michel, 1991, "Theory of Neutron Star Magnetospheres," *University of Chicago Press, Chicago. Press*, 1991, pp. 517.

[36] P. A. Sturrock, "A model of pulsars," *Astrophysical Journal*, Vol. 164, 1971, pp. 529 - 539.

[37] V. I. Bespalov and V. I. Talonov, *JETP Lett.*,Vol. 3, 1966, pp. 307.

[38] G. Sharma, S. Ghosh, Eur. Phys. J. D 11 2000, 301.

[39] P.K. Shukla, A.A. Mamun, Phys. Plasmas 11, 2004, 1233.

[40] S. Ghosh, N. Yadav, Acta Physica Polonica A 112, 2007, 29.

[41] N. Nimje, S. Dubey, S. Ghosh, Indian J. Phys. 84, 2010 ,1569.

[42] N. Nimje, S. Dubey, S. K. Ghosh, Eur. Phys. J. D 59, 2010, 265.

[43] G. P. Agarwal, *Nonlinear Fibre Optics 5.1.* Academic press, Boston, Massachusetts 1984.

[44] S. A. Akhmanov, V. A. Vyslolukh and A. S. Chirkin, *Phys. Lrsp.*, Vol. 29,1986, pp. 642.

[45] **A.** NEOGI and S. Ghosh, *Journal of Physics Chew. Solids*, Vol. 53, No. 7, 1992, pp. 941-947.

[46] A. Yariv, *Optical Electronics***,** 3rd edition, 1988, pp. 395-401.

[47] J. F. Drake, P. K. Kaw, C. Lee, Y., G. Schmidt , C. S. Liu and M. N. Rosenbluth , "Parametric Instabilities of Electromagnetic Waves in Plasmas," *Physics Fluids*, Vol. 17, 1974, pp. 778 -780.

[48] Md. Salimullah and T.Singh, *Journal of Physics Chemistry Solids*, Volume 43, 1982, pp. 1087 – 1089.

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I. INTRODUCTION

1.1 NATURE OF PLASMA

The aim of the thesis is to analyze the nonlinear wave interaction in semiconductor quantum plasma. Plasma is regarded as the fourth state of matter after solid, liquid and gas. It is an ionized gas which contains sufficient charged particles for the overall behavior of the system to be different from an ordinary gas. Plasma occurs naturally in many places such as in ionosphere and in the universe, 99% of the matter is in the form of plasma. It means that we live in 1% of the universe in which plasma does not occur naturally.

The definition of Plasma – The term Plasma denotes quasineutral ionized gas. Plasma is a "quasineutral" gas of charged and neutral particles which exhibits "collective behavior". Quasineutrality means number of positive charges is equal to average of negative charges in sufficiently large volume and large time intervals. Collective behavior" means motions that depend not only on local conditions but on the state of the plasma in remote regions as well. Plasma is a special state of matter is a collective behavior of a system to electromagnetic perturbations. The words "collective behavior of a system" means perturbation of some physical quantity (charge density, electric field strength, magnetic field strength, the particle number density). This perturbation is described by the wavelength which is much greater than average distance between particles in plasma.

$$\lambda << n_0^{\frac{-1}{3}} \qquad \dots (1.1)$$

In a gas of charged particles, plasmas, acoustic waves or any other type of waves appear by neutral particles where inter particle interactions.

Debye Shielding

The characteristic of the behavior of plasma is its ability to shield out electric potentials that are applied to it and Potential = KT/e [1].

The Debye length (λ_D) is a measure of the shielding distance or thickness of the sheath.

$$\lambda_D \equiv \left(\frac{\varepsilon_0 K T_e}{n e^2} \right)^{\frac{1}{2}} \qquad \ldots (1.3)$$

As the density is increased, λ_D decreases and λ_D increases with increasing KTe.

Quasineutrality: The Debye shielding analysis assumed that the plasma was initially neutral, i.e., that the initial electron and ion densities were equal. Consider initially neutral plasma with temperature T and calculate the largest radius sphere that could spontaneously become depleted of electrons due to thermal fluctuations. Let r_{max} be the radius of this presumed sphere. Complete depletion would occur if a random thermal fluctuation caused all the electrons originally in the sphere to vacate the volume of the sphere and move to its surface. The electrons would have to come to rest on the surface of the presumed sphere because if they did not, they would still have available kinetic energy, which could then be used to move out towards an even larger radius, violating the assumption that the sphere was the largest radius sphere that could become fully depleted of electrons [2]. This situation is extremely artificial electrons to be moving radially relative to some origin. In reality, the electrons would be moving in random directions.

1.2 SEMICONDUCTOR QUANTUM PLASMA

The free electrons and holes in semiconductors constitute plasma. Most of the electronic devices are built using semiconductors. The numbers of works have been extended into the study of charge transport in a semiconductor. Energy is exchanged between some external power supply and the internal electric field of the device. This field then accelerates the mobile charge carriers, the electrons and holes. Energy and momentum transfer between the field and these charges. As the charge carriers move though, they also interact with the media through which they move. This is usually modeled by having the charge carrier “emit” or “absorb” a phonon, a quanta of lattice vibrational energy. The heat energy stored in these phonons then flows out to a heat sink [3].

Quantum hydrodynamics (QHD) is a concept that was developed in by Madelung in 1926 [4, 5]. He transformed the Schrödinger equation for a single particle into the corresponding QHD equations. It was further developed by Bohm in 1953 [6, 7]. The motivation to name this field QHD is that by applying it one finds differential equations with a similar form to the well-known differential equations in classical hydrodynamics, like the continuity equation. Quantum hydrodynamics (QHD) have been a general method applicable to both pure and mixed states of quantum statistical systems widely used. The QHD equations are usually obtained by taking moments of the appropriate kinetic equation like, the Wigner function equation in analogy with the moments of the classical kinetic equation. This leads to the conservation laws for particle number, momentum and energy in terms of macroscopic variables by choosing some suitable closure scheme in an approximate way.

1.3 OBJECTIVES AND MOTIVATION

Objectives

- To study the interaction of nonlinear low frequency electrostatic modes in quantum plasma
- To calculate the attenuation and velocity of propagating ultrasonic waves in GaN semiconductor as measured by electromechanical coupling coefficient χ.
- To analyze the propagation of the acoustic waves in semiconductor symmetric pair plasma.
- An analytical investigation of the modulational dispersion and amplification in n-type InSb semiconductor plasma.
- To study the nonlinear wave in semiconductor quantum plasma for laser beam in a self consistent plasma channel.

Motivation

The motivation for research on plasma in semiconductor is the practical applications in the modern computer and telecommunication industry. The reason for the rapid development and success in the semiconductor technology is due to the ongoing miniaturization of semiconductor devices and the size of the element of integrated circuits is reducing every year. In such components, quantum phenomena can't be negligible. The electron density in semiconductors is much lower than in metals, even though the miniaturization of electronic components made up of semiconductors is based on the fact that the de Broglie wavelength of charge carriers in these media can be made comparable, to the spatial variation of the doping profiles. Hence, it is now possible to simulate typical quantum effects in semiconductors, like resonant tunneling and negative differential resistivity by using QHD [8]. Recently, various quantum hydrodynamic (QHD) models were used in semiconductor simulations [9].

1.4 PLAN OF THESIS

The thesis is composed of eight chapters, each of them dealing with different aspects of solving the problem. Chapter 1 is introductory and defines the nature of plasma. This chapter divided into two parts. Part 1 describes the nature of plasma and give conditions to satisfy the plasma. Part 2 deals with properties of semiconductor quantum plasma and the QHD model used.

The second chapter deals with literature review of nonlinear waves in semiconductor quantum plasma.

The third chapter deals with interaction of nonlinear low frequency electrostatic modes in quantum plasma. The electrons are degenerate and weakly correlated whereas ions are non-degenerate and strongly correlated. In this chapter, the dispersion relation have derived and shown the existence of shock wave in dissipation dominated due to ion-ion correlation in weakly nonlinear limit.

Motivated by the utility of nonlinear waves in semiconductor quantum plasma the author in chapter 4 has presented a detailed and systematic study of ultrasonic waves in piezoelectric semiconductor in the presence of electric field and measuring the attenuation and velocity of propagating ultrasonic waves. The propagation of sound in a high-frequency electric field in bulk GaN semiconductor has been studied in this chapter.

Chapter 5 deals with an attempt to investigate the effect of the acoustic waves in semiconductor symmetric pair plasmas. Symmetric pair plasmas, consisting of two species with opposite charge and equal masses is an exciting field. In pure symmetric pair plasma the acoustic structures are impossible and acoustic waves are possible only when impurity of electrons is added.

The phenomenon of modulational instability in a semiconducting medium can be described in terms of electric polarization equations which are cubic function of electric field amplitude. The third order nonlinear susceptibility is in general a complex quantity and is capable of describing the interference between various resonant and non-resonant processes. The third order susceptibility tensor can be conveniently used to explain the modulation process in a Kerr active medium. Therefore in chapter 6, has presented the characteristics as a result of quantum correction in semiconductor plasma medium.

The seventh chapter deals with nonlinear wave in semiconductor quantum plasma for laser beam in a self consistent plasma channel. In this research, investigating the distributed regimes laser beam on a self-made plasma channel. As the intensity of the laser beam increases, the effect of non-functional effect as well as the electrons is intended to discharge the transmutation of the medium electrical conductor. The disadvantage of numerical predictions is done for laser plasma interaction studies for common factors.

II. LITERATURE REVIEW

An attempt has been made to study the work existing in the literature regarding nonlinear waves in semiconducting quantum plasma.. It elaborates on methodology, procedures, designing and survey of data. To begin with the research has developed upon the theoretical report of research and different concepts of research. The propagation of nonlinear waves in quantum plasma using quantum hydrodynamic (QHD) has been a very important research topic because they have many physical systems, including many metals, semiconductors and superconductors. The propagation of ultrasound is studied in bulk GaN semiconductor in the presence of a strong AC field oscillating at a frequency much higher than that of the ultrasound and analytical expressions have been obtained for the attenuation coefficient (α) and the renormalized velocity (v) of the acoustic wave by **S.Y. Mensah** etal. in 2005 [10]. It is shown that the dependencies of the ultrasonic absorption coefficient of the conduction electrons and the renormalised sound velocity on the field amplitude and the sound frequency have an oscillatory character this can be used to determine the effective mass and mobility of the material.

The propagation of acoustic wave is studied in bulk GaN semiconductor in the presence of a slowly changing AC electric field and a constant electric field and analytical expressions have been obtained for the attenuation coefficient (α) and suggest use of this material as maser by **N.G. Mensah** in 2010 [11].

The parametric dispersion can be achieved by proper selection of doping level and pump field strength in semiconductor plasmas, parametric dispersion can be potential use in the study of squeezed states generation as well as in group velocity dispersion by **M. Singh** etal. in 2008 [12].

III. INTERACTION OF NONLINEAR LOW FREQUENCY ELECTROSTATICS MODES IN QUANTUM PLASMA

3.1 INTRODUCTION

In recent years, there has been rapidly growing interest in global properties of quantum plasma in field of modern sciences and technologies in compact of astrophysical objects, such as white-dwarfs, neutron stars and pulsars etc. Actually all plasmas are in some sense are quantum because it consists of charged particles as they obey the laws of quantum mechanics [13]. Although, the density of classical plasma increases or its temperature decreases, it can enter a region where quantum effect starts. Quantum plasmas are obtained in high density matter. Dense plasma can be described as the collective behavior of charged particle in which electrons are degenerate and weakly correlated whereas ions are non-degenerate and strongly correlated [14].

3.4 THEORETICAL FORMULATION

In order to study the weakly nonlinear low frequency electrostatic wave propagation characteristics we take the assumption for solve our problem.

The assumptions 1 and 3 determine highly dense quantum plasma system [(n_{eQ}, n_{SC} << n_{i0} << n_{iQ}]. Our assumptions are valid for a typical hydrogen plasma if plasma number density n_{i0} ~ (10^{28}-10^{32}) m^{-3} and $\phi = (T_i / T_e) = 1$.It means physical plasma system is highly dense, if ion coupling parameter $\Lambda_i >> 1$(strongly coupled) in which electrons form a degenerate quantum fluids with weak interactions whereas ions form a classical fluids with strong interactions.

3.5 NUMERICAL SOLUTION AND DISCUSSION

In order to get the existence of shock structure, it is necessary to apply the boundary condition on wave. The exact solution of KDVB is not possible because this equation is not exactly integral solution. A particular solution of KDVB is possible which exhibits only monotonic shock structure. Actually, a monotonic shock structure is possible only when dissipation dominates and oscillatory shock structure is possible only when dissipation is weak.

IV. THE ULTRASONIC WAVES IN PIEZOELECTRIC SEMICONDUCTOR IN THE PRESENCE OF ELECTRIC FIELD

4.1 INTRODUCTION

The number of electronic device is built with semiconductors. In 1953, Parmenter predicted [15] that the acoustic effect occurs only in metal. In 1956, G. Weinreich predicted [16] that the acoustic effect is not present in semiconductors because charge carriers of only one sign. In 1956, again Holstein predicted [17] that the acoustic defect may be present in semiconductors but only for those semiconductors which have complicated band structure. In 1961, Hutson et al. Predicted [18] that when electric drift velocity exceeds that of sound velocity then amplification of the acoustic signal within the applied electric field.

4.2 MATHEMATICAL FORMULATION

We following the approach in and consider the situation in which the conditions is $\Omega >> \omega_c \equiv \omega_p \tau$ and $\omega_p \tau << 1$ are fulfilled [69] (Ω is the ac frequency, ω_p is the electronic plasma frequency and τ is the average electronic relaxation time). This means that the electric field penetrates the semiconductor both for $\Omega\tau << 1$and for $\Omega\tau >> 1$ [19].

Here, Maxwell's electromagnetic field theory of electron sound wave interaction is applicable in which sound wave length is larger than electronic mean free path.

4.3 DISPERSION RELATION

We average eqns over the period of the high-frequency field. Since we are considering only waves with frequencies much smaller than the field frequency, it is sufficient to replace ν and u by their averages, and to retain only terms with p = 0 on the right sides of the equations.

4.4 RESULT AND DISCUSSION

In this chapter the attenuation and velocity of propagating ultrasonic waves in GaN semiconductor is measured by electromechanical coupling coefficient χ .

Using the parameters of Ridley [20], O'Clock, Duffy [21] and Shimada etal [22], for calculated the attenuation, velocity of propagating ultrasonic wave in GaN and the electromechanical coupling coefficient □. It is cleared that under high frequency electric field, the sound absorption coefficient and renormalization of sound velocity are affected with the roots of Bessel function $J_0^2(a)$ which can be used to determine mobility and effective mass of electron.

V. THE ACOUSTIC WAVES IN SEMICONDUCTOR SYMMETRIC PAIR PLASMAS

5.1 INTRODUCTION

The pair plasmas have been an important challenge for many plasma physicists. Symmetric pair plasmas are named plasmas of charged species which have equal particle masses. Electron-hole plasmas ($e{-}h{+}$ plasmas) in pure semiconductors also are symmetric pair plasmas if effective masses of electrons and holes are equal. The difference between the electron and ion masses in ordinary electron-ion plasma gives rise to different time-space scales [23] which are used to simplify the analysis of low- and high-frequency modes. Such time-space parity disappears when studying a pure pair plasma which consisting of only positive- and negative-charged particles with an equal mass, because the mobility of the particles in the electromagnetic fields is the same. Begelman et al. in 1984 and Miller & Witta in 1987 play an important role in the physics of electron-positron plasmas of a number of astrophysical situations [24, 25]. Sturrock in 1971 and Michel in 1991 suggested that the creation of electron-positron plasma in pulsars is essentially by energetic collisions between particles which are accelerated as a result of electric and magnetic fields in such systems [26, 27 and 28].

5.3 MATHEMATICAL FORMULATION

Consider the situation in which the conditions is acoustic waves in a symmetric pair fullerene plasmas such as C^{-}_{60} and C^{+}_{60} with two kind of electrons system such as cold and hot in one-dimensional form is in fluid approximation.

5.3 RESULT AND DISCUSSION

The analysis of propagation acoustic waves in solid state plasma has been a very important research topic. In this chapter, author studied the acoustic-like modes in Symmetric pair plasmas, C^{-}_{60} and C^{+}_{60} plasmas having mass opposite charged fullerene is almost equal have cold and hot electrons. The fullerenes are molecules containing 60 carbon atoms in a very regular geometric arrangement it is hoped that the present paper would be useful for explanation of the intriguing low and high frequency modes in pair plasma, which are out of the scope of the plasma fluid theory and the Boltzmann-Gibbs statistics. The nonlinear propagation in our fullerene pair plasmas with semiconductor the Korteweg-de Vries equation is derived. The steady state solution of Korteweg-de Vries equation is obtained.

VI. MODULATIONAL DISPERSION AND AMPLIFICATION IN SEMICONDUCTOR PLASMA

6.1 INTRODUCTION

Modulational instability refers to instability of a wave propagating in nonlinear dispersive media such that the steady state becomes unstable and evolves into a temporally modulated state [29]. The concept of transverse modulational instability originates from a space time analogy that exists when the dispersion is replaced by diffraction [30]. The well-known instability of a plane wave in a self-focusing Kerr medium [31] is an example of transverse modulational instability. There are number of papers published in this area is that modulational instability of a laser beam found in a piezoelectrically active semiconducting medium with a high dielectric constant.

6.4 THEORETICAL FORMULATION

In order to study the transverse modulational amplification in a magnetized piezoelectric semiconductor arising due to nonlinear effective susceptibility χ_{eff}, the hydrodynamic model of semiconductor plasma is considered. The momentum and energy exchange between these waves can be described by phase-matching condition: $\hbar w_o = hw_s + hw_a$. The phase-matching conditions enable one to consider $k_s + k_a = k$. We could neglect the nonuniforamility of the high-frequency electric field under the dipole approximation when the wavelength of the excited sound wave is very small compared to the scale length of the electromagnetic field variation [32].

6.5 RESULT AND DISCUSSION

The modulational amplification coefficient α_{eff} in a doped semiconductor is –

$$\alpha_{eff} = \frac{k}{2\varepsilon_1}\chi_{eff}\left|E_0^2\right| \qquad \dots (1)$$

If α_{eff} is negative, then the nonlinear growth of the modulated signal is possible. Therefore, the nonlinear growth of the modulated signal is possible only if χ_{eff} is negative. The pump electric field produces a shift in the resonance frequency in induced polarization term and it plays an important role in the enhancement of both modulational dispersion and amplification. Modulational Dispersion and Amplification in doped III–V Semiconductors like n-InSb crystal at 77 K duly irradiated by a nanosecond-pulsed 10.6 μm CO_2 laser. The magnitude of χ_{eff} can be increased considerably in a heavily doped medium by increasing the strength of the d.c. magnetic field.

VII. THE NONLINEAR WAVE IN SEMICONDUCTOR QUANTUM PLASMA FOR LASER BEAM IN A SELF-CONSISTENT PLASMA CHANNEL

7.1 INTRODUCTION

Recently the intensification of the laser beam is analyzed by the different reactions of magnetized [33, 34] and unmagnified plasma [35, 36] with regard to the non-inertial combustion of the nonlinear dielectric material. On the surveys we have made a self-generated plasma channel for serious gauge electromagnetic beam propulsion regimens. When an intense electromagnetic beam is multiplied through a plasma, its deep-minded driving force drives the plasma away from the high field, the beam is a wave guide that rarely pushes the density of the channel. The lower plasma density on the beam axis slows the phase velocity of the wave on-axis, imparting to the phase fronts a curvature that counters diffraction. This effect is also due to mass increases in the relativity of electrons and increases the intensity of plasma frequency reduction near the beam print. The laser beam is powerful enough, and the beam is self-stuck by a density subway or channel dug with enough to prevent the beam from diffracting it out in the plasma. As the intensity of the laser beam increases, the effect of non-functional effect as well as the electrons is intended to discharge the transmutation of the medium electrical conductor.

7.2 MATERIALS AND METHOD

In this section is concerned with a comprehensive investigation for propagation regimes of an intense short laser pulse in a self-created plasma channel. Various propagation regimes of electromagnetic wave are possible for various sets of parameters of the plasma and the beam; (a) The beam becomes focused, either immediately or after undergoing some expansion, before it reaches the critical surface m the plasma, the beam creates a self-sustaining channel along its own axis, and it penetrates into the plasma, to a density above the critical value. The depth of this bleaching of the plasma is limited. When the time scale of the order of we need to take into account the dynamics of the ions and to assume nonlinear re reaction forces increases and that the beam begins to defocus, (b) the beam becomes focused to a critical size and then expands rapidly, (c) The beam immediately undergoes defocusing. Based on WKB and paraxial ray theory, the steady state solution of an intense, Gaussian electromagnetic beam is studied for arbitrary large nonlinearity.

7.3 RESULTS AND DISCUSSION

As the intensity of the laser beam increases, the medium displays the neuromuscular electrical conductivity functioning as a result of the mass effectiveness of the effectiveness of the electrons as well as the intensity of the electrons .Based on Wentzel–Kramers–Brillouin and paraxial ray theory, the steady-state solution of an intense, Gaussian electromagnetic beam is studied. The differential equation of the distance with the beam width parameter is derived, including the relativistic effects of self-focusing (SF) and self-channeling ponder motive. Plasma propagation is a radial dynamical force, depending on the width of the beam and σ_p is greater plasma ratio frequency screws. Once the distribution regimes, the beam power beam width is obtained in plane and σ_p is a particular value characterized by standard deviation, oscillation, and diffusion regimes such as SF. The corresponding center parameters are intended for introduction of the plasma density curve, and the laser beam is spatially analyzed to the spatial plasma.

Performing this margin can lead to a long distance laser beam guide. The disadvantage of numerical predictions is done for laser plasma interaction studies for common factors.

VIII. CONCLUSION

8.1 CONCLUSION

Conclusions are drawn in chapter 8. The main aim of the thesis has been reached. Therefore, author has presented some important aspects of quantum term and effects on nonlinear mechanisms in semiconductor quantum plasma under different physical conditions. It can be concluded from the investigations made in the present thesis that the quantum effects are unavoidable in the case of fully degenerate quantum plasma considered as electrostatic modes. Inclusion of quantum correction term which uses statistical effects via the propagation equation becomes essential while dealing with intense short laser pulse in a self created plasma channel. Thus author hopes that this work shall be able to contribute to the understanding of the mechanism of interaction between nonlinear waves and semiconductor plasmas which may be useful for future generation of integrated circuits as well as for the fabrication of opto-electronic devices. It is also hoped that the reported characteristics may become useful as probe to study the properties of nano structured materials. The author recommends further modification in technology before any other uses are considered.

REFERENCES

[137] Francis F. Chen "Introduction to Plasma Physics and controlled Fusion," *Springer,* book, Second edition 1983.

[138] Robert O. Grondin, Samir M. El-Ghazaly and Stephen Goodnick, "A Review of Global Modeling of Charge Transport in Semiconductors and Full-Wave Electromagnetics," *IEEE Trans. on Microwave Theory Tech*., Vol. 47, 1999, pp. 817-829.

[139] Paul. M. Bellan. "Fundamentals of Plasma Physics" *Cambridge University Press*, 2006.

[140] E. Madelung, “Eine anschauliche Deutung der Gleichung von Schrödinger,” *The Science of Nature (Springer-Verlag),* Vol. 14, 1926, pp. 1004-1004.

[141] E. Madelung, “Quantentheorie in hydrodynamischer Form,” *The Science of Nature (Springer-Verlag),* Vol. 40, 1927, pp. 322-326.

[142] David Bohm, “A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variables. I,” Vol. 85, 1952, pp. 166.

[143] David Bohm, “A Suggested Interpretation of the Quantum Theory in Terms of "Hidden" Variables. II,” Vol. 85, 1952, pp. 180.

[144] I. Gasser, P.A. Markowich, D. Schmidt, A. Unterreiter, Proceedings of the Workshop on Mathematical Problems in Semiconductor Physics, Rome 1995.

[145] C.L. Gardner, C. Ringhofer, *Transport Theory and Statistical Physics*, Vol. 29, 2000, pp. 563.

[146] S.Y. Mensah, N.G. Mensah, V.W. Elloh, G.K. Banini, “Propagation of ultrasonic waves in bulk gallium nitride (GaN) semiconductor in the presence of high-frequency electric field” *Physica E (Elsevier)* , Vol. 25, 2005, pp.500-506.

[147] N.G. Mensah, “Amplification of acoustic waves in GaN in the presence of slowly changing periodic electric field” *Condensed Matter Physics (Elsevier)*, 2010.

[148] M. Singh, P. Aghamkar, S.K. Bhaker “Parametric dispersion and amplification in semiconductor plasmas: Effects of carrier heating,” *Optics & Laser Technology (Elsevier),* Vol. 41, 2008, pp. 64-69.

[149] A. Agrawal, N.Yadav and S.Ghosh “Diffusion induced modulational instability in semiconductor quantum plasma with strain dependent dielectric constant,” *IJESRT,* Vol. 6, 2017, pp. 381-389.

[150] P. K. Shukla and B. Eliasson “Colloquium: Nonlinear collective interactions in quantum plasmas with degenerate electron fluids,” *Reviews of modern physics (The American Physical Society),* Vol. 83, 2011, pp. 885 -909.

[151] R. H. Parmenter “The acoustoelectric effect,” *Physical Review Letters (The American Physical Society),* Vol. 113, 1959, pp. 102.

[152] G. Weinreich, “Acoustodynamics effects in semiconductors” *Physical Rev*iew *Lett*er *(The American Physical Society),* Vol. 104, 1956, pp. 321.

[153]T. Holstein, *Westinghouse Reprt.*, Vol.60, 94698-3-M15, 1956.

[154]A.R. Hutson, J.H. Mcfee and D.L. White, "Ultrasonic Amplification in CdS," *Physical Review Letters (The American Physical Society)*, Vol. 7, 1961, pp.237 – 240.

[155]V. L. Ginzburg, "Propagation of Electromagnetic Waves in Plasma," *GIFML Moscow*, 1960 (In Russian).

[156]B. K. Ridley, Quantum Processes in Semiconductors, Chapter 3, Clarendon Press, Oxford 1999, pp. 119.

[157]G. D. O' Clock and M. T. Duffy, "Acoustic surface wave properties of epitaxially grown aluminum nitride and gallium nitride on sapphire," *Apply. Phys. Lett.*, Vol. 23, 1973, pp.55-56.

[158]K. Shimada, T. Sota and K. Suzuki, "First principles study on electronic and elastic properties of BN, AIN and GaN," *Journal of Applied Physics (The American institute of Physics)*, Vol. 84, 1998, pp. 4951.

[159]W. Misner, K.S. Thorne and J.A. Wheeler, "Gravitation," by W. H. Freeman Company, San Francisco, 1973.

[160]Mitchell C. Begelman, Roger D. Blandford and Martin J. Rees, "Theory of extra Galactic radio Sources," *Review of Modern Physics (The American Physical Society)*, Vol. 56, 1984, pp. 255 - 270.

[161]H.R. Miller and P.J. Witta, *Active Galactic Nuclei (Springer)*, Berlin, 1987, pp. 202- 207.

[162]F. Curtis Michel, "Theory of pulsar Magnetospheres," *Review of Modern Physics (The American Physical Society)*, Vol. 54, 1982, pp. 1-66.

[163]F. Curtis Michel, 1991, "Theory of Neutron Star Magnetospheres," *University of Chicago Press, Chicago. Press*, 1991, pp. 517.

[164]P. A. Sturrock, "A model of pulsars," *Astrophysical Journal*, Vol. 164, 1971, pp. 529 -539.

[165]G. P. Agarwal, *Nonlinear Fibre Optics 5.1.* Academic press, Boston, Massachusetts 1984.

[166]S. A. Akhmanov, V. A. Vyslolukh and A. S. Chirkin, *Phys. Lrsp.*, Vol. 29,1986, pp. 642.

[167]V. I. Bespalov and V. I. Talonov, “Filamentary Structure of Light Beams in Nonlinear Liquids,” *Journal of Experimental and Theoretical Physics Letters,* Vol. 3, 1966, pp. 307.

[168]Chr. Flytzanis, “Third-order optical susceptibilities in IV-IV and III–V semiconductors,” *Physics Letters A (Elsevier),* Vol. 31, 1970, pp. 273 -274.

[169]A. Misra, P. Shukla, and C. Bhowmik, "Electron-acoustic solitary waves in dense quantum electron-ion plasmas," *Physics of Plasmas (The American institute of Physics),* Vol. 14, 2007, pp. 082309.

[170]S. Mahmood and Q. Haque, "Nonlinear electrostatic waves in inhomogeneous dense dusty magnetoplasmas," *Physics Letters A (Elsevier),* Vol. 374, 2010, pp. 872.

[171]P. K. Shukla, B. Dasgupta, and P. Sakanaka, "Nonlinear magneto hydrodynamics of electron–positron plasmas," *Physics Letters A (Elsevier),* Vol. 269, 2000, pp. 144.

[172]S. Mahmood, A. Mushtaq, and H. Saleem, "Ion acoustic solitary wave in homogeneous magnetized electron-positron-ion plasmas," *New Journal of Physics*, Vol. 5, 2003, pp. 28.