Physics Department

Faculty of Science

Ain Shams University

Study on Collective Behavior of Plasma Waves in Degenerate Plasma

A Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Physics

By

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Abstract

The present study concentrates on investigation of the collective behavior of surface plasma waves in degenerate plasma. It has been studied the effect of the different quantum effects (Fermi pressue, Bohm potential, and spin effect) on the excitation of the surface waves in quantum plasma under the influence of an external magnetic field. The effect of the previous quantum effects on the propagation of the electrostatic surface waves in electron-hole plasma has also been investigated.

The impact of the radical spin of electrons on the excitation of transverse electromagnetic surface waves in a magnetized quantum plasma is inspected. The quantum corrections arises from the Bohm potential and the magnetization energy of electrons due to their spins are taken into considration by employing a fluid formalism. Also, the excitation of electrostatic surface waves on a semi-bounded quantum plasma-vacuum interface parallel to an applied magnetic field with electron-hole degeneracy is investigated. The wave equations of the electrostatic potential and both of the perturbed electron and hole plasma densities have been solved analytically. The general dispersion relation of the surface modes is obtained.

It is found that the inclusion of the quantum effects give rise to the excitation of possible surface modes. The phase and group velocities of the surface plasma waves are increased due to the inclusion of the different quantum effects in both electromagnetic and electrostatic cases. Also, it has been found that the density ratio of hole-electron plasma plays an essential role on the

dispersion of the modes along the wavenumber in addition to the effect of the quantum effects and the magnetic field.

The previous results can be used to improve the efficiency of data transfer in the computer chips which based on the performance of the semiconductors. Data can be transferred on the surface by the surface waves without suffering diffraction. Also, the velocity of data transfer process can be increased by increasing the hole-electron density ratio.

Key words

Quantum plasma, quantum effects, Bohm potential, surface plasma wave (SPW), quantum magneto-hydrodynamic model (QMHD), spin quantum plasma, electron-hole plasma.

Chapter (1)

Introduction

The word plasma is a Greek word means moldable substance or jelly. The first one who used the term plasma to describe an ionized gas was Irving Langmuir in 1927. He was awaken to the way blood plasma carries white and red pellets by the way an electrified fluid carries ions and electrons. Langmuir, with Lewi Tonks in the main time, was researching the chemistry and physics of tungsten-filament light-bulbs, trying to find a way to extend its lifetime. He notice that certain regions of a plasma discharge tube displays periodic variations of the density of the electron, which we term Langmuir waves nowadays. This was the origin of the Plasma Physics. Nowadays, Langmuir's research forming the theoretical basis of most techniques of plasma processing for the fabrication integrated circuits (Fitzpatrick 2014).

Plasma is sometimes referred to as "the fourth state of matter". It is a gas that the atoms in it have been broken up into free negative electrons and positive ions, atoms that have lost electrons and become positively charged.

Of course, not any ionized gas can be referred to as a plasma; in any gas there is always some small degree of ionization. We can define the plasma as *"a quasi-neutral gas of charged and neutral particles which exhibits collective behavior"*. As the Quasi-neutrality means that if the dimension

L of the system is much larger than the Debye length λ_D, then whenever external potential is introduced into the system or local concentrations of charge arise, these are shielded out in a distance that is short compared with the dimension of the system L, leaving the bulk of the ionized gas free of large fields or electric potentials. And Collective behavior means that as the charged particles move, they can produce local concentrations of negative or positive charge, which rise the electric fields. Also, movement of charges produces currents, so magnetic fields. These fields, far away, effect on the movement of other charged particles (Chen and Von Goeler 2008).

1.1. Classical and Quantum Plasmas

Fluids are intense that we can ignore the movement of individual molecules. Furthermore, only single particle tracks are considerable in very low-density devices; collective effects becomes unimportant. Plasma, on the other hand, behaves sometimes like a collection of individual particles and in another times as fluids. Generally, a plasma is understood as a many-body system consists of a large number of charged particles, while its behavior is controlled by collective effects that are arranged by the electromagnetic force.

The temperature is an essential parameter of plasma. Our early universe was formed a 100% of plasma. According to Big Bang theory, the temperature was high enough that no molecules or atoms could have existed, but only the fully