Papers’ Titles and Authors

Dynamics of Electrons in Free Electron Laser with Square Core Waveguides
Farkhondeh Allahverdi, Amir Hossein Ahmadkhan Kordbacheh, and Farideh Allahverdi

Optical and Thermal Properties of Mixed Alkali Phosphate Based Glasses
Samira Vafaei and Mohammad Hossein Hekmatshoar

Taghi Mohsenpour, Hasan Ehsani Amri, and Zahra Norouzi

An Analytical Model for Rare Earth Doped Fiber Lasers Consisting of High Reflectivity Mirrors
Fatemeh Kazemizadeh, Rasoul Malekfar, and Fatemeh Shahshahani

Photonic Crystal-Based Polarization Converter for Optical Communication Applications
Mahmoud Nikoufard and Mohsen Hatami

Linear and Nonlinear Dust Acoustic Waves in Quantum Dusty Electron-Positron-Ion Plasma
Elham Emadi and Hossein Zahed

Analysis of Protein Concentration Based on Photonic Crystal Ring Resonator
Savarimuthu Robinson and Krishnan Vijaya Shanthi

Pages

69-79
81-90
91-100
101-110
111-116
117-122
123-130


International Journal of Optics and Photonics (IJOP)

ISSN: 1735-8590

EDITOR-IN-CHIEF: Habib Tajalli
University of Tabriz, Tabriz, Iran

ASSOCIATE EDITOR: Nosrat Granpayeh
K.N. Toosi University of Technology, Tehran, Iran

International Journal of Optics and Photonics (IJOP) is an open access journal published by the Optics and Photonics Society of Iran (OPSI). It is published online semiannually and its language is English. All publication expenses are paid by OPSI, hence the publication of paper in IJOP is free of charge.

For information on joining the OPSI and submitting papers, please visit http://www.ijop.ir, http://www.opsi.ir, or contact the society secretarial office via info@opsi.ir.

All correspondence and communication for Journal should be directed to:

IJOP Editorial Office
Optics and Photonics Society of Iran (OPSI)
Tehran, 1464675945, Iran
Phone: (+98) 21-44292731
Fax: (+98) 21-44255936
Email: info@ijop.ir

EDITORIAL BOARD

Mohammad Agha-Bolorizadeh
Kerman University of Technology Graduate Studies, Kerman, Iran

Reza Faraji-Dana
University of Tehran, Tehran, Iran

Hamid Latifi
Shahid Beheshti University, Tehran, Iran

Luigi Lugiato
University of Insubria, Como, Italy

Mohammad Kazem Moravvej-Farshi
Tarbiat Modares University, Tehran, Iran

Mahmood Soltanolkotabi
University of Isfahan, Isfahan, Iran

Abdonnaser, Zakery
Shiraz University, Shiraz, Iran

Muhammad Suhail Zubairy
Texas A & M University, TX, USA

ADVISORY COMMITTEE

Masud Mansuripur
University of Arizona, AZ, USA

Jean Michel Nunzi
University of Angers, Angers, France

Gang Ding Peng
University of N.S.W., Sydney, Australia

Nasser N. Peyghambarian
University of Arizona, AZ, USA

Jawad A. Salehi
Sharif University of Technology, Tehran Iran

Surendra Pal Singh
University of Arkansas, AR, USA
Linear and Nonlinear Dust Acoustic Waves in Quantum Dusty Electron-Positron-Ion Plasma

Elham Emadi and Hossein Zahed

Department of physics, Sahand University of Technology, Tabriz, Iran
Corresponding Author Email: zahed@sut.ac.ir

ABSTRACT— The behavior of linear and nonlinear dust acoustic waves (DAWs) in an unmagnetized plasma including inertialess electrons and positrons, ions, and mobile positive/negative dust grains are studied. Reductive perturbation method is employed for small and finite amplitude DAWs. To investigate the solitary waves, the Korteweg–de Vries (KdV) equation is derived and the solution is presented. By numerical analysis, it is found that the soliton structure of the dust acoustic wave depends upon plasma parameters like electron to ion Fermi temperature ratio, , dust to ion temperature ratio and quantum diffraction parameter H.

KEYWORDS: Quantum dusty plasma, Dust acoustic waves, Reductive perturbation method, soliton structure.

I. INTRODUCTION

Plasmas are generally associated with a hot gas of charged particles which behave classically. However, when the temperature is lowered and/or the density is increased sufficiently, the plasma particles (most importantly, electrons) become quantum degenerate, that is, the extension of their wave functions becomes comparable to the distance between neighboring particles. This is the case in many astrophysical plasma, such as those occurring in the interior of giant planets or dwarf and neutron stars, but also in various modern laboratory setups where charged particles are compressed by very intense ion or laser beams to multi megabar pressures. Finally, the exotic state of the Universe immediately after the Big Bang is believed to have been a quantum plasma consisting of electrons, quarks, photons, and gluons [1, 2]. The known mathematical methods such as Schrodinger–Poisson and Wigner-Poisson were widely used for description of hydrodynamic and statistical behaviors of plasma particles in quantum ranges. It is obvious that these methods are similar to the fluid and kinetic models of classical plasma physics. Quantum hydrodynamics (fluid) is generalizations of classical plasma fluid model, within transport equations is used in conservation laws for particles, momentum and energy. Quantum hydrodynamic model (QHD) is a reduced model that allows direct investigation of collective dynamics without challenging of complexities in Schrodinger–Poisson and Wigner-Poisson models. Using the standard definition of averaging macroscopic quantities, both Schrodinger–Poisson and Wigner-Poisson models can be lead to the QHD equations and also these methods create the same results [3]. Dust impurities exist in the quantum plasma, forming a quantum dusty plasma, for instance, microelectronic devices and metallic nanostructures are usually contaminated by the presence of highly charged dust impurities. These also appear in astrophysics (e.g. supernova environments) and are likely to be found in ultra intense laser-solid material plasma (clusters) interaction experiments [4]. There has been a number of works focusing on the linear or nonlinear properties of low-frequency DA waves in magnetized or unmagnetized plasmas. Shukla and Ali derived a linear dispersion relation for quantum dust
acoustic waves by using QHD model, and then obtained solitary wave solutions through the derivation of KdV equation in ultra-cold Fermi dusty plasmas [5, 6]. Misra et al. [7] studied the same system quantum dusty plasma considered in [5], to see the influence of quantum-mechanical effects on the modulation instability and envelope solitons by deriving the nonlinear Schrodinger NLS equation employing the well known reductive perturbation technique. They found that quantum mechanical effects affect both the dispersion and nonlinearity. Many researchers observed dust acoustic solitary waves with negatively charged dust grains. But positively charged dust grains are also observed in space due to Photo emission in the presence of flux of ultra-violate photons, thermionic emission induced by radiative heating, and secondary emission of electrons from the surface of dust grains [8]. Most of the theoretical studies are based on deriving Korteweg-deVries (KdV) and Kadomstev-Petviashvili (KP) equations by using reductive perturbation technique [9-11]. these techniques are valid for small amplitude solitary waves. In this paper the quantum hydrodynamic model is employed to study the linear and nonlinear structure of dust acoustic solitons in quantum dusty plasmas consisting of inertialess electrons and positrons, ions, and negatively/positively charged dust particles. The manuscript is organized as follows: In Section II the basic equations for DIA solitons in a four component quantum plasma are presented. In Section III the linear behavior of DIA solitons are investigated. In Section IV, a Kdv equation is derived for nonlinear structure. The results are summarized in Section V.

**II. Basic Equations**

We consider an unmagnetized plasma composed of inertialess quantum electrons and positrons, ions, and positively/negatively charged dust grains and then assume that the plasma particles in a zero-temperature Fermi gas obey the pressure law

\[ p_j = \frac{m_j v_j^2}{3 n_{j0}} n_j^3 \]

where \( V_j = \sqrt{\frac{2 k_B T_j}{m_j}} \) is Fermi speed and \( n_{j0} \) is the equilibrium number density of the \( j \)th species \((j = e, i, p, d)\). Plasma components neutrality condition is \( \beta - p = -e + I \) where \( \beta = \pm 1 \) (+1 for negative and -1 for positive dusts),

\[
p = \frac{n_{pe}}{Z_{d0} n_{d0}}, \quad e = \frac{n_{po}}{Z_{d0} n_{d0}}, \quad I = \frac{n_{io}}{Z_{d0} n_{d0}}.
\]

The dynamic of DAWs is governed by following normalized QHD model:

\[
\frac{\partial n_d}{\partial t} + \frac{\partial (n_d u_d)}{\partial x} = 0 \tag{1}
\]

\[
\frac{\partial^2 \phi}{\partial x^2} = -\mu (\beta - I) n_e + \beta n_d - \ln_j - (1 - \mu)(\beta - I)n_p \tag{2}
\]

\[
\frac{\partial u_d}{\partial t} + u_d \frac{\partial u_d}{\partial x} = \beta \frac{\partial \phi}{\partial x} - \frac{\partial n_d}{\partial x} \frac{\partial n_d}{\partial x} \tag{3}
\]

\[
-\frac{\partial \phi}{\partial x} - n_i \frac{\partial n_i}{\partial x} = 0 \tag{4}
\]

\[
\frac{\partial \phi}{\partial x} - \sigma n_e \frac{\partial n_e}{\partial x} + \frac{H^2}{2} \frac{\partial}{\partial x} \left( \frac{1}{\sqrt{n_e}} \frac{\partial^2 \sqrt{n_e}}{\partial x^2} \right) \tag{5}
\]

\[
\frac{\partial \phi}{\partial x} + \gamma n_p \frac{\partial n_p}{\partial x} - \frac{H^2}{2} \frac{\partial}{\partial x} \left( \frac{1}{\sqrt{n_p}} \frac{\partial^2 \sqrt{n_p}}{\partial x^2} \right) \tag{6}
\]

The normalization has been made by the following non-dimensional variables: \( t \rightarrow t \omega_{pd} \), \( x \rightarrow x / \lambda_D \), \( u_j \rightarrow u_j / C_d \), \( n_j \rightarrow n_j / n_{j0} \), \( \phi \rightarrow e \phi / 2 k_B T_F \), where \( \omega_{pd} = \sqrt{4 \pi Z_{d0}^2 e^2 n_{d0} / m_d} \) is the dust plasma frequency, \( \lambda_D = \sqrt{2 k_B T_F / 4 \pi Z_{d0}^2 e^2 n_{d0}} \) and \( C_d = \sqrt{2 Z_{d0} k_B T_F / m_d} \) is Debye length and dust acoustic speed. Further, \( \mu = 1 - p / (\beta - i) \), \( \gamma = T_F / T_{Fi} \), \( \sigma = T_{Fe} / T_{Fi} \), \( \delta = T_{Fd} / (Z_{d0} T_{Fi}) \) and \( H = \sqrt{\frac{\hbar^2 Z_{d0} \omega_{pd}^2}{m_e m_p C_d^2}} \) are dimensionless quantum parameters [11].
III. LINEAR DAWs–DISPERSION RELATION

To study the properties of linear DAWs, Fourier transforming the first order perturbed quantities of the Eqs. 1-6, we obtain the dispersion relation for DAWs in form of

$$\omega^2 = k^2\left(\gamma + \frac{H^2}{4}k^2\right) + \left(\gamma + \frac{H^2}{4}k^2\right)[k^2 + I] + k^2[-\mu(\beta - I) + (1 - \mu)(\beta - I)]$$

(7)

Note that, we assume the Fermi temperatures of electrons and positrons to be equal ($\sigma = \gamma$). In Fig. 1 the dispersion relation of DAWs is plotted for plasma consisting of positive or negative dust particles. It is shown that despite similar behaviors, in the small wavelength regime, the phase velocity in plasma with positive dust grains is greater than negative one. But in very small and large wavelength regime, both dispersion relation curves are coincident and phase velocity are equal.

Fig. 1 Dispersion relation of linear DAWs for negative ($\beta = +1$) and positive ($\beta = -1$) dust grains for small amount of k, with fixed values $u_0 = 1$, $\sigma = \gamma = 20$, $\delta = 0.005$, $\mu_+ = 1.63$, $\mu_- = 0.13$, $I = 1.18$, $H = 0.61$.

Figure 2 shows the plot of frequency versus $\sigma$, $\delta$, $H$, and $I$. It indicates that increasing of electron to ion Fermi temperature ratio $\sigma$ and quantum diffraction parameter $H$, can be lead to the increasing in frequency for plasma with negative dust grains and vice versa for positive one.

Increasing of dust to ion temperature ratio $\delta$ can be leads to the faster increasing of frequency, while increasing of ion to dust initially density ratio I, can be leads to the
faster decreasing of frequency for plasma with negative dust grains.

IV. THE NONLINEAR DAWS LIMIT AND SMALL AMPLITUDE

We employ the reductive perturbation method to Eqs. 1-6 to obtain the nonlinear Korteweg devries (KdV) equation for one-dimensional DAWs. For this purpose, plasma parameters can be expanded in powers of \( \epsilon \) as [12]

\[
\begin{align*}
    n_j &= 1 + \epsilon n_{j_1} + \epsilon^2 n_{j_2} + \ldots \\
u_j &= \epsilon u_{j_1} + \epsilon^2 u_{j_2} + \ldots \\
\phi &= \epsilon \phi_1 + \epsilon^2 \phi_2 \\
\end{align*}
\]

with the coefficients

\[
A_1 = \frac{-2 \beta^2 \lambda}{(\lambda^2 - \delta)^2}
\]

\[
A_2 = \left[ \frac{\mu (\beta - I)}{\sigma^2} + I + \frac{(1-\mu)(\beta - I)}{\gamma} + \left( \frac{3 \lambda^2 \beta^3 + \delta \beta^2}{\lambda^2 - \delta} \right) \right]
\]

\[
A_3 = \left[ \frac{-\mu (\beta - I) H^2}{4 \sigma^2} + \frac{(1-\mu)(\beta - I) H^2}{4 \gamma^2} - 1 \right]
\]

collecting the various order terms of \( \epsilon \), we obtain a KdV equations

\[
A_1 \frac{\partial \varphi_1}{\partial \tau} + A_2 \varphi_1 \frac{\partial \varphi_1}{\partial \xi} + A_3 \frac{\partial^3 \varphi_1}{\partial \xi^3} = 0
\]

We also introduce the following independent variables scaled as \( \xi = \sqrt{\epsilon} (x - \lambda) \) and \( \tau = \sqrt{\epsilon} t \). Substituting Eq. 8 into Eqs. 1-6 and}

![Fig. 3. Electrostatic potential in terms of \( \eta \) for positive (a) and negative (b) charge of dust grains for different value of \( u_0 \) with fixed values \( \sigma = 20 \), \( \delta = 0.005 \), \( \mu_+ = 1.63 \), \( \mu_- = 0.13 \), \( I = 1.18 \), \( H = 0.61 \).](image)

![Fig. 4. Plot of electrostatic potential in terms of \( \eta \) for positive (a) and negative (b) charge of dust grains for different value of \( \delta \).](image)
By imposing boundary conditions \( \varphi_1 \to 0 \), \( \partial \varphi / \partial \xi \to 0 \), \( \partial^2 \varphi / \partial x^2 \to 0 \) at \( \xi \to \pm \infty \), the possible stationary solution of Eq. 9 is

\[
\varphi_1 = \varphi_0 \sec \left( \eta / \Delta \right) \cdot \frac{3A_1 u_0}{A_2}
\]

where \( \Delta = \sqrt{A_1 / A_0} \). Figures 3-5 show the variation of the electrostatic potential \( \varphi_1 \) as a function of \( \eta \). It is noted that the nonlinear DAW is associated with a negative (positive) potential, which is due to the presence of negative (positive) charged dust grains in an ultracold Fermi gas.

Fig. 4 indicates that increasing in speed \( u_0 \) can leads to the increasing the amplitude of electrostatic potential In both quantum dusty plasma with negative or positive dust grains. Figs. 4 and 5 show that decreasing in \( \delta \) and \( \sigma \) increase the amplitude of electrostatic potential. In Fig. 6, we could observe that quantum diffraction correction does not affect the amplitude of positive or negative potential, while increasing in \( H \), decreases (increase) the width of electrostatic potential in quantum dusty plasma with positive (negative) dust grains.

**V. CONCLUSION**

In this paper by using the quantum hydrodynamics model (QHD), the properties of linear and nonlinear DAWs are investigated. For nonlinear DAWs with small amplitude, reductive perturbation method is applied. It is shown that for linear DAWs, in the small wavelength regime, the dispersion relation gradient (phase velocity) of plasma including positive dust grains is greater than the plasma with negative one. It is also found that, increasing of \( \sigma \) and \( H \), can be lead to increasing in the frequency of these waves for
E. Emadi and H. Zahed

Linear and Nonlinear Dust Acoustic Waves in Quantum Dusty Plasmas

plasma with negative dust grains and vice versa for plasma with positive one. The KdV equation is derived to investigate DA solitary waves. From numerical analysis, it is found that the quantum diffraction effects are significant in plasmas with ultrahigh density, which may be found in the atmospheres of neutron stars and the interior of white dwarfs. The soliton is also found to be affected by electron to ion Fermi temperature ratio $\sigma$ and dust to ion temperature ratio $\delta$. This work is aimed to study some basic features of DAWs in dense quantum plasmas, which are ubiquitous in massive astrophysical objects.

REFERENCES


Hossein Zahed, received his PhD degree in plasma physics from Tabriz University in 2006. He is currently Assistant Professor at Sahand University of Technology, He is a member of Physics, Optics and Photonics Society of Iran.

Elham Emadi received her M.Sc. degree in plasma physics from Sahand University of Technology in 2014. She is currently Ph.D. student at Sahand University of Technology. She is a member of Physics, Optics and Photonics society of Iran.
SCOPE

Original contributions relating to advances, or state-of-the-art capabilities in the theory, design, applications, fabrication, performance, and characterization of: Lasers and optical devices; Laser Spectroscopy; Lightwave communication systems and subsystems; Nanophotonics; Nonlinear Optics; Optical Based Measurements; Optical Fiber and waveguide technologies; Optical Imaging; Optical Materials; Optical Signal Processing; Photonic crystals; and Quantum optics, and any other related topics are welcomed.

INFORMATION FOR AUTHORS

International Journal of Optics and Photonics (IJOP) is an open access Journal, published online semiannually with the purpose of publication of original and significant contributions relating to photonic-lightwave components and applications, laser physics and systems, and laser-electro-optic technology. Please submit your manuscripts through the Web Site of the Journal (http://www.ijop.ir). Authors should include full mailing address, telephone and fax numbers, as well as e-mail address. Submission of a manuscript amounts to assurance that it has not been copyrighted, published, accepted for publication elsewhere, and that it will not be submitted elsewhere while under consideration.

MANUSCRIPTS

The electronic file of the manuscript including all illustrations must be submitted. The manuscript must be in double column with the format of IJOP Paper Template which for ease of application all over the world is in MS-Word 2003. The manuscript must include an abstract. The abstract should cover four points: statement of problem, assumptions, and methods of solutions, results and conclusion or discussion of the importance of the results. All pages, including figures, should be numbered in a single series. The styles for references, abbreviations, etc. should follow the IJOP format. For information on preparing a manuscript, please refer to the IJOP webpage at: http://www.ijop.ir.

Prospective authors are urged to read this instruction and follow its recommendations on the organization of their paper. References require a complete title, a complete author list, and first and last pages cited for each entry. All references should be archived material such as journal articles, books, and conference proceedings. Due to the changes of contents and accessibility over time, Web pages must be referenced as low as possible.

Figure captions should be sufficiently clear so that the figures can be understood without referring to the accompanying text. Lettering and details of the figures and tables should be large enough to be readily legible when the drawing is reduced to one-column width of the double column article. Axes of graphs should have self-explanatory labels, not just symbols (e.g., Electric Field rather than E). Photographs and figures must be glossy prints in electronic files with GIF or JPEG Formats.

Article Keywords are mandatory and must be included with all manuscripts. Please choose approximately 4 to 8 keywords which describe the major points or topics covered in your article.

COPYRIGHT TRANSFER FORM

Authors are required to sign an IJOP copyright transfer form before publication. Authors must submit the signed copyright form with their manuscript. The form is available online at http://www.ijop.ir.