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ORIGINAL ARTICLE

Head-on collision of electron-acoustic Korteweg-de Vries solitons in a magnetized quantum plasma

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Abstract The head-on collision between two electron-acoustic waves (EAWs)in a magnetized quantum plasma is studied. Using the extended Poincaré-Lighthill-Kuo (PLK) method we have obtained the two-sided Korteweg-de-Vries (KdV) equations. The analytical phase shifts and the trajectories after the head-on collision of two solitons have been derived. We provide the theoretical predictions about the existence of compressive and rarefactive EAWs in the considered model, we have observe that collisions are possible only among the same polarity solitons. Moreover the phase shifts are significantly affected by the quantum diffraction parameter, by the ratio between the hot to cold electron number densities, by the phase velocity and by the normalized electron gyrofrequency. The important observations of this manuscript are that the waves reach a maximum amplitude which is superposition of the initial amplitude and they suffer a time delay during their collision. Our results may be useful in space and laboratory plasmas as well as in plasma applications.

Keywords Electron acoustic waves · Magnetized quantum plasma · Phase shifts · PLK method · KdV equations · Head-on collision

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1 Introduction

Lately, attention has been paid for quantum plasma because of its wide range of applications in microelectronic devices like quantum diodes (Ang and Zhang 2007; Shukla and Eliasson 2008), in intense laser-solid density plasma interaction experiments (Hu and Keitel 1999; Glenzer and Redmer 2009), in laser-based inertial fusion (Marklund and Shukla 2006) and in dense astrophysical objects (Shapiro and Teukolsky 1983; Lai 2001; Benvenuto and De-Vito 2005). The quantum effect is considered to be important (Manfredi 2005) in plasma when the thermal de Broglie wavelength λ_B is similar to or larger than the average inter-particle distance $n^{-\frac{1}{3}}$ i.e. when $n\lambda_B^3 \geq 1$, while in classical plasma the thermal de Broglie wavelength λ_B associated with plasma particles are so small that the particles are considered to be point like. Since the de Broglie wavelength $\lambda_B = \frac{\hbar}{\sqrt{mK_BT_F}}$ depends upon the mass of the α particle and on the thermal energy $E_F = K_BT_F$ and since the mass of the electron is always less than that of the ions, so the quantum effect associated with the electron are more important than that of the ion. Equivalently the quantum effects are important if the system temperature is comparable to or lower than the Fermi temperature. Hence if the ratio $\chi = \frac{T_F}{T} = \frac{1}{2}(3\pi^2)^{2/3}n_e^{2/3} \geq 1$, where $E_F = \frac{\hbar^2}{2m_e}(3\pi^2)^{2/3}n_e^{2/3}$, then the quantum effects becomes important in plasmas.

The electrostatic wave with high frequency in comparison with the ion plasma frequency is commonly known as electron acoustic waves (EAWs) (Ghorui et al. 2013). Here small number of inertial cold electrons oscillate against a dominant thermalize background of inertialess hot electrons which provides the necessary restoring force. The phase speed of EAWs is much larger than the thermal speeds of cold electrons and ions but is much smaller than that of the hot electrons. Thus the phase speed of EAWs must be