Indian J.Sci.Res. 5(1): 135-138, 2014
ISSN: 0976-2876 (Print)
ISSN: 2250-0138 (Online)

CHARGED PARTICLE ACCELERATION IN A MAGNETIC MIRROR

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ABSTRACT

In the present study, a proposition of electron acceleration medium is developed by a large breadth lower cold-blooded surge(LHW) via a glamorous glass having frequence lower than the tube frequence. It has a Gaussian mode profile and is localized due to parabolic tube viscosity and glamorous field profile. The mode is launched LHW from outdoors. The large breadth LWHs have the eventuality to axially trap the electrons while moving near to its resemblant phase haste. Some parameter of electrons is enhanced at the moment of electrons acceleration. The acceleration conceivably happens as it gets out of phase with the surge and the transverse field of the mode favors glass confinement. This medium proposition can produce electron energy up to a many MeV.

KEYWORDS: Electron Acceleration, Lower Hybrid Wave, Magnetic Mirror, Mode, Plasma Density

Over the last few decades, much work on particle acceleration has been done due to its vast field applications such as high energy Physics, industry, power generation and medical, etc. (Huang *et al.*, 2006; Belloni *et al.*, 2005; Tajima and Dawson, 1979; Bingham *et al.*, 2004). The first model of electron acceleration was proposed by Tajima and Dawson with using high power intense laser of the order $10^{18} W/cm^2$. An ultra-high intense laser and energetic particle beams potentially generate plasma waves. The plasma wave can accelerate the relativistic and non-relativistic charged particles by the wake-field excitation (Geddes *et al.*, 2004). Moreover, the relativistic charged particle can be achieved when the phase velocity of the wave is close to the velocity of light in a vacuum. Since higher energetic charged particles can be accelerated in low plasma density regime. However large density plasma also energetically accelerates if one looks into such crystals that undergo plasma inhomogeneity having very low emittance (Shi, 2007). A 2- dimensional simulation of wake-field acceleration promises electron acceleration nearby 1 TeV. It makes stabilization using two-stream instability causes the minimization in the transformation ratio of Wakefield acceleration. Further, wakefield acceleration by guided supersonic hydrogen gas jet plasma provided high-quality radio frequency accelerators (Suk *et al.*, 2001). Y.-J. SHI proposed the acceleration of electron by wake excitation of intense laser pulses with adiabatic attenuated dense plasma. It gains some extra energy by trapped electron and dephasing length associated with Wakefield (Salamin, 2006). Electrons are trapped in the region of underdense plasma with Wakefield using the one-dimensional Hamiltonian analysis and simulation that shows the intense acceleration mechanism (Kumar *et al.*, 2010).

High power petawatt laser with an axicon Gaussian mode profile has the potential to accelerate electron upto GeV order energy (Gupta and Suk, 2006). A special type of electron cyclotron wave is generally known as electron Bernstein wave assurances particle acceleration up to few MeV in the plasma channel (Gupta *et al.*, 2007) with a parabolic density profile and magnetic mirror (Sajal and Tripathi, 2008). Chirped laser having an ultra-short pulse profile can be accelerated the electron using the cross focusing arrangement of two laser beams. This causes the gain of energy and chirped frequency seeded electron momentum large (Popov *et al.*, 2009). It has been proposed that a radially polarized laser-accelerated the electron up to a few GeV energy with the external magnetic field (Bingham *et al.*, 1994). The Beating waves of two crossed cosh-Gaussian laser beams have the potential to accelerate electron in the relativistic ponder motive regime (Bingham *et al.*, 2002).

In this paper, we have taken an attempt to electron acceleration mechanism by the lower hybrid wave in a magnetic mirror. A large-amplitude lower hybrid wave can be trapped electrons have a frequency less than plasma frequency. Lower hybrid Eigen-mode derived in inhomogeneous plasma that depends upon the magnetic field. The static magnetic field changes the LHW mode structure of the Gaussian amplitude profile. Dephasing arises during electron acceleration which is considered negligible for the large-amplitude lower hybrid wave at a longer distance regime. In sec 2, we derive the mode structure of the lower hybrid waves in the inhomogeneous plasma channel with magnetic mirror confinement. Sec 3, inform the acceleration mechanism of the electron having a Gaussian potential profile. Sec 4 provides the Results and discussion, Finally Sec 5 Summary and conclusion of our theory.

Lower Hybrid Eigen Mode

Consider a magnetic mirror machine having magnetic field profile $B_s\hat{z} + B_r\hat{r}$. On taking account of small r, the inhomogeneous plasma density profile for electrons and ions is given as $\omega_p^2 = \omega_{p0}^2(1 - x^2/L^2)$,

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$\omega_{pi}^2 = \omega_{pi0}^2(1 - x^2/L^2)$, $\omega_c = \omega_{c0}(1 + x^2/L^2)$, $\omega_{ci} = \omega_{ci0}(1 + x^2/L^2)$. If we take the approximations as $\omega_c \gg \omega \gg \omega_{ci}$, $k_\perp \rho_e < 1$, $k_\perp \rho_i > 1$, $k_z v_e < \omega$, $kv_i < \omega$, one may assume that a large amplitude of LHW exists in the plasma having electrostatic potential profile

$$\emptyset = \emptyset_0(x)\exp[-i(\omega t - k_y y - k_z z)], \quad (1)$$

Electron Acceleration

Since if one applied the electric field then the positive ions are accelerating in the direction of the applied field whereas the electrons are accelerating reverse to the direction of the applied field. Ions are heavy mass than the electron, hence neglect the ions acceleration contribution and considering the only electron acceleration in the lower hybrid wave. The response of an energetic electron to the lower hybrid wave is governed by the equation of motion as

$$\frac{d\boldsymbol{p}}{dt} = e\nabla\emptyset - \frac{\omega_c}{\gamma}\boldsymbol{p} \times \hat{z} + \frac{\omega_{c0}}{\gamma}\frac{z}{L^2}\boldsymbol{p} \times (x\hat{x} + y\hat{y}), \quad (2)$$

RESULTS AND CONCLUSIONS

In fig.1, we have plotted the variation between normalized X and Z. It depicts the negatively gyrating as make a variation in Z from 0 to 657 and further exceeding Z it get positive variation. While analyzing the fig. 2, normalized variations of Y and Z depicts the positively gyrating as make a variation in Z over 0 to 503 and further increases than this value of Z, it saturated. The normalized momentum graph with variation of Z is shown in fig. 4, 5, 6 and 7. In fig. 3, the variation of P_X with Z depicts the gyrating in P_X up to Z=430 and further exceeding Z, it linearly increases. Normalized P_Y over Z graph has shown in fig. 4.

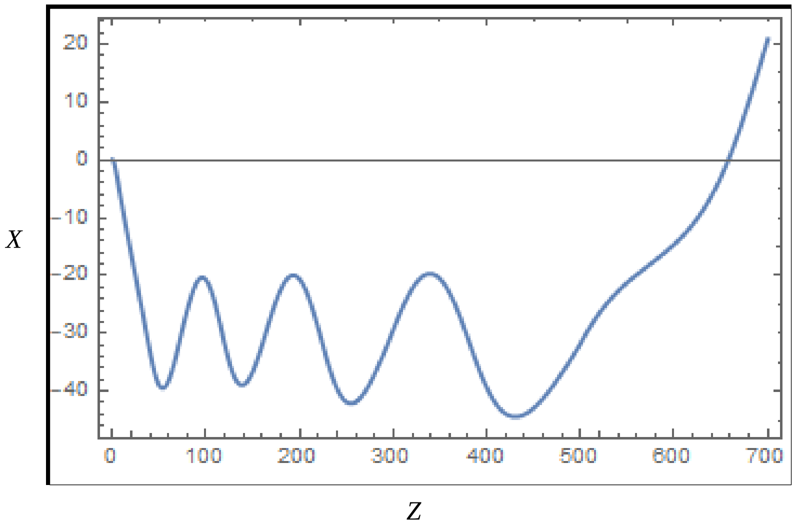

Figure 1: Variation of normalized coordinate *X* as a function of normalized coordinate *Z* for the parameter $A_0' = 0.01, X_0 = 45, k_y c/\omega = 10, k_z c/\omega = 1, \Psi_{no} = \pi, L = 300, \omega_{c0}/\omega = 0.9$

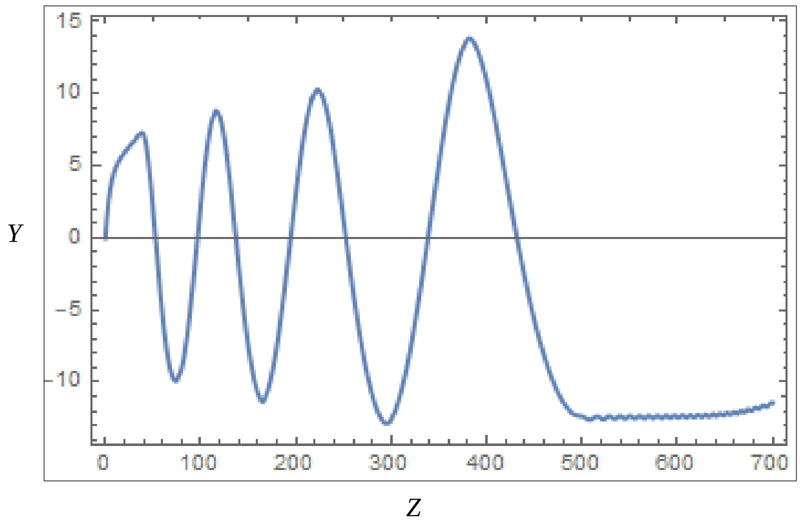

Figure 2: Variation of normalized coordinate *Y* as a function of normalized coordinate *Z* for the parameter $A_0' = 0.01, X_0 = 45, k_y c/\omega = 10, k_z c/\omega = 1, \Psi_{no} = \pi, L = 300, \omega_{c0}/\omega = 0.9$

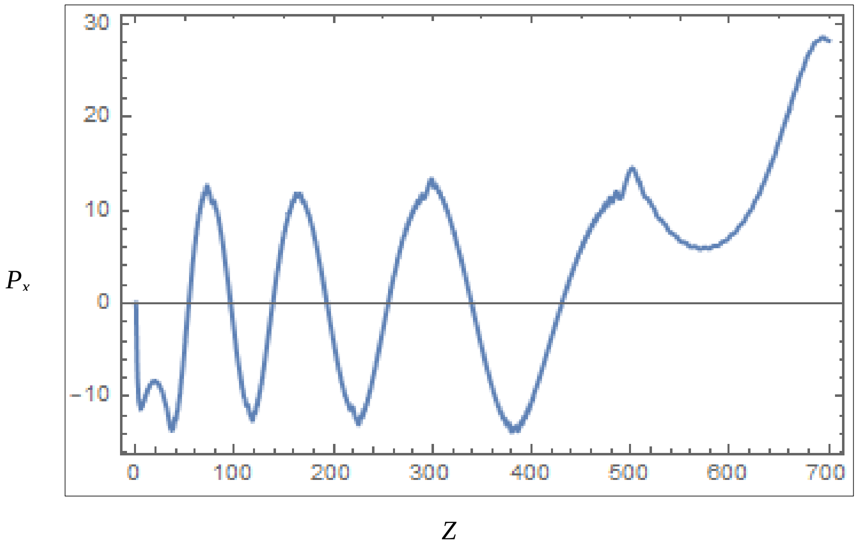

Figure 3: Variation of normalized coordinate P_X as a function of normalized coordinate Z for the parameter $A_0' = 0.01, X_0 = 45, k_y c/\omega = 10, k_z c/\omega = 1, \Psi_{no} = \pi, L = 300, \omega_{c0}/\omega = 0.9$

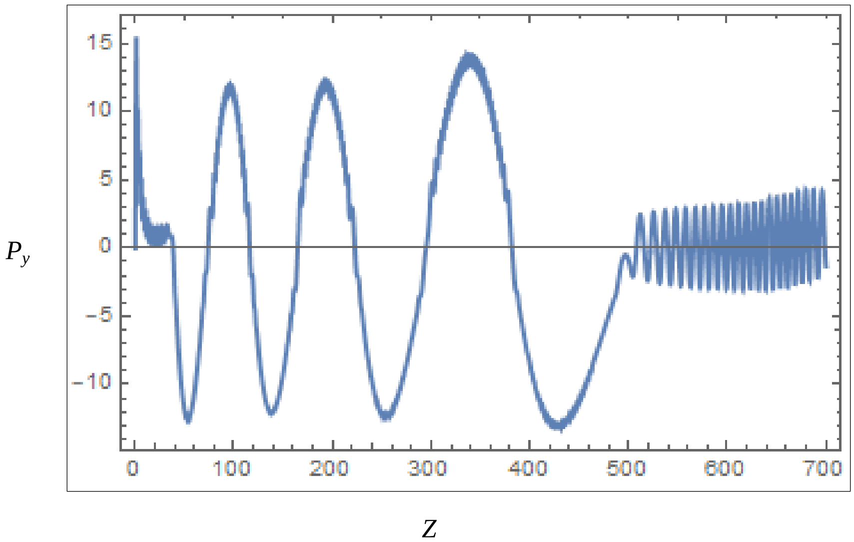

Figure 4: Variation of normalized coordinate P_Y as a function of normalized coordinate Z for the parameter $A_0' = 0.01, X_0 = 45, k_y c/\omega = 10, k_z c/\omega = 1, \Psi_{no} = \pi, L = 300, \omega_{c0}/\omega = 0.9$

SUMMARY AND CONCLUSION

The large amplitude lower hybrid wave has potential to accelerate the electron up to a few MeV in a plasma channel with magnetic mirror confinement. The energy can be achieved as large value by optimized the initial phase. Normalized momentum graphs supported that electrons gyrate about axial magnetic field. The cyclotron frequency ω_c is raised by make a variation in the static magnetic field B_s. Since one can relate γ with ω_c, which increases with the change in ω_c. Hence enhancement of energy in electron can be achieved by making a variation in the static magnetic field. The maximum energy can be found at large value of Z. But after a further increase in normalized distance Z, it decreases owing to the dephasing mechanism in wave particles. This dephasing parameter depends upon the initial phase of LHW. Since dephasing is raised by large gyration of wave particles which can be reduced by longer length regime. Hence one may point the correlation between the gain in energy of the electron and the gyration effect. One can also see this static magnetic field changes the LHW mode structure. It has a Gaussian amplitude profile. Further generalizes this theory of electron acceleration by taking the stochastic process of acceleration, it may be applicable for analyzing the auroral field lines.

ACKNOWLEDGEMENT

The authors express his gratitude to the Principal and Department of Physics, K.N. Govt. P.G. College, Gyanpur, Sant Ravidas Nagar, Bhadohi, U.P., India, for their insightful discussions and constructive suggestions.

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