CHAPTER-7

EFFECT OF PERIODIC FREQUENCY CHIRP ON ELECTRON ACCELERATION BY RADIALLY POLARIZED LASER PULSE IN VACUUM

7.1 INTRODUCTION

Particle acceleration to relativistic energies by using a high intensity laser has been originated as a developing field of research during last few decades [13, 35, 57, 70, 64]. Many schemes have been proposed for the investigation of charge particle dynamics under the influence of laser fields in vacuum and plasma [35, 57, 70, 64]. Malka *et al.* [13] described the experimental results of vacuum acceleration of electron and reported the energy gain of the order of MeV by using an ultra-intense linearly polarized laser pulse. Wang *et al*. [35] have presented a simulation model with a three-dimensional (3D) test particle for laser-induced vacuum acceleration of electron. They have presented the energy spectrum of the capture and acceleration scenario (CAS) for a bunch of electrons. Accordingly the intense laser field can capture and accelerates an electron to the energies of the order of GeV with gradients of the order of GeV/cm. The characteristics variations of polarization states of laser pulse have been analysed for betterment of laser electron interaction with high energy gains [61, 64, 96]. Energy enhancement appears with a circularly polarized (CP) laser pulse due to its axial symmetry in comparison with linearly polarized (LP) laser pulse. However, with a focused radially polarized (RP) Gaussian laser beam, there appears a relatively stronger longitudinal component of field which improves the electron acceleration [61]. RP laser pulses have inherent property of cylindrical symmetry which enforces better trapping of electrons with narrow divergence and narrow spread than that with linearly polarized and circularly polarized laser pulse. Gupta *et al*. [66] did simulations and proposed the electron energy gain of $1.5GeV$ with a RP laser pulse with about $1MG$ of applied magnetic field. The accelerated electron after acquiring the maximum gain goes out of phase with the laser field. The accelerated electron can retain a confined trajectory for larger distance during interaction with a chirped laser pulse. An accelerating distance of about three times the Rayleigh length was proposed with retaining of electron energy of the order of GeV by using a LP chirped laser pulse [122]. Lu *et al*. [102] presented a comparative analysis of electron acceleration using a frame work for a plane-wave angular spectrum and paraxial approximation for a tightly focused RP few-cycle laser pulse propagating in vacuum. Enhancement in electron acceleration appears, if a proper and static magnetic field is externally applied [58]. About 70% enhancement in electron energy was observed with an axial magnetic field than that without magnetic field with a RP laser pulse [126].

Frequency chirp induced electron acceleration by laser has presented an effective interaction of laser with electron [17, 46, 56, 73, 121]. A high gradient of about $62 GeV/m$ was reported with a CP chirped laser pulse of intensity about $1.7\times10^{19}\ W/cm^2$ [121]. Khachatryan *et al*. [46] analysed the charged particle dynamics under transverse and longitudinal momentum with a chirped laser pulse and obtained $8.55 MeV$ as an energy equivalent of final longitudinal momentum of electron acceleration due to a linearly chirped pulse. The resonant improvement of electron energy was observed in plasma with a plane polarized chirped laser pulse in the presence of an azimuthal magnetic field [73]. The characteristic variation of chirp parameter for frequency chirp such as linear, quadratic, non linear and periodic chirp, improves the electron energy gain during laser electron interaction [117-119]. Afhami and Eslami [117] analysed the generation of plasma wake field under the effect of non linear chirped Gaussian laser pulse. They proposed that the maximum amplitude of excited wake field with periodic chirped laser pulse is three times larger than that with a linear chirped laser pulse. Liu *et al.* [103] investigated and found a single proton energy gain to sub-GeV level with a RP chirped laser pulse of peak intensity around $10^{22} W/cm^2$ for the protons injected with initial energy of $45 MeV$. Galow *et al.* [99] demonstrated the theoretically the possibility of creating proton beams of high energy and quality, with a hydrogen gas target and a properly selected chirped laser pulse of intensity about $10^{21} W/cm^2$ which can be accessible by state-of-the-art laser systems [50]. A number of experimental investigations reported the effect of a chirped laser pulse interaction with electron [29, 37, 112]. Solid state laser systems present a high intensity laser pulses with a few percent of frequency chirp [26]. Leemans *et al*. [37] studied experimentally a self-modulated (SM) laser wake-field acceleration to observe forward Raman scattering (FRS) and electron yield with a positively chirped laser pulse. Rao *et al.* [112] employed positively as well as negatively chirped Ti:sapphire laser pulses with duration $\geq 45 fs$ for SM-LWFA and observed an improved FRS with higher electron yield. The previous studies of electron acceleration with a RP laser pulse [66, 97, 126] and proton acceleration with a RP chirped laser pulses [103] inspired us to investigate the impact of chirping on electron acceleration with a RP laser pulse in vacuum.

In this chapter we investigate the effects of linear and periodic frequency chirp on electron acceleration and obtain high quality electron beam of GeV energy by a high intensity chirped RP laser pulse in vacuum. An electron while interacting with a laser pulse attains rapid oscillations in the direction of propagation of laser pulse and gains high energy with a RP laser pulse. The frequency chirped laser pulse enforces an effective electron laser interaction. The betatron resonance between the electron and the electric field of the laser pulse is maintained for a longer duration with a RP chirped laser pulse. Thus the electron with few MeV of initial energy gains high energy of the order of GeV with a chirped RP laser pulse. The electron beam quality has been analysed by the correlation between electron energy and scattering angle. This chapter is organized as follows. The next sections describe the frequency chirped functions, electromagnetic fields, and electron dynamics required to study the electron acceleration. Results and discussion are included in section 7.5. Finally, conclusion is drawn in the last section.

7.2 PERIODIC FREQUENCY CHIRP

In chapter 4, we have defined the basic form of frequency chirp, which is called linear chirp. The chirp form in which the instantaneous frequency varies periodically in the form of sin or tan function during the chirped pulse is called periodic chirp. Periodic chirped laser pulse enhances the electron laser interaction time and hence enhances the electron acceleration. The electron energy gain can relatively be improved with a periodically chirped laser pulse than that with a linearly chirped laser pulse.

The arbitrary frequency chirp $\omega(\xi)$ is expressed as:

$$\omega(\xi) \;=\; \left\{ \begin{array}{ll} \omega_0(1+\alpha\xi) & \text{for a linear frequency chirp [121]} \\ \omega_0(1+\alpha\sin(\beta\xi+\phi_0)) & \text{for a periodic frequency chirp [117]} \end{array} \right\} \quad (7.1)$$

where α and β is the frequency chirp parameters, and ϕ_0 is the initial phase of a periodic frequency chirp, ω_0 is the initial frequency of laser, $\xi = z - ct$ is the retarded coordinate, and c is the velocity of light in vacuum. Periodic frequency chirp function can also be represented in terms of $\cos$, $\tan$, or other hyperbolic terms.

7.3 FIELD DISTRIBUTION FOR RADIALLY POLARIZED CHIRPED LASER PULSE

A simple paraxial approximation solution of a RP laser pulse was defined for electron acceleration [97, 126] We have introduced a frequency chirp in the profile of a RP laser beam propagating along the z-axis.

The electric field ($\vec{E} = \hat{r}E_r + \hat{z}E_z$) components of a frequency chirped RP laser beam is expressed as:

$$E_r = E_0 \frac{r}{r_0 f^2}\cos(\phi)\exp\left[-\frac{(\xi-\xi_0)^2}{\sigma^2} - \frac{r^2}{r_0^2 f^2}\right], \quad (7.2)$$

$$E_z = E_0 \frac{2}{k_0 r_0 f^2}\left[\left(1-\frac{r^2}{r_0^2 f^2}\right)\sin(\phi) - \frac{zr^2}{Z_R r_0^2 f^2}\cos(\phi)\right]\exp\left[-\frac{(\xi-\xi_0)^2}{\sigma^2} - \frac{r^2}{r_0^2 f^2}\right], \quad (7.3)$$

where $\phi = k(\xi)\xi + 2\tan^{-1}(z/Z_R) - zr^2/(Z_R r_0^2 f^2) + \varphi_0$, $k(\xi) = \omega(\xi)/c$ is the wave number, $\omega(\xi)$ is an arbitrary frequency chirp [122], $f^2 = 1 + (z/Z_R)^2$ is the beam width parameter, $Z_R = kr_0^2/2$ is the Rayleigh length, $\tan^{-1}(z/Z_R)$ is the Gouy phase, r is the radial coordinate, φ_0 is the initial phase, σ is the laser pulse length, r_0 is minimum laser spot size, and ξ_0 is the initial position of the pulse peak. The components of magnetic field due to laser pulse can be derived by using Maxwell's equations and expressed by using the relation:

$$\vec{B} = -ic\frac{\vec{\nabla}\times\vec{E}}{\omega(\xi)}, \quad (7.4)$$

7.4 ELECTRON DYNAMICS AND RELATIVISTICS ANALYSIS

The electron momentum and energy governing equations are:

$$\frac{dp_r}{dt} = -eE_r\left(1 - \frac{v_z}{c}\right), \tag{7.5}$$

$$\frac{dp_z}{dt} = -e\left(E_z + \frac{v_r}{c}E_r\right), \tag{7.6}$$

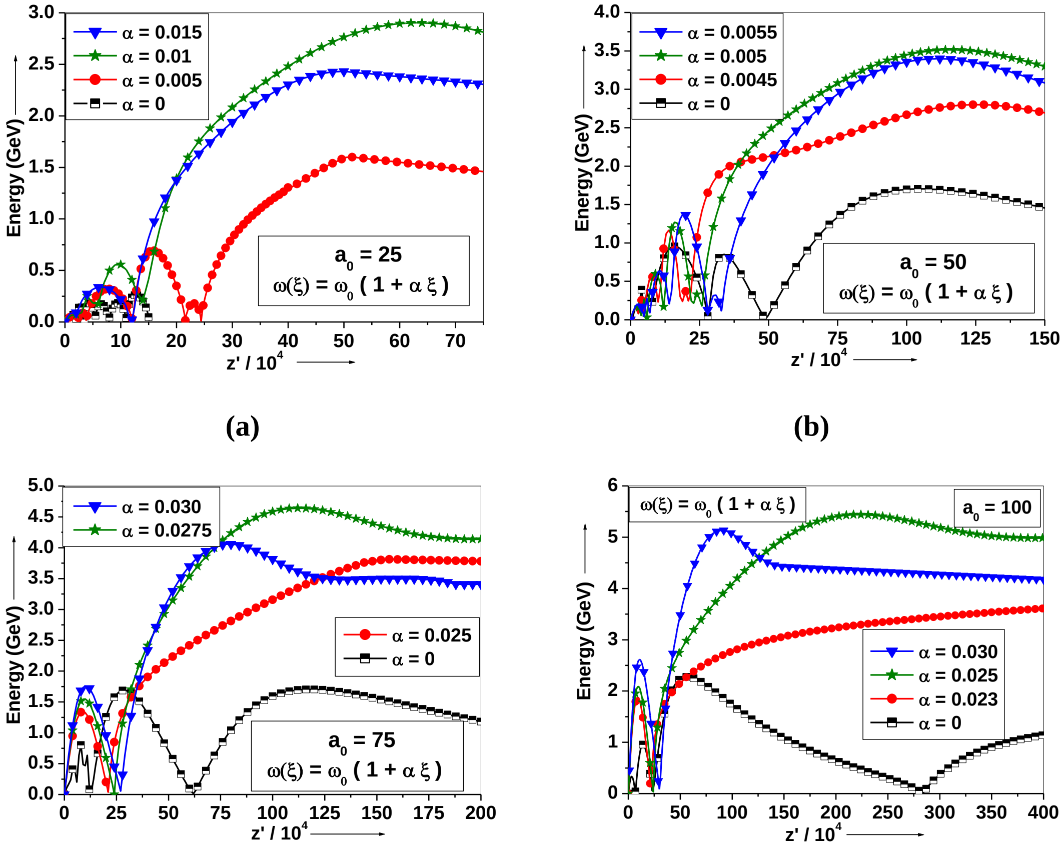
$$\frac{d\gamma}{dt} = -e\vec{v}.\vec{E}\,, \tag{7.7}$$

where $\gamma^2 = 1 + (p_r^2 + p_z^2)/m_0^2c^2$ is the Lorentz force factor, p_r and p_z are the radial and longitudinal components of the electron momentum ($\vec{p} = \hat{r}p_r + \hat{z}p_z$), v_r and v_z are the radial and longitudinal components of the electron velocity ($\vec{v} = \hat{r}v_r + \hat{z}v_z$), and $-e$ and m_0 are the electron's charge and rest mass respectively. Throughout this chapter, time, length, velocity, momentum, and energy are normalized by $1/\omega_0$, c/ω_0, c, m_0c, and m_0c^2 respectively. The normalized laser intensity and normalized magnetic field parameter can be expressed as, $a_0 = eE_0/m_0\omega_0c$ and $b_0 = eB_0/m_0\omega_0c$ respectively.

The momentum and energy equations have been solved by using a relativistic single particle simulation code. We assume the initial electron momentum $p_0 = m_0\gamma_0v_0$, where v_0, and γ_0 is the initial velocity and kinetic energy of the electron respectively.

7.5 RESULTS AND DISCUSSION

The dimensionless parameters for numerical analysis are: $a_0 = 25$ (corresponds to laser intensity $I \sim 8.5\times10^{20}\ W/cm^2$), $a_0 = 100$ (corresponds to laser intensity $I \sim 1.36\times10^{22}\ W/cm^2$) and wave length $\lambda_0 \sim 1\mu m$; $r_0' = 700$ (corresponds to laser spot sizes $r_0 \sim 120\mu m$), $\sigma' = 70$ (corresponds to laser pulse duration of $200fs$); initial position of pulse peak $\xi_0' = -100$; initial electron position $z_i' = 0$ and $r_i' = 0$; initial phase $\varphi_0 = 0$ and $p_0' = 1$.



(a) (b)

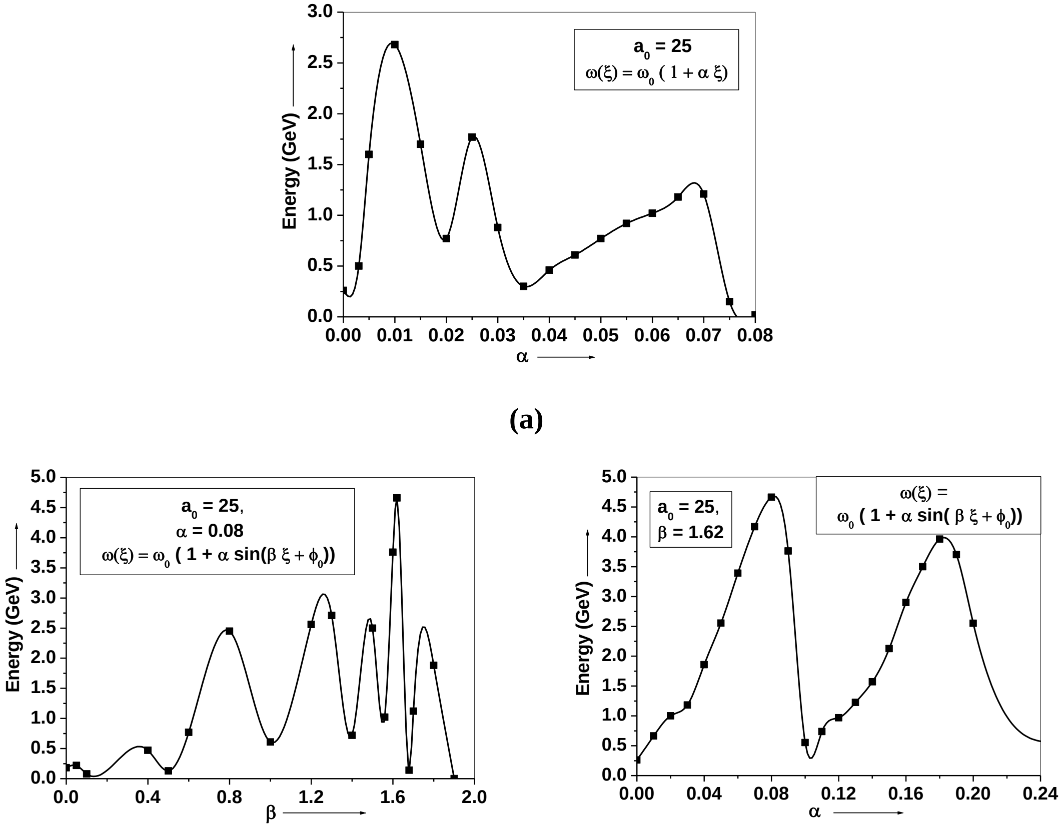
(c) (d)

Figure 7.1. Electron energy variation with normalized distance z' in the absence and presence of linear chirp function $\omega_0(1+\alpha\xi)$ at distinct values of laser intensity parameter a_0. (a) $a_0 = 25$ and $\alpha = 0$, 0.005, 0.01, and 0.015 (b) $a_0 = 50$ and $\alpha = 0$, 0.0045, 0.005, and 0.0055 (c) $a_0 = 75$ and $\alpha = 0$, 0.025, 0.0275, and 0.03, and (d) $a_0 = 100$, and $\alpha = 0$, 0.023, 0.025 and 0.03. The other parameters are $p_0' = 1$, $r_0' = 700$, $\sigma' = 70$, $\xi_0' = -100$, $z_i' = 0$, $r_i' = 0$, and $\varphi_0 = 0$.

In Figure 7.1, we have plotted the electron energy gain with normalized longitudinal distance z' at distinct values of laser intensity parameter $a_0 = 25$, 50, 75 and 100 with and without a linear chirp. We consider a linear chirp function $\omega_0(1+\alpha\xi)$ and investigate the variation of electron energy gain for distinct values of chirp parameter α.

The electron energy gain first increases with the normalized distance z' and reaches at maximum after some time. One may notice that after passing of the laser pulse, betatron oscillations set up between the electron and the electric field of the laser pulse. Hence, the electron retains considerable energy. The net electron energy gain by the electrons during their acceleration appears sensitive to the laser intensity and chirping. The presence of frequency chirp improves the duration time of interaction between the laser pulse and the electron, and resonance is maintained during this interaction, hence electron gains considerable high energy. Singh and Kumar [97] used an unchirped RP laser pulse and obtained the highest electron energy of $140 MeV$ and $1.4 GeV$ for $a_0 = 25$ and $a_0 = 75$ respectively. However, we have employed a chirped RP laser pulse and obtained the highest electron energy of about $2.7 GeV$ and $4.7 GeV$ for $a_0 = 25$ and $a_0 = 75$ respectively as depicted in fig. 7.1(a) and 7.1(c). For $a_0 = 50$ with linear chirp parameter $\alpha = 0.005$, the energy gain is about $3.5 GeV$, which is higher than the energy of $2.75 GeV$, attainted with the chirp parameter $\alpha = 0.0045$. Thus the value $\alpha = 0.005$ is an optimum value of chirp parameter α for the maximum energy gain with $a_0 = 50$. Therefore, the value of chirp parameter is very sensitive to the electron energy gain. If we make small change in the value of chirp parameter, a significant enhancement in the electron energy gain can be seen. For $a_0 = 100$ and optimum linear chirp parameter, above $5.2 GeV$ electron energy is achieved whereas the electron energy gain is about $2.25 GeV$ with same intensity without chirping as depicted in fig. 7.1(d). It is interesting to notice that the maximum energy gain in the presence of a linearly chirped RP laser pulse is about 2.5 times greater than that in the absence of chirping. Moreover the observed values of α have been quite small and in the range $0.03 < \alpha < 0$. The chirp parameter $\alpha = 0.03$ corresponds to $1.06592 \times 10^{29} s^{-2}$ and is in accordance with the simulation reported values of linear chirp parameter [119].

Figure 7.2, shows the variation plot of electron energy gain with chirp parameters for laser intensity parameter $a_0 = 25$ with linear and periodic chirp functions. One can see the optimized values of the chirp parameters α and β for which the maximum energy gain is obtained.



(a)

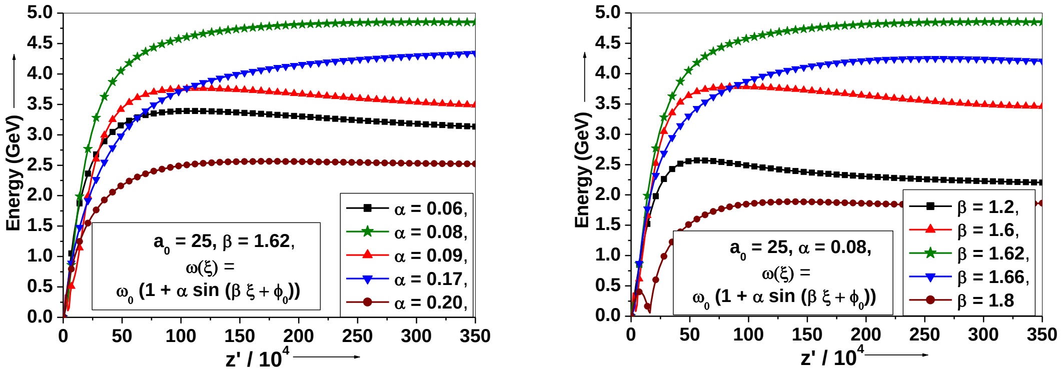
(b) **(c)**

Figure 7.2. Electron energy variation with chirp parameters α and β for laser intensity $a_0 = 25$ (a) Linear chirp function $\omega_0(1+\alpha\xi)$, (b) Periodic chirp function $\omega_0(1+\alpha\sin(\beta\xi+\phi_0))$ with $\alpha = 0.08$ and (c) Periodic chirp function $\omega_0(1+\alpha\sin(\beta\xi+\phi_0))$ with $\beta = 1.62$. The other parameters are same as used in fig. 7.1 and $\phi_0 = 0$.

The optimum value of chirp parameter plays a vital role in maintaining the resonance for longer duration. One should realize the sensitiveness of the chirp parameter while optimizing the value of chirp parameter for maximum electron energy gain. For $a_0 = 25$, with linear chirp function the maximum energy gain of about $2.7GeV$ is observed at $\alpha = 0.01$ as shown in fig. 7.2(a). Figure 7.2(b) and 7.2(c), shows the variation plot of electron energy gain for chirp parameters α and β with a periodic chirp frequency function $\omega_0(1+\alpha\sin(\beta\xi+\phi_0))$. For $a_0=25$, the optimum values of chirp parameter are $\alpha=0.08$ and $\beta=1.62$ for which maximum energy gain of about $4.8GeV$ is observed. Salamin and Jisrawi [119] proposed that the maximum energy gain with a linear chirp is almost two times of that with a quadratic chirp for electron laser acceleration in vacuum. We observe that the maximum energy gain for a periodic chirp is almost double of that with a linear chirp for the electron acceleration with RP laser pulse in vacuum. This is because the laser field with linear chirped posses more oscillations than the periodically-chirped ones. Thus the periodic chirp appears more advantageous than a linear chirp for high energy gain.

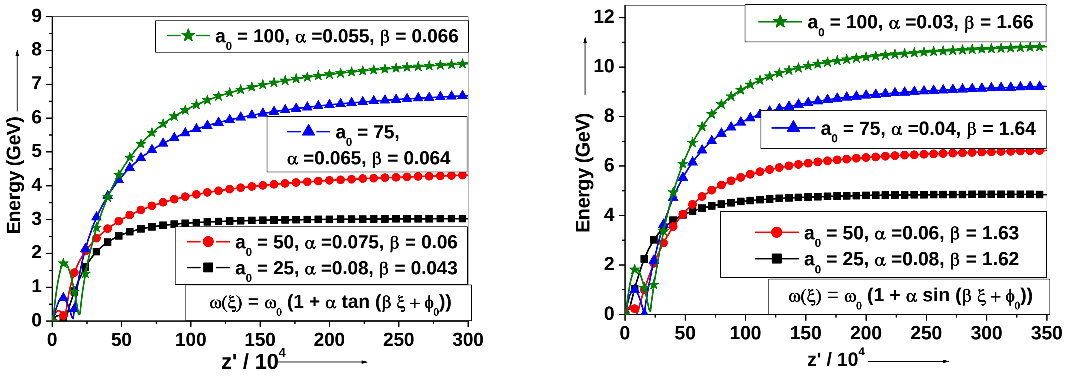
Figure 7.3 shows the variation plot for electron energy gain with normalized longitudinal distance z at distinct values of chirp parameters α and β of periodic chirp function $\omega_0(1+\alpha\sin(\beta\xi+\phi_0))$ for laser intensity $a_0=25$. In fig 7.3(a), the variation of electron energy gain is plotted for different values of chirp parameter β keeping the parameter α constant at 0.08. In fig 7.3(b), the variation of electron energy gain is plotted for different values of chirp parameter α keeping the parameter β constant at 1.62. We have observed that the optimum values of chirp parameter are $\alpha=0.08$ and $\beta=1.62$ for which the maximum energy gain appears. The small variation in values of chirp parameters α and β varies the electron energy gain significantly. We calculated the electron energy gain above $4.5GeV$ with chirped RP laser pulse of intensity $a_0=25$.

Figure 7.4 shows the variation plots for electron energy gain with normalized longitudinal distance z at distinct values of laser intensity parameter $a_0=25$, 50, 75 and 100 with periodic chirping. In fig 7.4(a), we obtain an electron energy gain of about $7.6GeV$ with laser intensity $a_0=100$ and optimum chirp parameters $\alpha=0.055$ and $\beta=0.066$ for periodic chirp function $\omega_0(1+\alpha\tan(\beta\xi+\phi_0))$. Afhami and Eslami [117] proposed in their simulation results that the higher wake field will be produced with $\alpha<0.1$ and $\phi_0=0$ in the case of periodic chirp function $\omega_0(1+\alpha\tan(\beta\xi+\phi_0))$ which is suitable for higher energy gain by electron. We have observed a smaller value of α



(a) **(b)**

Figure 7.3. Electron energy variation with normalized distance z' for periodic chirp function $\omega_0(1+\alpha\sin(\beta\xi+\phi_0))$ at different values of chirp parameters α and β for laser intensity $a_0 = 25$. (a) $\alpha = 0.08$ and $\beta = 1.2$, 1.6, 1.62, 1.66, and 1.8, (b) $\beta = 1.62$ and $\alpha = 0.06$, 0.08, 0.09, 0.17, and 0.20. The other parameters are same as used in fig. 7.1 and $\phi_0 = 0$.



(a) **(b)**

Figure 7.4. Electron energy variation with normalized distance z' for periodic chirp functions at different values of laser intensity parameter $a_0 = 25$, 50, 75, and 100. (a) $\omega_0(1+\alpha\tan(\beta\xi+\phi_0))$, and (b) $\omega_0(1+\alpha\sin(\beta\xi+\phi_0))$. The other parameters are same as used in fig. 7.1 and $\phi_0 = 0$.

which is less than 0.09 and $\phi_0 = 0$ for the periodic chirp function $\omega_0(1+\alpha\tan(\beta\xi+\phi_0))$ as well as $\omega_0(1+\alpha\sin(\beta\xi+\phi_0))$ for higher energy gain by electron. Salamine [61] observed that the maximum energy gain is above $3GeV$ with an unchirped petawatt (PW) axicon Gaussian laser beam of peak intensity $2.342\times10^{22}W/cm^2$. Gupta *et al.* [66] proposed an electron energy gain of about $5GeV$ from a PW RP unchirped laser pulse with magnetic field in vacuum. We have depicted an energy gain of above $8.7GeV$ as appearing in fig. 7.4(b) for a periodic chirp function $\omega_0(1+\alpha\sin(\beta\xi+\phi_0))$ with $a_0 = 75$ (corresponding to intensity $I \sim 7.75\times10^{21}\,W/cm^2$) . An energy gain of about $10.5GeV$ is observed with laser intensity parameter $a_0 = 100$ and optimum periodic chirp parameters $\alpha = 0.03$ and $\beta = 1.66$. As the chirp parameters α and β are sensitive to electron energy gain, small change in the value of chirp parameters α and β can affect the electron energy gain significantly. From fig. 7.4, one may clearly notice that on increasing the value of laser intensity parameter, the values of α decreases slowly, however, the value of β increases linearly. So in this way we can optimize the value of α and β corresponds to the laser intensity for periodic chirp.

We optimized chip parameters (α, β) for maximum energy gain $\gamma_{\max}$ by electron with intensity parameter a_0 (Table 7.1). This information will be a great help for experimentalists to use the appropriate chirp parameter for higher electron energy gain while laser electron interactions. We have employed laser peak intensity of the order of $10^{22}W/cm^2$. Such a range of laser intensity is feasible to achieve with a state-of-the-art high-intensity laser systems [50].

Figure 7.5 shows the electron ejection angle with energy gain for $a_0 = 25$ and $a_0 = 100$ for a periodic chirped RP laser pulse. The ejection angle is obtained by using the relation $\theta = \tan^{-1}(v_r/v_z)$ and is representing the ejection of electron with respect to the parallel axis of propagation of laser pulse. It is observed that the value of ejection angle decreases with the electron energy gain and the intensity of laser pulse. The value of angle of electron ejection appears to be low for a high intensity periodically chirped laser pulse with high energy gains.

Table 7.1. Optimized chip parameters (α , β) for maximum energy gain $\gamma_{\max}$ by electron with intensity parameter a_0

Chirp function $\omega(\xi)$	α and β for $\gamma_{\max}$ with:			
	$a_0 = 25$	$a_0 = 50$	$a_0 = 75$	$a_0 = 100$
Linear: $\omega_0(1+\alpha\xi)$	$\alpha = 0.01,$ $\gamma_{\max} = 2.7GeV$	$\alpha = 0.005,$ $\gamma_{\max} = 3.5GeV$	$\alpha = 0.0275,$ $\gamma_{\max} = 4.7GeV$	$\alpha = 0.025,$ $\gamma_{\max} = 5.5GeV$
Periodic: $\omega_0(1+\alpha\tan(\beta\xi+\phi_0))$	$\alpha = 0.08,$ $\beta = 0.043,$ $\gamma_{\max} = 3.0GeV$	$\alpha = 0.075,$ $\beta = 0.06,$ $\gamma_{\max} = 4.2GeV$	$\alpha = 0.065,$ $\beta = 0.064,$ $\gamma_{\max} = 6.5GeV$	$\alpha = 0.055,$ $\beta = 0.066,$ $\gamma_{\max} = 7.6GeV$
$\omega_0(1+\alpha\sin(\beta\xi+\phi_0))$	$\alpha = 0.08,$ $\beta = 1.62,$ $\gamma_{\max} = 4.5GeV$	$\alpha = 0.06,$ $\beta = 1.63,$ $\gamma_{\max} = 6.5GeV$	$\alpha = 0.04,$ $\beta = 1.64,$ $\gamma_{\max} = 8.7GeV$	$\alpha = 0.03,$ $\beta = 1.66,$ $\gamma_{\max} = 10.5GeV$

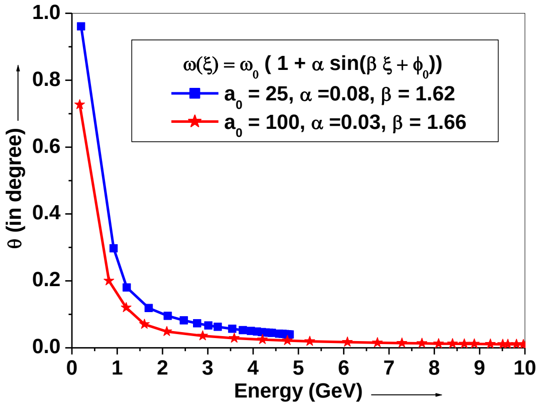


Figure 7.5. Electron ejection angle as a function of electron energy with a periodic chirp function $\omega_0(1+\alpha\sin(\beta\xi+\phi_0))$ for laser intensity $a_0 = 25$ and 100. The other parameters are as referred in fig. 7.1 and $\phi_0 = 0$.

The radiative loss during deceleration can be obtained by the following expression (Lienard result) of the radiated power [38]:

$$P(t) = \frac{2e^2\gamma^6}{3c}\left[\left(\frac{d(\vec{v})}{dt}\right)^2 - \left(\vec{v}\times\frac{d\vec{v}}{dt}\right)^2\right]. \qquad (7.7)$$

This expression shows that the radiated power strongly depends on electron quiver velocity. As per numerical values of parameters taken, the radiation loss $(\Delta W \sim P\times\Delta t)$ appears to be very large, where Δt is the interaction duration. The gained energy loses via radiations. However, if the electron is pre-accelerated then it can retain significant energy and radiation loss remains small. We have employed a pre-accelerated electron with normalized initial momentum $p_0' = 1$. Thus the radiation loss can be ignored in our case.

7.6 CONCLUSION

In present study, we have highlighted the effect of periodic frequency chirp on electron acceleration to GeV energy by a RP laser in vacuum. With an unchirped RP laser the accelerated electron after attaining maximum energy gets out of phase with the field. A proper linear chirp not only increases the electron energy gain but also support in retaining the gained energy for longer distances. We have observed about 2.5 times higher energy gain with a linearly chirped RP laser pulse than that with an unchirped RP laser pulse. A periodic chirp presents an efficient electron laser interaction with an effective enhancement in electron energy gain. This is because the periodic chirping increases the duration of electron laser interactions and hence maintains the betatron resonance for longer distances. The maximum energy gain from a periodic chirp is almost twice that of a linear chirp. The chirp parameters are sensitive to the electron energy gain and a small change in chirp parameter affect the electron acceleration significantly. Sensitiveness of chirp parameters is very crucial in electron acceleration and it would undoubtedly be a key factor in achieving maximum electron energy gain. We have also observed a low value of angle of electron ejection with a high intensity periodically chirped laser pulse for higher energy gains. We have achieved an energy gain of about $10.5 GeV$ with an optimum periodic chirp of a RP laser pulse of peal intensity $I \sim 1.36\times10^{22}\ W/cm^2$ in vacuum. The chirp parameters and related results presented in this paper will be useful for designing laser assisted charged particle acceleration experiments.