LASER DRIVEN ELECTRON ACCELERATION BY *q*-GAUSSIAN LASER PULSE IN PLASMA: EFFECT OF SELF-FOCUSING[**]

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A scheme for electron acceleration by self-focused q-Gaussian laser pulses in under-dense plasma has been presented. The relativistic increase in the mass of plasma electrons gives nonlinear response of plasma to the incident laser pulse resulting in self-focusing. Under the combined effects of the saturation nature of relativistic nonlinearity of plasma, self-focusing and diffraction broadening of the laser pulse, the beam width of the laser pulse evolves in an oscillatory manner. An electron initially on the pulse axis and at the front of the self-focused pulse, gains energy from it until the peak of the pulse is reached. When the electron reaches the tail of the pulse, the pulse begins to diverge. Thus, the deacceleration of the electron from the trailing part of the pulse is less, compared to the acceleration provided by the ascending part of the pulse. Hence, the electron leaves the pulse with net energy gain. The differential equations for the motion of electrons have been solved numerically by incorporating the effect of self-focusing of the laser pulse.

Keywords: *q-Gaussian, self-focusing, variational theory, electron acceleration.*

ЛАЗЕРНОЕ УСКОРЕНИЕ ЭЛЕКТРОНОВ *q*-ГАУССОВЫМ ПУЧКОМ В ПЛАЗМЕ С УЧЕТОМ ЕГО САМОФОКУСИРОВКИ

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УДК 621.375.826:533.9

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(Поступила 26 сентября 2022)

Представлена схема ускорения электронов самофокусированными q-гауссовыми лазерными импульсами в неплотной плазме. Релятивистское увеличение массы электронов плазмы приводит к нелинейному отклику плазмы на падающий лазерный импульс, что вызывает самофокусировку. При совместном воздействии насыщающего характера релятивистской нелинейности плазмы, самофокусировки и дифракционного уширения лазерного импульса ширина луча лазерного импульса изменяется колебательно. Электрон, первоначально находящийся на оси импульса и во фронте самосфокусированного импульса, получает от него энергию до достижения пика импульса. Когда электрон достигает хвоста импульса, импульс расходится. Замедление электрона от замыкающей части импульса меньше по сравнению с ускорением, которое обеспечено восходящей частью импульса. Следовательно, электрон покидает импульс с чистым выигрышем в энергии. Дифференциальные уравнения движения электронов решены численно с учетом эффекта самофокусировки лазерного импульса.

Ключевые слова: *q-гауссиан, самофокусировка, вариационная теория, ускорение электронов.*

Introduction. Whenever we think of particle accelerators, we consider them to be meant only for research at the very edge of known physics as these enormous facilities take decades to build [1–3]. However, along with this lofty goal, particle accelerators are being used for decidedly more down-to-earth projects such as medical treatments, diagnostics [4] and sterilization [5], security screening [6], material science [7], biological processes [8], and many more [9]. The use of energetic electrons in these applications depends on the modes of the interaction of electrons with matter and electromagnetic fields. These modes are ionization,

[**] Full text is published in JAS V. 90, No. 5 (http://springer.com/journal/10812) and in electronic version of ZhPS V. 90, No. 5 (http://www.elibrary.ru/title_about.asp?id=7318; sales@elibrary.ru).

chemical changes, heating, bremsstrahlung, and synchrotron radiation. The most common industrial uses of electron beam irradiation rely on the ionization caused by the beam in irradiated material that in turn alters its chemical or physical properties. This happens due to secondary reactions caused by the free radicals, i.e., molecular fragments with unpaired electrons, created by the electron beam, in the bombarded material. Such processes can be classified into two categories: radiation processing and radiation treatment. Radiation processing is used for industrial applications like polymer grafting and cross-linking and the curing of monomers, oligomers, and epoxy-based composites. Radiation treatment is used for sterilization of medical products, wastewater treatment, disinfestations and preservation of foodstuffs, decontamination of chimney and flue gases, and degradation of plastics for use in coatings and inks.

With the plans for the world's largest accelerator like Superconducting Supercollider, accelerator technology is approaching practical limits. There are two reasons for this: the magnetic forces are becoming so great that the magnets that produce them would themselves be torn apart [10]; the electrical field strength is reaching the ionization threshold of atoms; electrons from nuclei in the accelerator's support structures would be torn. In this regard, a new scheme for the acceleration of charged particles by intense laser pulses propagating through plasmas has gained significant interest among researchers [11, 12].

The electric field problem can be mitigated by using plasma as a medium in particle accelerator due to its immunity against ionization-induced damages. The principle of plasma particle accelerators is that the electrons can be accelerated by the electric fields generated within a plasma with the help of intense laser pulses. Plasma is a state of matter heated to such a high temperature that electrons are stripped from their atomic hosts. Thus, because the plasma is already in an ionized state, plasma-based particle accelerators are not susceptible to electron dissociation. In theory, they can sustain accelerating fields thousands of times stronger than conventional technologies, enabling plasma particle accelerators to dodge structural failure issues.

Accelerating particles does not necessarily mean increasing their velocity with time. Accelerated particles moving with velocities nearly the speed of light are already available from modern particle accelerators. The particles are accelerated in the sense that their mass and, hence, momentum increases in accordance with the theory of relativity as they absorb energy from a field. The particles' velocity, however, may increase very little [13].

There are two schemes to accelerate the electrons by using laser beams. By exciting a large phase velocity plasma wave into the plasma by the beat wave mechanism, the resulting plasma wave can accelerate electrons to hundreds of MeV energy [14, 15]. The beat-wave method generates plasma waves from two intense laser beams whose light has different frequencies. The beams are combined so that the light waves interfere, forming alternating regions where the two waves are in phase (and reinforce) and regions where they are out of phase (and cancel). The result is a beat wave in the composite wave, oscillating at a frequency equal to the difference in the frequencies of the parent beams. If the composite beam is then focused into a plasma, the beam creates regions of high and low radiation pressure. If the frequency of the beats is equal to the plasma's natural frequency of oscillation, the plasma electrons respond resonantly and produce powerful plasma waves. In the beat-wave process, both the evolution of the plasma wave and the propagation of the two laser beams through the plasma are highly complex.

The second way of electron acceleration by lasers is ponderomotive acceleration [16–18]. In this mechanism, the electron is accelerated by the radiation pressure exerted by an intense laser pulse. During the ascending part of the pulse, the electron is accelerated in the forward direction and backward in the trailing part of the pulse. As a result, the average acceleration of the electron will be zero. However, if the accelerated electron leaves the laser pulse before being decelerated, it will have net energy gain.

The advantage of the proposed scheme is that it can accelerate the electrons that are initially at rest. At relativistic intensities, the ponderomotive acceleration mechanism can significantly accelerate the electron. Another advantage of this scheme is that it does not require an extractor as the electrons can easily be driven out of the interaction region by the radial component of the ponderomotive force.

It is a well-established fact that the optical nonlinearity of plasmas is highly dependent on irradiance profiles of the laser pulses [19–22], and thus the beams with different amplitude structures will affect intensity ripples in different ways. However, previous investigations on laser-driven electron acceleration have been carried out for ideal Gaussian laser pulses [14–18]. In contrast to this picture, the experimental investigations on the spatial irradiance profiles of laser pulses [23] reveal that the actual irradiance over the cross section of the laser pulse is significantly deviated from the Gaussian profile. A significant amount of laser energy was found to be lying outside the full-width half maximum of the irradiance profile. The best irradiance profile that fits into the experimental data [24] is Tsalli's q-Gaussian distribution [25]. To the best of author's knowledge, earlier investigations on the effect of self-focusing of the laser pulse on electron acceleration in plasmas have been reported for q-Gaussian laser beams. Thus, the aim of this paper is to give the first theoretical investigation on laser-driven electron acceleration on self-focused q-Gaussian laser pulses in plasma.

Self-focusing of laser pulse. Consider the propagation of a circularly polarized laser pulse with angular frequency ω_0 and wave number k_0 through a plasma with equilibrium electron density n_0. The electric field vector of the laser pulse is given by

$$\mathbf{E} = A_0\, e^{i(k_0 z-\omega_0 t)} e^{-\frac{((t-z)/v_G)^2}{2\tau_0^2}} \left(\mathbf{e_x} + i\mathbf{e_y}\right), \tag{1}$$

where, v_G is the group velocity of the laser pulse and τ_0 is its pulse duration. The dielectric function of plasma can be written as

$$\varepsilon = 1 - \omega_p^2/\omega_0^2,$$

where

$$\omega_p^2 = \frac{4\pi e^2}{m_e} n_0 \tag{2}$$

is the equilibrium plasma frequency, m_e and e are the electronic mass and charge, respectively. Under the intense field of the laser pulse, the oscillations of the plasma electrons become relativistic and the mass m_e of the electron in Eq. (2) needs to be replaced by the relativistic mass, which is related to the pulse amplitude as [26]:

$$m_e = m_0 \sqrt{1 + \frac{e^2}{m_0^2 c^2 \omega_0^2} A_0 A_0^\star}\ . \tag{3}$$

Thus, in the presence of a laser pulse, the dielectric function of plasma gets modified as

$$\varepsilon = 1 - \frac{\omega_{p0}^2}{\omega_0^2}\left(1 + \frac{e^2}{m_0^2 c^2 \omega_0^2} A_0 A_0^\star\right)^{-1/2}, \tag{4}$$

where

$$\omega_{p0}^2 = \frac{4\pi e^2}{m_0} n_0 \tag{5}$$

is the equilibrium plasma frequency. Thus, the relativistic effects make the index of refraction of plasma intensity dependent, which in turn, due to the spatial dependence of the amplitude structure of the laser pulse, resembles that of graded index fiber. Separating the dielectric function of plasma into linear (ε_0) and nonlinear (φ) parts as $\varepsilon = \varepsilon_0 + \varphi(EE^*)$ we get

$$\varepsilon_0 = 1 - (\omega_{p0}^2 / \omega_0^2) \tag{6}$$

and

$$\varphi\left(EE^\star\right) = \frac{\omega_{p0}^2}{\omega_0^2}\left\{1 - \left(1 \Big/ \left(1 + \frac{e^2}{m_0^2 c^2 \omega_0^2} A_0 A_0^\star\right)^{1/2}\right)\right\}. \tag{7}$$

Now, the wave equation governing the evolution of amplitude A_0 of the laser pulse is

$$i\frac{\partial A_0}{\partial z} = \frac{1}{2k_0}\nabla_\perp^2 A_0 + \frac{k_0}{2\varepsilon_0}\varphi\left(A_0 A_0^\star\right) A_0 . \tag{8}$$

We have used variational theory [27, 28] to find the semi-analytical solution of Eq. (8). According to this theory, Eq. (8) is a variational problem for the action principle based on Lagrangian density

$$\mathcal{L} = i\left(A_0 \frac{\partial A_0^\star}{\partial z} - A_0^\star \frac{\partial A_0}{\partial z}\right) + \left|\nabla_\perp A_0\right|^2 - \frac{\omega_{p0}^2}{c^2}\int^{A_0 A_0^\star}\left\{-1 \Big/ \left(1 + \frac{e^2}{m_0^2 c^2 \omega_0^2} A A_0^\star\right)^{1/2}\right\} d\left(A_0 A_0^\star\right). \tag{9}$$

We have considered the trial function of the form

$$A_0(x,y,z) = \frac{E_{00}}{f}\left\{1 + \frac{r^2}{q r_0^2 f^2}\right\}^{-q/2}. \tag{10}$$

Here, E_{00} is the axial amplitude of the field of the laser pulse and r_0 is the initial beam width of the main laser pulse. The phenomenological parameter q is related to the deviation of amplitude structure from the ideal Gaussian profile and is termed as the deviation parameter. The value of deviation parameter q varies from laser to laser and can be obtained by fitting it into the experimental data for a given laser system. f is the currently undetermined real function of longitudinal coordinate z. Upon multiplication with r_0, it gives the instantaneous spot size of the laser pulse. Thus, function f is termed as a dimensionless beam width parameter.

Substituting the trial function given by Eq. (10) in Lagrangian density and integrating it over the entire cross section of the laser pulse, we get the reduced Lagrangian as $L = \int \mathcal{L} d^2 r$. The corresponding Euler–Lagrange equation

$$\frac{d}{dz}\left(\frac{\partial L}{\partial(\partial f/\partial z)}\right) - \frac{\partial L}{\partial f} = 0$$

gives

$$\frac{d^2 f}{dz^2} = \frac{1}{2k_0^2 r_0^4}\frac{1}{f^3}\left(1-1/q\right)\left(1-2/q\right)\left[\left(1+1/q\right)^{-1} + \left(\langle L_1\rangle \frac{\langle L_1\rangle}{E_{00}^2} f^2 + 2\frac{E_{00}^2}{f^3}\frac{\partial\langle L_1\rangle}{\partial f}\right)\right], \quad (11)$$

where

$$\langle L_1\rangle = \frac{\omega_{p0}^2}{c^2}\int\left(\int_0^{A_0A_0^\star}\left\{-\left(1+\frac{e^2}{m_0^2\omega_0^2c^2}\frac{E_{00}^2}{f^2}\left(1+\frac{r^2}{qr_0^2 f^2}\right)^{-q}\right)^{-1/2}\right\} d\left(A_0A_0^\star\right)\right) dr .$$

Eq. (11) can be written as

$$\frac{d^2 f}{dZ^2} = \left(\frac{c}{\omega_0 r_0}\right)^4\left[\frac{\left(1-1/q\right)\left(1-2/q\right)}{\left(1+1/q\right)}\frac{1}{f^3} - \left(1-1/q\right)\left(1-2/q\right)\left(\frac{\omega_{p0}^2 r_0^2}{c^2}\right)\frac{a_0^2}{f^3} I\right], \quad (12)$$

where

$$I = \int_0^\infty u^3\left(1+\frac{u^2}{q}\right)^{-2q-1}\left(1+\frac{\beta E_{00}^2}{f^2}\left(1+\frac{u^2}{q}\right)^{-q}\right)^{-3/2} du ,\ d' = dk_0 r_0^2,\ u = r/(r_0 f),\ Z = z\omega_0/c,\ a_0 = eE_{00}/(m_0\omega_0 c).$$

Equation (12) is the differential equation governing the evolution of beam width of the q-Gaussian laser pulse during its journey through the plasma. The first terms on the right-hand side (RHS) of this equation corresponds to the linear propagation of the laser pulse, i.e., its propagation through a vacuum or through the media whose index of refraction is independent of the intensity of the laser pulse. The second terms on the RHS of this equation corresponds to the nonlinear response of the medium.

Equations of motion of an electron. The electric field vector of the laser pulse given by Eq. (1) can also be written as

$$\mathbf{E} = \frac{E_{00}}{f}\left\{1+\frac{r^2}{qr_0^2 f^2}\right\}^{-q/2} e^{-\frac{\left((t-z)/v_G\right)^2}{2\tau_0^2}} \left(\cos\left(k_0 z - \omega_0 t\right)\mathbf{e_x} + \sin\left(k_0 z - \omega_0 t\right)\mathbf{e_y}\right). \quad (13)$$

Under the combined effects of electric and magnetic fields of the laser pulse, the equation of motion of an electron can be written as

$$d\mathbf{p}/dt = -e\mathbf{E} - (e/c)\mathbf{v}\times\mathbf{B}. \quad (14)$$

The magnetic field vector of the laser pulse can be obtained by using Maxwell's equation:

$$\nabla\times\mathbf{E} = (-1/c)(\partial\mathbf{B}/\partial t).$$

In its component form, Eq. (14) can be written as

$$\frac{dp_x}{dz} = -\frac{eE_x}{v_z} + \frac{e}{c}B_y,\quad \frac{dp_y}{dz} = -\frac{eE_y}{v_z} - \frac{e}{c}B_x,\quad \frac{dp_z}{dz} = -\frac{e}{c}\frac{v_x}{v_z}B_y + \frac{e}{c}\frac{v_y}{v_z}B_x. \quad (15)$$

In writing the set of Eqs. (15), we have made use of the transformation $d/dt = v_z d/dz$. The corresponding equations for time evolution and trajectory of the electron are

$$dx/dz = p_x/p_z,\quad yx/dz = p_y/p_z,\quad dt/dz = m_0\gamma/p_z - 1/c, \quad (16)$$

where

$$\gamma = \sqrt{1 + \frac{p_x^2}{m_0^2 c^2} + \frac{p_y^2}{m_0^2 c^2} + \frac{p_z^2}{m_0^2 c^2}} \tag{17}$$

is the energy gained by the electron. Now using the transformations

$$X \to x\omega_0/c,\ Y \to u\omega_0/c,\ P_X \to p_x/(m_0c),\ P_Y \to p_y/(m_0c),\ \ P_Z \to p_z/(m_0c),\ \ T \to \omega_0\tau$$

eqs. (15)–(17) can be written as

$$\frac{dP_X}{dZ} = \left(1 - \frac{\gamma}{P_Z}\right)\frac{a_0}{f}\left\{1\frac{\left(X^2 + Y^2\right)c^2}{qr_0^2\omega_0^2 f^2}\right\}^{-q/2} e^{-\frac{(T-Z)^2}{2\omega_0^2\tau_0^2}} \cos\left(T - Z\right),$$

$$\frac{dP_Y}{dZ} = -\left(1 - \frac{\gamma}{P_Z}\right)\frac{a_0}{f}\left\{1\frac{\left(X^2 + Y^2\right)c^2}{qr_0^2\omega_0^2 f^2}\right\}^{-q/2} e^{-\frac{(T-Z)^2}{2\omega_0^2\tau_0^2}} \sin\left(T - Z\right),$$

$$\frac{dP_Z}{dZ} = \frac{a_0}{f}\left[-\left(\frac{P_X}{P_Z}\right)\cos\left(T - Z\right) + \left(\frac{P_Y}{P_Z}\right)\sin\left(T - Z\right)\right]\left\{1\frac{\left(X^2 + Y^2\right)c^2}{qr_0^2\omega_0^2 f^2}\right\}^{-q/2} e^{-\frac{(T-Z)^2}{2\omega_0^2\tau_0^2}}, \tag{18}$$

$$dX/dZ = P_X/P_Z,\ \ dY/dZ = P_Y/P_Z,\ \ dT/dZ = \gamma/P_Z - 1,\ \ \gamma = \sqrt{1 + P_X^2 + P_Y^2 + P_Z^2}\ .$$

Results and discussion. Equation (12) governs the evolution of beam width of the laser pulse with the distance of propagation, whereas the set of Eq. (18) governs the dynamics of accelerated electrons. These equations have been solved numerically for the following set of laser-plasma parameters to see the effect of self-focusing of the laser pulse on energy gained by the electrons: $\omega_0 = 1.78\times10^{15}$ rad/s, $\tau_0 = 15\times10^{-15}$ s, $r_0 = 15$ μm, $T(0) = 0.2$, $P_X(0) = 0.01$, $P_Y(0) = 0.01$, $P_Z(0) = 0.02$, and $q = (3,4,\infty)$, $a_0^2 = (3,3.5,4)$, and $(\omega_{p0}r_0/c)^2 = (9,12,15)$.

Figure 1a depicts the effect of deviation parameter q of the laser pulse on the evolution of its beam width. It can be seen that the beam width of the laser pulse evolves in an oscillatory manner over the distance of propagation. These oscillations of beam width of the laser pulse are the signature of saturation effect of relativistic mass nonlinearity. Initially the convergence of the laser pulse dominates over the diffraction effect and thus the laser pulse starts converging. However, as the intensity of the laser pulse increases due to its self-focusing, its intensity increases, whereas the radial gradient in the nonlinear index of refraction decreases and thus the diffraction starts dominating convergence. Hence, after attaining minimum possible beam width, the beam starts diverging towards its original beam width. These processes keep on repeating themselves and thus the laser pulse width depicts an oscillatory behaviour.

It can be seen that with increase in the value of deviation parameter q, the extent of self-focusing of the laser pulse gets reduced. This is due to the fact that for laser pulses with a larger value of q, most of the energy is concentrated around a narrow region around the beam axis. Hence, such laser pulses get a little contribution from the axial rays towards the nonlinear refraction. As the phenomenon of self-focusing is a homeostasis of nonlinear refraction of the optical beam due to optical nonlinearity of the medium, increase in the value of deviation parameter q reduces the extent of self-focusing of the laser pulse. Thus, compared to q-Gaussian laser pulse, ideal Gaussian laser pulses possess minimum focusing character. It can also be seen that instead of their reduced focusing, laser pulses with higher values of deviation parameter q possess faster focusing along both of the transverse directions, due to the faster focusing character of the rays closer to beam axis. Being away from the beam axis, axial rays take longer to become self-focused. As there are more numbers of off axial rays in laser pulses with lower values of deviation parameter q, these beams possess slower focusing character.

Figure 1b depicts the effect of the intensity of the laser pulse on its self-focusing. It can be seen that with increase in initial intensity of the laser pulse, there is considerable increase in the extent of its self-focusing. This is due to the fact that with increase in initial intensity of the laser pulse, the relativistic mass nonlinearity of the plasma electron increases, which in turn enhances the self-focusing of the laser pulse.

Figure 1c illustrates the effect of equilibrium plasma density on the extent of self-focusing of the laser pulse. It has been observed that with increase in plasma density, the extent of self-focusing of the laser pulse increases. This is due to the fact that with increase in equilibrium plasma density, the number of electrons contributing to relativistic nonlinearity in the index of refraction of plasma increases. This enhanced nonlinearity in the index of refraction of plasma results in an increase in the extent of self-focusing of the laser beam.

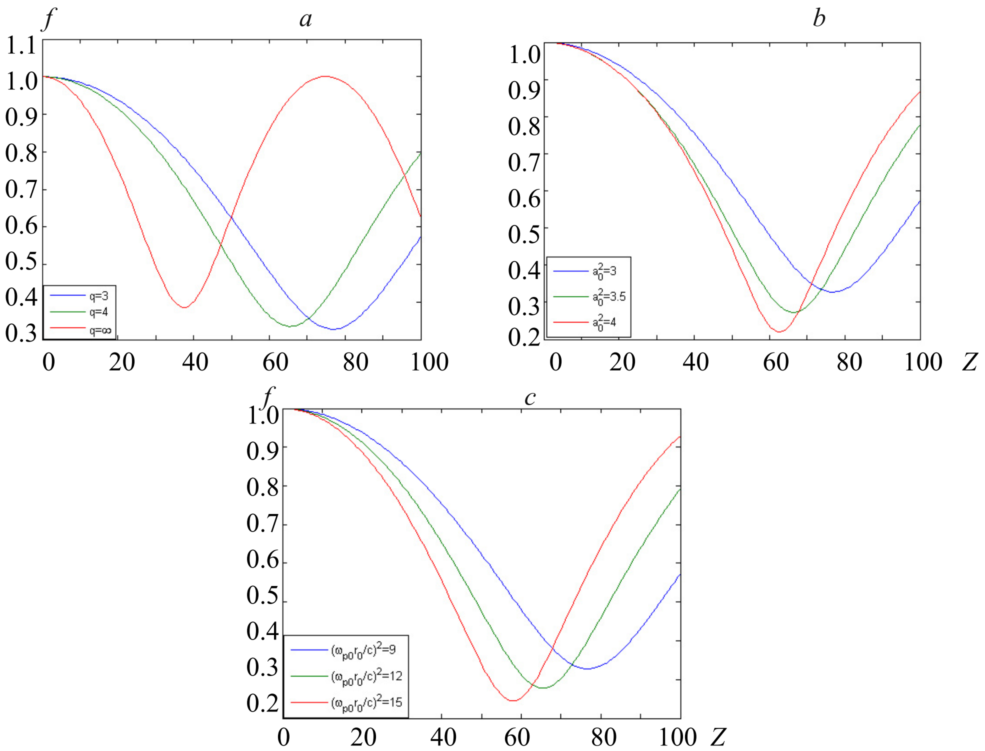

Fig. 1. Evolution of beam widths f of the laser beam with distance of propagation through plasma for (a) $q = (3,4,\infty)$, $a_0^2 = 3$, and $(\omega_{p0}r_0/c)^2 = 9$, (b) $q = 3$, $a_0^2 = (3,3.5,4)$, and $(\omega_{p0}r_0/c)^2 = 9$, (c) $q = 3$, $a_0^2 = 3$, and $(\omega_{p0}r_0/c)^2 = (9,12,15)$.

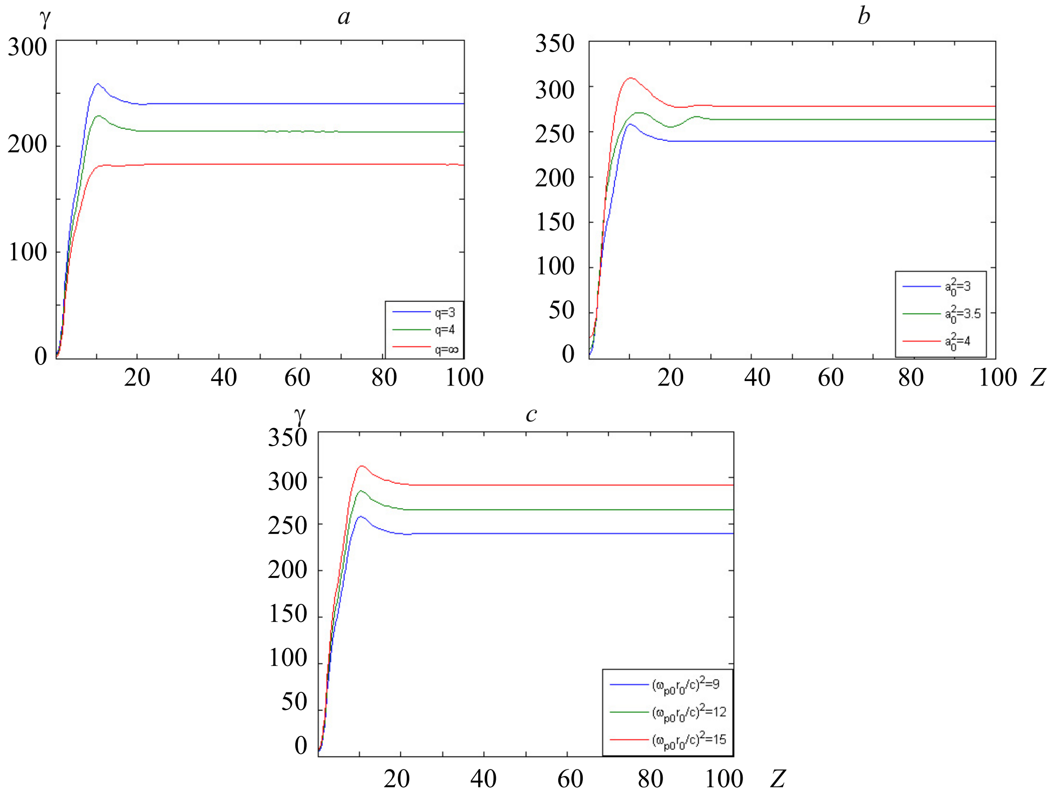

Fig. 2. Evolution of electron energy with distance of propagation through plasma for (a) $q = (3,4,\infty)$, $a_0^2 = 3$, and $(\omega_{p0}r_0/c)^2 = 9$, (b) $q = 3$, $a_0^2 = (3,3.5,4)$, and $(\omega_{p0}r_0/c)^2 = 9$, (c) $q = 3$, $a_0^2 = 3$, and $(\omega_{p0}r_0/c)^2 = (9,12,15)$.

Figure 2a depicts the variation of normalized electron energy with distance of propagation. It can be seen that initially the electron gained energy from the laser pulse almost linearly then, after some distance of propagation, its energy became saturated with a little decrease from the maximum energy gained. This is due to the fact that, during the rising part of the pulse, the electron keeps on gaining energy from it untill the peak of pulse is reached. When the electron reaches the tail of the pulse, the pulse begins to diverge. Thus, the deacceleration of the electron from the trailing part of the pulse is less compared to the acceleration provided by the ascending part of the pulse. Hence, the electron leaves the pulse with net energy gain. It can also be seen that with the increase in deviation parameter q of the laser pulse, there is decrease in net energy gained by the electron. This is due to the fact that the higher the extent of self-focusing of the laser pulse, the higher its peak intensity will become. Thus, there is one to one correspondence between the extent of self-focusing of the laser pulse and net energy gained by the electron. As with the increase in deviation parameter q of the laser pulse, there is decrease in its extent of self-focusing, which results in a decrease in net energy gained by the electron.

Figures 2b and 2c depict the initial intensity of the laser pulse and equilibrium plasma density, respectively on energy gained by the electron. It can be seen that there is an increase in net energy gained by the electron with an increase in either the initial intensity of the laser pulse or the equilibrium plasma density.

Figure 3a depicts the electron trajectories for different values of deviation parameter q of the laser pulse. It can be seen that the electron moves along a helical path. This is due to the fact that due the circular polarization of the laser pulse the electron follows circular orbit and as the electron gain momentum along z axis, its trajectory becomes helical. It can also be seen that with increase in deviation parameter q of the laser pulse, the radius of electron's orbit decreases. This is due to the fact that the radius of the electron orbit is directly proportional to its velocity. As with the increase in the deviation parameter q of the laser pulse the energy of electron reduces, this further reduces the radius of electron's orbit.

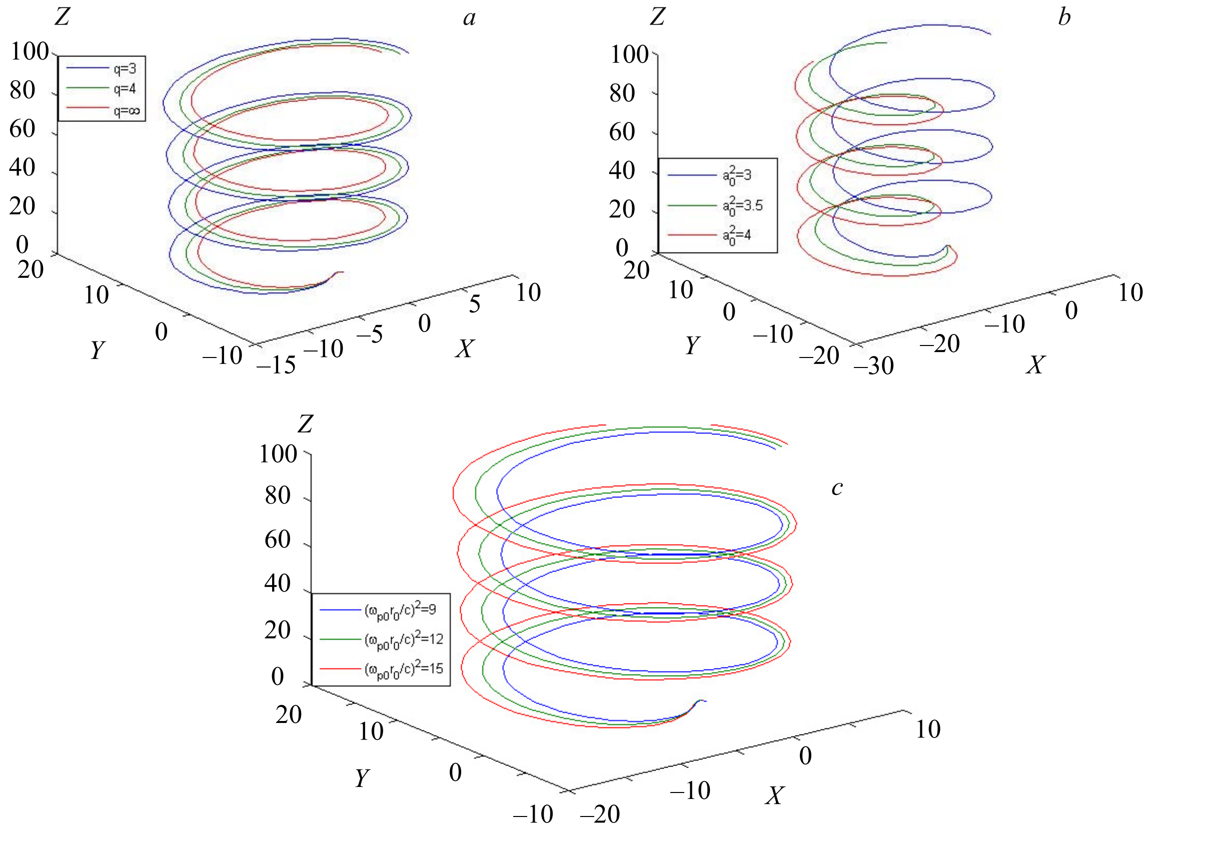

Fig. 3. Evolution of electron trajectories for (a) $q = (3,4,\infty)$, $a_0^2 = 3$, and $(\omega_{p0}r_0/c)^2 = 9$, (b) $q = 3$, $a_0^2 = (3,3.5,4)$, and $(\omega_{p0}r_0/c)^2 = 9$, (c) $q = 3$, $a_0^2 = 3$, and $(\omega_{p0}r_0/c)^2 = (9,12,15)$.

Figures 3b and 3c depict the effect of initial intensity of the laser pulse and equilibrium plasma density on trajectories of electron. It can be seen that with increase in the initial pulse intensity of equilibrium plasma density, the radius of electron trajectories increases. This is due to an increase in electron energy along with an increase in initial pulse intensity or equilibrium plasma density.

Conclusions. In conclusion we have investigated laser-driven electron acceleration in plasmas. The effect of self-focusing of the laser beam on energy gained by the electron has been incorporated. From the results of the present investigation, it can be concluded that self-focusing of the laser beam as well as irradiance profile of the laser beam have significant effects on energy gained by the accelerated electron. Laser beams with a lower value of deviation parameter *q,* i.e., beam with expanded wings, are more suitable for electron acceleration. The results of the present investigation may serve as a guide for researchers working on laser-driven acceleration.

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