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Comment on "Electron acceleration by a chirped Gaussian laser pulse in vacuum" [Phys. Plasmas 13, 123108 (2006)]

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Sohbatzadeh *et al.* [Phys. Plasmas **13**, 123108 (2006)] have presented a scheme of vacuum electron acceleration by using a chirped Gaussian laser pulse. They assume a linear polarization of the laser pulse in this scheme. We point out that this might be an important assumption in their work and it can seriously influence the electron energy gain during laser acceleration. In this Comment, the circular polarization of a chirped laser pulse is employed and our results show higher electron energy gains. © *2007 American Institute of Physics*. [DOI: 10.1063/1.2714335]

Direct laser electron acceleration in vacuum has received much attention in recent years.[1–4] Chirp-pulse amplification[5] renewed the research interest of electron acceleration in vacuum. Recently, Sohbatzadeh *et al.*[6] have proposed a scheme for vacuum electron acceleration by linearly polarized negative chirped laser. They have found that the maximum electron energy gain during the acceleration by linearly polarized chirped laser pulse is higher than that of the case of unchirped laser pulse. Before this, Gupta and Suk[7,8] studied vacuum electron acceleration schemes by using a chirped laser pulse, where the effect of a magnetic field was also considered and the laser field in our previous work was also linearly polarized. Here we would like to point out that the circular polarized chirped laser should be better for vacuum electron acceleration. We expect that due to the axial symmetry of circular polarized laser fields better acceleration effect can be achieved.

The electric-field ($\vec{E}$) components of a circularly polarized chirped laser pulse are expressed as follows:

$$E_x = E_0 \frac{W_0}{W(z)} \exp\left[-\frac{r^2}{W(z)^2}\right] \cos\left[\frac{kr^2}{2R(z)} - \phi(z) + \omega(\zeta)\zeta + \varphi_0\right] \exp\left(-\frac{\zeta^2}{\tau_p^2}\right), \quad (1)$$

$$E_y = E_0 \frac{W_0}{W(z)} \exp\left[-\frac{r^2}{W(z)^2}\right] \sin\left[\frac{kr^2}{2R(z)} - \phi(z) + \omega(\zeta)\zeta + \varphi_0\right] \exp\left(-\frac{\zeta^2}{\tau_p^2}\right), \quad (2)$$

and

$$E_z = \frac{i}{k}\left(\frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y}\right), \quad (3)$$

where all the signs are the same as those in Sohbatzadeh *et al.*[6]

Here we would like to mention that the y component of the laser electric field is assumed zero in Ref. 6, because of the assumption of linear polarization. Due to the circular polarization of the laser pulse, the E_y component will survive and, furthermore, the E_z component will be modified as mentioned above. The magnetic field related to the laser electric field can be obtained from $\vec{B} = -(i/\omega)\nabla \times \vec{E}$.

Hence, Eqs. (19)–(22) of Ref. 6 are not valid anymore if the circularly polarized laser pulse is considered. In this Comment, we use three–dimensional test particle simulations to study the electron dynamics in the field of a circularly polarized chirped laser pulse. The equations governing electron momentum and energy are

$$\frac{d\vec{p}}{dt} = -e(\vec{E} + \vec{\beta} \times \vec{B}), \quad (4)$$

$$\frac{d\gamma}{dt} = -e\vec{\beta}\cdot\vec{E}, \quad (5)$$

where the momentum $\vec{p} = \gamma\vec{\beta}$ is normalized in the unit of m_0c, the energy is normalized in the units of m_0c^2, $\gamma = (1 - \beta^2)^{-1/2}$ is the Lorentz factor, $\vec{\beta}(\beta_x, \beta_y, \beta_z)$ is the electron velocity in the unit of c, m_0 is the electron mass, and c is the velocity of light in vacuum. Other normalizations are the same as in Ref. 6.

Figure 1(a) shows the electron energy gain (γ) with the initial phase (φ_0) for chirp parameter $b' = 0.005$. Other numerical parameters are the same as those of Fig. 5(a) of Ref. 6. The solid squares (■) are for our simulation results and the hollow squares (□) are for the model given by Sohbatzadeh *et al.*,[6] where the linearly polarized chirped laser is used. It is observed that the final electron energy gain is significantly higher in our case for all values of the initial phases. The retained electron energy is very sensitive to the initial phase of the field. Figure 1(b) shows the obtained electron energy as a function of the laser spot radius. The energy shown by the solid square is for the case of a circularly polarized chirped laser. In Fig. 2, the variation of electron energy against the longitudinal distance (kz) is shown. Finally, the maximum electron energy with the chirp parameter is shown in Fig. 3. It is found that electrons can gain a maximum energy for chirp parameter $b' = 0.015$. However, the electron energy is maximized for $b' = 0.008$ in the case of a linearly polarized chirped laser pulse. Hence, a suitable

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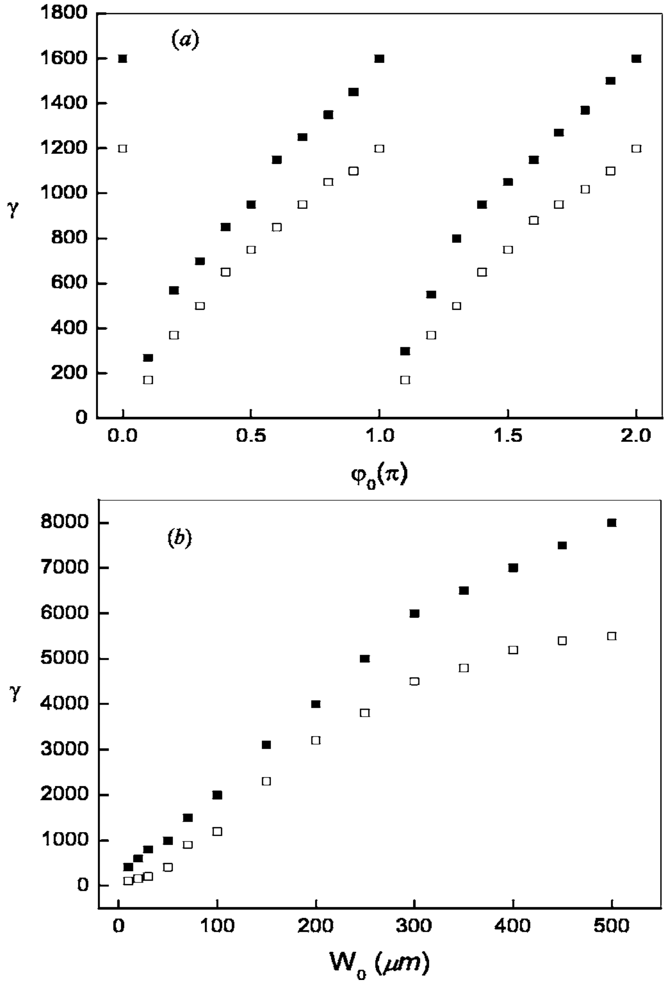

FIG. 1. (a) Final electron energy with the initial phase of the laser field for a=2.15, λ_0=800 nm, and b'=0.005. (b) Final electron energy with the laser beam waist for a=2.15, λ_0=800 nm, t_p=100 fs, b'=0.005, and φ_0=0. The solid squares (■) are for our simulation results and the hollow squares (□) are for the model given by Ref. 6.

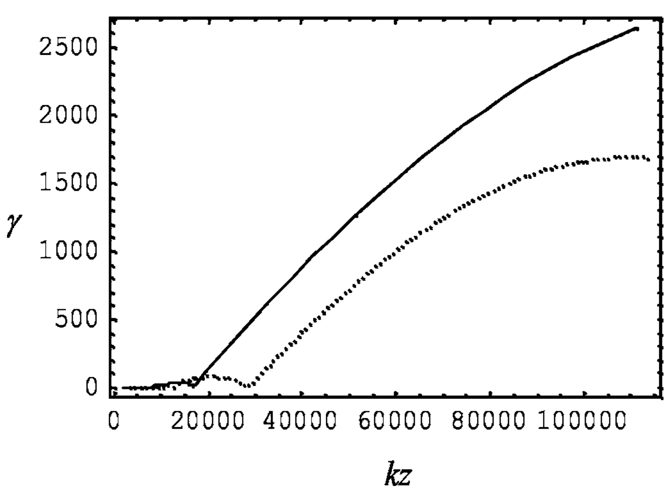

FIG. 2. Variation of electron energy with kz for β_{0z}=0.9, b'=0.008, a =2.15, t_p=100 fs, λ_0=800 nm, and φ_0=0.9π. The solid line is for our simulation results and the dotted line is for the model given by Ref. 6.

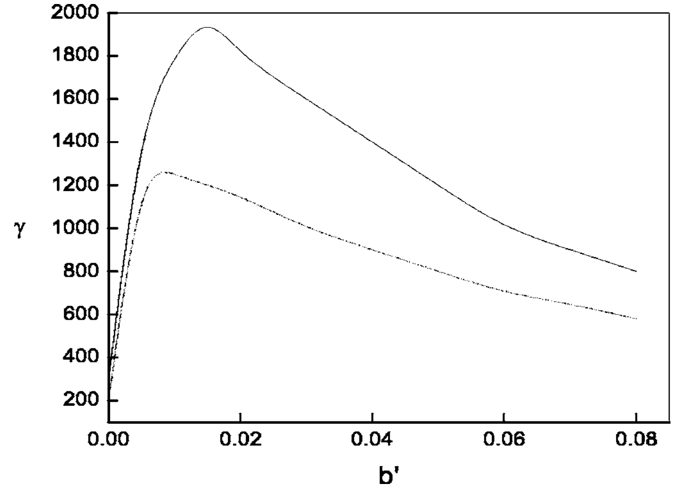

FIG. 3. Final electron energy with chirp parameter for a=2.15, β_{0z}=0.99, t_p=100 fs, and λ_0=800 nm. The solid line is for our simulation results and the dotted line is for the model given by Ref. 6.

frequency chirp is necessary for efficient energy exchange between laser and electron. Here we would like to mention that we have used the laser intensity parameter a=2.15 corresponding to Ref. 6. However, for a circularly polarized laser this should be a=1.52 to keep the total pulse energy the same. Although, according to our simulation, in this case, the electron energy would be somewhat reduced but of course it would be much higher than that was observed in Ref. 6.

In conclusion, our numerical results show that the electron energy gain is much higher if a circularly polarized chirped laser is employed for electron acceleration in vacuum. In the case of a linearly polarized laser pulse, the parameters of the laser pulse interaction with an electron depend upon the direction of polarization and the resonance absorption has an inhomogeneous distribution, which reduces the efficiency of the acceleration process. In the case of a circularly polarized laser pulse, the resonance absorption has axial symmetry and electrons can gain significantly higher energies.

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[1]H. Hora, Nature (London) **333**, 337 (1988).
[2]K. P. Singh, Appl. Phys. Lett. **87**, 254102 (2005).
[3]G. Malka, E. Lefebvre, and J. L. Miquel, Phys. Rev. Lett. **78**, 3314 (1997).
[4]B. Quesnel and P. Mora, Phys. Rev. E **66**, 066501 (2002).
[5]M. D. Perry, and G. A. Mourou, Science **264**, 917 (1994).
[6]F. Sohbatzadeh, S. Mirzanejhad, and M. Ghasemi, Phys. Plasmas **13**, 123108 (2006).
[7]D. N. Gupta and H. Suk, Phys. Plasmas **13**, 044507 (2006).
[8]D. N. Gupta and H. Suk, Phys. Plasmas **13**, 013105 (2006).