Laser-electron interaction in plasma channel with dispersion effect

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Synopsis Laser-electron interaction in a plasma channel is presented, taking into the action of superluminosity of the laser phase velocity induced by the dispersion of the plasma and the channel.

Electron acceleration in laser-plasma physics is gaining growing attention. Beams of electron at GeV have been produced by laser wakefield acceleration [1]. However, wakefield acceleration typically requires very expensive and multiterawatt laser systems. Unlike wakefield acceleration, direct laser acceleration is a linear process with no threshold intensity, and it offers an attractive alternative for producing energetic electrons. Direct laser acceleration has been demonstrated in gases, vacuum[2], and preformed plasma channels [3, 4].

However, there are many open questions, both from the basic principle and the understanding in underling process, needed to be further discussed in the production of highly energetic electron in laser-plasma interaction. Particularly, each direct acceleration scheme has to focus on overcoming one of the underlying assumptions of the Lawson-Woodward theorem to achieve net energy gain. Furthermore, previous work [4] neglected the response of laser in ion channel, by using the assume that the laser pulse propagates as the light velocity in a plasma channel with no electromagnetic dispersion. Generally, the presence of the plasma and plasma channelling could independently lead the laser pulse being subject to wave dispersion.

To solve the critical problem (electrons gain nonzero net energy in laser-plasma interaction), we investigate the dynamics of electron irradiated by a linearly polarized laser pulse in a plasma channel, and introduce the dispersive nature of electromagnetic waves in plasma channel via the specification of an arbitrary phase velocity. The coupled effects of laser phase velocity and plasma channel on electron acceleration are discussed in detail. The superluminosity of the laser results in rich and complex electron dynamics which are depicted in the plane of the phase velocity and plasma charge density in figure 1. For weak superluminosity (regions I and IV), the electron oscillation is mainly depends on the plasma charge density, and the effect of the phase velocity can be neglected. For moderate superluminosity (region II), a cross-over region can exist, where the highly energetic electron could be found and the net energy gain is several times greater than energy gain in vacuum. For strong superluminosity (regions III), although the maximum electron energy is limited, the electron could get adjustable net energy gain from the laser, due to the superluminosity of the laser. The electron oscillations are no longer limited by the charge density threshold and the electron can always get net energy from the laser.

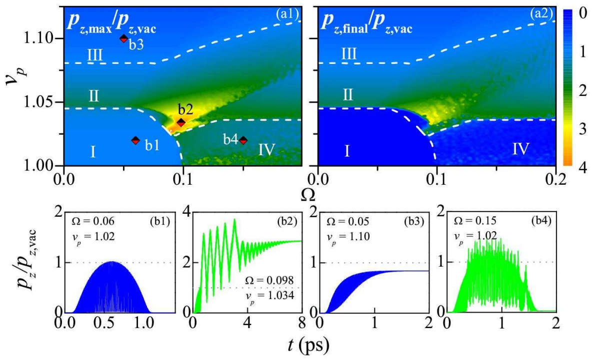

Figure 1. (color online) Longitudinal momentum of electron irradiated by the laser pulse for different phase velocity v_p and plasma charge density Ω.

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References

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