Direct laser acceleration in plasmas with a density gradients

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The interaction of high-intensity laser pulses with plasmas can be used to accelerate particles. Among the many mechanisms proposed to achieve effective acceleration is direct laser acceleration (DLA). The main advantage of DLA compared to other mechanisms is its ability to provide high charge ($\sim$ 100 nC) electron beams with a broad Maxwellian-like energy spectrum.

When an intense laser pulse propagates through an underdense plasma, it creates a plasma channel that triggers betatron oscillations of electrons around its central axis. When conditions are favorable, the resonance between betatron oscillations and oscillations in the field of the laser pulse can lead to electron acceleration. The mechanism has been well-described for an ideal case of a constant plasma density considering an immobile ion background. However, the potential advantages of using plasmas with a varying density profile are still not well understood.

In our work, we describe the most important differences between the regimes with constant and varying density using quasi 3D geometry of particle-in-cell code OSIRIS. We show that the density profile influences the self-focusing of the laser pulse which strongly impacts the resulting interaction with the plasma electrons. Furthermore, we propose a way how to utilize the varying density profile to maximize the electron beam energy and charge.

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