New and Emerging Concepts in Laser-Plasma Acceleration

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I will describe some of the recent work from several groups aimed at integrating direct laser acceleration (DLA) and laser wakefield acceleration (LWFA). While LWFA is an inherently near-field acceleration technique, the DLA is an example of a far-field accelerator that directly transfers the energy from the laser pulse to relativistic electrons undergoing betatron oscillation inside a plasma channel or a plasma bubble. One of the well-known limitations of LWFA is dephasing: the propensity of ultra-relativistic electrons to slip forward with respect to the wakefield, thereby advancing into the decelerating phase of the wake. Far-field accelerators, such as IFELs, suffer from their own limitations: the acceleration gradient rapidly falls as the function of the electron energy. I will demonstrate that these limitations of the far and near-field accelerators can be overcome in a hybrid laser wakefield/direct laser accelerators because these two accelerating mechanisms can operate simultaneously and synergistically, which implies two things. First, the distinct energy gains from the plasma wake and directly from the laser pulse are compounding, thereby increasing the total energy gain. Second, the energy gain from the wakefield is further increased because of the delayed dephasing caused by the DLA. I will show that the resulting phase space of self-injected plasma electrons is split into two, containing a subpopulation that experiences wakefield acceleration beyond the standard dephasing limit because of the multidimensional nature of its motion that reduces the phase slippage between the electrons and the wake. Several new concepts of combining DLA and LWFA will also be reviewed. One such concept involves combining a long-wavelength IR pulse ($\lambda \sim 2\mu$m) with a trailing short-wavelength ($\lambda \sim 0.8\mu$m) DLA laser.