Optimizing Direct Laser Acceleration

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Modern laser technology and the realization of high-intensity, short-pulse laser systems using Chirped-Pulse Amplification has led to the development of novel laser-based acceleration schemes. For high-intensity, picosecond duration pulses, where the pulse duration exceeds the plasma period, the laser pulse will expel nearly all of the electrons within the focal volume, creating an ion channel. Electrons that become trapped in the ion channel will gain energy directly from the laser field through the v $\times$ B force through a process known as Direct Laser Acceleration (DLA). Here, we present experimental measurements of electrons accelerated by the Omega Extended Performance (EP) laser system, through the interaction of a with 1 ps laser pulse with an underdense CH plasma plume. These results demonstrate the existence of an optimal plasma density for electron acceleration by DLA, producing electron beams with energies up to a record 0.6 GeV and 10s of nC charge. Two-dimensional PIC simulations conducted using the EPOCH code, with conditions designed to match Omega EP, confirm DLA as the dominant acceleration mechanism. Particle tracking enables further investigation into the dynamic role of quasi-static channel fields on electron energy enhancement, beam pointing and divergence, elucidating the mechanisms and action of DLA at different plasma densities and pulse durations. Electron beams generated by this scheme could be used to obtain brilliant, spatially coherent X-rays with the capability to be accurately synchronized to short pulse laser-initiated events and for experimental verification of the two-photon Breit-Wheeler process.