Transient Relativistic Plasma Grating to Tailor High-Power Laser Fields, Wakefield Plasma Waves, and Electron Injection

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We show the first evidence of the transverse laser interference for electron injection into the laser-plasma accelerators. An intense, ultrashort laser pulse (driver) can drive a large-amplitude plasma wave in underdense plasma. In the presented scheme, an additional laser pulse (injector) with similar parameters collides with the driver at a small acute angle. The collision generates a transverse standing wave, which in turn induces relativistic transient electron grating in plasma. A fraction of electrons is dephased in the grating and preaccelerated. These electrons are subsequently trapped by the plasma wave and further accelerated to 10s of MeVs. Such an injection is different from previous methods with different collision geometries because the injection is triggered solely due to the transverse plasma modulations caused by the deviation from a collinear geometry. As a result, the injection exhibits new features. For instance, the role of the driver and injector can be switched by tuning the relative delay between the pulses. In addition, electrons are trapped into later acceleration buckets of the plasma wave, creating a train of electron beams with femtosecond durations that are temporally spaced by only a few tens of femtoseconds. With optimal plasma tapering, the dephasing limit of such unprecedented electron beams could be potentially increased by an order of magnitude. As a consequence, the length of the accelerator can be significantly decreased. Such a train of short electron beams can be used as a source of bright X-rays that can be beneficial for many applications, such as a diagnostic tool to resolve the structure and dynamics of warm dense matter in laboratory astrophysics. The research is supported by experimental results carried out with the Diocles Ti:Sapphire laser system at the Extreme Light Laboratory as well as particle-in-cell simulations in the SMILEI code.