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Electromagnetic field growth triggering super-ponderomotive electron acceleration during multi-picosecond laser-plasma interaction

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A new regime of laser-plasma interaction (LPI) studies, i.e., multi picosecond (multi-ps) relativistic LPI, has been realized due to the development of kilojoule-class high power lasers. Although electron acceleration using a conventional sub-picosecond laser pulse has been explained theoretically as the interaction of a single electron with a laser field, it is necessary to consider the collective effect of electrons when the pulse duration reaches the multi-ps range. Energetic relativistic electrons (RE) generation was experimentally clarified with an average energy far beyond the ponderomotive scaling using the prepulse-free LFEX laser. During the multi-ps interaction, a quasi-static electric field is generated by plasma expansion. In addition, a quasi-static magnetic field is gradually generated due to three different mechanisms of the $\nabla n \times \nabla I$ effect, the $\nabla T \times \nabla n$ effect, and a loop current driven by the $E \times B$ drift. The third mechanism of the current loop rapidly amplifies the magnetic field strength by positive feedback between the electric and magnetic fields and the field-driven drift current.

Under the quasi-static electric field, REs are accelerated efficiently above ponderomotive scaling by the laser field because the dephasing rate of the REs from the laser field is reduced. Furthermore, when the quasi-static magnetic field becomes sufficiently strong to reflect REs back to the relativistic LPI region, the reflected REs gain additional energy.[1] The RE acceleration mechanism with re-injection has been investigated as loop injected direct acceleration (LIDA) (Fig. 1). The boosting timing of electron acceleration by the LIDA mechanism is related to the transition time of the relativistic LPI state from the hole-boring phase to the blowout phase. The equation for the transition time can be derived from the equations for the motion of a relativistic critical density interface and the equations for the electron density where the hole-boring terminates.[2]

This presentation consists of experimental and theoretical works. Developed the theoretical model to describe a hydrodynamic motion of a critical surface that interacts with a multi-picosecond PW laser pulse.[1] And, they pointed out that the expansion of a PW laser-irradiated plasma is the trigger of boosting the electron acceleration.[2] This electron acceleration mechanism becomes important in experiments performed on kJ-PW laser facilities such as LFEX (Japan), LMJ-PETAL (France), OMEGA-EP, and NIF-ARC (US).

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References

[1] S. Kojima et al., Communications Physics, **2**, 99 (2019).

[2] N. Iwata et al., Nature Communications, **9**, 623 (2018)

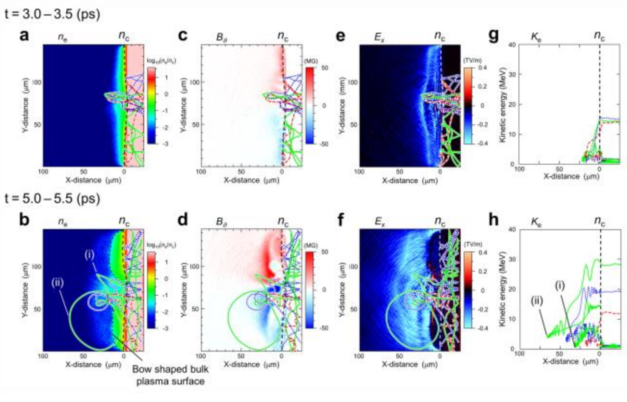

Fig. 1 Three examples of relativistic electron (RE) trajectories at two different periods (t = 3.0–3.5 and 5.0–5.5 ps) overlaid on the electron densities ((a) and (b)), self-generated azimuthal magnetic fields ((c) and (d)), and self-generated electric fields ((e) and (f)). (g), (h): Kinetic energies of REs along the longitudinal position for the two different periods.