Electron and proton acceleration in the regime of relativistic self-trapping of an intense Joule-class ultrashort laser pulse

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The results of numerical 3D PIC simulation of efficient proton acceleration from near-critical-density targets irradiated by femtosecond laser pulses with an energy of 2.2J are presented. The role of the relativistic self-trapping (RST) regime of a powerful laser pulse in the formation of an exploding cavity, where high-charge electron bunches are generated, has been investigated. These bunches create a combined accelerating field—a superposition of the double-layer field and the uncompensated charge field of the laser-accelerated electron bunch trapped in the cavity—providing proton injection and subsequent directed Coulomb explosion as the cavity passes through the target boundary. For pulse durations of 6–20fs, the efficiency of explosion-driven ion generation reaches 10–20MeV/J, exceeding the results obtained with thin-foil targets. Considering the prospects of high-repetition-rate laser systems and gas-jet targets, the obtained characteristics pave the way toward compact sources of protons, deuterons, and neutrons for radiobiology and material science applications.