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Ion acceleration mechanism driven by multi-picosecond PW laser pulses

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We demonstrate that high-contrast multi-picosecond pulses are advantageous for proton acceleration. By extending the pulse duration from 1.5 to 6 ps with fixed laser intensity of 10^{18} Wcm^{-2}, the maximum proton energy is improved more than twice (from 13 to 33 MeV). The proton energies observed are discussed using a plasma expansion model newly developed that takes the electron temperature evolution beyond the ponderomotive energy in the over picoseconds interaction into account.

Laser-driven ion acceleration with the laser intensity ranging from 10^{18} Wcm^{-2} to 10^{22} Wcm^{-2} is predominantly governed by the absorption mechanism of laser energy into electrons. Recently, it has been reported [1–3] that the plasma electrons are heated beyond the typical scaling low, ponderomotive potential [4] through the nonlinear motion of the electrons. In this paper, we investigate the electron heating in multi-picosecond (ps) time scale and its effect on the ion acceleration [5,6].

The experiment was performed using LFEX laser of ILE, Osaka University, which provides four beams of 1.5-ps (FWHM) duration. By setting intervals of 1.5 ps between the four pulses, we obtained duration-extended pulses of 3 ps, when we use two beams, and 6 ps, as the longest case using the four pulses. The maximum laser energy in total is 1 kJ (250 J for each laser beam), and the intensity is 2.3×10^{18} Wcm^{-2} on the target. Note the focal spot diameter is set to be 60 µm (FWHM), which makes a beneficial effect on the electron recirculation around the target, mentioned later. The accelerated ions were analyzed by a Thomson Parabola (TP) at the normal direction of the target rear surface. The electrons generated from the plasma were also measured by an electron spectrometer (ESM) located at the target rear side. The angle between the TP and the ESM was 20.9°.

As shown in Fig. 1(b), when we expand the pulse duration of the laser from 1.5 ps to 3 ps at the fixed laser intensity, the electron temperature is drastically enhanced up to 1.1 MeV, which clearly exceeds the ponderomotive potential around 0.2 MeV for the laser intensity of 2.3×10^{18} Wcm^{-2}. In addition, the proton energy, analyzed simultaneously with the electron

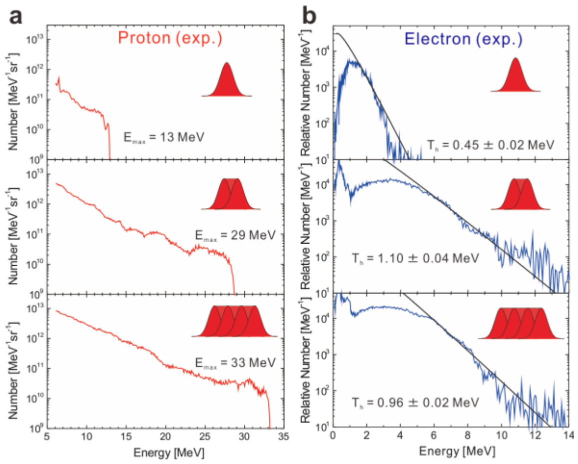

Fig. 1: The energies of protons (a) and electrons (b), evolving temporally at the fixed laser intensity.

temperature, reaches 29 MeV at 3 ps and saturates around 30 MeV at 6 ps. Our PIC simulation reveals that electrons continue to recirculate between the front and rear sides of the foil plasma during the laser incidence and are heated through the nonlinear mechanism depending on the laser pulse duration. The details will be discussed in the presentation.

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