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Appearance of a dense electron flow efficient for core heating in PW laser-driven fast ignition

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Towards the achievement of laser fusion energy, enhancing the efficiency of dense plasma heating is crucial. Electron-driven fast ignition has been studied as one of the heating methods, in which the energy of laser-accelerated fast electrons is transferred to the thermal electron energy in the core plasma through collisional processes. The energy distribution of fast electrons is critically important for the efficient heating, since the heating property depends largely on the electron mean free path determined by the electron energy. Conventionally, increasing the laser intensity is considered to degrade the heating efficiency, because the fast electrons will be accelerated to high energies and become collisionally transparent. This has been a crucial difficulty in delivering a sufficient amount of energy to the core in the fast ignition scheme.

In this study, we report an efficient heating regime appearing in petawatt high-intensity laser irradiation onto a dense plasma. Laser light with relativistic intensities pushes the overdense plasma surface by its radiation pressure, known as the hole boring. There exists the limit density n_{limit} for the hole boring, which is the maximum plasma density the laser light can reach, $n_{\mathrm{limit}} = 8a_0^2Rn_c$ [1], where a_0 is the normalized laser amplitude, R is the reflectivity, and n_c is the critical density. For the laser intensity of 10^{21} W/cm^2, n_{limit} becomes approximately 700 n_c with $R = 0.1$, and a steep laser-plasma interface is established, which is confirmed by a collisional particle-in-cell (PIC) simulation with the PICLS code. We found that, when we keep irradiating the laser light onto the steep surface after reaching the limit density, a quasi-steady electron energy flux with the density of n_{limit} flows into the dense plasma. Considering the energy flux conservation between laser light and plasma [2], the average energy E_{limit} of the electrons flowing with the limit density is derived to be much lower than the ponderomotive energy $a_0 m_ec^2$ for $a_0 >> 1$. The dense electron flow with the average energy of E_{limit} realizes an efficient heating of the dense plasma towards the core, with forming a fast-propagating heatwave. The establishment of the dense electron flow requires a continuous laser irradiation over multi-picoseconds. We will present the theoretical modeling and collisional PIC simulations of the electron flow formation.

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