Heating a solid isochorically over keV temperature high energy density state by a multi-picosecond intense laser light

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We demonstrated a creation of high energy density (HED) plasmas over keV temperature driven by a multi-picosecond (ps) intense laser light using collisional two-dimensional particle-in-cell simulations. Such a high energy density plasma, sufficiently long-lived, well-characterized, as a sample of HED matter in the laboratory, is important to explore HED science.

Having a high contrast intense multi-ps laser light $< 10^{-10}$; the laser can directly interact with a solid, and it can heat the solid surface without being interfered by large preformed plasmas. Then a high energy density plasma with keV temperature at solid density, which is equivalent to a pressure exceeding gigabar, is can be formed. The heating mechanism is identified as diffusive heating from the hot surface, and heat wave propagates with a speed of a few micron per picosecond if we could hold the hot surface over ps. Such the diffusive heating process is critically important, since it could heat a solid over keV temperature, for applications in high energy density physics, i.e. compact keV x-ray and neutron sources, laboratory astrophysics, and the fast ignition in the inertial confinement fusion as an ultimate goal.

We had derived the theoretical scaling of the diffusive heating and also the condition to have the diffusive heating during the laser-plasma interaction. The scaling tells that we could control the diffusive heating with laser amplitude and pulse length, and a plasma with a few hundred eV to over 10keV at solid density is producible. We performed a two-dimensional Particle-in-Cell (PIC) code, PICLS [1], which is capable to simulate the collisional diffusive processes including ionization dynamics. In the PICLS simulation, we study the isochoric heating of a solid aluminum target with changing the pulse duration and intensity while keeping the pulse energy. The simulation results show that the target is heated over 10 keV in only the case which satisfies the diffusive condition that we have derived. As a conclusion, a series of PIC simulations indicate that the diffusive heating of multi-ps laser light with intensity of $\sim 10^{18}$ W/cm^2 is the most effective for heating bulk electrons in a solid.

[1] Y. Sentoku and A. J. Kemp, J. Comp. Phys. 227, 6846 (2008)