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Fast heatwave ignition in laser fusion

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Laser fusion has become an urgent issue for the establishment of high-efficiency schemes after the achievement of ignition at the National Ignition Facility (NIF) in the U.S. The NIF uses the central ignition scheme in which a thin shell containing the fusion fuel is simultaneously imploded and heated by X-rays emitted from a MJ laser heated gold hohlraum. The fast ignition (FI) scheme, on the other hand, separates the implosion and heating processes, and after forming a high-density core plasma, the core plasma is heated before being disassembled in picoseconds by a petawatt laser to achieve ignition burning. The key to success is how efficiently the heating laser delivers its energy to the core plasma.

We have performed basic experiments of laser fusion with GEKKO-XII and LFEX lasers and demonstrated the effectiveness of FI scheme [1]. In this FIREX experiment, GEKKO-XII lasers (4kJ/ns/2ω) imploded a solid ball, instead of a thin shell, to densities about 10 times of solid, and the core plasma was heated to an electron temperature of 2keV with a petawatt laser LFEX (1kJ/1ps). The total laser energies used in this experiment is about 5kJ. The efficient heating was achieved by the fast diffusion above the solid density from hot-dense plasma pumped by resistive heating driven by fast electron currents.

To deepen the understanding of FI physics and design a high-gain laser fusion with the FI scheme, we have comprehensively studied the propagation, absorption, and energy transport processes of heating laser beams in imploding plasmas with a help of multi-dimensional kinetic plasma simulations, PICLS [2], which cooperates with Coulomb collisions, ionizations, and radiation physics. We found that the efficient heating is realized when the heating pulse is sufficiently intense, greater than 10^{20}W/cm2, to reach the density cliff of imploded fuel core by the hole-boring in ablation plasma. At the density cliff the heating pulse then steepens the absorption interface by photon pressure and produces hot electrons with energies much less than the ponderomotive scaling with density of the cliff [3]. Our finding is a paradigm shift from the conventional direction of FI where the heating laser intensity should be reduced to adjust fast electron energy to a few MeV for efficient drag heating in the core. What we find is that the higher intensity lasers can heat core much more efficiently by entering "heatwaves" mode from the density cliff, see Fig. 1.

In this talk, I would like to share the story of the efficient fast heating scenario and explain how to make the efficient hole-boring mode and what is the physics behind the heatwave heating.

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References
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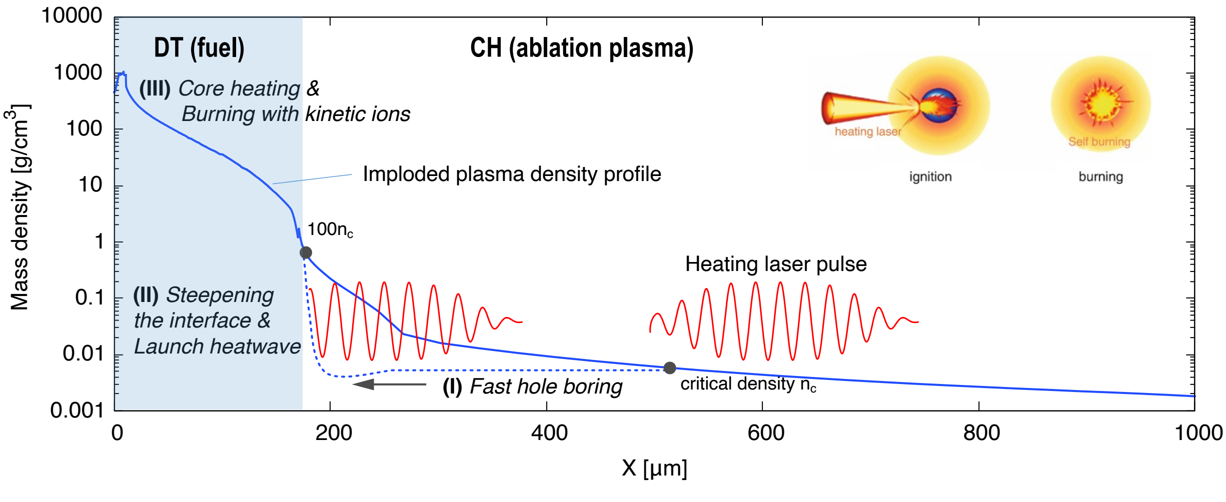

Figure 1. Scenario of efficient laser fusion with fast heatwave ignition scheme, three steps (I), (II) and (III).