Double-Cone Ignition Scheme for Inertial Confinement Fusion

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Since the central ignition concept of inertial confinement fusion (ICF) was proposed in 1972, the laboratory demonstration of thermonuclear ignition has been the primary pursuit for decades for the ICF research. While major progress has been made in the indirect-drive scheme with the operation of the National Ignition Facility (NIF), significant challenges on the coupling of laser energy to the fuel pellet remain in the pursuit of ignition. On the other hand, the direct-drive scheme has the capability to achieve much higher coupling efficiency. The challenge of higher compression symmetry over indirect-drive scheme however remains. This demands an enhanced laser beam uniformity.

In order to tackle the challenges, great international efforts have been made and various advanced ignition schemes (such as fast ignition, shock ignition and impact ignition) have been proposed and intensively investigated. Different from the central ignition schemes of ICF, the heating process was separated from the compression process in the advanced ignition schemes. The compression of the fuel is carried out at a moderate speed, resulting in a higher compression density. The requirements on symmetry and stability are remarkedly relaxed. The pre-compressed fuel is then fast heated by beams of MeV fast electrons generated by ps, petawatt (PW) laser pulses in fast ignition scheme. It was found that the fuel heating efficiency is relatively low due to the large divergence of the MeV fast electrons. To mitigate this difficulty, a cone-inserted target was adopted under certain conditions. While significant progresses were made, the heating efficiencies are still too low for ignition. With such a low efficiency, up to hundreds of kJ of the PW heating laser energy would be required. This is beyond the capacity of the current laser technology. Other important advanced ignition schemes including shock ignition and impact ignition have also be proposed to overcome the difficulties of the conventional central ignition schemes.

In this talk, I shall propose a double-cone ignition scheme for ICF [1]. The scheme is composed of four progressive controllable processes, as shown in Figure 1. 1) quasi-isentropic compression, 2) acceleration, 3) head-on collision and 4) kT magnetic-field guided fast heating of the compressed fuel. Quasi-isentropic compression of fuels in head-on double cones is performed by specially tailored laser pulses of 10 ns. At the later stage of the compression, the plasmas in the cones are accelerated by a series of 100 ps pulses to forward velocities of hundreds of km/s. The head-on collisions of the accelerated fuels from the cones transfer the kinetic energy into internal energy, leading to a preheat of the colliding plasma. The colliding plasma with a density of over 300 g/cm^3 and a temperature of 1 keV is then rapidly heated by hot electrons guided by a ns-duration laser-produced strong magnetic field to reach a temperature over 5 keV. Preliminary experimental and simulation results [2-4] will be presented in this talk, with a detailed plan to upgrade Shenguang II upgrade laser facility to conduct demonstration experiments.

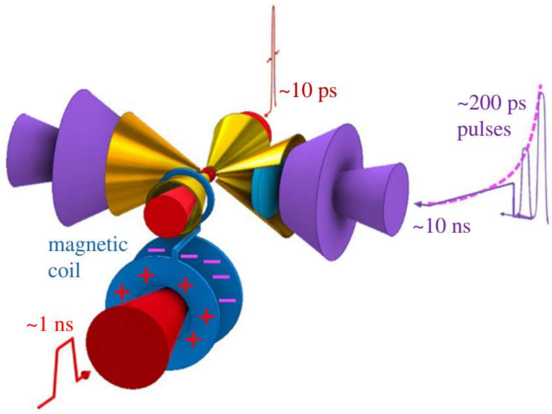

Figure 1. Schematic of the double-cone ignition scheme. The fuel is initially embedded in the entrance of two main cones, where the compression and acceleration processes are implemented. A couple of additional cones are placed in the vertical plane to guide the ps, PW heating laser pulses and the generated hot electron beams with magnetic field guiding.

Reference

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