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Magnetically assisted fast ignition scheme for inertial confinement fusion

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Fast ignition scheme was proposed in 1994 to rapidly heat a compressed fusion fuel by a short-duration (10ps=10^{11}s), high-power (PW=10^{15}watt) ignition laser and then gain huge energy by nuclear fusion. It requires that fast electrons of MeV produced by the ignition laser are transported over 100μm distance in coronal plasma to heat a highly compressed core region at hundreds of solid density. The key is how to achieve a coupling above 10% from the laser to the core. Coupling of 20% was demonstrated experimentally in 2001 [Nature 412, 798] with a 0.6 ps laser and a cone-inserted target. However, a recent OMEGA experiment with a 10 ps laser reported much lower coupling of only a few percent. The different results could be related to different preplasmas formed by the ignition laser prepulses in the cones. A commonly acknowledged factor causing the low coupling is large divergence of the fast electrons generated in the cones.

To reduce the effect of the large divergence, we propose a magnetically assisted (MA) fast ignition scheme[1] using a cone-free target supplemented by an external 20-megagauss magnetic field to confine the fast electron motion. Such a spherically symmetric target does not suffer from asymmetry in target compression , as is the case for a cone-inserted target. The effect of the ignition laser prepulse can also be avoided. The MA scheme was demonstrated by our integrated particle-in-cell (PIC) simulation using a two-system PIC approach developed recently by us[2] in which the fast electron generation and transport in real density (300g cm^{-3}) plasma. With this PIC approach we directly obtained the laser-to-core coupling of 14%. Quantitative comparison among the MA scheme, the cone-inserted scheme, and the original scheme was performed. It is shown that the coupling can be enhanced by 7-fold with the magnetic field, which can even exceed that obtained with the cone-inserted scheme.

Recently, our multi-dimensional integrated simulations shows that the fast-ignition conditions could be achieved via the MA scheme when two 2.8 petawatt, 0.35-μm-wavelength heating laser pulses counter-propagate along a 3.5 kilotesla external magnetic field. Within a period of 5 picoseconds, the laser pulses heat a nuclear fuel to reach the ignition conditions. Furthermore, we present a parameter window of lasers and magnetic fields required for ignition for experimental test, which also shows that it is impossible to achieve ignition provided conventional 1.05-μm-wavelength laser pulses are adopted.

References

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