Influence of the solid-to-plasma transition on the laser energy deposition in targets and subsequent hydrodynamics for direct drive inertial confinement fusion

Romain Liotard[1], Arnaud Colaïtis[1], Guillaume Duchateau[2]

[1]*University of Bordeaux-CNRS-CEA, CELIA, 351 cours de la libération, 33405 Talence, FRANCE*

[2]*CEA-CESTA, 15 Avenue des Sablières, CS60001, 33116 Le Barp, FRANCE*

ABSTRACT.

Direct drive inertial confinement fusion is a method considered for achieving nuclear fusion reaction by irradiating a target by multiple high intensity laser pulses. This target is a sphere made of a solid material named “ablator” (usually polystyrene, a dielectric material), that surrounds a fusion fuel (usually cryogenic DT). Due to the laser irradiation, the ablator is ejected and the target implodes by the so called rocket effect. The mechanical work exerted in the hotspot (the center of the target) during the implosion is expected to ignite fusion reactions.

Currently, the hydrocodes used to simulate ICF implosions assume generally an initial plasma state for the ablator whereas it is in a solid state. This solid state is expected to play a role during the early interaction between the lasers and the target. First, because of the initial transparency of the ablator, the laser can penetrate the target, this is the so called shine through effect. Second, the laser energy deposition is affected, possibly leading to a different shock formation and subsequent propagation.

This poster presents the introduction of a solid-to-plasma transition model in a hydrocode, in order to study such an influence on ICF implosions. It is based on the model presented in Refs. [1, 2]. The simulations are carried out with a numerical tool coupling the 3D laser propagation code IFRIIT [3] with the 3D Eulerian hydrodynamic code ASTER [4].

In order to validate this code, simulations have been carried out with laser parameters corresponding to the OMEGA facility (LLE, Rochester, USA). Simulations with a single beam have confirmed the validity of the implementation, and have provided information about the dynamics of the transition: the ablator undergoes the solid-to-plasma transition, i.e. transforms from transparent to reflective optical state, on a timescale of ~50ps.

Results are shown to depend on whether the solid-to-plasma transition is included or not, The solid-to-plasma transition delays the shock formation and leads to a volumetric energy deposition into the ablator. The subsequent target dynamics is affected which should be considered for future ICF designs.

REFERENCES

[1] G. Duchateau u.a. , “Modeling the solid-to-plasma transition for laser imprinting in direct-drive inertial confinement fusion”, PRE, 100, 033201, (2019).

[2] A. Pineau u.a., ”Modeling the electron collision frequency during solid-to-plasma transition of polystyrene ablator for direct-drive inertial confinement fusion applications”, Phys. Plasmas, 27, 092703, (2020).

[3] A. Colaïtis u.a., “Inverse ray tracing on icosahedral tetrahedron grids for non-linear laser plasma interaction coupled to 3D radiation hydrodynamics” JCP, 443, 110537, (2021).

[4] I. V. Igumenshchevu.a., “Three-dimensional modeling of direct-drive cryogenic implosions on OMEGA”, Phys. Plasmas, 23, 052702, (2016).