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PhD thesis – Physics

Multiscale modeling of the influence of the solid-to-plasma transition within the context of inertial confinement fusion

The CELIA laboratory carries out studies on various schemes for inertial confinement fusion by high energy lasers in order to find a solution to the production of large scale energy. The experimental and theoretical works at CELIA are supported by experiments carried out on various large laser facilities in France (as Laser MégaJoule at CEA) or abroad (Omega laser at Laboratory for Laser Energetics (LLE) in Rochester, USA). In order to optimize the target implosion which eventually gives rise to thermonuclear reactions, the laser pulse is shaped in space and time, notably with a prepulse which full width at half maximum is 100 ps and maximum intensity is hundreds of TW/CM2. However, this prepulse induces spatial inhomogeneities on the surface of the target due to the initial solid state of the matter [1]. These laser imprint damages the initial spherical symmetry of the target in the course of implosion, and ultimately decrease the efficiency of the inertial confinement design. Up to now, numerical hydrodynamic codes dedicated to model the inertial fusion assume a plasma as the initial state of matter (the initial solid state is not included), and are not able to account for experimental observations [1].

A quantum model describing the solid-to-plasma transition within the present framework has recently been developed at CELIA [2]. The first objective of the thesis is to introduce this microscopic model in a macroscopic numerical code including both laser propagation and hydrodynamics [3]. When this development will be performed, numerical simulations will be done to study the influence of the solid-to-plasma transition on the subsequent dynamics of the target. Two issues will be considered in particular. The first addresses the formation timescale and the velocity of the first shock induced by the laser prepulse. The second one deals with the influence of the initial solid state regarding optical properties. This state being initially transparent (dielectric material), a given amount of laser radiation is expected to be transmitted into the target bulk which could heat the deuterium-tritium mixture, damaging the design of the inertial confinement scheme. Such influences will be quantified during the thesis and the efficiency of the inertial confinement scheme will be evaluated under such conditions. Finally, the thesis will be devoted to develop solutions to preserve to the best the spherical symmetry of the target in course of implosion. All developed models will be validated by comparing their predictions to experimental results. The candidate will have the opportunity to stay a few months at LLE to collaborate with a team working on the same topic.

The candidate should have followed a formation in physics including programmation and numerical simulations. The PhD grant is supported by CEA and Region Nouvelle-Aquitaine (waiting for confirmation). Expected starting date of the thesis is 01 October 2020.

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[1] J. L. Peebles *et al*, « Direct-drive measurements of laser-imprint-induced shock velocity nonuniformities », Physical Review E **99**, 063208 (2019)
[2] G. Duchateau *et al*, « Modeling the solid-to-plasma transition for laser imprinting in direct-drive inertial confinement fusion », Physical Review E **100**, 033201 (2019)
[3] A. Colaïtis *et al*, « Adaptive inverse ray-tracing for accurate and efficient modeling of cross beam energy transfer in hydrodynamics simulations », Physics of Plasmas **26**, 072706 (2019)