Design of ICF Targets for Energy Production - TARANIS Project

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High-gain Inertial Confinement Fusion (ICF) [1] represents a major strategic goal for carbon-free energy production. Recently, the National Ignition Facility (NIF) achieved the first net gain in ICF. In this context, the TARANIS project specifically focuses on optimizing target designs and laser configurations to advance ICF towards practical energy production.

ICF research involves plasma physics, laser-matter interaction, and high-power laser technology. Given the complexity and limited experimental access, high-performance simulations play a crucial role in refining target geometry, laser parameters, and energy output predictions.

To effectively analyze simulation results, a set of diagnostic parameters [2] was first established in post-processing. This framework enabled a systematic optimization study across different target designs, such as dynamic shell scheme [3] and layered targets. For each configuration, the laser parameters, including the intensity and pulse shape, were varied to maximize the gain of the reaction.

Large databases of simulation results were compiled, allowing for detailed performance analysis and trend identification. In addition, a machine learning technique [4] was employed to refine laser profiles and identify trends across extensive simulation datasets, enhancing both design optimization and predictive capabilities.

A major milestone of this research is the upcoming experimental campaign at the Laser Mégajoule (LMJ), where we will conduct the first high-energy dynamic shell experiment in a polar-drive configuration. This unprecedented experiment will provide crucial validation of our simulation results and further refine our predictive models for ICF performance. The combination of high-fidelity simulations, AI optimization, and large-scale experimental validation represents a significant step toward achieving high-gain fusion.

References

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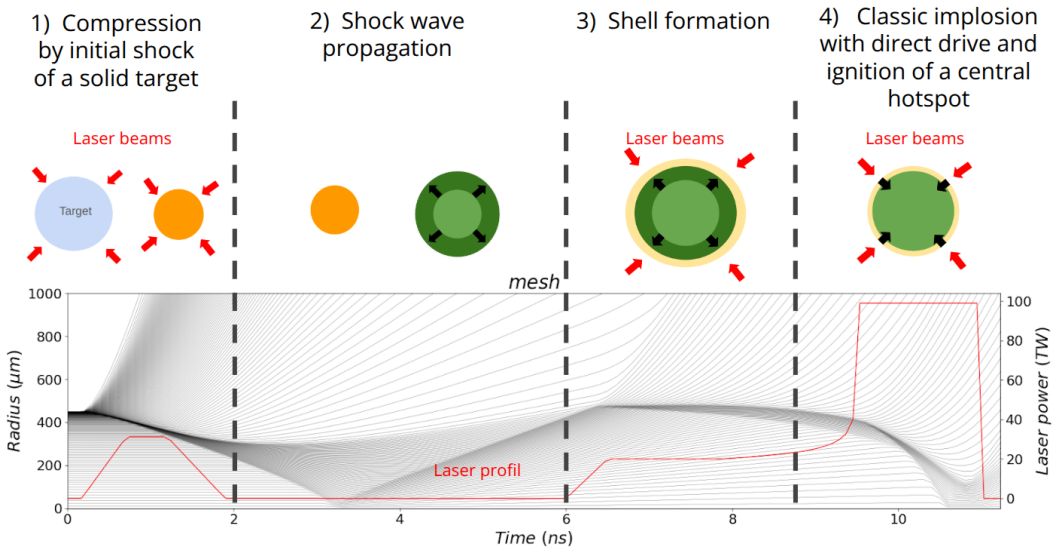

Figure 1: Scheme of the ignition with the dynamic shell concept (top), and simulated diagram of a CDD target implosion in the dynamic shell configuration (bottom). The red line represents the laser pulse.