Multi-scale simulations of proton-driven fast ignition of inertial fusion targets

P. Gibbon, J. J. Honrubia, V. Ospina-Bohorquez, A. Mateo-Aguaron S. Atzeni, M. Brönner, L. Savino, X. Vaisseau, D. Callahan, W. Theobald, P. Patel, M. Roth

Focused Energy GmbH, Darmstadt, Germany

The recent ignition success at the National Ignition Facility (NIF) [1] has boosted the exploitation of Inertial Fusion Energy (IFE) as a potential carbon-free energy source. Several start-up companies such as Focussed Energy have proposed ambitious plans for fusion pilot plants based on (IFE). The difficulties found in NIF for achieving ignition and low energy gain have led to exploring new concepts envisioning alternative ignition schemes [2], such as the proton fast ignition investigated by Focused Energy (FE) [3]. After a short review of how ignition was achieved on NIF, the simulation toolset and the extensive computing campaigns already carried out by FE on European HPC facilities will be presented and discussed.

One of the main scientific challenges of laser-driven fusion is the broad range of densities and temperatures found in DT fuel targets, which go from ideal low-density plasmas in the laser interaction region to degenerate plasmas at densities exceeding 1000x the solid density of the igniting fuel. Also, the plasma target evolution necessarily involves highly nonlinear physical phenomena with vastly different space- and time-scales, including ultra-intense laser-plasma interactions (fs), multi-dimensional radiation-hydrodynamics (ns) and fusion reactions (ps).

The fast ignition scheme of IFE, in which fuel compression is deliberately separated from ignition, inevitably involves multiple time and length scales. Fuel compression is produced by laser pulses of intensities of $10^{14} – 10^{15}$ Wcm^{-2} and durations of tens of nanoseconds, while the ignition hot spot is generated by ultra-intense laser pulses of 10^{19} - 10^{20} Wcm^{-2} with picosecond duration. Simulations of proton fast ignition of fusion targets [4] carried out on the *JUWELS*, *VEGA* and *KAROLINA* HPC facilities will be presented, covering studies of capsule implosions using multi-dimensional radiation hydrodynamics, Particle-In-Cell modelling of laser-proton acceleration for current and future experiments, and hybrid simulations of proton fast ignition of imploded fuel capsules.

References

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