Nuclear Fusion - Open Questions For Research

Dov Shvarts

The Nuclear Research Center-Negev, Beer-Sheva, Israel.
<schwartz@bgumail.bgu.ac.il>

Keywords: Fusion, Inertial Confinement Fusion, Instability Simulation.

Abstract

Nuclear fusion, as one of the main energy source for the 21st century, is still in the stage of extensive scientific research which is aimed toward achieving thermonuclear ignition. In the present talk I will shortly review the status of the main approaches to achieve net thermonuclear fusion energy and will mainly describe the achievements and open questions of the Inertial Confinement Fusion method, where intense lasers are used to compress and heat a small pellet of DT up to ignition and burn conditions.

It is well recognized that the main obstacle to achieve ignition in the ICF approach is the development of hydrodynamic instabilities on both sides of the compressed shell that may cause shell breakup and ignition failure. In the present work, we review our recent theoretical, numerical and experimental work that contribute to a better understanding the evolution of instabilities at the various stages of the pellet implosion.

The perturbations, from which the instabilities grow, are seeded by both surface roughness and laser intensity non-uniformity. In order to study the laser imprint process we have carried out numerical simulations and modeling in order to get the equivalent mass perturbation in the target as a function of perturbation wavelength, laser intensity and pulse shape and laser smoothing technique. Using the initial mass perturbation spectrum we estimating what is the required initial perturbation amplitude (from both surface roughness and laser imprint) that will not cause shell breakup.

Until recently, most of the simulations and models developed to describe the evolution of the instability were done in two-dimensions(2D). We have recently performed full numerical simulations and extended our models to describe the evolution of three-dimensional(3D) perturbations. It was found that there are differences between the evolution of the instability in 2D and 3D, which is caused by the differences in the kinematic drag force that is decelerating the instability evolution in its nonlinear stage. The differences between the 2D and the 3D evolution were confirmed by shock-tube experiments.

Finally, we have study the effects of these perturbation on the ignition conditions, using new self-similar solutions for perturbed burn wave propagation. The margin of a target to a given initial perturbation and the required increase in the implosion velocity and laser energy necessary to achieve ignition is obtained for various spectrum of perturbation wave numbers and amplitudes.