Academic research on the inertial confinement thermonuclear fusion in Europe

V. T. Tikhonchuk
Centre Lasers Intenses et Applications, Université de Bordeaux – CNRS – CEA, Talence, France
ELI-Beamlines, Institute of Physics, Czech Academy of Sciences, Dolní Břežany, Czech Republic

High power, high energy lasers may bring matter in extreme states of pressure and density sufficient to excite fusion of hydrogen isotopes and release a large amount of energy. Two laser system are actually capable to approach the threshold of ignition of fusion reactions: the National Ignition Facility (NIF) in the USA and the Laser MegaJoule (LMJ) in France. While construction of both large scale installations is motivated by the defense, the international scientific community profit from them to understand the underlying physical processes and to design the schemes capable to produce fusion energy. European scientists are developing alternative ignition schemes that are promising for future fusion reactors a reduced ignition laser energy, a better target performance and more efficient energy production. In spite of general attractiveness of these schemes, the experience of last 15 years of international research shows considerable challenges on the way to their practical realization. The common denominator of these problems are the energetic electrons, the physics of their generation and transport and the control of their energy deposition. In this review I present the recent advanced in the physics of energetic electron transport in application to the ignition schemes studied on the high power laser installations in the Europe, USA and Japan.

The major challenge for the fusion scheme called “fast ignition” is the divergence of the relativistic electron beam. Developed recently technique of a strong magnetic field generation with laser driven coils provides an efficient electron transport over the distance of a hundred microns and allowed to achieve a record ion temperature of 3 keV in the compressed core in the integrated experiment on the GEKKO-LFEX laser system in Japan. Hot electrons created in laser plasma interaction with solid targets at laser intensities above 10^{15} W/cm^2 can deposit their energy in depth of the target thus augmenting the strength of the shock and/or preheating the target upstream the shock. These issues are of a vital importance for the fusion scheme called “shock ignition”. Our studies demonstrate the vulnerability of the standard target design to the fast electron preheat and a necessity of a better control of the hot electron generation and transport. Several results related to the control of hot electron generation and transport in the converging geometry on the OMEGA laser system at the University of Rochester will be presented as well as the design for the strong shock experiment on the LMJ facility scheduled for the April 2019.

I will conclude my talk with consideration of the future developments in the inertial confinement fusion, and in a more general sense of high energy density physics, which are related to the commissioning of the Extreme Light Infrastructure (ELI-Beamlines) in the Czech Republic. This is a new generation of high power laser systems with the laser shot rate increased by two orders of magnitude making a significant step towards the fusion energy production.

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