Status and prospects for nuclear fusion with lasers

Riccardo Betti

Laboratory for Laser Energetics, University of Rochester

For decades, scientists have been trying to develop clean and unlimited energy by fusing light nuclei as occurs in the center of the sun. A critical step in the quest for nuclear fusion is the demonstration of thermonuclear ignition of fusion fuel in the laboratory. Giant lasers have been prime candidates to achieve fusion ignition of deuterium-tritium (DT) fuel due to their ability to compress and heat material to pressures of billions of atmospheres and temperatures of millions of degrees. Recent progress in laser fusion has improved the prospects of achieving ignition of millimeter-size capsules with megajoule-class lasers. Laser fusion uses either direct illumination of the capsule (direct-drive) or indirect illumination of the capsule via X-rays produced by laser heating of a metal enclosure called a hohlraum (indirect-drive). Direct-drive is pursued at the OMEGA laser facility of the University of Rochester while indirect-drive is pursued at the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory. Recent implosion experiments at the NIF have achieved the conditions of pressure and confinement time that are about 70% of the values required for thermonuclear ignition. The improvements came from enhanced control of the hohlraum energetics and use of capsules of more-efficient ablators. When scaled to NIF laser energies, recent direct-drive implosions on OMEGA are expected to produce more than 500 kilojoules of fusion energy. Those implosions have benefited from a significant increase in implosion velocity obtained through larger-diameter targets. A new statistical approach[1] used in designing OMEGA targets has demonstrated a considerable predictive capability, thereby enabling the design of targets with improved performance. A review of the steps leading to this improved performance is presented together with an assessment of future expectations of achieving thermonuclear ignition via laser fusion. This material is based upon work supported by the Department of Energy National Nuclear Security Administration. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

[1] V. Gopalaswamy et al.,”Tripled yield in direct-drive laser fusion through statistical modelling”, Nature, Vol. 565, p. 581-586 (2019)