New technique may help achieve mass production fusion energy

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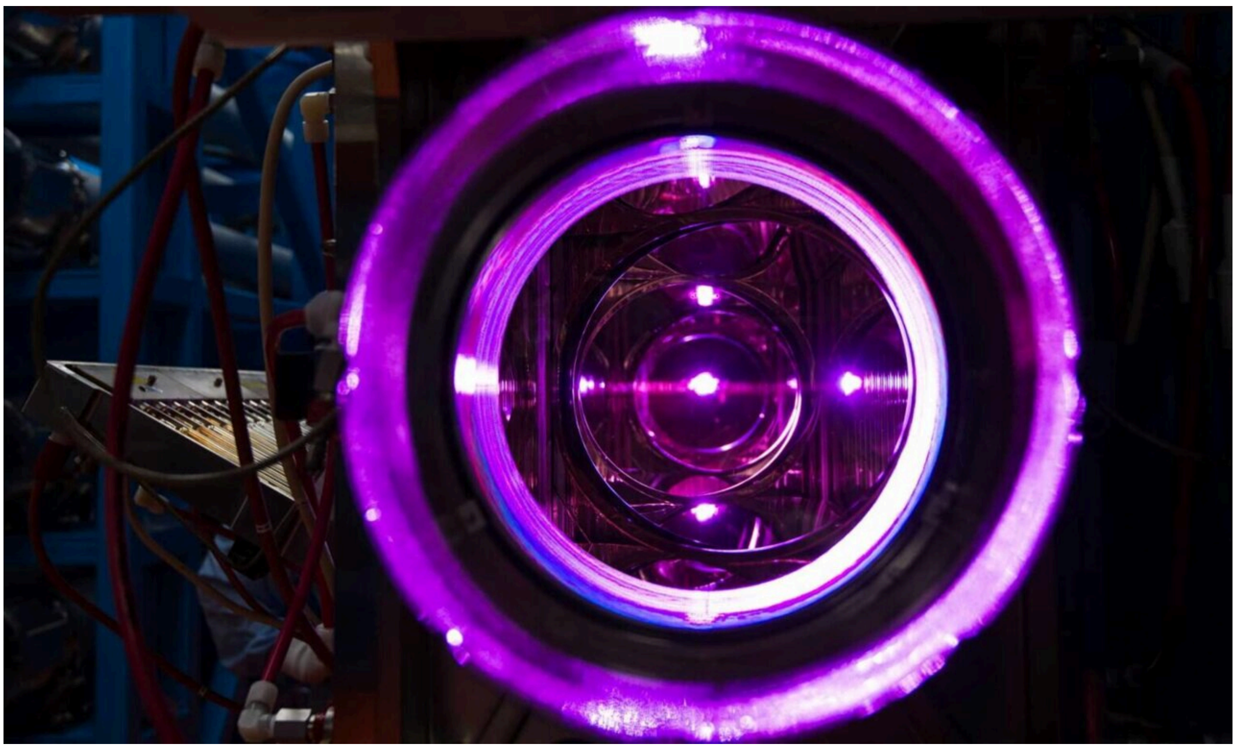

View through the OMEGA laser's 20-cm disk amplifiers at the Laboratory for Laser Energetics. In a scaled-down, proof-of-principle experiment, Rochester researchers used the laser to demonstrate a critical step in the dynamic shell concept. Credit: University of Rochester photo / J. Adam Fenster

Fusion, which replicates the same reaction that powers the sun, has long been viewed as an ideal energy source due to its potential to be safe, clean, cheap, and reliable.

Since the early 1960s, scientists have pursued the possibility of using high-powered lasers to compress thermonuclear material long enough and at high enough temperatures to trigger ignition—the point at which the resultant output of inertial fusion energy is greater than the energy delivered to the target.

Scientists achieved ignition in December 2022 at the National Ignition Facility at Lawrence Livermore National Laboratory, but many hurdles remain in making fusion energy technically and commercially viable for mass production and consumption.

Researchers at the University of Rochester's Laboratory for Laser Energetics (LLE) have, for the first time, experimentally demonstrated a method called dynamic shell formation, which may help achieve the goal of creating a fusion power plant.

The researchers, including Igor Igumenshchev, a senior scientist at LLE, and Valeri Goncharov, a distinguished scientist and theory division director at LLE and an assistant professor (research) in the Department of Mechanical Engineering, discuss their findings in a paper published in *Physical Review Letters*.

"This experiment has demonstrated feasibility of an innovative target concept suitable for affordable, mass production for inertial fusion energy," Igumenshchev says.

The conventional approach to inertial fusion energy

In the conventional approach to inertial fusion energy, a target consisting of a small amount of hydrogen fuel—in the form of the hydrogen isotopes deuterium and tritium—is frozen solid into a spherical shell.

The shell is then bombarded by lasers, heating the central fuel to extremely high pressures and temperatures. When these conditions are achieved, the shell collapses and ignites, undergoing fusion.

The process releases an enormous amount of energy that has the potential to drive a carbon-free power plant. But a fusion power plant, still hypothetical, would require nearly a million targets per day. The current methods for fabricating targets using a frozen preparation process are costly and the targets are difficult to produce.

Dynamic shell formation: More feasible, less costly

Dynamic shell formation is an alternative method to create targets in which a liquid droplet of deuterium and tritium is injected into a foam capsule. When bombarded by laser pulses, the capsule develops into a spherical shell, then implodes and collapses, resulting in ignition. Dynamic shell formation does not require the costly cryogenic layering that conventional methods of generating inertial fusion energy employ, because it uses liquid targets. These targets will also be easier to make.

Goncharov first described dynamic shell formation in a paper in 2020, but the concept hadn't been demonstrated experimentally. In a scaled-down, proof-of-principle experiment, Igumenshchev, Goncharov, and their colleagues used LLE's OMEGA laser to shape a sphere of plastic foam that had the same density as deuterium-tritium liquid fuel into a shell, demonstrating a critical step in the dynamic shell concept.

To actually generate fusion using the dynamic shell formation technique, future research will require lasers with longer and more energetic pulses, but the current experiment suggests that dynamic shell formation could be feasible as a path toward more practical fusion energy reactors.

"Combining this target concept with a highly efficient laser system that is currently under development at LLE will provide a very attractive path to fusion energy," Igumenshchev says.

More information: I. V. Igumenshchev et al, Proof-of-Principle Experiment on the Dynamic Shell Formation for Inertial Confinement Fusion, *Physical Review Letters* (2023). DOI: 10.1103/PhysRevLett.131.015102

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