Preface

Since the late 1940s, researchers have used magnetic fields to confine hot, turbulent mixtures of ions and free electrons called plasmas so they can be heated to temperatures of 100–300 million Kelvin (180–540 million degrees Fahrenheit). Under those conditions, positively charged deuterium nuclei (containing one neutron and one proton) and tritium nuclei (two neutrons and one proton) can overcome the repulsive electrostatic force that keeps them apart and "fuse" into a new, heavier helium nucleus with two neutrons and two protons. The helium nucleus has a slightly smaller mass than the sum of the masses of the two hydrogen nuclei, and the difference in mass is released as kinetic energy according to Albert Einstein's famous formula $E = mc^2$. The energy is converted to heat as the helium nucleus, also called an alpha particle, and the extra neutrons interact with the material around them.

In the 1970s, scientists began experimenting with powerful laser beams to compress and heat the hydrogen isotopes to the point of fusion, a technique called inertial confinement fusion, or ICF. In the "direct drive" approach to ICF, powerful beams of laser light are focused on a small spherical pellet containing micrograms of deuterium and tritium. The rapid heating caused by the laser "driver" makes the outer layer of the target explode. In keeping with Isaac Newton's Third Law ("For every action there is an equal and opposite reaction"), the remaining portion of the target is driven inward in a rocket-like implosion, causing compression of the fuel inside the capsule and the formation of a shock wave, which further heats the fuel in the very center and results in a self-sustaining burn. The fusion burn propagates outward through the cooler, outer regions of the capsule much more rapidly than the capsule can expand. Instead of magnetic fields, the plasma is confined by the inertia of its own mass—hence the term inertial confinement fusion.

Inertial Confinement Fusion (ICF) aims at achieving fusion by compressing the fusion fuel to high densities albeit for a short period time. Lasers or high-energy particle beams can be utilized to create conditions that make fusion achievable. This process takes place in about two microseconds; they are able to heat the isotopes of Hydrogen (H), namely Deuterium (D) and Tritium (T), to 100 million degrees Celsius or 180 million degrees Fahrenheit by imploding them via inertial pressure and at a sufficient speed to release fusion energy, very similar process that happens at the sun in the nature.

Similar process can be observed in an astrophysical scale in stars and terrestrial uber world that have exhausted their nuclear fuel, hence interially or gravitationally collapsing and generating a supernova explosion.

National Ignition Facility (NIF), located at Lawrence Livermore National Laboratory (LLNL), will be the first laser in which the energy released from the fusion fuel will equal or exceed the laser energy used to produce the fusion reaction—a condition known as ignition. Unlocking the stored energy of atomic nuclei will produce ten to 100 times the amount of energy required to initiate the self-sustaining fusion burn. Creating inertial confinement fusion and energy gain in the NIF target chamber will be a significant step toward making fusion energy viable in commercial power plants. LLNL scientists are also exploring other approaches to developing ICF as a commercially viable energy source, a process that is considered as Fast Ignition (FI).

Fast Ignition is the approach, which is being taken by the National Ignition Facility to achieve thermonuclear ignition, and burn is called the “central hot-spot” scenario. This technique relies on simultaneous compression and ignition of a spherical fuel capsule in an implosion, roughly like in a diesel engine. Although the hot-spot approach has a high probability for success, there is also considerable interest in a modified approach called fast ignition (FI), in which compression is separated from the ignition phase. Fast ignition uses the same hardware as the hot-spot approach but adds a high-intensity, ultrashort-pulse laser to provide the “spark” that initiates ignition. A deuterium-tritium target is first compressed to high density by lasers, and then the short-pulse laser beam delivers energy to ignite the compressed core—analogous to a sparkplug in an internal combustion engine.

Because modern thermonuclear weapons use the fusion reaction to generate their immense energy, scientists will use NIF ignition experiments to examine the conditions associated with the inner workings of nuclear weapons.

Ignitions experiments also can be used to help scientists have a better understanding of the hot, dense interiors of large planets, stars, and other astrophysical phenomena.

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