Inertial Confinement Fusion at the National Ignition Facility

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The United States faces significant challenges in how to meet its long-term electricity generation demand. By 2050, our nation’s fleet of power plants will need to be replaced. Replacing the electricity fleet presents a huge opportunity to shape our next-generation energy mix; energy from fusion can play an important role in meeting demand for baseload electricity.

Fusion is a method of generating power that forces two atoms together, releasing tremendous amounts of energy.

“Inertial Confinement Fusion” is the method of starting fusion by heating and imploding a fuel pellet; powerful lasers are the most widely used and effective method for this.

The lasers force the fuel pellet to actually implode and the atoms within it to “fuse” together. This fusion reaction creates enormous amounts of energy.

A single “shot” lasts less than a billionth of a second and the reaction ends. There is no danger of a run-away reaction.

We know that fusion works: it is happening every day in labs around the world.

The challenge with this type of fusion energy is the precise configuration required to initiate the reaction is still being worked on.

The goal is to generate more energy than is put into the reaction. This goal is within reach: the remaining barriers are related to engineering and cost challenges.

The National Ignition Facility (NIF), housed in the Lawrence Livermore National Laboratory in California, is the world’s leading facility for this type of fusion method - inertial confinement fusion.

The NIF is a part of the National Ignition Campaign, a nationwide collaboration with some of the nation’s leading scientific institutions that is attempting to demonstrate “ignition”. Ignition is the point at which fusion releases more energy than it creates. This will be an important scientific milestone that demonstrates the potential for fusion to be a viable energy source.
How does Inertial Confinement Fusion work?

- Inertial confinement fusion uses very powerful lasers to heat a tiny fuel pellet and push its mass inward.

- The fuel pellet used at the NIF is two millimeters in diameter and is made of a mixture of two types of hydrogen (deuterium and tritium).

- The lasers heat the pellet to more than 100 million degrees, hotter than the surface of the sun.

- At the same time, the lasers implode the pellet at a velocity of nearly 700,000 miles per hour.

- All of this happens within about 20 billionths of a second.²

- The combination of extreme temperature and pressure force the atoms together, overcoming nuclear forces that would otherwise naturally repel each other.

- Following Einstein’s equation, $E=MC^2$, the action of forcing the atoms together releases tremendous amounts of energy.

- For example, burning just a tiny 12 mg fuel pellet could produce 4.2 gigajoules of energy, equivalent to about the electricity consumption of one and a half U.S. households for an entire month.³

- Fusion is inherently safe; there is no chance of a Fukushima-style runaway chain reaction.

What is the National Ignition Facility?

- Construction of the National Ignition Facility began in 1997 and was completed in 2009 at a total cost of just $3.5 billion.

- It currently employs 1,200 scientists, engineers, technicians and administrators.

- The NIF consists of 192 lasers, each of which is the largest and most energetic in the world.

- A “pulse” shot can last anywhere from 100 trillionths to 25 billionths of a second.⁴
Each of the NIF’s 192 lasers start as a small, low-energy laser pulse. As it moves through its 1,500 meter path to the target chamber, the laser’s energy is multiplied by a factor of more than one quadrillion.

When the 192 beams hit the fuel pellet simultaneously, huge amounts of energy (2 million joules) are applied to the target.\(^5\)

Precision is as important as power. The lasers must strike within a range of 50 micrometers, comparable to the diameter of a human hair.\(^6\)

The NIF has three missions:

- **Stockpile Stewardship:**
  - The NIF is the only facility that can simulate the conditions at the heart of a nuclear explosion without having to test a weapon.
  - This allows the NIF to affirm the integrity of America’s nuclear weapon arsenal.

- **Inertial Fusion Energy**
  - The NIF is the world’s leading research institution on inertial confinement fusion.
  - Demonstrating that ignition with energy gain is possible in a laboratory setting would allow plans to move forward for a demonstration power plant.
  - Fusion energy promises a virtually limitless energy potential.

- **Understanding the Universe**
  - The conditions within the NIF can be made to closely resemble conditions within supernovas and black holes
  - A closer understanding of these conditions could unlock the secrets of the fundamental elements of the universe.
Achievements

- In March 2009, NIF delivered a 1.1 megajoule laser shot, the first time fusion lasers ever surpassed one megajoule.\(^7\)

- Only three years later, in July 2012, NIF’s lasers delivered a laser shot that was almost 70% more powerful, delivering a record-setting 1.85 megajoule of laser energy to the target. This is 100 times more energy than any other lasers produce today.\(^8\)

- For an instant, NIF’s lasers deliver 500 terawatts of power; more than 1,000 times the amount of electrical power being produced in the entire United States at one moment in time.\(^9\)

- In its status report on inertial confinement fusion, the National Academy of Sciences stated that it is “impressed with the quality of the science and technology and how much progress has been made in the past decade.”\(^10\)

- The NIF is currently producing record levels of fusion output, having progressed many orders of magnitude in its first two years of operation.

Looking Forward

Critical scientific and engineering barriers remain before a full-scale demonstration plant can be constructed.\(^11\)

- Despite delays, scientists at NIF believe they are only a few steps away from achieving ignition with energy gain – a fusion burn that produces more energy out than is put in.

- Once complete, the NIF’s scientists calculate that the fuel will generate 10 to 100 times more energy than was required to start the reaction.\(^12\)

- With a successful demonstration of ignition, a demonstration plant called Laser Inertial Fusion Energy (LIFE) will move forward. It is planned for construction mid-2020’s and is estimated to cost $4 billion.\(^13\)

- The LIFE plant would prove that inertial fusion could continuously produce the energy that is needed for a fusion power plant to be economically viable.\(^14\)
Conclusion

Inertial Confinement Fusion, as one of the two major approaches to fusion energy, holds great promise for America’s energy future.

It is clean, safe, secure, and sustainable, with none of the drawbacks that characterize today’s energy sources.

The NIF is one of the world’s premier scientific institutions. This is a venue for extreme cutting-edge science: it is achieving temperatures, pressures, and densities at a level higher than any ever controlled within a laboratory before.

The NIF is one of the ‘crown jewels’ of American science, and the scientists working there deserve our applause and support.

The NIF is making tremendous progress on fusion energy and we need to continue long-term support for their important work.

Once the NIF achieves “ignition,” and proves the ability to produce net energy, America can move forward with the LIFE project. This full-scale pilot plant will demonstrate the commercial viability of fusion energy.

Bibliography


Endnotes

1. The members of the National Ignition Campaign are: Lawrence Livermore, Los Alamos and Sandia National Laboratories, the Laboratory for Laser Energetics at the University of Rochester and General Atomics


Building a New American Arsenal

The American Security Project (ASP) is a nonpartisan initiative to educate the American public about the changing nature of national security in the 21st century.

Gone are the days when a nation's strength could be measured by bombers and battleships. Security in this new era requires a New American Arsenal harnessing all of America's strengths: the force of our diplomacy; the might of our military; the vigor of our economy; and the power of our ideals.

We believe that America must lead other nations in the pursuit of our common goals and shared security. We must confront international challenges with all the tools at our disposal. We must address emerging problems before they become security crises. And to do this, we must forge a new bipartisan consensus at home.

ASP brings together prominent American leaders, current and former members of Congress, retired military officers, and former government officials. Staff direct research on a broad range of issues and engages and empowers the American public by taking its findings directly to them.

We live in a time when the threats to our security are as complex and diverse as terrorism, the spread of weapons of mass destruction, climate change, failed and failing states, disease, and pandemics. The same-old solutions and partisan bickering won't do. America needs an honest dialogue about security that is as robust as it is realistic.

ASP exists to promote that dialogue, to forge consensus, and to spur constructive action so that America meets the challenges to its security while seizing the opportunities the new century offers.