Lasers: Fueling Reactors with Unprecedented Power?

Description


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Damien Jemison A technician adjusts some of the optical equipment of the National Ignition Facility.
Damien Jemison

The National Ignition Facility in California uses powerful lasers to spark fusion reactions

Deep under the Nevada desert in the 1980s the US conducted secret nuclear weapons research.

Among the experiments was an effort to see if nuclear fusion, the reaction which powers the sun, could be sparked on earth in a controlled setting.

The experiments were classified, but it was widely known among physicists that the results had been promising.

That knowledge caught the attention of two young graduate students working at the Los Alamos National Laboratory in the late 2000s, Conner Galloway and Alexander Valys.

The Los Alamos lab was originally set up in 1943 as a top-secret site to develop the first nuclear weapons. Located near Santa Fe, New Mexico it is now a US government research and development facility.

"When Alex and I learned about those tests at Los Alamos, our reaction was like 'wow, inertial fusion has already worked!'. Laboratory-scale pellets were ignited, the details were classified, but enough was made public that we knew that ignition was achieved," says Mr Galloway.

Nuclear fusion is the process of fusing hydrogen nuclei together, which produces immense amounts of energy. The reaction creates helium and not the long-lived radioactive waste of the fission process which is used in existing nuclear power stations.

If fusion can be harnessed, then it promises abundant electricity, generated without producing CO2.

Those tests in the 1980s led to the US government building the National Ignition Facility (NIF) in California, a project to see if nuclear fuel pellets could be ignited using a powerful laser.

After more than a decade of work, in late 2022 researchers at NIF made a breakthrough. Scientists conducted the first controlled fusion experiment to produce more energy from the reaction than that supplied by the lasers which sparked it.

A graphic showing the fusion reaction

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While physicists around the world marvelled at that breakthrough, it had taken the scientists at NIF much longer than expected.

"They were energy starved," says Mr Galloway.

He doesn't mean they needed more snacks, instead the NIF laser was only just powerful enough to ignite the fuel pellet.

Mr Galloway and Mr Valys think that more powerful lasers will make it possible to build a working fusion reaction that can supply electricity to the power grid. To do that they founded Xcimer, based in Denver.

NIF had to make do with a laser that could pump out two megajoules of energy. Mr Galloway and Mr Valys are planning to experiment with lasers that can supply up to 20 megajoules of energy.

"We think 10 to 12 [megajoules] is the sweet spot for a commercial power plant," says Mr Galloway.

Such a laser beam would hit the fuel capsule with a powerful punch. It would be like taking the energy of a 40-tonne articulated lorry travelling at 60mph and focusing it on the centimetre-sized capsule for a few billionths of a second.

More powerful lasers will allow Xcimer to use larger and simpler fuel capsules than NIF, which found it difficult to perfect them.

Xcimer Conner Galloway (left) and Alexander Valys standing in the big empty factory which will one day h

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Xcimer

Conner Galloway (left) and Alexander Valys founders of fusion firm Xcimer

Xcimer joins dozens of other organisations around the world trying to build a working fusion reactor.

There are two main approaches. Smashing a fuel pellet with lasers falls under the category of inertial

confinement fusion.

The other way, known as magnetic confinement fusion, uses powerful magnets to trap a burning cloud of atoms called plasma.

Both approaches have daunting engineering challenges to overcome.

In particular, how do you extract the heat generated during fusion so you can do something useful with it, like drive a turbine to make electricity?

"I suppose my scepticism is, I haven't yet even seen a persuasive conceptual diagram of how you manage the process of taking energy out while keeping the fusion reaction going," says Prof Ian Lowe at Griffith University in Australia.

He has spent his long career working in energy research and policy. While Prof Lowe supports the development of fusion technology, he just argues that a working fusion reactor won't come fast enough to help bring down CO2 emissions and tackle climate change.

"My concern is that even the most optimistic view is that we'd be lucky to have commercial fusion reactors by 2050. And long before then we need to have decarbonized the energy supply if we're not going to melt the planet," he says.

Another challenge is that the fusion reaction produces high energy particles that will degrade steel, or any other material that lines the reactor core.

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Vocabulary List:

1. **Fusion** /ˈfjuːʒən/ (noun): The process of merging two or more things into one particularly in the context of nuclear reactions.
2. **Ignition** /ɪgˈnɪʃən/ (noun): The process of setting something on fire or starting a combustion process.
3. **Pellet** /ˈpɛlɪt/ (noun): A small rounded mass of material often used in the context of fusion fuel.

4. **Reactor** /riˈæktər/ (noun): A structure or device in which nuclear or chemical reactions occur.
5. **Confinement** /kənˈfaɪnmənt/ (noun): The act of keeping something within bounds or limits often referring to magnetic or inertial confinement in physics.
6. **Degrade** /dɪˈgreɪd/ (verb): To lower in dignity or quality; to cause something to deteriorate.

Comprehension Questions

Multiple Choice

1. What is the main focus of the National Ignition Facility in California?

   Option: Laser technology development
   Option: Nuclear weapons research
   Option: Fusion reactions
   Option: Solar power generation

2. Which approach uses powerful magnets to trap a burning cloud of atoms called plasma?

   Option: Inertial confinement fusion
   Option: Magnetic confinement fusion
   Option: Nuclear fission
   Option: Solar energy harvesting

3. What is the process of fusing hydrogen nuclei together known as?

   Option: Fission
   Option: Combustion
   Option: Magnetic confinement
   Option: Fusion

4. Where was the Los Alamos National Laboratory located?

   Option: New York, USA
   Option: Texas, USA
   Option: Santa Fe, New Mexico, USA
   Option: Los Angeles, California, USA

5. What is one potential advantage of nuclear fusion over fission in power generation?

   Option: Long-lived radioactive waste
   Option: High energy particle emissions

Option: CO2 emissions
Option: Scarcity of fuel source

6. What was the outcome of the first controlled fusion experiment at NIF in late 2022?

Option: Laser failure
Option: Energy loss in the reaction
Option: More energy produced than supplied by the lasers
Option: Halted due to safety concerns

Answer

Multiple Choice: 1. Fusion reactions 2. Magnetic confinement fusion 3. Fusion 4. Santa Fe, New Mexico, USA 5. CO2 emissions 6. More energy produced than supplied by the lasers

Vocabulary quizzes

Multiple Choice (Select the Correct answer for each question.)

1. What is the process by which two atomic nuclei combine to form a heavier nucleus?

Option: Fusion
Option: Pellet
Option: Degrade
Option: Locomotion

2. Which prehistoric reptile had wingspans of up to 33 feet?

Option: Implications
Option: Pterosaur
Option: Moderation
Option: Detection

3. Which term is used to describe something that is forbidden by law rules or custom?

Option: Accountable
Option: Anticipated
Option: Illicit
Option: Revamp

4. Which word is used to describe things related to the sky or outer space?

Option: Speculation
Option: Mesmerized

Option: Celestial
Option: Prevailing

5. What is false or inaccurate information especially that which is deliberately intended to deceive?

Option: Flagship
Option: Misinformation
Option: Complicity
Option: Revamp

6. Which term means to give something a new and improved version?

Option: Adaptations
Option: Complicity
Option: Revamp
Option: Detection

7. Which term refers to the power or ability to do something?

Option: Implications
Option: Capabilities
Option: Anticipated
Option: Fusion

8. What is prolonged public disagreement or heated discussion often about a political or social issue?

Option: Locomotion
Option: Pellet
Option: Controversy
Option: Spectacle

9. What term is used to describe something that fills a person with awe or amazement?

Option: Awe-inspiring
Option: Pellet
Option: Degrade
Option: Detection

10. Which word describes things that are related to mysticism or spiritual practices?

Option: Mystical
Option: Anticipated
Option: Detection
Option: Fusion

Gap-Fill (Fill in the blanks with the correct word from the vocabulary list.)

11. The _____ of the rocket engines signaled the start of the space mission.

12. Prisoners are kept in _____ as part of their punishment.

13. The stock market is often influenced by investor _____ about future performance.

14. The long-_____ rainfall brought relief to the drought-stricken region.

15. The new luxury store is the company's _____ location showcasing their best products.

16. The security system was designed to provide early _____ of any unauthorized access.

17. The criminal was charged with _____ in the theft ring.

18. The rising temperatures are putting many species at risk of _____.

19. Animals develop various _____ to survive in their changing environments.

20. It is important to eat in _____ and maintain a balanced diet for good health.

Matching Sentences (Match each definition to the correct word from the vocabulary list.)

21. The nuclear generates power through controlled nuclear reactions.
22. The new law has wide-reaching for businesses and consumers alike.
23. The artist her latest paintings at the gallery opening last night.

24. The early of the virus outbreak helped contain the spread.
25. The audience was by the magician’s unbelievable illusions.
26. The moon the path through the dark forest for the travelers.
27. The fireworks display was a dazzling in the night sky.
28. The owl regurgitated a small of undigested bones and fur.
29. Plants have developed various to thrive in different climates.
30. Despite the storm the ship reached its destination with the winds guiding it.

Answer

Multiple Choice: 1. Fusion 2. Pterosaur 3. Illicit 4. Celestial 5. Misinformation 6. Revamp 7. Capabilities 8. Controversy 9. Awe-inspiring 10. Mystical
Gap-Fill: 11. Ignition 12. Confinement 13. Speculation 14. Anticipated 15. Flagship 16. Detections 17. Complicity 18. Extinction 19. Adaptations 20. Moderation
Matching sentence: 1. Reactor 2. Implications 3. Exhibited 4. Detection 5. Mesmerized 6. Illuminated 7. Spectacle 8. Pellet 9. Adaptations 10. Prevailing

CATEGORY

1. Sci/Tech - LEVEL5

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