Super Laser at the NIF & Super Laser

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Listen to it online http://www.kqed.org/quest/radio/view/726

QUEST SUBJECTS

Life Science — Biology, Health, Environment

Earth Science — Geology, Weather, Astronomy

Physical Science — **Physics, Chemistry, Engineering**

CA SCIENCE STANDARDS

Grades 9-12 Chemistry
Conservation of Matter and Stoichiometry
3. (a) writing balanced equations

Chemical Thermodynamics
7. (a,b) motion of molecules; exothermic reactions

Reaction Rates
8. (b) temperature and pressure as factors

Nuclear Processes
11. (a,b) nuclear forces; nuclear fusion and fission; $E=mc^2$

Grades 9-12 Earth Science
Earth's Place in the Universe
1. (e) nuclear fusion in the sun

PROGRAM NOTES

It's the largest laser beam in the world and it's being built in the Bay Area. The National Ignition Facility at Lawrence Livermore National Laboratory will shoot tremendous bursts of energy at an area the size of a pencil eraser. The goal? To recreate fusion, which powers the sun and some nuclear bombs, perhaps harnessing a new source of clean energy for the 21st Century.

In this segment you'll find…

- an explanation of nuclear fission and fusion.

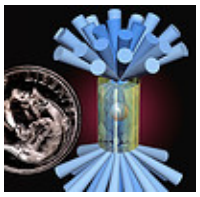
- how lasers work.
- why some scientists think nuclear fusion may be the answer to clean energy.

TOPIC BACKGROUND

Nuclear fusion is the process that powers the sun and stars. In a fusion reaction, two lighter hydrogen nuclei combine together, or fuse, to form an atom of helium with a somewhat larger nucleus. The easiest fusion reaction to replicate is to combine two isotopes of hydrogen – deuterium, which has a nucleus composed of one neutron and one proton, and tritium which has two neutrons and one proton in its nucleus. The resulting products are one atom of helium (with two protons and two neutrons), one neutron, and the release of energy as described by Einstein's famous equation $E=mc^2$.

For a fusion reaction to occur, the atoms of hydrogen must be heated to millions of degrees and subjected to high pressure. When done properly, the positively charged nuclei of the hydrogen isotopes, which naturally repel each other, combine.

At the National Ignition Facility, run by Lawrence Livermore National Laboratory, scientists are creating a system to replicate the fusion described above by using lasers to create the high heat and pressure needed. At the center of the project is a gold cylinder the size of a dime. This gold cylinder, called the hohlraum, houses a capsule containing the hydrogen isotopes – the fuel for the fusion reaction. NIF scientists will blast the hohlraum with 192 laser beams simultaneously (containing a total of 1.8 million joules of energy) for a few billionths of a second. The cylinder will produce x-rays that compress and heat the capsule resulting in a nuclear fusion reaction.



Additional background resources:

How Lasers Work: https://lasers.llnl.gov/education/how_lasers_work.php

How to Make a Star: https://lasers.llnl.gov/programs/nic/icf/

Researchers Seek to Recreate Fusion Power:
http://www.npr.org/templates/story/story.php?storyId=13746131

Fusion: The Hydrogen Bomb:
http://www.teachersdomain.org/resources/phy03/sci/phys/matter/fusionbomb/index.html

VOCABULARY

Fission – the splitting of the nucleus of an atom into nuclei of lighter atoms, accompanied by the release of energy

Fusion - a nuclear reaction in which nuclei combine to form more massive nuclei with the simultaneous release of energy

NIF – National Ignition Facility

Nuclear force – the force that binds protons and neutrons into atomic nuclei

Kinetic energy – the energy an object possesses due to its motion

Laser (Light Amplification by Stimulated Emission of Radiation) – an optical device that produces an intense monochromatic beam of coherent light

Atom – the smallest particle that comprises a chemical element

Electron – the subatomic particle that carries a negative charge

Joule – the SI unit that measures heat, electricity, and mechanical work

Nucleus (plural = nuclei) – the dense center region of an atom consisting of protons and neutrons

PRE-VIEWING / PRE-LISTENING

- What do you already know about fission, fusion, and nuclear reactions?
- List as many ways humans generate power as you can think of and label each as renewable or non-renewable.
- What are isotopes?

VIEWING / LISTENING FOCUS

For any story, see the following student handouts:

- Segment Summary Student Sheet
  http://www.kqed.org/quest/downloads/QUEST_SegSum_StudentSheet.pdf
- Personal Response Student Sheet
  http://www.kqed.org/quest/downloads/QUEST_PersResp_StudentSheet.pdf

- List the differences between fission and fusion.
- What are the reactants and products for the reaction at NIF? Write a chemical equation showing this.
- Is this an exothermic or endothermic reaction? How do you know?
- On what outside factors, beyond the chemical reactants, does this reaction depend?
- How does this story demonstrate $E=mc^2$?
- What is the controversy with the research being done at NIF? What are your thoughts on it?

QUEST CORNER

Video

LIDAR: Lasers Nab Leadfoots
http://www.kqed.org/quest/television/view/287

Nobel Laureate George Smoot and the Origin of the Universe
http://www.kqed.org/quest/television/view/251

Nanotechnology Takes Off
http://www.kqed.org/quest/television/view/189

- Educator Guide
  http://www.kqed.org/quest/dfiles/106a_nanotechnologytakesoff.pdf

Blog

Super Laser Radio Story Blog
http://www.kqed.org/quest/blog/2008/01/10/super-laser/

Photos

Super Laser Radio Story Photo Set
http://www.flickr.com/photos/kqedquest/sets/72157603687811897/

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The Bay Institute
www.bay.org

California Academy of Sciences
www.calacademy.org

Chabot Space and Science Center
www.chabotspace.org

East Bay Regional Park District
www.ebparks.org

Exploratorium
www.exploratorium.edu

Girl Scouts of Northern California
www.girlscoutsbayarea.org

Golden Gate National Parks Conservancy
www.parksconservancy.org

The J. David Gladstone Institutes
www.gladstone.ucsf.edu

Lawrence Berkeley National Laboratory
www.lbl.gov

Lawrence Hall of Science
www.lawrencehallofscience.org

Monterey Bay Aquarium
www.mbayaq.org

Monterey Bay Aquarium Research Institute
www.mbari.org

Oakland Zoo
www.oaklandzoo.org

The Tech Museum of Innovation
www.thetech.org

UC Berkeley Natural History Museums
http://bnhm.berkeley.edu/

U.S. Geological Survey
www.usgs.gov

LESSON PLANS & RESOURCES from PBS, TEACHERS' DOMAIN and NPR

NOTE: Resources from the Teachers' Domain collection require a fast and free registration.

Island of Stability NOVA scienceNOW
http://www.pbs.org/wgbh/nova/teachers/viewing/3313_02_nsn.html
Review atom-related terms, and learn about the relationship between atomic numbers and atomic mass weight. Conceptualize the general architecture of an atom.

Exploring Alternative Energy Sources NewsHour with Jim Lehrer
http://www.pbs.org/newshour/extra/teachers/lessonplans/science/alternative_energy.html
Calculate the increased cost of heating homes and fueling cars since the recent rise in energy prices. Investigate alternative renewable and nonrenewable energy sources that can be used to decrease Americans' dependency on fossil fuels.

Fusion: The Hydrogen Bomb Teachers' Domain
http://www.teachersdomain.org/resources/phy03/sci/phys/matter/fusionbomb/index.html
Just after World War II, nuclear scientists turned their attention from fission to fusion. This video segment adapted from *AMERICAN EXPERIENCE* looks at the beginnings of thermonuclear power generation.

FAQ About Nuclear Power Teachers' Domain
http://www.teachersdomain.org/resources/phy03/sci/phys/energy/questions/index.html
In this interview transcript published on the *FRONTLINE* Web site, Dr. Charles Till, a nuclear physicist and Associate Lab Director at Argonne National Laboratory West in Idaho, addresses a number of issues surrounding nuclear power produced by fission, including its great energy potential and whether public fears over its dangers are valid. Dr. Till presents one side of a larger debate.

Fusion: Testing the First Hydrogen Device Teachers' Domain
http://www.teachersdomain.org/resources/phy03/sci/phys/matter/fusiontest/index.html
This video segment adapted from *AMERICAN EXPERIENCE* features original footage of the U.S. test of the first hydrogen device, code-named "Mike," that would trigger thermonuclear fusion.

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PHOTO CREDITS

Lawrence Livermore National Laboratory

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NOTES/QUESTIONS

Forget the man on the moon. Over in Livermore, scientists say they're almost finished with the one of the most expensive high-tech projects the country has ever undertaken. What is it? Well, depends on who you ask. Proponents say it could be the future of clean energy. Critics call it a sandbox for nuclear weapons designers. Amy Standen reports.

Moses: We're walking up to the National Ignition Facility, here at Lawrence Livermore National Laboratory

Ed Moses directs the massive, $4 billion dollar science experiment known as the National Ignition Facility, or NIF. He's also one of its most enthusiastic tour guides.

Moses: And this facility houses what will be, in a very short time, the world's most energetic laser.

If this project inspires superlatives, that's because its goal is something never before done on Earth: to aim those powerful lasers at a hydrogen-filled capsule, creating, they hope, nuclear fusion, like a tiny star in a laboratory.

It will happen inside here.

Moses: This is the target chamber! Amy: Wow. I don't even know how to describe what this looks like.

But I'll try. It looks like something out of an Austin Powers movie, maybe... a time travel machine for Dr. Evil. It's a gleaming metal ball, the size of a small house. Protruding from it, like porcupine quills, are about fifty metal ducts.

Moses: Instead of air ducts, they're light air ducts, where the laser beams come in. And in each one of those ducts there's four laser beams.

You know little those laser pen pointers? You'd need a billion *billion* of them to match the cumulative power of all these lasers. Yes, a *billion billion*. And when scientists finally flip the switch on those lasers, here's how long it will last:

Moses: Not a hundredth or a thousand, but a billionth of a second

In that moment, the energy from those lasers will be a thousand times the strength of the entire United States electrical grid. The heat, unimaginable.

Moses: We will raise the temperature of the target to a hundred million degrees, pressures that are a hundred billion atmospheres. That's hotter than the center of the sun.

Inside that tiny, BB-sized target, the heat and pressure will be so intense that the hydrogen atoms -– scientists hope -- will smash together, with tremendous force.

Moses: And when you do they come so close together on a nuclear level that the nuclei penetrate each other, and make helium and a neutron pops out.

That is nuclear fusion – and the reaction releases more energy than the lasers put in. Supporters hope decades from now this could be a clean energy source. Or it could help us understand how the universe works.

NOTES/QUESTIONS

Moses: Instead of using our telescopes and looking at something that happened a thousand and million, a billion years ago, what if you could say "I would like to have a supernova on March 21st at 2 in the afternoon" and bring all your instruments and snuggle them right up to the target, and do your experiment. And that's something we'll be able to do.

Nuclear fusion also powers hydrogen bombs, which explains why the government got involved in this project in the first place.

Back in 1996, the United States signed the Comprehensive Nuclear Test Ban Treaty, which bars member countries from exploding actual nuclear bombs. But if America can't test its nuclear weapons, how do we know they still work? Well, says Moses, is where NIF comes in.

One of its original goals was to create conditions that exist in a nuclear weapon without actually having a nuclear weapon.

Since then, NIF has run years behind schedule and billions over budget. But Moses says the benefits of the project are worth it.

Traditional nuclear power plants use fission – or the separation of atomic particles -- to make energy. But a fusion plant where atoms are smashed together would create no long-term nuclear waste, and run on water. Moses says it would change the world. But critics are less optimistic.

Paine: Well that's complete nonsense.

Christopher Paine is with the Natural Resources Defense Council in Washington DC, and a longtime critic of the NIF project. He says even if NIF scientists achieve fusion – and Paine is deeply skeptical they will, it could take a century to scale that multi-billion dollar technology into an affordable power plant. Given global warming, he says, that's a luxury we don't have -- especially when we already have a source of unlimited nuclear fusion power.

Paine: It's readily known to most people as the sun. And had the billions that been expended on NIF and will be expended on NIF been directed towards our ability to convert solar energy into electricity, the country could be much better off.

Paine believes that, when it comes down to it, the National Ignition Project isn't really about electricity. It's about nuclear weapons.

Paine: There is an application for NIF and that is preserving and even enhancing US capabilities to design new nuclear weapons, conceivably without nuclear testing.

NIF Director Ed Moses points out that Congress has debated these points again and again – and continued to fund the project. But, for some, the verdict may rest on what happens a year or so from how: when scientists fire up those lasers and hold their breath.

For Quest, I'm Amy Standen, KQED Public Radio.