Women
in
Science and Engineering

Mary L. Spaeth

Tunable Laser Inventor

by Holly B. Martin

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Mary L. Spaeth, a physicist specializing in laser optics, was a pioneer who discovered the world's first "tunable" laser.

Spaeth graduated from Valparaiso University in Indiana and then earned a master's degree in nuclear physics at Wayne State University in Detroit. In 1962, she went to work at Hughes Aircraft Company in Culver City, California.

While researching ruby lasers at Hughes, Spaeth "came to believe that dyes would make excellent lasers." Dyes are strongly colored chemicals that can be used to add color to a material, such as hair or cloth.

The year was 1966, only six years after the first laser was invented.

How a laser works

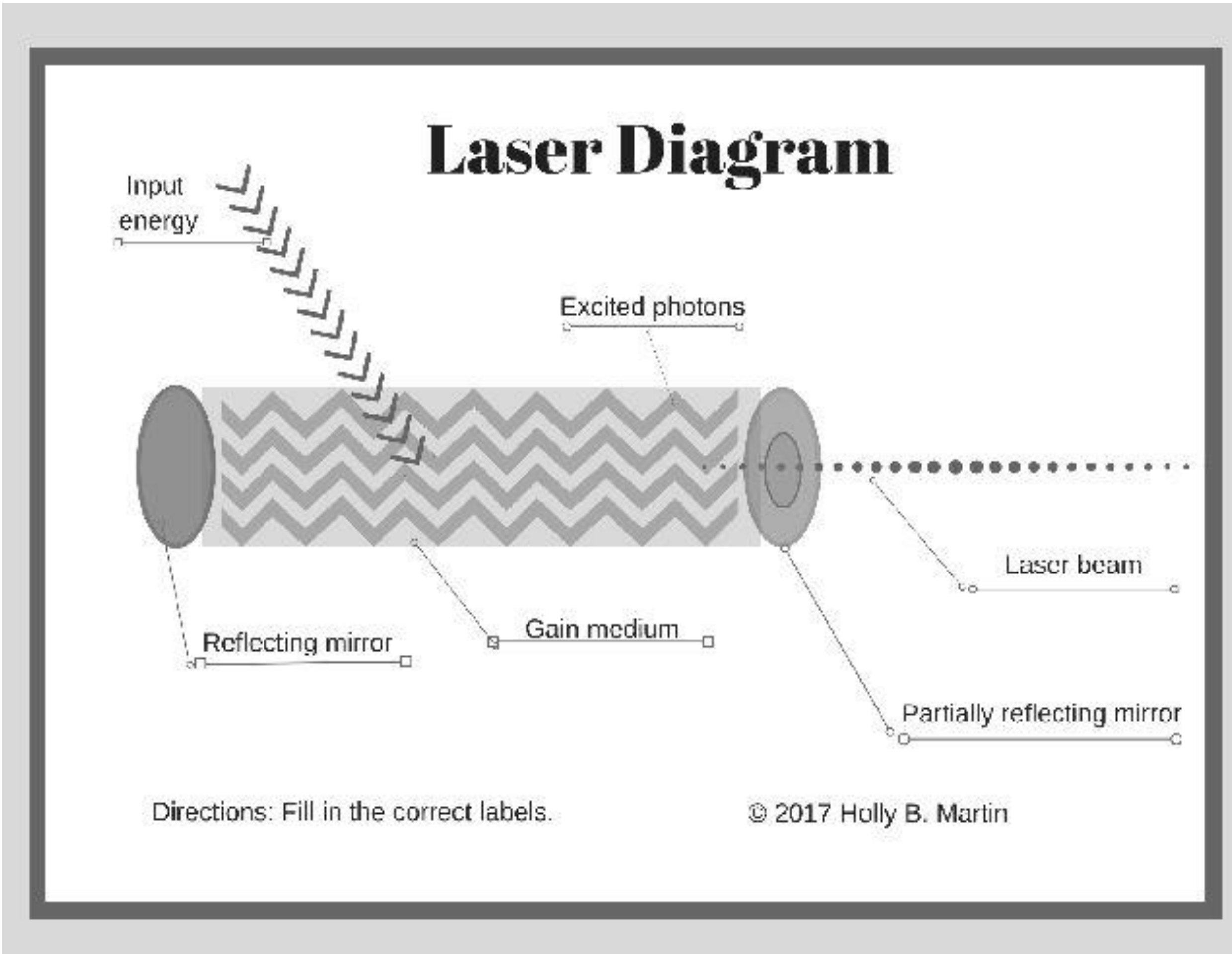
The term "laser" stands for Light Amplification for the Stimulated Emission of Radiation.

Here's how a laser works. First, a flash of light or electrical energy is aimed onto a lasing "medium," such a crystal rod or a container of liquid dye. The column-shaped laser medium is laid flat, with two mirrors facing each other at opposite ends of the medium. One of the end mirrors has been specially treated, or half-silvered, so that it only partially reflects light and partially allows it to pass through.

The light flash is so strong that it stimulates, or excites the atoms in the medium, causing them to jump up to a higher energy state. But the excited atoms naturally seek a lower energy state. They do this by releasing photons, the basic particle of light.

The mirrors at each end of the medium cause the photons to reflect back and forth between them. As the photons speed through the medium, they collide with other atoms, exciting them also – and causing them to release even more photons, all moving in the same direction.

Eventually, many photons are moving through the medium. At last, the photons burst through the half-silvered mirror in the form of a powerful, straight beam of coherent light.



"Coherent" means that every photon inside the beam has the same wavelength. The particles move like a row of ocean waves exactly the same height with all their crests in a perfect line hitting the beach at exactly the same time. It is the coherence of the photons that makes the laser beam very focused, even over long distances.

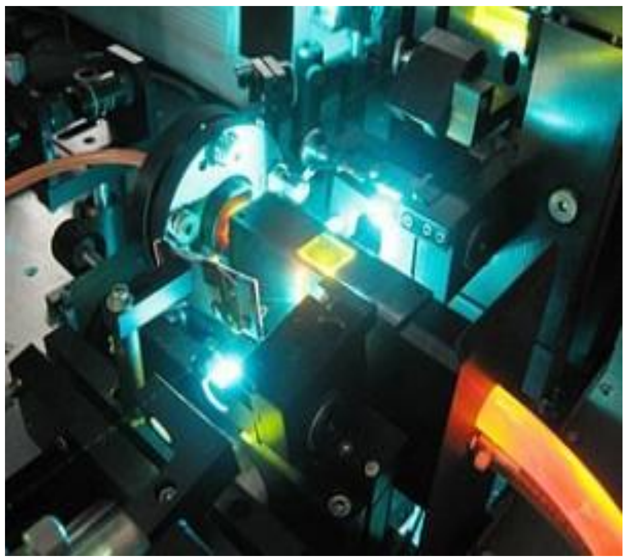
Race to find more lasers

Coherent light is very different from the scattered light shining out in all directions from a light bulb. Many scientists of Spaeth's day could imagine all sorts of interesting things that coherent laser light could accomplish.

Once the first laser was invented in 1960, every scientist wanted to get in on the action. They began trying different mediums to see which ones would create a stimulated emission of radiation.

Laboratories all over the world were involved in this mad push in laser research, and Spaeth wasn't the only one to think of using a container of liquid dye for a laser medium.

It turned out that a research group at IBM led by Peter Sorokin also came up with the concept of dye lasers, and IBM's was the first successful dye laser to be reported. Sorkin ultimately got the credit for inventing this brand new type of laser, though Spaeth was not far behind. Her work was different because she chose a different dye.



Coherent dye laser. Credit: Han-Kwang at the AMOLF Institute, Amsterdam

"We had designed the [dye laser] equipment and were getting ready to test it when we heard about Sorokin's work," Spaeth said.

However, she didn't let that stop her. "Since there was so much difference in the [choice of dye] molecules we proposed to use, the decision was made to proceed," she said.

That decision was an important one, because Spaeth's dye laser turned out to be tunable, unlike Sorokin's.

"Tunable" means that the laser can be tuned to operate in a range of wavelengths, similar to the way that a radio dial can be tuned up or down to catch different stations. Other lasers, including Sorokin's, only produce a single wavelength of light.

And so Spaeth became the first person to design and operate a tunable laser.

“No one at Hughes believed that it was an actual laser because it was tunable and no tunable lasers had yet been seen,” she said.

Winning with AVLIS

Her success inventing the tunable laser led Spaeth to a new project at the Department of Energy's Lawrence Livermore National Laboratory (LLNL) in Livermore, California.

In the 1970s, scientists there proposed using Atomic Vapor Laser Isotope Separation (AVLIS) to enrich uranium. Nuclear power plants need enriched uranium as fuel in order to create electricity.

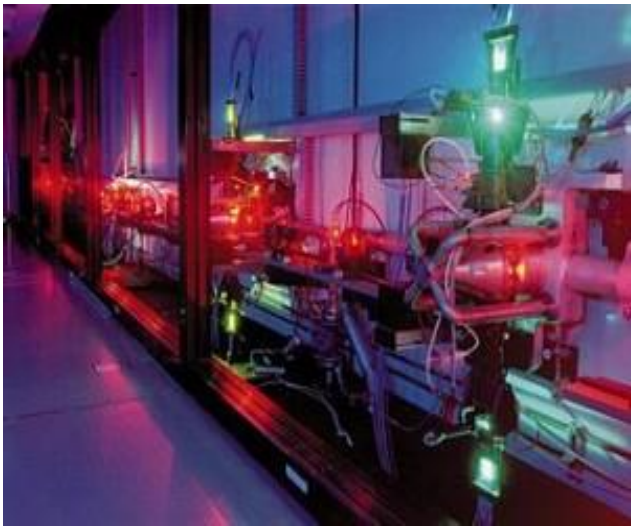
Enriched uranium has been treated so it contains a larger percentage of the uranium-235 (U-235) isotope than is found in nature. Isotopes are molecules with the same number of protons, but a different number of neutrons. For example, U-235 has three fewer neutrons than U-238. They are both isotopes of the element uranium.

Tuning is the key

The key to making laser enrichment work was Spaeth’s tunable laser concept. By fine-tuning its wavelength, the laser beam is able to energize (ionize) only the U-235 molecules, without affecting the U-238 molecules. The ionized molecules become attracted to an electrical collector plate, leaving the non-ionized molecules to pass through untouched.

Tunable lasers and the AVLIS technology were predicted to cost much less, save a lot of energy, and produce less hazardous waste than other enrichment methods.

In 1986, Spaeth became the deputy program leader of AVLIS. She was responsible for managing a year-long process to determine which advanced enrichment technology should be chosen – laser isotope separation with AVLIS, or the advanced gas centrifuge technology.



A highly tuned dye laser producing the orange light in the AVLIS project. Credit: LLNL

“We were pitted against four major companies in the U.S.,” Spaeth said. “$3.5 billion dollars of U.S. citizens’ money had been invested in the competing technology, but we were the winners.”

Spaeth said, “The judges were convinced that the process we were developing had a bigger chance for doing what the U.S. needs—a progression from something that’s just a gleam in your eye to a business worth more than $100 million a year."

Back in 1986, Spaeth counted the AVLIS win as her highest achievement. “When I came to the program 12 years ago, nobody would have given two cents for the probability that we would be in the position we’re in today,” she said.

Chief Technology Officer at NIF

In 1992, LLNL demonstrated a complete, working AVLIS system. The AVLIS technology was then leased to the U.S. Enrichment Corporation (USEC) to begin commercial operation.

Unfortunately in 1999, USEC abandoned laser enrichment of uranium. Laser isotope separation technology is still being developed in other countries and may be useful in other applications like astronomy, medicine, materials processing and power plant nuclear waste recycling.

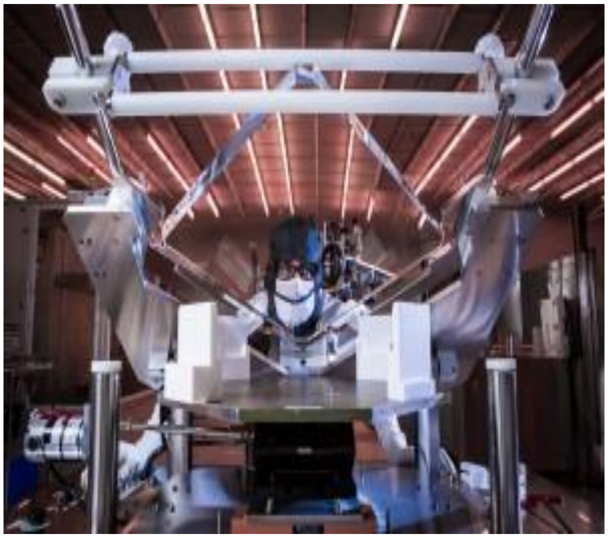
The National Ignition Facility preamplifiers. Credit: LLNL

By that time, Spaeth had already moved on. In 1991, Livermore Lab chose her to help start up a grand new project—the National Ignition Facility (NIF).

At the NIF, scientists hope to learn whether bombarding a small target of hydrogen fuel with a gigantic laser pulse could create a sustainable nuclear fusion reaction and become a new source of renewable energy in the future.

In addition to engineering large laser systems, Spaeth worked with laser optics, the polished glass lenses and mirrors used to direct a laser beam and keep it stable over long distances.

When high-energy beams pass through the optics, their electro-magnetic energy sometimes damages the pure glass structure. The tiniest fracture, impurity or contamination in the optics will slow down the laser beam, and reduce the power delivered to the target.



Optics processing of Target Wedged Focus Lens. Credit: LLNL

At NIF, Spaeth was known for designing a “Loop Strategy” to repair and recycle damaged optics, rather than throwing them away.

On being female in a “male occupation”

By the time Spaeth retired in 2012, she had become Chief Technology Officer of NIF. She left less than one year before researchers there demonstrated a ground-breaking energy positive fusion reaction. Her contributions, in laser optics and in systems engineering management, were no doubt critical to the mission’s success.

On the subject of being a woman engineer in a traditionally male occupation, Spaeth said back in 1986, “I don’t think of myself as anything other than a person who is trying to accomplish a task.”

“There are always individuals that will give you a hard time,” she said. “But at Livermore, you are judged by whether or not you deliver a product.” And Mary Spaeth's long and fruitful career as a woman engineer testifies to the truth of her statement.

Ref.: Bigelow, Holly and Susan Lamping. Women in Lasers: An Investigation. *Lasers & Applications*. Jan. 1986. Pp. 59-65. http://hollybmartin.com/wp-content/uploads/2013/01/Women-in-Lasers.pdf

Questions for Discussion

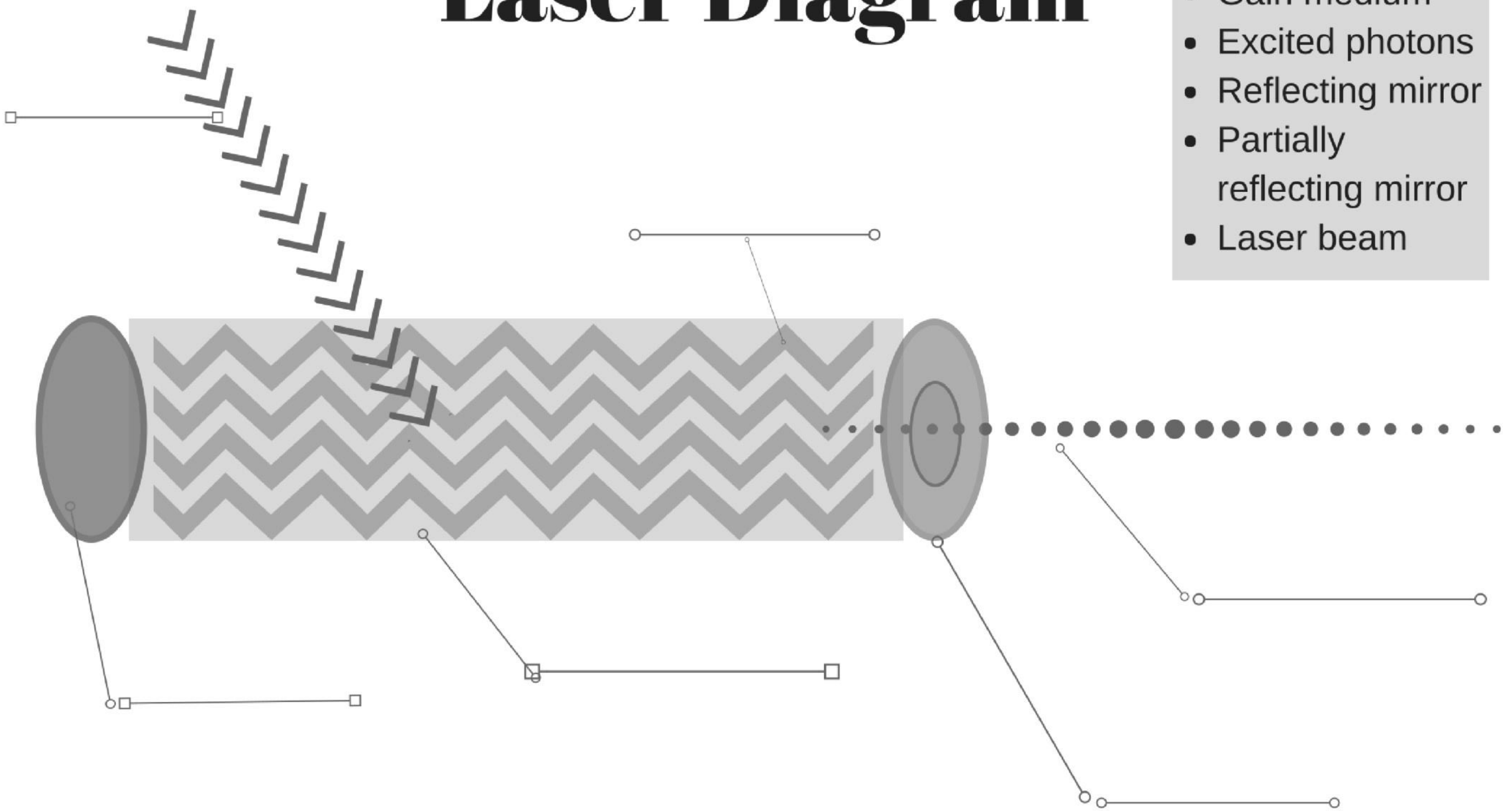
1. What impressed you most about Mary Spaeth's engineering career?
2. Can you describe how a laser works?
3. What are some things that lasers are used for today?
4. What does it mean to "enrich" uranium? How is it used?
5. How did the tunable laser make it easier to enrich uranium?
6. Why do you think Spaeth thought of AVLIS as her highest achievement, rather than the invention of tunable lasers?
7. Do you agree or disagree with Spaeth's idea that she was just "a person who is trying to accomplish a task"?
8. Do you think the cultural atmosphere for female scientists is less welcoming, more welcoming, or about the same as in the 1980s?

About the Author

Holly Bigelow Martin grew up in the "Secret City" of Oak Ridge, Tennessee, where the nuclear fuel for the first two atomic bombs was created during WWII. Holly studied engineering in college, and later became a writer and editor for technical magazines and websites. Visit her online at http://hollybmartin.com.

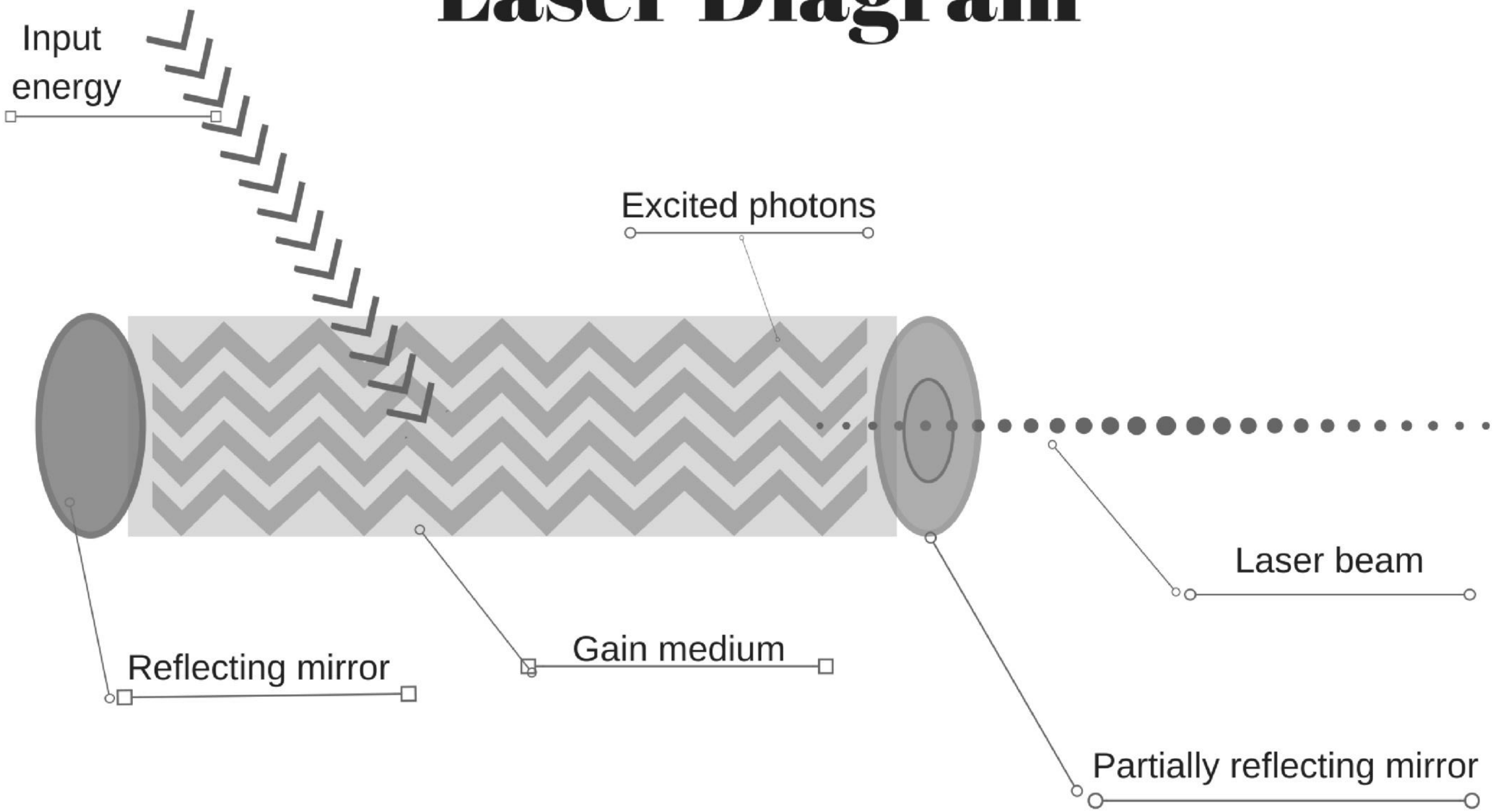
Laser Diagram

- Input energy
- Gain medium
- Excited photons
- Reflecting mirror
- Partially reflecting mirror
- Laser beam



Directions: Fill in the correct labels.

Laser Diagram



Directions: Fill in the correct labels.

Laser Word Scramble

Unscramble the letters to find the words on the vocabulary list.

1. tpcsio __________
2. ebatnuel __________
3. pnooth __________
4. yde __________
5. ebma __________
6. eelnwaghvt __________
7. ayrotlbao __________
8. gneeyr __________
9. dratnoiai __________
10. moats __________
11. hglit __________
12. pamiftcnoiila _________
13. aslre __________
14. mustdeialt ____________
15. rhoctene __________
16. rasehcre __________

Laser
Light
Amplification
Stimulated
Radiation
Atoms
Energy
Photon
Dye
Coherent
Wavelength
Laboratory
Research
Tunable
Beam
Optics