Laser technology, definition, applications, and challenges

Laser technology, definition, applications, and challenges

Modern Physics, Spring 2015

Farhad Eftekhar

- **Background**
- **Initial questions**
- **Selected problem**
- **Own explanation (original hypothesis)**
  - Definition
  - Applications
    - Computer devices
    - Astronomy and communication applications
    - Medicine, surgery, and health
    - War machines, guns and tanks
    - Metallurgy industry
    - Robotics
    - Toys
- **Critical evaluation**
  - Strengths
  - Weakness
  - What we need to find out more?
  - How could we improve my explanation?
  - What do you not understand or know yet about this topic?
- **Search results**
  - How laser works?
  - How do the flash tube and the crystal make laser light?
  - How is laser light different from ordinary light?
  - Types of laser
  - Applications of laser
    - Medical applications
Background

For our final review in modern physics course, we had to choose between some topics regarding the course material, therefore, I selected following initial questions to work on my report.

Initial questions

- How laser technology works?
- What are the applications of laser technology?
- How laser technology got invented?

Selected problem

- All of the above questions

Own explanation (original hypothesis)

I will start by giving my opinion about laser technology, and suggest the applications of such technologies based on the devices and applications I encountered and briefly describe my beliefs about the invention of such practical technology.

Definition

In my opinion, the laser technology comes from focusing photons of lights on a single spot and such approach makes it more powerful than a beam of light. In addition, I heard many times that it is dangerous to point out a laser dot in someone's eye.
Furthermore, as we learned about LEDs and that recently blue LED got invented, now that I think about it, I assume I have never seen a blue laser, although I’ve seen red laser and in few cases green laser. Therefore, I assume lasers and LEDs must have a very similar structure for that reason. (additional question: why blue laser was the last one to be invented, if it got invented, and is it similar to LED concept and reason?) I also assume practically it is harder to create green laser comparing to red ones, since, red light laser devices are much more and cheaper comparing to green ones. (additional question: why is it more difficult and more expensive to create green laser comparing to red ones?)

Applications

Laser technology must have a various application fields, in almost any of the science field you may observe laser technology applications and devices. In the following I mention the applications of such technology as far as I encountered, observed, used, or read about:

- Computer devices such as laser mouse, laser presentation, CD ROMs and DVD ROMs
- Astronomy and communication applications
- Medicine, surgery, and health
- War machines, guns and tanks
- Cutting matters in metallurgy industry and related industries
- Robotics, especially in image processing and calculating distances
- Toys

Computer devices

In computer industry there are several devices which I encountered that they were using laser technology to function. The reason for selecting such technology were three main reasons. First, the reason was to show a laser light and show a certain spot in places, such as presentations. Second, the reason was to use this technology as a method to navigate through surfaces to understand movement, for instance, laser mouses. Third, the reason was to emit a laser light and by receiving that certain laser understand the data, for instance CD ROMs and DVD ROMs that they emit a laser beam and it hit the surface of a CD or a DVD then it reflects to a receiver looking like an eye and it determines if the data was 0 or 1. (additional question: how optical drives read data?)

Astronomy and communication applications

In astronomy field, I’ve seen a documentary that briefly described the application of communicating satellites with each other using lasers. My assumptions is that they use binary to communicate with each other. By sending bits of data for instance 0 and 1. (additional question: how satellites use lasers to communicate with each other?)

Medicine, surgery, and health

In health related topics, lasers had great impact. By using lasers scientists and doctors are able to point out to cancer cells to destroy them and sometimes they do not need to cut the patient’s body in order to apply their surgery in cases that cutting may create other disease and in some parts may not even be possible. (additional question: how scientists may use lasers to go through humans tissues and work with an inner organ?)
War machines, guns and tanks

There are guns that by using laser beams it will fully show the place of bullet in the target's object. And laser more heavy machinery may use laser as a weapon to create a devastatingly strong armor. (additional question: how is it possible to create such strong laser beam to use it as a weapon to destroy heavy machinery?)

Metallurgy industry

To shape, and cut strong matters sometimes in related fields they use laser.

Robotics

In robots you may also encounter the applications of laser. Sensors may detect laser beams and by using them they can calculate distance. Robots can point out a laser beam from its sender and by using image processing the receiver may determine the diameter of such beam and calculate the distance of the robot from the other objects and surfaces. (additional question: how in robotics you may use laser to determine the distance of the robot from another object?)

Toys

Lasers are very interesting and amusing objects, therefore, we even may see their applications in toys for children.

Critical evaluation

We know that factors like heat can change the physical and chemical state of the compound.

Strengths

- Diverse variety of fields which indicated my knowledge in the applications of such technology
- Having a true interest in such technology and its applications
- Using my own knowledge without googling.
- Most of the stuff I wrote makes sense.
- Trying to use a proper scientific style of writing.
- Coming up with related further questions.

Weakness

- I do not have any reference to support our arguments.
- I am not sure if my analysis are completely true.
- I need to provide more scientifically explanations according to the laws of physics.
What we need to find out more?

- I need to find more information on the creation of laser beams.

How could we improve my explanation?

- I can improve our explanations by adding references to reliable sources.

What do you not understand or know yet about this topic?

- The challenge to create this technology in practice, and why it was hard to create such devices after many years of introduction of the concept.

Search results

“Laser” is an acronym for Light Amplification by Stimulated Emission of Radiation.

How laser works?

A laser is effectively a machine that makes billions of atoms pump out trillions of photons all at once so they line up to form a really concentrated light beam.

A red laser contains a long crystal made of ruby with a flash tube surrounding it. The flash tube is similar to a fluorescent strip light, only it’s coiled around the ruby crystal and it flashes every so often like a camera’s flash.
How do the flash tube and the crystal make laser light?

1. A high-voltage electric supply causes the tube flash to become on and off.
2. When the tube flashes, it directs energy into the ruby crystal to make it inject energy into the crystal in the form of photons.
3. Atoms in the ruby crystal absorbs this energy in a process called absorption. When an atom absorbs a photon of energy, one of its electrons goes from a low energy level to a higher one (E level). The electron can stay in the higher energy level only for a few milliseconds. It falls back to its original level, giving off the energy it absorbed as a new photon of light radiation. This process is called spontaneous emission.
4. The photons that atoms give off zoom up and down inside the ruby crystal, traveling at the speed of light.
5. Time to time, one of these photons hits an already excited atom. When this happens, the excited atom gives off two photons of light instead of one. This is called stimulated emission. Now one photon of light has produced two, so the light has been amplified.
6. A mirror at one end of the laser tube keeps the photons bouncing back and forth inside the crystal over and over again.
7. A partial mirror at the other end of the tube bounces some photons back into the crystal but allow some of them to escape.
8. The escaping photons form a very concentrated beam of powerful laser light. [1]
How is laser light different from ordinary light?

Much more concepts relies on lasers other than being just powerful flashlights. The difference between ordinary light and laser light is somehow difference between ripples in your bathtub and huge waves on the sea. When we move our hands and create waves in the bathtub they keep being stronger and stronger. Imagine you be able to continue this process as much as you be able to create waves as huge and as strong as ocean waves. In this concept, a laser does something similar with light waves to make them much stronger than ordinary light waves. [1]

Types of laser

Based on the medium you use, type of lasers may be varied. And they will be available for research, medical, industrial, and commercial uses.

Solid state lasers emits infrared light at 1.064 micrometers. And they have lasing material distributed in a solid matrix.

Gas lasers (helium and helium-neon, HeNe, are the most common gas lasers) have a output of a visible red light.
Excimer lasers use reactive gases such as chlorine and fluorine mixed with inert gases such as argon, krypton, or xenon. They produce light in the ultraviolet range.

Dye lasers use complex organic dyes like rhodamine 6G in liquid solution or suspension as lasing media. They are tunable over a broad range of wavelengths.
Semiconductor lasers (diode lasers) are not solid-state lasers. These electronic devices are generally very small and use low power. [2]

![Diagram of a semiconductor laser](image)

**Figure 5. Semiconductor lasers**

**Applications of laser**

Here are the list of the applications of laser: [3]

**Medical applications**

The highly collimated beam of a laser may be further focused to a microscopic dot of extremely high energy density. This concept makes it useful for cutting and cauterizing instrument.

**Welding and Cutting**

The highly collimated beam of a laser may be further focused to a microscopic dot of extremely high energy density for welding and cutting.

For instance, the automobile industry makes extensive use of carbon dioxide lasers with powers up to several kilowatts for computer controlled welding on auto assembly lines.

**Surveying**

Helium-neon and semiconductor lasers have become standard parts of the field surveyor's equipment. A fast laser pulse is sent to a corner reflector at the point to be measured and the time of reflection is measured to get the distance.
Garment industry

Computer controlled laser garment cutters can be programmed to cut out 400 size 6 and then 700 size 9 garments. The usefulness of the laser for such cutting operations comes from the fact that the beam is highly collimated and can be further focused to a microscopic dot of extremely high energy density for cutting.

Laser nuclear fusion

Telephone fiber drivers may be solid state lasers the size of a grain of sand and consume a power of only half a milliwatt. They can sent 50 million pulses per second into an attached telephone fiber and encode over 600 simultaneous telephone conversations.

Communication

Digital data transmission plays a pivotal role in modern society. Optical communication is any form of telecommunication that uses light as the transmission medium. An optical communication system consists of a transmitter, which encodes a message into an optical signal, a channel, which carries the signal to its destination, and a receiver, which reproduces the message from the received optical signal. [4]

Laser printing

The laser printer has in a few years become the dominant mode of printing in offices. It employs a semiconductor laser and the xerography principle. The laser is focused and scanned across a photoactive selenium coated drum where it produces a charge pattern which mirrors the material to be printed.

CDs and optical discs

Analog sound data is digitized by sampling at 44.1 kHz and coding as binary numbers in the pits on the compact disc. As the focused laser beam sweeps over the pits, it reproduces the binary numbers in the detection circuitry.
Laser spectroscopy has led to advances in the precision with which spectral line frequencies can be measured, and this has fundamental significance for our understanding of basic atomic processes.

**Heat treatment**
Heat treatments for hardening or annealing have been long practiced in metallurgy. But lasers offer some new possibilities for selective heat treatments of metal parts.

**Barcode scanners**

Supermarket scanners typically use helium-neon lasers to scan the universal barcodes to identify products. The laser beam bounces off a rotating mirror and scans the code, sending a modulated beam to a light detector and then to a computer which has the product information stored. Semiconductor lasers can also be used for this purpose.

**Laser cooling**

Starting in about 1985 with the work of Steven Chu and others, the use of lasers to achieve extremely low temperatures has advanced to the point that temperatures of 10-9 K have been reached.

**Summary (New explanation)**

Lasers are powerful beams of electromagnetic radiation. Laser beams can be made from visible light, x-rays, ultraviolet light or infrared light.

Laser beams may be created in 8 different steps as it was fully explained before. Laser beams comparing to ordinary light has a important difference and such difference is due to being much more powerful comparing to the ordinary light.

Based on the medium we use to create such beams, we create several laser types such as solid state lasers, gas lasers, excimer lasers, dye lasers, and semiconductor lasers.

Such powerful laser beams may have various applications in different fields of science, research, and industry. Applications in Medical applications, welding and Cutting, surveying, garment industry, laser nuclear fusion, communication, laser printing, CDs and optical discs, spectroscopy, heat treatment, barcode scanners, laser cooling.

Because of lasers applications research in this field is really essential and vital to the other field of science and such aspect made this topic a very practical and important topic.

**Additional questions**

- Why blue laser was the last one to be invented, if it got invented, and is it similar to LED concept and reason?
- Why is it more difficult and more expensive to create green laser comparing to red ones?
- How optical drives read data?
- How satellites use lasers to communicate with each other?
- How scientists may use lasers to go through humans tissues and work with an inner organ?
- How is it possible to create such strong laser beam to use it as a weapon to destroy heavy machinery?
• How in robotics you may use laser to determine the distance of the robot from another object?

References