The Laser and Its Applications

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Lab Section L1

The LASER, or light amplification by stimulated emission of radiation, is a common technology in today's world. Due to its wide scope of uses, the laser has undergone constant scientific study and improvement. It has brought revolutions in the industrial and medical fields, as well as being used in anything from electronics to military weaponry.

Over the last 60 years, the laser has been in constant development. The concept is that an excited state atom encounters a photon of the same energy as the difference in energy between the atoms excited and ground state. When the encounter happens, another photon of the same energy is emitted from the collision. Albert Einstein first suggested this in a 1916 paper that proved Plank's law of radiation. However, this scenario was rare, and scientists did not experiment with the idea until much later.

Charles H. Townes created the precursor to the laser, the maser, in 1954. The maser would amplify electromagnetic radiation of wavelengths in the microwave range. The development process started after World War II, when scientists working on radar developments continued to investigate microwave radiation with surplus military equipment. Townes produced his maser using excited ammonia molecules, however, due to physical separation of excited state molecules, the action would end after the initial emission. This resulted in the first maser incapable of

Townes with his Maser.

continuous output. To create a maser with continuous output, systems with multiple energy levels were designed. Nikolai Basov and Alexander Prokhorov of the USSR were the first to develop a continuous maser, and received the 1964 Nobel Prize in Physics for their efforts.

With the maser developed, scientists began looking at stimulated emission in other regions of the electromagnetic spectrum. Townes, with Arthur Schawlow, was the first to begin theorizing an optical maser. However, it would not be until 1960 that the first working laser would be built by Theodore Maiman. Maiman's 3 energy level pulsed laser would soon be outdone by Peter Sorokin ad Mirek Stevenson's 4 level laser, theoretically capable of continuous output [1].

Dr. Theodore Maiman

After 1960 the development of working continuous lasers continued until we have today's multitude of laser types. From these developments, lasers have found a huge number of applications in today's world. The medical field has many uses for the laser. Since lasers can be highly focused and energy dense they make excellent cutting tools. This allows them to cut tissue with unmatched precision compared to the

A laser drills microscopic holes in a heart to improve blood flow.

scalpel. Since the beam is constant and does not vary with energy, consistently deep cuts are always made. Lasers also cauterize blood vessels with their hot beams as it cuts. This allows the laser to be used in a multitude of procedures, including cutting tissue in surgical procedures, cleaning clogged arteries, whitening teeth, and reshaping the cornea of the eye, among other things. Because of the laser, doctors can now perform angioplasties – removing plaque from arteries – with minimal bleeding and recovery time. A small incision is made in the artery for the laser and a fiber optic camera is inserted. This allows the plaque to be burned out and removed with next to no bleeding.

In the case of ophthalmology, lasers have made many breakthroughs in curing a multitude of problems. The cornea, the coating over the eye, admits light into the interior of the eye. Since it's purpose is to let light pass through, lasers can enter the eyeball with no harm done to the outer eye. This allows the laser to operate on the inside of the eye. One use is to remove extra blood vessels that can form on the retina. These vessels can cause partial or complete blindness, often from diabetes. A laser can be aimed through the cornea and burn away the tangle of blood vessels covering the retina. The procedure can be completed in minutes in a doctor's office. Lasers an even "weld" a torn retina back into place, removing the need for extremely complicated operations and greatly raising the success rate. The most popular laser eye surgery is LASIK. LASIK is the modification of the cornea to enhance

Early laser eye surgery.

eyesight. A part of the cornea is opened up using a surgical knife, the patient's prescription is effectively carved into the cornea, and the corneal flap is put back into place. When successful the surgery gives the patient near perfect vision, eliminating the need for glasses or contacts.

Lasers can also be used for cosmetic surgery. Removal of birthmarks is the most common use, though tattoo and hair removal follow close behind. Port-wine stains, a common birthmark that can be found on the face and neck, can be removed with lasers. The mark is a reddish purple blotch that is made of a group of thousands of malformed blood vessels that strongly absorbs a shade of green light. To treat the mark, doctors shine a low-power beam of green light across the area. The blood vessels absorb the laser light and become so hot that they burn away. The surrounding skin, being a different color, is unaffected by the laser. This removes the mark with only a small chance of minor scarring. Similar methods are used for tattoo removal. A laser bleaches the dye in the tattoo without burning surrounding skin. The same concept is also used in laser hair removal. The beam of light is only absorbed into the hair follicle, which then heats up and destroys the follicle [2].

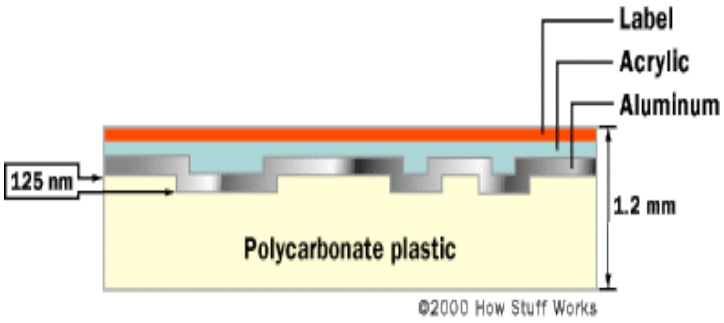
Birthmark and Tattoo laser removal.

Lasers also have a large variety of applications in industry. Lasers can be used in place of tools due to their many advantages. Lasers don't require contact, eliminating the need so sharpen or replace tools. Lasers can also work with more brittle or pliable materials, such as ceramic or rubber, which would be difficult or impossible to machine with other tools. Because of these advantages, high-powered lasers are often used to cut, weld, or drill many different materials. Depending on the material and the type of work to be done to it, the laser's power (and frequency if pulsed) is determined. Low intensity lasers are used for heat treating and welding, while higher-powered lasers can be used for material removal or creating plasma. However, the laser does have some disadvantages when it comes to manufacturing. Due to the high intensities needed to vaporize metal, the laser's beam must be focused. This causes the holes produced to be conical. This means that holes can only be drilled to about 10 times the lasers diameter before the intensity is unable to cut. To get around this, it is possible to move the laser around the circumference of the hole, though gas must be blown over the surface to remove vapors that can re-deposit on the hole [3].

Laser cutting.

Lasers are commonly found in consumer electronics. Perhaps the most common occurrence is in CD or DVD players. In these, the laser is meant to read the

data encoded into the disk. A typical CD is made up of a layer of aluminum sandwiched in between acrylic and polycarbonate plastic. The plastic layer is pressed with a long spiral path of microscopic bumps. The aluminum layer is then laid over the plastic layer to provide a reflective surface. The laser in the CD drive is shined on the CD and reflected back into a laser pickup. This pickup reads the data from the laser as either a 1 or a 0. The bumps on the CD determine the data number by reflecting the laser at a different angle. If the laser hits the pickup, the data is read as a 1. If the laser is reflected by a bump and misses the pickup, the data is read as a 0. These bits of data are then streamed through the CD player and outputted as an image or music.



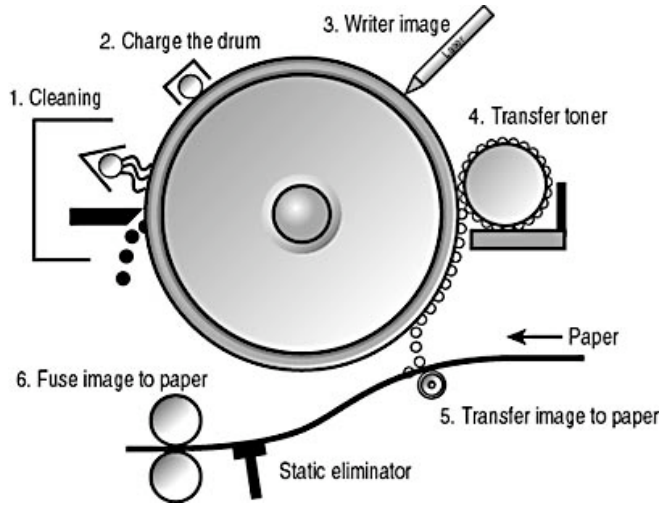
CD cross section.

The bumps on a standard CD are around 0.5 microns wide and 125 nanometers high. The spiral track would straighten out to be around 3.5 miles long. All of this data translates to about 783 megabytes of data, or around 74 minutes of music [4]. To increase the storage capacity of CDs manufacturers decided to decrease the size of the bumps, to allow more over the same area. This created DVDs and eventually BluRay discs. However, to read this decreased bump, manufacturers had to decrease the wavelength of the laser. CD's require a 780-nanometer laser, while DVD needs a laser of 640 nanometers, and BluRay needing a 405-nanometer laser [5].

Another use of lasers in consumer electronics is the laser mouse. Working off the same principle as an optical mouse, laser mice shine a beam down onto the surface, which reflects back up to the sensor. The movement of the mouse causes the laser to deflect differently, allowing the sensor to move the cursor on the screen. The main advantage of the laser mouse is accuracy. A standard optical mouse has a resolution of around 400 to 800 dpi, or dots-per-inch. This is the area of information the mouse can take in. Higher resolutions give more information and result in a smoother and more sensitive mouse. Laser mice commonly have resolutions of 2000 dpi, allowing it to be up to 5 times more accurate than an optical mouse. This accuracy will be rarely noticed by the everyday user, however graphic designers or gamers – with a large need to make small, precise movements – require the precision that a laser mouse provides [9].

Laser mouse's laser and sensor.

An additional use of the laser in electronics is the laser printer. Laser printers work through six steps. First the printer charges a photoreceptor with an electrostatic charge. Next, a laser converts this charge into an image. The laser is aimed at a series of mirrors that copies the image



onto the photoreceptor. When the laser makes contact with the roller, the electromagnetic charge is reversed. Then, the printer exposes the photoreceptor to toner, a dry powder that sticks to the negatively charged areas of the photoreceptor. This image is then pressed onto the paper and heated to set in the ink. A rubber blade then cleans the roller and the process is repeated. The laser printer works much faster than a standard inkjet printer and has a much lower cost to maintain, making it ideal for computer labs or offices with many computers [11].

The military is also a big advocate of the laser. The military uses lasers for both weaponry and non-weaponry uses. For example, laser sights for guns are often uses in the battlefield. A laser is attached to a soldier's gun and simply aims where the gun is pointed. This can be used for targeting and a variety of other uses. For example, since the laser is visible to anyone, it can be used to point out objects or locations to others. It is also an efficient means of crowd control. A person causing trouble tends to be more cooperative once he "notices the bright red dot on his chest". Lasers are also used in Reflex and Holographic Sights. In a Reflex Sight, a laser projects the aiming reticule to the lens of the sight, which in turn projects the reticule and image to the users eye. The lens itself is tuned to only allow the wavelength of the reticule illumination system – usually an LED – to be

Holographic Sight in contrast to Iron Sights.

reflected. This creates a nearly clear "window" with an aiming reticule projected into the center. This is much more accurate than iron sights, since complete head alignment is not needed to be accurate. There is also minimal vision obstruction due to the sight. The Holographic Sight is extremely similar, except the lens will reflect the whole image. This makes a sight that adjusts itself to head alignment, making aiming much quicker than even that of the Reflex Sights [8]. Lasers are also used for range finders, giving accurate estimates of distances in the field [7]. Range finders use the laser's travel time to find accurate distances [6]. Similar technology can be used to designate targets for smart bombs. A laser is aimed onto the target, and the bomb tracks the laser to hit a target much more accurately than by normal means. Lasers are also used for training, by running combat simulations that use lasers instead of live ammunition. This eliminates obvious safety concerns and creates a safe training environment, while keeping as much realism as possible [7].

The military has also developed lasers for use as weaponry. One such example is the PHaSR, a rifle sized weapon that uses multiple laser wavelength to "deter, prevent, or mitigate an adversary's effectiveness." The laser emitted by the weapon blinds aggressors, impairing their ability to see the laser source. The PHaSR is the first weapon of its kind, using a power source that makes it completely self-contained. The weapon uses two low-

PHaSR

power diode-pumped lasers, one in the visible spectrum and one in the infrared wavelength. Before the PHaSR, lasers were too powerful at close ranges and ineffective at long ranges. The PHaSR contains a range finder, which allows the user to locate the target and apply the maximum safe energy level on the target, regardless of range. This gives the user and his team a tactical advantage and can be used to reduce casualties in the battlefield [10].

In conclusion, the laser has revolutionized many facets of our society. From military weaponry to cosmetic surgery, lasers are quickly replacing conventional tools. Without a doubt, the laser has a bright future. As technology advances the laser will only further dominate civilization as we know it.

Sources Cited

[1] – "A Technical History of the Laser." essortment. 16 April 2010.

<http://www.essortment.com/all/historyoflaser_rsny.htm>

[2] – "Medical Uses of Lasers." Science Clarified. 16 April 2010.

<http://www.scienceclarified.com/scitech/Lasers/Medical-Uses-of-Lasers.html>

[3] – "Lasers In Industry." 16 April 2010.

<http://www1.union.edu/newmanj/lasers/Applications/lasers_in_industry.htm>

[4] - Marshall Brain. "How CDs Work." How Stuff Works. 17 April 2010.

<http://electronics.howstuffworks.com/cd1.htm>

[5] - Gayle A. Alleman. "How DVDs Work." How Stuff Works. 17 April 2010.

<http://electronics.howstuffworks.com/dvd6.htm>

[6] – "Bushnell Laser Rangefinder Info." Optics Planet. 17 April 2010.

<http://www.opticsplanet.com/info/htb-rangefinder.shtml>

[7] – Jerimiah Carr Harrell. "Military Applications of Laser." 17 April 2010.

[8] – "Electronic Sights." Ultimak. 18 April 2010.

<http://www.ultimak.com/understandinge-sights.htm>

[9] – Marshall Brain, Carmen Carmack. "How Computer Mice Work." 18 April 2010.

<http://computer.howstuffworks.com/mouse5.htm>

[10] – "Personnel Halting and Stimulation Response (PHaSR)." United States Air Force.
<http://www.kirtland.af.mil/shared/media/document/AFD-070404-043.pdf>

[11] – "How do Laser Printers Work?" Laser Printers Etc. 18 April 2010.
<http://www.laserprintersetc.com/laserprinters.htm>