A Brief Introduction To Laser Principles

Rashed S. Al-Rogaibah
Student Of Electrical Engineering
King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia.
E-Mail: s200552430@kfupm.edu.sa

***Abstract*- This technical paper is intended for people who need to understand the basic principles of how lasers work and their main applications. It will also present the different types of lasers available today. The paper plan is as follows: The introduction (Part I) describes the history behind the invention of the laser. Part II explains the basic theory of laser. Part III focuses on how does laser work. Part IV lists some of the possible applications. Finally, Part V describes the different types of laser, according to their medium.**

I. INTRODUCTION

The word laser is actually an acronym for "Light Amplification by Stimulated Emission of Radiation." The laser generates and amplifies light energy. It stimulates electrons to give off photons of light in an organized fashion and then channels them with mirrors to form a single beam. Instead of many colors of randomly directed light, like the light emitted from a light bulb, the light waves are emitted at the same wavelength, heading in the same direction at the same frequency. This coordinated beam of light may then be used for many applications. The process which makes lasers possible, Stimulated Emission, was proposed in 1917 by Albert Einstein. No one realized the incredible potential of this concept until the 1950's, when practical research was first performed on applying the theory of stimulated emission to making lasers. It wasn't until 1960 that the first true laser was made by Theodore Maimam, out of synthetic ruby. Many ideas for laser applications quickly followed. Still, the early pioneers of laser technology would be shocked and amazed to see the multitude of ways that lasers are used by everyone, everyday, in today's world.

II. THEORY

A basic understanding of a theory helps in understanding the laser device. Fig. 1 shows that electromagnetic radiation is emitted whenever a charged particle such as an electron gives up energy. This happens every time an electron drops from a higher energy state, Q1, to a lower energy state, Q0, in an atom or ion as occurs in a fluorescent light. This also happens from changes in the vibrational or rotational state of molecules. The color of light is determined by its frequency or wavelength. The shorter wavelengths are the ultraviolet and the longer wavelengths are the infrared. The smallest particle of light energy is described by quantum mechanics as a photon. The relation energy, E, of a photon is determined by its frequency, V, and Planck's constant, h and can be written as

$$E = h \cdot V \qquad (1)$$

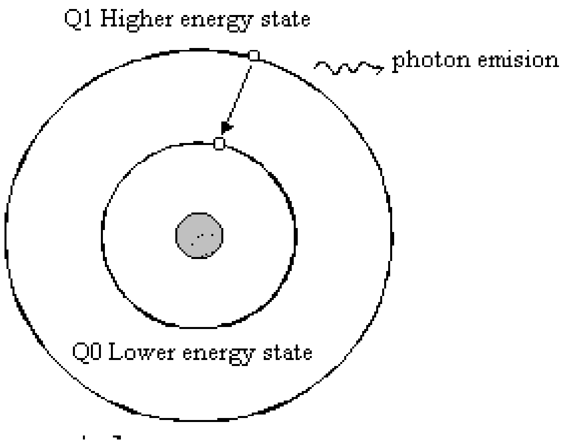

Fig. 1 Emission of radiation from an atom by transition of an electron from a higher energy state to a lower energy state

The velocity of light in a vacuum, c, is 300 million meters per second. The wavelength, λ, of light is related to V from the following equation:

$$\lambda = \frac{c}{V} \qquad (2)$$

The difference in energy levels across which an excited electron drops determines the wavelength of the emitted light.

III. HOW DOES WORK

In a laser, the lasing material is excited or "pumped," with light or electricity to get the atoms into an excited state. This causes the atoms to have higher-energy electrons. As usually, most of the electrons are in the ground state at room temperature. To get laser action it is necessary to get more electrons in a high energy state than in the state below. This is called a population inversion. Each excited electron absorbed some energy to reach this excited level, it can release energy as it drops back down to a lower energy state. This energy is emitted as a photon (light) and, in the case of a laser, this process is stimulated by the presence of another photon of equivalent energy. Two identical atoms with electrons in identical states will release photons of identical wavelengths. This is why laser light is of one single wavelength. If this photon (possessing acertain energy and phase) should encounter another atom that has an electron in the same excited state, further stimulated emission can occur and the light is amplified.

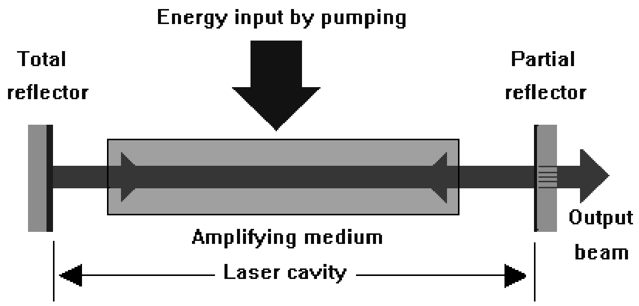

Fig. 2 Structure of a parallel-plate laser

As each electron falls to the lower energy level and releases its energy as a photon, all photons have the same frequency, phase and direction as the incoming photon. Fig. 2 shows the mirrors at the ends of the laser. The photons reflect off the mirrors to travel back and forth through the lasing material. In the process, they stimulate other electrons to fall to lower energy levels and release photons. The mirror at one end of the laser is "half-silvered," meaning it reflects some light and lets some light through. The light that makes it through is the laser light.

IV. Applications

The characteristics of laser light make lasers a valuable tool in many areas, such as communications, industry, medicine, military and scientific research.

Communications: Lasers working in the infrared area are right now revolutionizing the communications industry. A laser transmits voice or data via fiber optic cables at much improved speed and capacity. These lasers are part of the broadband revolution we hear about daily. Other everyday, low power applications for lasers are CD and DVD players.

Industry: Lasers are used to cut, drill, weld, guide and measure with high accuracy. For some of these applications very powerful lasers (10,000 Watts) are used, and the laser light is focused in a very small area (0.0025 mm), which produces an extreme heat (10,000 F) that can cut through and melt extremely hard materials. Commonly used lasers in industrial environments are Excimer, Neodymium YAG, and Carbon Dioxide

Medicine: Surgeons use lasers to remove deceased body tissue, with little damage to surrounding area. In addition lasers seal off blood vessels severed during the surgery, thus reducing the amount of bleeding. Laser eye surgery is becoming common for correcting near sightedness as well as for reattaching retinas. Commonly used lasers in medicine are Excimer, several different harmonics of YAG lasers as well as Carbon Dioxide lasers.

Military: Lasers are used in military applications both as weapons and for guidance systems for weapons. Future applications may include very powerful lasers that can down planes and missiles (SDI).

V. Types

There are many ways to define the type of laser. Based on its pumping scheme a laser can be classified as

- Optically pumped laser
- Electrically pumped laser

On the basis of the operation mode, laser fall into classes of

- Continuous Wave Lasers
- Pulsed Lasers.

According to the materials used to produce laser light, lasers can be divided into three categories :

- Gas Lasers
- Solid State Lasers
- Semiconductor Lasers
- Other Laser Devices

Acknowledgment

Thanks are due to “Dr. Husain M. Masoudi, Associate Professor, King Fahd University of Petroleum and Minerals KFUPM, Dhahran, Saudi Arabia” for giving me the opportunity to learn how a technical report is constructed and the strategies involved.

References

[1] Balembois, François. "The Laser : Basic Principles." December 2007. 6 Dec 2008 <http://prn1.univ-lemans.fr/prn1/siteheberge/optique/M1G1_FBalembois_ang/co/Module_M1G1_anglais_1.html>.

[2] Birner , Stefan. "The Principles of Laser." October 1998. 4 Dec 2008 <http://www.asamnet.de/~birners/public_html/laser.html>.

[3] Townes, Charles H. "The first laser." 2003. 10 Dec 2008 <http://www.press.uchicago.edu/Misc/Chicago/284158_townes.html>.

[4] Weschler, Matthew. "How Lasers Work." howstuffworks. 6 Dec 2008 <http://science.howstuffworks.com/laser.htm>.