CALCULATION OF OPTICAL GAIN AS A FUNCTION OF PUMP-POWER

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ABSTRACT

To get the proper wavelengths to generate the chain reaction, first electricity or another energy source is "pumped" into a chamber filled with a particular atoms or molecules. Then this "pumping" radiation causes the transition of atoms from ground state to higher energy excited state. From this short-lived state the atoms come down through non-radiative transition to the long-lived metastable state. Once in metastable state many atoms can be accumulated in one place and in the same state. The LASER or MASER beam, stimulated emission, arises when all these accumulated atoms simultaneously make transition to the ground state, releasing their energy of wavelength λ ,creating a beam of microwave radiation (or visible light in case of laser)which can be sent on the other atoms to cause the chain reaction. Since all the resulting photons have the same wavelength and the laser beams are extremely focused and coherent.

INTRODUCTION

In 1957, Charles Hard Townes and Arthur Leonard Schawlow, then at Bell Labs, began a serious study of the infrared MASER. The concept was originally known as "optical maser". Bell Labs filed a patent application for their proposed optical maser a year later. Schawlow and Townes sent a manuscript of their theoretical calculations to Physical Review, which published their paper in that year. (Volume 112, Issue 6)

At the same time Gordon Gould, a graduate student at Columbia University, was working on a doctoral thesis on the energy levels of excited thallium. Gould and Townes met and had conversations on the general subject of radiation emission. Afterward, Gould made notes about his ideas for a "laser" in November 1957, including suggestions using an open resonator, which became an important ingredient of future lasers.

In 1958, Prokhorov independently proposed an idea to use an open resonator. This idea was published for the first time. Schawlow and Townes also settled an open resonator design, apparently unaware of both the published work of Prokhorov and unpublished work of Gould.

The term "laser" was first introduced to the public in Gould's 1959 in the research paper of a conference "The Laser, Light Amplification by Stimulated Emission of Radiation" [5]. Gould intended "-aser" to be a suffix, to be used with an appropriate prefix for the spectra of light emitted by the device(x-ray laser = xaser, ultraviolet laser = uvaser, etc.). None of the other terms became popular, although "raser" was used for a short time to describe radio-frequency emitting devices.

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Gould's notes included possible applications for a laser, such as spectrometry, interferometry, radar and nuclear fusion .He continued working on his idea and filed a patent application in April 1959.The U.S. patent office denied his application and awarded a patent to Bell Labs in 1960.

Ruby laser as the first working laser was made by Theodore H. Maiman in 1960 [6] at Hughes Research Laboratories in Malibu, California, beating several research teams including those of Townes at Columbia University, Arthur L .Schawlow at Bell Labs [7] and Gould at a company called TRG (Technical Research Group). Maiman used a solid-state flashlamp-pumped synthetic ruby crystal to produce red laser light at 694 nanometres wavelength. Maiman's laser, however, was only capable of pulsed operation due to its three energy level pumping scheme. Later in 1960 the Iranian physicist Ali Javan, working with William Bennet and Donald Herriot, made the first gas laser using helium and neon. Javan later received the Albert Einstein Award in 1993.

Since the early period of laser history, laser research has produced a variety of improved and specialized laser types, optimized for different performance goals, including:

- New wavelength bands
- Maximum average output power
- Maximum peak output power
- Minimum output pulse duration
- Maximum power efficiency
- Maximum charging
- Maximum firing

(i) Absorption

If light (photons) of frequency ν_{21} pass through the group of atoms, there is possibility of light being absorbed by atoms which are in ground state, which will cause them to be excited to higher energy state. The probability of absorption is proportional to the radiation intensity of light and also to the number of atoms currently in ground state, N_1.

In order to describe the process of absorption, let us consider an enclosure containing atoms. The energy of atom can take on only definite (discrete) values, these are the discrete energy states or levels .The transition of an atom from one energy level say level-1 to another say level-2 occurs in jump and is called quantum transition. Quantum transition may be induced by various causes, such as through collision with other particles. In particular transition can also occur through the absorption of electromagnetic radiation of proper frequencies. Continuous Wave Lasers or Continuous Mode:

In continuous wave mode of operation, the output of a laser is relatively consistent with respect to time .The population inversion required for lasing is continually maintained by a steady pump source. For e.g. He-Ne laser is a CW laser, Ar^+ laser etc.

when pump energy stored in laser medium is at desired level, the (Q) is adjusted to favourable conditions, releasing the pulse .The result in high peak powers as the average power of laser is packed into a shorter time frame. Thus a giant pulse can be obtained by Q-Switching.

DISCUSSION

Thermal effects can occur in gain media because a part of the pump power is usually converted into heat.

The resulting temperature gradients can cause lensing effects, distorting the amplified beam .Such effects can spoil the beam quality of laser and sometimes even destroy the gain medium. The frequency range in which significant gain is available from an amplifier is called gain bandwidth. Optical gain can only occur for a finite range of optical frequencies .The gain bandwidth is basically the width of this frequency range. There is lot of confusion about exact meaning of term gain bandwidth because gain e.g. of a laser amplifier drops rather smoothly and there are different ways of quantifying gain, so that there is not a single straight forward definition.

The gain bandwidth of gain medium of laser can be important in following cases:

- It can limit the range for wavelength tuning.
- A small gain bandwidth is preferable for stable single frequency operation.

Pumping

Laser pumping is the act of energy transfer from an external source into laser gain medium, producing excited states in its atoms. When the number of particles in one excited state exceeds the number of particles in ground state or a less excited state, population inversion is achieved. In this condition, the mechanism of stimulated emission can take place and medium can act as a laser or an optical amplifier. The pump power must be higher than the lasing threshold of the laser.

The pump energy is usually provided in the form of light or electric current but more exotic sources have been used, such as chemical or nuclear reactions.

(i) Optical Pumping
(ii) Electrical Pumping

Optical Pumping: Flash lamps are the oldest energy source for lasers. They are used for lower energies in both solid state and dye lasers. They produce a broad spectrum of light, causing most of the energy to be wasted as heat in the gain medium. Flash lamps also tend to have a short lifetime.

In the most common configuration, gain medium is in the form of a rod located at one focus of a mirrored cavity of elliptical cross section perpendicular to the rod’s axis. The lamp is a cylinder located at the other focus of the ellipse. Often the mirror’s coating is chosen to transmit shorter wavelengths to minimize thermal lensing. In other cases, an absorber for these

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wavelengths is used. The larger the ellipse, the smaller the aberrations, giving higher intensity in the centre of rod. The closer the ellipse is to a circle, the more symmetric the pumping is, which improves beam quality. Typically, the lamp is surrounded by a cylindrical jacket with a dielectric coating that reflects unsuitable wavelengths of light back into the lamp. This light is absorbed and some of it is re-emitted at suitable wavelengths by means of fluorescence. The jacket also serves to protect the rod in the event of a violent lamp failure, and may provide a flow path for coolant. The rod and lamp are relatively long to minimize the effect of losses at the end faces and to provide a sufficient length of the gain medium [12]. Flat mirrors are also often used at the ends of the pump cavity to reduce loss. Cylindrical laser rods support whispering gallering modes due to total internal reflection between the rod and cooling water, which is not true for other rod cross sections. Inexpensive rods have unpolished outer diameter while expensive rods can have a cylindrical lens on one side to focus the pump light into the rod. An unpolished rod lowers the intensity at the centre of the rod worsening the beam profile. A lamp jacket or rod without an antireflection coating also leads to losses.

Results

As described above, a population inversion is required for laser operation, but cannot be achieved in our theoretical group of atoms with two energy levels when they are in thermal equilibrium. In fact any method by which the atoms are directly and continuously excited from the ground state to excited state will eventually reach equilibrium with the de-exciting processes of spontaneous and stimulated emission.

For the laboratory availability of the x-ray and γ-ray lasers the serious difficulties are on many fronts: (i) for having proper powerful pumps (ii) suitable and efficient gain medium (iii) suitable cavities for oscillations (iv) suitable geometrical methods.

REFERENCES

1. a b Gould, R. Gordon (1959). "The LASER, Light Amplification by Stimulated Emission of Radiation". In Franken, P.A. and Sands, R.H. (Eds.). The Ann Arbor Conference on Optical Pumping, the University of Michigan, 15 June through 18 June 1959. p. 128. OCLC 02460155.
2. "laser". Reference.com. Retrieved 2008-05-15.
3. Conceptual physics, Paul Hewitt, 2002
4. "Schawlow and Townes invent the laser". Lucent Technologies. 1998. Retrieved 2006-10-24.
5. a b Chu, Steven; Townes, Charles (2003). "Arthur Schawlow". In Edward P. Lazear (ed.),. Biographical Memoirs. vol. 83. National Academy of Sciences. p. 202. ISBN 0-309-08699-X.

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6. lase. Dictionary.reference.com. Retrieved 2011-12-10.
7. G.P. Karman, G.S. McDonald, G.H.C. New, J.P. Woerdman, "Laser Optics: Fractal modes in unstable resonators", Nature, Vol. 402, 138, 11 November 1999.
8. a b Steen, W. M. "Laser Materials Processing", 2nd Ed. 1998.
9. (Italian) "Il rischio da laser: cosa è e come affrontarlo; analisi di un problema non così lontano da noi ("The risk from laser: what it is and what it is like facing it; analysis of a problem which is thus mot far away from us."), Programma Corso di Formazione Obbligatorio anno 2004, Dimitri Batani (Powerpoint presentation >7Mb)". wwwold.unimib.it. Retrieved January 1, 2007.
10. The Nobel Prize in Physics 1966 Presentation Speech by Professor Ivar Waller. Retrieved 1 January 2007.
11. Joan Lisa Bromberg, The Laser in America, 1950–1970 (1991), pp. 74–77 online
12. Maiman, T.H. (1960). "Stimulated optical radiation in ruby". Nature 187 (4736): 493–494. Bibcode 1960Natur.187..493M. doi:10.1038/187493a0.
13. Townes, Charles Hard. "The first laser". University of Chicago. Retrieved 2008-05-15.
14. Hecht, Jeff (2005). Beam: The Race to Make the Laser. Oxford University Press. ISBN 0-19-514210-1.

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