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Laser Technology and Applications in Assorted Domains

Rashmi

Research Scholar

Department of Physics

Sri Venkateshwara University,

Uttar Pradesh, India

Dr. Nempal Singh

Associate Professor

Department of Physics

Sri Venkateshwara University

Uttar Pradesh, India

Abstract

The word laser started as an acronym for "light amplification by stimulated emission of radiation". In this usage, the term "light" includes electromagnetic radiation of any frequency, not only visible light, hence the terms infrared laser, ultraviolet laser, X-ray laser and gamma-ray laser. Because the microwave predecessor of the laser, the maser, was developed first, devices of this sort operating at microwave and radio frequencies are referred to as "masers" rather than "microwave lasers" or "radio lasers". In the early technical literature, especially at Bell Telephone Laboratories, the laser was called an optical maser; this term is now obsolete. A laser that produces light by itself is technically an optical oscillator rather than an optical amplifier as suggested by the acronym. It has been humorously noted that the acronym LOSER, for "light oscillation by stimulated emission of radiation", would have been more correct. With the widespread use of the original acronym as a common noun, optical amplifiers have come to be referred to as "laser amplifiers".

Keywords: Laser Technology, Applications of Laser, Laser in Engineering

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Introduction

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. Laser technology must have a various application fields, in almost any of the science field that may observe laser technology applications and devices.

- 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

A laser can be classified as operating in either continuous or pulsed mode, depending on whether the power output is essentially continuous over time or whether its output takes the form of pulses of light on one or another time scale. Of course even a laser whose output is normally continuous can be intentionally turned on and off at some rate in order to create pulses of light. When the modulation rate is on time scales much slower than the cavity lifetime and the time period over which energy can be stored in the lasing medium or pumping mechanism, then it is still classified as a "modulated" or "pulsed" continuous wave laser. Most laser diodes used in communication systems fall in that category.

Continuous wave operation

Some applications of lasers depend on a beam whose output power is constant over time. Such a laser is known as continuous wave (CW). Many types of lasers can be made to operate in continuous wave mode to satisfy such an application. Many of these lasers actually lase in several longitudinal modes at the same time, and beats between the slightly different optical

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frequencies of those oscillations will, in fact, produce amplitude variations on time scales shorter than the round-trip time (the reciprocal of the frequency spacing between modes), typically a few nanoseconds or less. In most cases, these lasers are still termed "continuous wave" as their output power is steady when averaged over any longer time periods, with the very high-frequency power variations having little or no impact in the intended application. (However, the term is not applied to mode-locked lasers, where the intention is to create very short pulses at the rate of the round-trip time.). For continuous wave operation, it is required for the population inversion of the gain medium to be continually replenished by a steady pump source. In some lasing media, this is impossible. In some other lasers, it would require pumping the laser at a very high continuous power level which would be impractical or destroy the laser by producing excessive heat. Such lasers cannot be run in CW mode.

Pulsed operation

Pulsed operation of lasers refers to any laser not classified as continuous wave, so that the optical power appears in pulses of some duration at some repetition rate. This encompasses a wide range of technologies addressing a number of different motivations. Some lasers are pulsed simply because they cannot be run in continuous mode. In other cases, the application requires the production of pulses having as large an energy as possible. Since the pulse energy is equal to the average power divided by the repetition rate, this goal can sometimes be satisfied by lowering the rate of pulses so that more energy can be built up in between pulses. In laser ablation, for example, a small volume of material at the surface of a work piece can be evaporated if it is heated in a very short time, while supplying the energy gradually would allow for the heat to be absorbed into the bulk of the piece, never attaining a sufficiently high temperature at a particular point. Other applications rely on the peak pulse power (rather than the energy in the pulse), especially in order to obtain nonlinear optical effects. For a given pulse energy, this requires creating pulses of the shortest possible duration utilizing techniques such as Q-switching. The optical bandwidth of a pulse cannot be narrower than the reciprocal of the pulse width. In the case of extremely short pulses, that implies lasing over a considerable bandwidth, quite contrary to the very narrow bandwidths

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typical of CW lasers. The lasing medium in some dye lasers and vibronic solid-state lasers produces optical gain over a wide bandwidth, making a laser possible which can thus generate pulses of light as short as a few femtoseconds (10^{-15} s).

In a Q-switched laser, the population inversion is allowed to build up by introducing loss inside the resonator which exceeds the gain of the medium; this can also be described as a reduction of the quality factor or 'Q' of the cavity. Then, after the pump energy stored in the laser medium has approached the maximum possible level, the introduced loss mechanism (often an electro- or acousto-optical element) is rapidly removed (or that occurs by itself in a passive device), allowing lasing to begin which rapidly obtains the stored energy in the gain medium. This results in a short pulse incorporating that energy, and thus a high peak power.

A mode-locked laser is capable of emitting extremely short pulses on the order of tens of picoseconds down to less than 10 femtoseconds. These pulses will repeat at the round trip time, that is, the time that it takes light to complete one round trip between the mirrors comprising the resonator. Due to the Fourier limit (also known as energy-time uncertainty), a pulse of such short temporal length has a spectrum spread over a considerable bandwidth. Thus such a gain medium must have a gain bandwidth sufficiently broad to amplify those frequencies. An example of a suitable material is titanium-doped, artificially grown sapphire (Ti:sapphire) which has a very wide gain bandwidth and can thus produce pulses of only a few femtoseconds duration.

Such mode-locked lasers are a most versatile tool for researching processes occurring on extremely short time scales (known as femtosecond physics, femtosecond chemistry and ultrafast science), for maximizing the effect of nonlinearity in optical materials (e.g. in second-harmonic generation, parametric down-conversion, optical parametric oscillators and the like). Due to the large peak power and the ability to generate phase-stabilized trains of ultrafast laser pulses, mode-locking ultrafast lasers underpin precision metrology and spectroscopy applications.

Another method of achieving pulsed laser operation is to pump the laser material with a source that is itself pulsed, either through electronic charging in the case of flash lamps, or another laser which is already pulsed. Pulsed pumping was historically used with dye lasers where the inverted population lifetime of a dye molecule was so short that a high energy, fast pump was needed. The way to overcome this problem was to charge up large capacitors which are then switched to discharge through flashlamps, producing an intense flash. Pulsed pumping is also required for three-level lasers in which the lower energy level rapidly becomes highly populated preventing further lasing until those atoms relax to the ground state. These lasers, such as the excimer laser and the copper vapor laser, can never be operated in CW mode.

Chemical lasers are powered by a chemical reaction permitting a large amount of energy to be released quickly. Such very high power lasers are especially of interest to the military, however continuous wave chemical lasers at very high power levels, fed by streams of gasses, have been developed and have some industrial applications. As examples, in the hydrogen fluoride laser (2700–2900 nm) and the deuterium fluoride laser (3800 nm) the reaction is the combination of hydrogen or deuterium gas with combustion products of ethylene in nitrogen trifluoride.

Laser is an optical device that generates intense beam of coherent monochromatic light by stimulated emission of radiation. Laser light is different from an ordinary light. It has various unique properties such as coherence, monochromacity, directionality, and high intensity. Because of these unique properties, lasers are used in various applications.

The most significant applications of lasers include:

- Lasers in medicine
- Lasers in communications
- Lasers in industries
- Lasers in science and technology

- Lasers in military

Lasers in Medicine

1. Lasers are used for bloodless surgery.
2. Lasers are used to destroy kidney stones.
3. Lasers are used in cancer diagnosis and therapy.
4. Lasers are used for eye lens curvature corrections.
5. Lasers are used in fiber-optic endoscope to detect ulcers in the intestines.
6. The liver and lung diseases could be treated by using lasers.
7. Lasers are used to study the internal structure of microorganisms and cells.
8. Lasers are used to produce chemical reactions.
9. Lasers are used to create plasma.
10. Lasers are used to remove tumors successfully.
11. Lasers are used to remove the caries or decayed portion of the teeth.
12. Lasers are used in cosmetic treatments such as acne treatment, cellulite and hair removal.

Lasers in Communications

1. Laser light is used in optical fiber communications to send information over large distances with low loss.
2. Laser light is used in underwater communication networks.
3. Lasers are used in space communication, radars and satellites.

Lasers in Industries

1. Lasers are used to cut glass and quartz.
2. Lasers are used in electronic industries for trimming the components of Integrated Circuits (ICs).
3. Lasers are used for heat treatment in the automotive industry.

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4. Laser light is used to collect the information about the prefixed prices of various products in shops and business establishments from the bar code printed on the product.
5. Ultraviolet lasers are used in the semiconductor industries for photolithography. Photolithography is the method used for manufacturing printed circuit board (PCB) and microprocessor by using ultraviolet light.
6. Lasers are used to drill aerosol nozzles and control orifices within the required precision.

Lasers in Science and Technology

1. A laser helps in studying the Brownian motion of particles.
2. With the help of a helium-neon laser, it was proved that the velocity of light is same in all directions.
3. With the help of a laser, it is possible to count the number of atoms in a substance.
4. Lasers are used in computers to retrieve stored information from a Compact Disc (CD).
5. Lasers are used to store large amount of information or data in CD-ROM.
6. Lasers are used to measure the pollutant gases and other contaminants of the atmosphere.
7. Lasers helps in determining the rate of rotation of the earth accurately.
8. Lasers are used in computer printers.
9. Lasers are used for producing three-dimensional pictures in space without the use of lens.
10. Lasers are used for detecting earthquakes and underwater nuclear blasts.
11. A gallium arsenide diode laser can be used to setup an invisible fence to protect an area.

Lasers in Military

1. Laser range finders are used to determine the distance to an object.

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2. The ring laser gyroscope is used for sensing and measuring very small angle of rotation of the moving objects.
3. Lasers can be used as a secretive illuminators for reconnaissance during night with high precision.
4. Lasers are used to dispose the energy of a warhead by damaging the missile.
5. Laser light is used in LIDAR’s to accurately measure the distance to an object.

Conclusion

Some of the world's most powerful and complex arrangements of multiple lasers and optical amplifiers are used to produce extremely high intensity pulses of light of extremely short duration, e.g. laboratory for laser energetics, National Ignition Facility, GEKKO XII, Nike laser, Laser Mégajoule, HiPER. These pulses are arranged such that they impact pellets of tritium–deuterium simultaneously from all directions, hoping that the squeezing effect of the impacts will induce atomic fusion in the pellets. This technique, known as "inertial confinement fusion", so far has not been able to achieve "breakeven", that is, so far the fusion reaction generates less power than is used to power the lasers, but research continues. Directed energy weapons are being developed, such as Boeing's Airborne Laser which was constructed inside a Boeing 747. Designated the YAL-1, it was intended to kill short- and intermediate-range ballistic missiles in their boost phase. Another example of direct use of a laser as a defensive weapon was researched for the Strategic Defense Initiative (SDI, nicknamed "Star Wars"), and its successor programs. This project would use ground-based or space-based laser systems to destroy incoming intercontinental ballistic missiles (ICBMs). The practical problems of using and aiming these systems were many; particularly the problem of destroying ICBMs at the most opportune moment, the boost phase just after launch. This would involve directing a laser through a large distance in the atmosphere, which, due to optical scattering and refraction, would bend and distort the laser beam, complicating the aiming of the laser and reducing its efficiency. Another idea from the SDI project was the nuclear-pumped X-ray laser. This was essentially an orbiting atomic bomb, surrounded by laser media in the form of glass rods; when the bomb exploded, the rods would be bombarded with highly-energetic gamma-ray photons, causing spontaneous and stimulated emission of X-ray photons in the atoms making up the rods. This would lead to optical amplification of the X-ray photons, producing an X-ray laser beam that would be minimally affected by atmospheric distortion and capable of destroying ICBMs in flight. The X-ray laser would be a strictly one-shot device, destroying itself on activation. Some initial tests of this concept were performed with underground nuclear testing; however, the results were not encouraging. Research into this approach to missile defense was discontinued after the SDI program was cancelled.

References

[1] Duley, W. W., Duley, W. W., & Duley, W. W. (1999). Laser welding (pp. 187-195). New York: Wiley.

[2] Ferguson, B., & Zhang, X. C. (2002). Materials for terahertz science and technology. Nature materials, 1(1), 26.

[3] Faure, J., Glinec, Y., Pukhov, A., Kiselev, S., Gordienko, S., Lefebvre, E., ... & Malka, V. (2004). A laser–plasma accelerator producing monoenergetic electron beams. Nature, 431(7008), 541.

[4] Feng, L., Wong, Z. J., Ma, R. M., Wang, Y., & Zhang, X. (2014). Single-mode laser by parity-time symmetry breaking. Science, 346(6212), 972-975.

[5] Painter, O., Lee, R. K., Scherer, A., Yariv, A., O'brien, J. D., Dapkus, P. D., & Kim, I. (1999). Two-dimensional photonic band-gap defect mode laser. Science, 284(5421), 1819-1821.

[6] Köhler, R., Tredicucci, A., Beltram, F., Beere, H. E., Linfield, E. H., Davies, A. G., ... & Rossi, F. (2002). Terahertz semiconductor-heterostructure laser. Nature, 417(6885), 156.

[7] Altug, H., Englund, D., & Vučković, J. (2006). Ultrafast photonic crystal nanocavity laser. Nature physics, 2(7), 484.