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LASER: An Innovative Tool For Multidisciplinary Applications

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Light in general and lasers in particular are ruling the world of science and technology for decades now. Interdisciplinary applications of lasers are in the fields of medical science, communication, defence, security, data storage and more.

The most important application of light as a laser is in day-to-day challenges faced by people of the world, due to its unique characteristics. This article focuses on laser and its major applications.

What laser is

The word laser stands for light amplification by stimulated emission of radiation. The unique property of laser, emission of coherent light, makes the applications of laser cutting and lithography possible. Laser pointing is also an application based on the property of the laser to follow a narrow path over great distances.

In the vast heaps of applications, laser finds a place in optical disk drives, laser printers, optical fibres (hence, optical communication), barcode readers, laser surgery, dermatology, cutting, welding, photo rejuvenation, endarterectomy, ophthalmology, military law enforcement devices for locating targets and measuring range and speed, and laser lighting displays in entertainment, among others.

Having properties like coherence and mono-chromaticity, a laser can be focused as a narrow beam over a very small area up to distant places without any reduction in power. Hence, a laser produced by stimulated emission of light can be employed in applications where light, if required, cannot produce spatial coherence using simpler technologies.

During 1960s, when the laser was invented, it was known as the solution looking for a problem, as a laser finds its utility in varied applications.

Applications of lasers

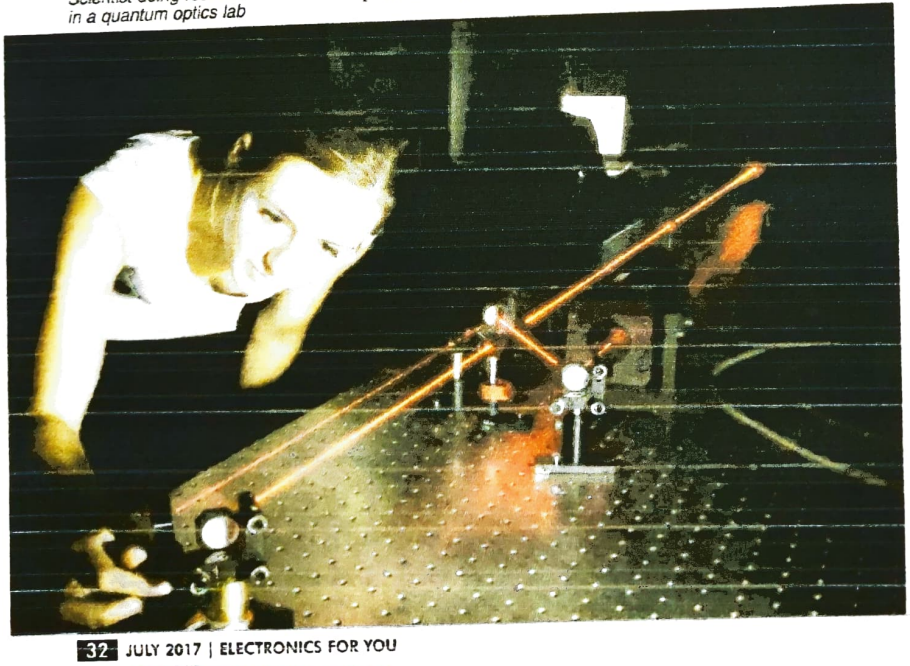
The various applications of lasers are described below.

Defence. The purpose of knocking down an enemy tank requires that the range (locating the target) is accurate. High intensity and low divergence of the laser satisfies this need. Neodymium and carbon-dioxide lasers are used as standard items for artillery and tanks. Laser range-finders are lightweight, having reliability and superior range accuracy.

When a laser beam is directed towards a target and reflected light from the target is received by an optical system and detected, corresponding time taken is measured. Half the time recorded is multiplied by the velocity of light and product to calculate range.

A laser finder is powerful

Scientist doing research in a quantum optics lab



than a microwave radar as the former provides better collimation, which makes high angular resolution possible. Having the advantage of greater radiant brightness and the fact that it is directional even after travelling long distances, the size of emitting system is gradually reduced. A laser rangefinder of medium range (up to 10km) is used in several defence areas, including:

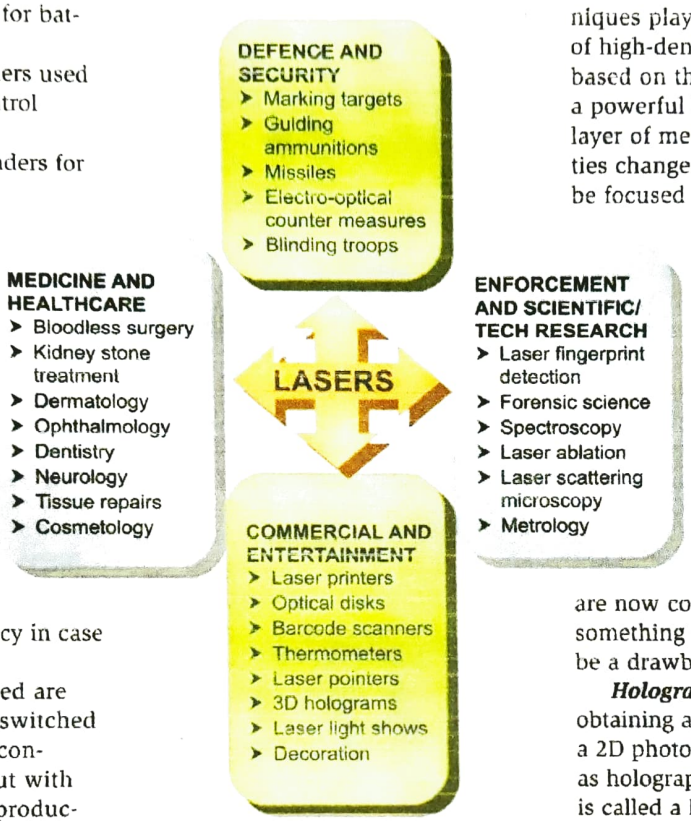
1. Tank laser rangefinders for battle tanks
2. Portable laser rangefinders used in field artillery fire-control systems
3. Air-borne laser rangefinders for air forces
4. Laser walkie-talkie rangefinders

Another application of laser is lidars (or, laser radars). These are better than microwaves, as lasers can be focused with lenses and mirrors easily while microwaves need huge antennae and components. Moreover, dimension and distance of target can be obtained with high accuracy in case of lidars.

The types of lasers used are carbon-dioxide lasers, Q-switched or gallium-arsenide semiconductor. High power output with requisite spectral purity production capacity of CO_2 laser is better for this purpose. High frequency of CO_2 lasers also produces high Doppler shift even from slow-moving targets. Fine beam width and high Doppler shift give CO_2 lasers an unparallelled imaging capability. Radar systems are used for measuring radial velocities to track low-flying aircraft and slow-moving objects.

Then, there are laser-guided anti-missile systems that can be guided by an infrared beam emitted from a laser, with extremely small divergence that can be achieved in the following four ways:

1. The laser beam is used to illuminate the target tank. The anti-missile system then homes in on the target, as the latter becomes a source of back-scattered radiation.
2. A laser beam is used to provide guidance instructions to the missile.



Applications of lasers

3. The missile itself carries a laser scanner and a seeker for active homing on target.
4. The missile rides the laser beam towards the target.

In an anti-missile defence setup, a laser is used to dispose of the energy of the warhead, by partially damaging the missile. Tremendous energy is required to completely destroy the missile. According to predictions, lasers will ultimately make inter-continental ballistic missiles obsolete.

There are many limitations, however, to the laser playing an anti-missile role. Huge power stations are required to produce huge power lasers. CO_2 and chemical lasers developed in the USA and Russia produce huge power in continuous mode, which is sufficient to destroy enemy battle tank.

Data storage. Optical techniques play a major role in storage of high-density data. These are based on the principle that, when a powerful laser illuminates a thin layer of metal, its optical properties change. As a laser beam can be focused on points smaller than one micro diameter, it takes less than one square micro to record one bit of data, that is, 100 million per square cm. There are laser CDs and DVDs available in the market with the required data stored in the form of audio, video, document, etc. Interestingly, erasable disks are now coming into the picture, something that was considered to be a drawback.

Holography. The technique of obtaining an image of a 3D body on a 2D photographic plate is termed as holography. The stored image is called a hologram. The whole process is based on the interference produced by the interaction of two-beam monochromatic light waves under certain conditions.

The hologram is recorded when a part of the emitted laser beam or reference beam goes directly to the photographic plate and the other part being object beam is reflected from the object and made to fall on the photographic plate, hence interfering with the reference beam to produce an interference pattern, which is called a

hologram. Even if the hologram is broken into pieces, single pieces produce the whole image of the body with reduced intensity.

Holography is used for diagnosis in various fields of medicine, non-destructive testing, holographic information storage, display devices and pattern-matching procedures in credit cards and identity card verification. It is also used for establishing a secret communication system by storing secret documents, maps and objects as holograms and reconstructing the image only at the receivers' end. It is expected that in the near future, holography may even be used for target recognition from air to ground, and we may have holographic movies and TVs.

Communication. Properties of a laser like wide bandwidth and narrow beam width over long distances enable its utility in this field. The semiconductor laser is generally used for optical-fibre communication, which is excited directly by electric current to yield a laser beam in the infrared region. Capacity of the communication channel is directly proportional to the bandwidth of frequency. So at optical frequencies, the information-carrying capacity is higher than at lower frequencies.

Communication of signals where light is used as a signal carrier and optical fibres as transmission medium is called optical-fibre communication. The first ever optical-fibre communication system was established in 1977. Since then, millions of dollars have been spent on long-distance communication where data or signals are converted into light pulses or codes using a suitable light source.

Light signals are transmitted through the core of optical fibres, amplified at the receiving end and converted into readable electrical signals by decoding light signals and, hence, getting the required original information. As light has high information-carrying capacity, optical-fibre communication is most probable these days. Moreover, light can easily be transmitted through extremely-thin hair-like fibres to large distances without reducing the intensity.

Advantages of optical-fibre communication are:

1. High information-carrying capacity
2. Free from electromagnetic interference
3. Lightweight
4. Minimum signal leakage

Due to these advantages this system finds many applications in the field of telecommunications. The telecommunication market for optical fibres has exploded in several developed countries like the USA, the UK, France, Denmark, Germany and Japan.

Medicine. No talk on laser in medicine can be done without mentioning Leon Goldman, the father of laser medicine. He was the first to use laser to treat a skin disease, which developed as dermatology.

Photo-rejuvenation is a process in which lasers are used to evaporate moisture from tissues responsible for wrinkles, dark spots and the like, from the face and create a layer of self-healing wounds.

Lasers have been extensively used in surgery, the very first being eye surgery where a laser was used to weld detached retinas and photocoagulate the vessels that grow in retinas,

Institutes/Research organisations in the field of lasers

1. RRI (DST), Bengaluru, Karnataka
2. IISc, Bengaluru, Karnataka
3. LEOS (ISRO), Bengaluru, Karnataka
4. Manipal University, Karnataka
5. NCBS, Bengaluru, Karnataka
6. PRL, Ahmedabad (ISRO), Gujarat
7. SGSIT, Indore, Madhya Pradesh
8. DAVV, Indore, Madhya Pradesh
9. RRCAT, Indore (DAE), Madhya Pradesh
10. UGC-DAE CSR - Indore, Madhya Pradesh
11. TIFR, Mumbai (DAE), Maharashtra
12. BARC (DAE), Mumbai, Maharashtra
13. Pune University, Maharashtra
14. SAMEER, Mumbai (MeitY), Maharashtra
15. DIAT, Pune (DRDO), Maharashtra
16. IIT Mumbai, Maharashtra
17. UGC-DAE CSR - Mumbai, Maharashtra
18. IRDE, DEHRADUN (DRDO), Uttarakhand
19. ARCHEM, University of Hyderabad, Telangana
20. CLPM, ARCI - Hyderabad (DST), Telangana
21. IIT, Patna, Bihar
22. LASTEC (DRDO), New Delhi
23. IIT Delhi, New Delhi
24. Delhi University, Delhi
25. NPL, Delhi (CSIR), Delhi
26. IISER, Mohali, Punjab
27. NCESS (MoEs), Kerala
28. ISP, CUSAT (Kochi) - Centre of Excellence in Lasers & Optoelectronic Sciences (CELOS), Kerala
29. IIST (ISRO), Trivendrum
30. Sathyabama University, Chennai, Tamil Nadu
31. IGCAR, Kalpakkam (DAE), Tamil Nadu
32. NCUFP, University of Madras, Tamil Nadu
33. IIT Madras, Tamil Nadu
34. UGC-DAE CSR - Kalpakkam, Tamil Nadu
35. SN Bose National Centre For Basic Sciences, Kolkata (DST), West Bengal
36. IICB (CSIR), Kolkata, West Bengal
37. Calcutta University, Kolkata, West Bengal
38. Jadavpur University, Jadavpur, West Bengal
39. IISER, Kolkata, West Bengal
40. SINP (DAE), Kolkata, West Bengal
41. IIT Kharagpur, West Bengal
42. IACS (DST), Kolkata, West Bengal
43. UGC-DAE CSR, Kolkata, West Bengal
44. IIT Kanpur, Uttar Pradesh
45. IIT Guwahati, Assam
46. BS Abdur Rahman University, Chennai, Tamil Nadu
47. University of Kerala, Thiruvananthapuram, Kerala

thereby blocking vision. Laser beams easily pass through transparent portions of the eye, including the cornea and lenses, to reach the region where energy of the laser is absorbed and used for treatment.

Traditionally, the use of xenon arc lamps and sunlight to focus over the choroid coat was really painful and required high-level anesthesia. Introduction of high-pulsed lasers like Nd:YAG was a major breakthrough when dealing with eyes. When focused on a tiny spot at the detached retina in order to weld it to the choroid coat, it leads to painless surgery.

Lasers are also used to burn small tumors on the surface of the eye or its vessels. These are being used to treat coma, cataract, sealing of retina and viral diseases of the eye.

As lasers are less damaging than x-rays, these are extensively and effectively used to treat different types of cancers by removing those enlarged tissues that are responsible for the cancer.

Lasers are also effective in curing diseases of gynecology, ear, nose, throat, tongue, palate and cheeks. These are effective in reducing tumors, too.

Photodynamic therapy (PDT) is the new form of cancer treatment, which combines laser with light-sensitive dye, hemato-porphyrin derivative (HPD), which is derived from cow's blood, and travels through the body of a patient and settles in malignant tissues. An argon red light is used to activate the HPD, which energises to release a highly-reactive chemical that destroys cancer cells. Reports say that PDT is 80 to 90 per cent successful in causing total regression of tumors.

Lasers are also used to treat colonic and gastro-intestinal cancers. Tools like endoscopes use laser energy to destroy neuro-plastic tissue while preserving the bowel wall integrity. Lasers also find a role in clearing kidney stones.

Lasers are used for dental treatment, too. Using a process called laser glazing to perform tooth decay clearance, a high-intensity laser is focused on the decayed tissues of the tooth. This destroys the infections in the affected areas in a fraction of a second. EFY

Professional bodies in laser and allied fields

1. Indian Laser Association
2. Photonics Society of India
3. Optical Society of India
4. IEEE-Photonics Society
5. IEEE-Laser and Electro-Optics Society
6. SPIE - The International Society for Optics and Photonics