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Study and Application of laser

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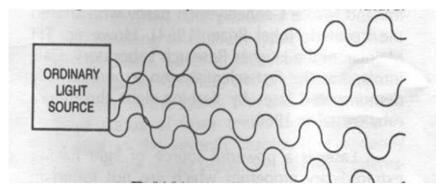
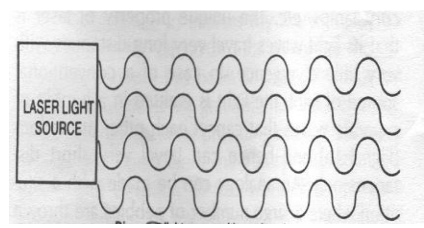
Introduction

No other scientific discovery of the 20th century has been demonstrated with so many exciting applications as laser acronym for (Light Amplification by Stimulated Emission of Radiation). The basic concepts of laser were first given by an American scientist, Charles Hard Townes and two Soviet scientists, Alexander Mikhailovich Prokhorov and Nikolai Gennediyevich Basov who shared the coveted Nobel Prize (1964). However, TH Maiman of the Hughes Research Laboratory, California, was the first scientist who experimentally demonstrated laser by flashing light through a ruby crystal, in 1960.

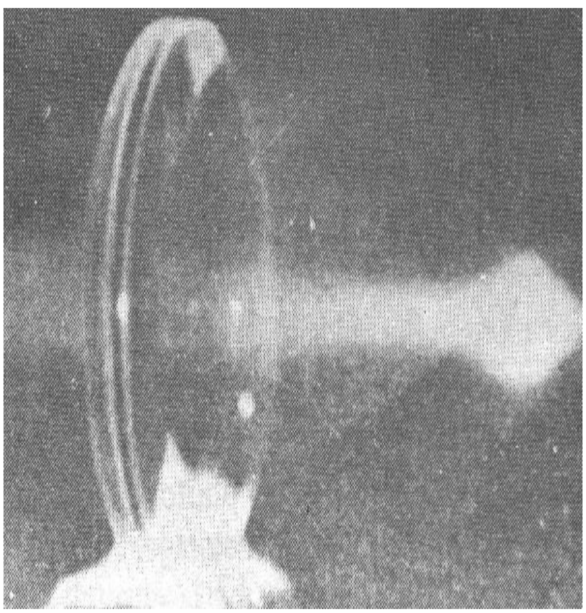
Laser is a powerful source of light having extraordinary properties which are not found in the normal light sources like tungsten lamps, mercury lamps, etc. The unique property of laser is that its light waves travel very long distances with e very little divergence. In case of a conventional e source of light, the light is emitted in a jumble of e separate waves that cancel each other at random (Fig. 1.a) and hence can travel very short distances only. An analogy can be made with a situation where a large number of pebbles are thrown It into a pool at the same time. Each pebble generates a wave of its own. Since the pebbles are thrown at random, the waves generated by all the pebbles cancel each other and as a result they travel a very short distance only. On the other hand, if the pebbles are thrown into a pool one by one at the same place and also at constant intervals of time, the waves thus generated strengthen each other and travel long distances. In this case, the waves are said to travel coherently. In laser, the light waves are exactly in step with each other and thus have a fixed phase relationship (Fig. 1b).

It is this coherency that makes all the difference to make the laser light so narrow, so powerful and so easy to focus on a given object. The light with such qualities is not found in nature.





A high degree of directionality and monochromatic is also associated with these light beams. Therefore, in a laser beam the light waves not only are in the same phase but also have the same color (wavelength) throughout their journey. The beam of the ordinary light spreads out very quickly. On the other hand, the laser beam is highly collimated and spreads very little as it 'Fig. travels through space; even after traveling to the , surface of the moon the spread of laser light has been found to be only about 3 km across. Hypothetically, if ordinary light was able to travel to the so moon, its beam would have fanned out to such an extent leading to a diameter of the light on . the moon as much as 40, 000 km. Another remarkable feature of laser is the concentration of its energy to extremely high intensities, the intensity remaining almost constant over long distances because of low divergence. If a laser beam with a power of a few megawatts (106 W) is focused by a lens at a spot with a diameter of 1/1000th of a centimeter, the beam intensity increases to a few hundred billion watts per sq. cm. This concentrated energy is so intense that it easily ionizes the atmospheric air to create sparks (Fig. 2). With the beam focused from a high power laser, even the hardest material like "diamond can be melted in a fraction of a second.



These unique characteristics of laser have made it an important tool in various applications. The initial notable application of laser was made c on the lunar ranging experiment of Apollo II Mission of 1969, when an array of retro reflectors was mounted on the surface of the moon and pulses from a ruby laser were sent from the earth. The reflected beams were received by suitable detectors and by measuring the time taken by the pulses in going from the earth to the moon and back, the distance of the moon from the earth was calculated to an accuracy of 15 cm.

After the first demonstration of laser in 1960, new applications of lasers in the various field are announced almost every day. Laser finds applications In the fields of communication, Industry, medicine, military operations, scientific research, etc. Besides, laser has already brought great benefits in surgery, photography, holography, engineering and data storage. Though it is not possible to illustrate all the laser applications reported so far in this small book, the more important ones are covered in the Chapters on Laser Applications.

How Laser Works

Laser Action & Quantum Theory

Laser action is based on well-established principles of quantum theory. Albert Einstein, the greatest modern physicist, enunciated that an excited atom or a molecule, when stimulated by an electromagnetic wave (i.e., light), would emit photons (packets of light) having the same wavelength as that of the impinging electromagnetic wave. Charles Townes was the first person who took advantage of this stimulated emission process as an amplifier by conceiving and fabricating the first maser (acronym for Microwave Amplification by Stimulated Emission of Radiation). The first maser was produced in ammonia vapour at a wavelength of 1.25 cm. Extending the maser principle to optical wavelengths, Townes along with Arthur Leonard Schawlow developed the concept of using a laser amplifier and an optical mirror cavity to provide the multiple reflections necessary for rapid growth of light signal into an intense visible beam.

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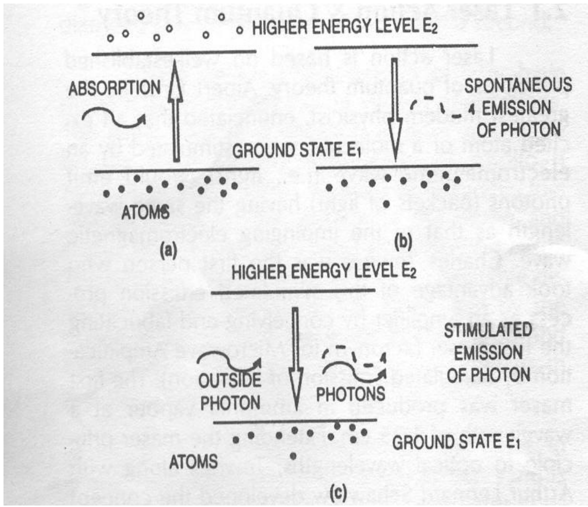
Principle of Laser Action



Every atom, according to the quantum theory, can have energies only in certain discrete states or energy levels. Normally, the atoms are in the lowest energy state or ground state. When light from a powerful source like a flash lamp or a mercury arc falls on a substance, the atoms in the ground state can be excited to go to one of the higher levels. This process is called absorption. After staying in that level for a very short duration (of the order of 10^{-8} second), the atom returns to its initial ground state, emitting a photon in the process, This process is called spontaneous or a emission. The two processes, namely, absorption and , spontaneous emission, take place in a conventional light source, In case the atom, still in Its urns to excited state, is struck by an outside photon having precisely the energy necessary for spontaneous emission, the outside photon is augmented by the one given up by the excited atom, Moreover, both the photons are released from the same excited state in the same phase, This process, called stimulated emission, is fundamental for laser action (Fig, 2.1). Thus, the atom is stimulated or induced to give up its photon earlier than it would have done ordinarily under spontaneous emission, The laser is thus analogous to a spring that is wound up and cocked, It needs a key to release it, In this process, the key is the photon having exactly the same wavelength as that of the light to be emitted.

Amplification & Population Inversion

When favorable conditions are created for the stimulated emission, more an more atoms are forced to give up photons thereby initiating a chain reaction and releasing vast amount of energy, This results in rapid build up of energy of emitting one particular wavelength (monochromatic light), traveling coherently in a precise, fixed direction. This process is called amplification by stimulated emission. The number of atoms in any level at a given time is called the population of that level. Normally, when the material is not excited externally, the population of the lower level or ground state is greater than that of the upper level. When the population of the upper level exceeds that of the lower level, which is a reversal of the normal occupancy, the process is called population inversion. This situation is essential for a laser action. For any stimulated emission, It is necessary that the upper energy level or met stable state should have a long life time, i.e., the atoms should pause at the met stable state for more time than at the lower level. Thus, for laser action, pumping mechanism (exciting with external source) should be from a such, as to maintain a higher population of atoms in the upper energy level relative to that in the lower level.

Designing a Laser

A laser generally requires three components for its operation: (a) an active medium in the form of a laser rod, with energy levels that can be selectively populated; (b) a pumping process to

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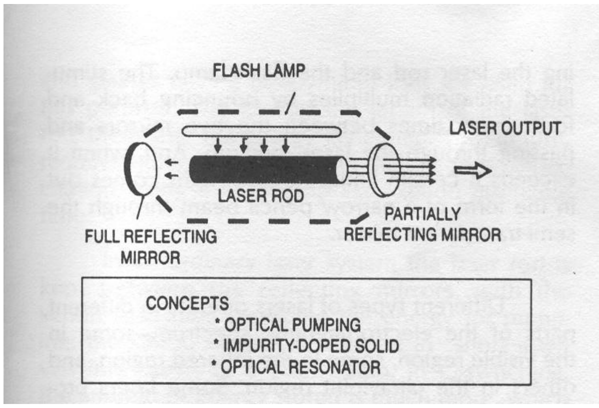
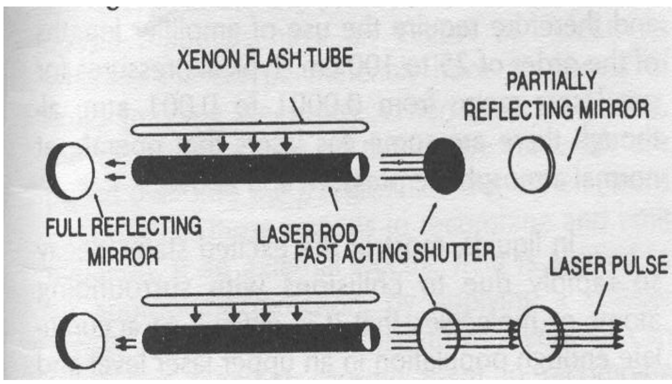
produce population inversion between some of these energy levels; and (c) a resonant cavity containing the active medium which serves to store the emitted radiation and provides feedback to maintain the coherence of the radiation (Fig. 2).



The main problem in designing a laser is to involve produce a sufficiently high population of atoms in the excited state. For this, many ingenious ways fully all have been evolved. The most common method of cent re excitation is by sending an intense beam of light from a flash lamp or a continuous source of light through the material in the form of a cylindrical rod or a container tube with a suitable gas. Only those materials which can be pumped to achieve population inversion, are used to give laser radiation. The existence of states whose mean life times are relatively long so as to help pile up considerable energy in the excited levels, is necessary. Long life time of a level and the sharpness of the spectrum lines usually go together, and so, the materials that can be best used to give laser radiation are crystals with sharp lines, and gases at low pressure. An important aspect of the laser operation involves the design of a resonator cavity to maximize the process of stimulated emission. Two carefully aligned mirrors, one having more than 99 percent reflectivity and the other having less reflectivity, are placed at either end of the cavity containing the laser rod and the flash lamp. The stimulated radiation multiplies by bouncing back and forth many times between the two mirrors and passing through the laser medium. And, when it exceeds a certain limit, the laser light comes out citation in the form of a narrow pencil beam through the semi-transparent mirror. Different types of lasers operate in different xenon f parts of the electromagnetic spectrum-some in the visible region, some in the infrared region, and others in the ultraviolet region. Some lasers produce continuous light beams while others give pulses of light (of less than millisecond duration). Basically, there are two types of lasers-the continuous wave (CW) laser and the pulsed beam allow laser. In the CW laser, the light is emitted as a, steady continuous beam, generally, with less intensity. Gas lasers belong to this category. On the other hand, the pulsed lasers produce powerful bursts of light of short duration. Crystals, glass and liquid types of lasers belong to this category. Normally the solid state lasers operate intermittently, mainly due to the large amount of heat developed In the crystal.

Increasing the Laser Power

The power of an ordinary pulsed laser can be Increase enormous by Q-switching or Q- spoiling, a technique known to be used for some of its applications in range finding, drilling, and cutting. In such systems, the power of the laser beam ranges from a few million to a few hundred billion watts and usually some rare earth crystals and glasses having neodymium ions are used for back and this purpose. The greater the length of the laser rod, the higher the energy generated. This, in turn, requires hundreds of joules in milliseconds for excitation,- using a flash lamp like xenon discharge tube. In an ordinary laser system the laser rod is kept between the reflecting mirrors, with the xenon flash tube providing the energy for pumping; the stored energy is released in short intervals into bursts of a laser beam. In Q-switching, lasers pro- the amount of energy stored is much more, which is achieved by interposing a fast acting shutter in duration). between one end of the laser rod and the partially reflecting mirror (Fig. 3). The shutter does not allow the laser radiation to be released for a predetermined time. After sufficient energy is stored in the energy level, the shutter is opened for a very short interval of about a nanosecond (one-billionth of a second) and all the stored energy is released as one giant pulse. This technique can be compared to a river dam where the lifting of a sluice gate releases water in a gush.



There are several ways of blocking and unblocking the optical paths between the mirrors. Different types of Q-switches like rotating prism, polarizing device, and dye solutions are employed. The tremendous energy released in this way can pierce through not only thick metallic plates but also the hardest material like diamond.

Inversion Mechanisms

Population inversion, which gives rise to laser action, is brought about in different media by various mechanisms. In gases, metal vapors, and plasmas, the inversion is brought out by applying a voltage drop across the elongated gain medium thereby producing an electric field that accelerates the electrons. These rapidly moving electrons then collide with gas atoms and excite them to a number of excited energy levels. Some of these levels decay faster than the others, leaving population inversions with some higher levels. If the population in the excited levels is high enough, then the gain may be sufficient to make a laser. Most gas lasers have relatively low gains and therefore require the use of amplifier lengths of the order of 25 to 100 cm. Typical pressures for gas lasers range from 0.0001 to 0.001 atm, although there are some gas lasers that operate at normal atmospheric pressure and above. In liquids, most of the excited states decay so rapidly due to collisions with surrounding atoms or molecules that it 1s difficult to accumulate enough population in an upper laser level and to achieve significant gain. Fluorescent dyes are the best liquid media for lasers; their excited energy levels are populated either by flash lamps or by lasers.

In solid state lasers, population inversions are brought out by implanting impurities (which give the laser action) within a. host material, such as a crystal or a glass and then exciting them with a suitable light. The impurity concentration is usually in the range of 0.01-3.0 per cent. In most of the solid state lasers, the impurities are in the form of ions in which the energy states are shielded from the surrounding atoms so that the energy levels are narrow. A flash lamp is used to excite the ions to a large number of upper energy levels. The excited ions decay quickly to the met stable upper level where they stay for considerable time (of the order of milliseconds) before terminating of the lower energy level, leading to the stimulatede mission no flase radiation. Inversions in semiconductors are produced when a p-n junction is created by joining two slightly different semi conducting materials, viz., n- and p-type materials (similar to a transistor). Then-type materials have an excess of electrons whereas the p-type materials have an excess of holes (missing electrons). When they are joined, excess electrons of the n-type materials are pulled over into the p-region causing the electrons and holes in those regions to recombine and emit radiation. If an external electric field is applied in an appropriate direction, by applying a voltage across the junction, more electrons and holes can be pulled together causing them to recombine and emit more radiation producing inversion

Laser Beam Properties

The use of a laser for various applications depends upon the beam properties of laser, such as direction, divergence, and wavelength or frequency characteristics, which can be adjusted by the laser components. The features affecting the beam properties of laser include: size of the gain medium, location, separation and reflectivity of the mirrors of the optical cavity, and presence of losses in the beam path within the cavity. Some of these features determine the unique properties of the laser beam, referred to as laser modes. The laser modes are wavelike properties relating to the oscillating character of the beam as the beam passes back and forth through the amplifier and grows at the expense of existing losses. The development of laser modes involves an attempt by competing light beams of similar wavelengths to fit an exact number of their waves into the optical cavity. For example, a laser mode of green light having a wavelength of exactly 5 x 10^{-5} cm will fit exactly 1,000,000 full cycles of oscillations between laser cavity mirrors separated by a distance of exactly 50 cm. Most lasers have several modes operating simultaneously in the form of both longitudinal and transverse modes which give rise to a complex frequency and spatial structure within the beam which otherwise appears as simple pencil-like beam

Laser Application

Defense

Laser Range Finder

To knock down an enemy tank, it is necessary to range it very accurate!y. Because of its high intensity and very low divergence even after travelling quite a few kilometres, laser is ideally suited for this purpose. The laser range finders using neodymium and carbon dioxide lasers have become a standard item for artillery and tanks. These laser range finders are light weight and have higher reliability and superior range accuracy as compared to the conventional range finders.

The laser range finder works on the principle of a radar. It makes use of the characteristic properties of the laser beam, namely, monochromaticity, high intensity, coherency, and directionality. A collimated pulse of the laser beam is directed towards a target and the reflected 1ight from the target is received by an optical system and detected. The time taken by the laser beam for the to and fro travel from the transmitter to the target is measured. When half of the time thus recorded is multiplied by the velocity of light, the product gives the range, i.e., the distance of the target.

The laser range finder is superior to microwave radar as the former provides better collimation or directivity which makes high angular resolution possible. Also, it has the advantage of greater radiant brightness and the fact that this brightness is highly directional even after travelling long distances, the size of the emitting system is greatly reduced. The high monochromaticity permits the use of optical band pass filter in the receiver circuit to discriminate between the signal and the stray light noise.

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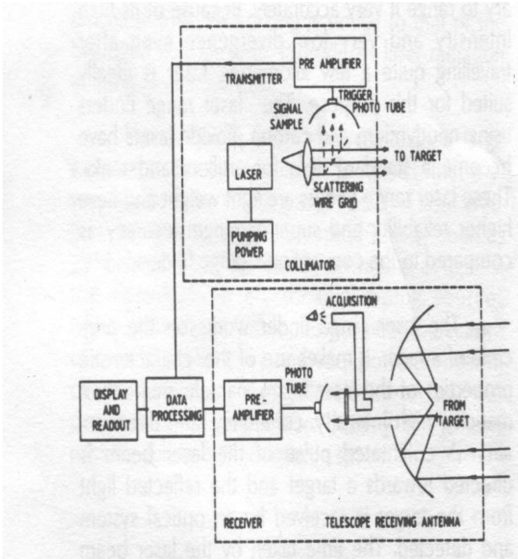

A typical laser range finder can be functionally divided into four parts: (i) transmitter, (ii) receiver, (iii) display and readout, and (iv) sighting telescope. An earlier version of a laser range finder is schematically shown in Fig. 4.1. The transmitter uses a Q-switched Nd:YAG laser which sends out single, collimated and short pulse of laser radiation to the target. A scattering wire grid directs a small sample of light from the transmitter pulse on to the photodetector, which after amplification is fed to the counter. This sample of light starts the counter. The reflected pulse, received by the telescope, is passed through an interference filter to eliminate any extraneous radiation. It is then focused on to another photodetector. The resulting signal is then fed to the counter. A digital system converts the time interval into distance. The range, thus determined by the counter, is displayed in the readout. The lighting telescope permits the operator to read the range while looking at the target

Special circuits have been used to eliminate Spurious signals with the help of range gating and to make the use of laser range finder Possible under all weather conditions for which the targets can be seen visually through the sighting telescope. The modern versions of the laser range finders Use either high repetition pulsed Nd:YAG laser or carbon dioxide laser with range gating system. In ranging a target about 10 km away using these systems, an accuracy within 5 m is easily obtained. The laser range finders of medium range (up to 10 km) are used in several Defence areas, including

- Tank laser range finder for artillery, an armoured vehicle, or a truck.
- Portable laser range finders, used in the field artillery fire control systems. These are intended for field application in conjunction with artillery fire control systems

- Airborne laser range finder, pod-mounted and servo-positioned for the Air Force. In any airborne weapon system, one of the i.e., the distance of the target. The laser range finder combines the characteristic features of a laser with gyroscope stabilisation to provide an equipment which is more accurate and has a faster response than any other means of deriving air-to-surface or air- to-air range. At the same time, it is more compact than any radar.
- The laser walkie-talkie range finder, a compact small instrument, weighing less than 4 kg, useful to range objects at distances less than 5 km. This range finder uses the semiconductor diode laser In emitting short duration pulses. With this, it is possible to which transmit and receive audio/visual communications, or pinpoint targets with a hand-held laser, even from unsteady environment in a helicopter or on a ship being tossed around by the rolling seas. There are no separate tripods, unwieldly power packs, or other external accessories.It gives an immediate readout of distance and elevation right on the instrument.

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Underwater Laser

Lasers can also be used as a source of underwater transmission. For this purpose, a laser giving radiation in the blue-green region is most suitable as the transmission in this region is maximum for sea water. The attenuation in underwater transmission is due to (i) absorption by materials in water, (ii) scattering by suspended particles, and (iii) variation in optical density along the light path. The blue-green lasers have assumed much importance in the systems related to naval applications.

At present, the submarines have to rely on a sonar to find the enemy crafts and to avoid the underwater objects. This has serious limitations. The whales, dolphins and other marine life give false signals. A typical sonar cannot give a well-defined picture because the sonar beam is broadened or scattered by sea water. A difference in the saltiness of water can cause the sonar beam to bend and make the target appear where it is not. Another problem of using sonar is that it gives away to the enemy the position of the ship from which it is transmitted. Lasers can be used efficiently for ranging and detection of underwater objects. For this purpose, a frequency doubled *Nd:YAG* laser or an argon ion gas laser or a Raman shifted xenon chloride laser is used. A schematic diagram of an .underwater ranging and viewing system is shown in Fig. .2. It consists of the laser transmitter which sends high power laser pulses of about 10 ns duration to the target at the rate of 30 to 50 per second through a beam splitter and a diffuser small amount of the laser light reflected by the beam splitter is made to fall on the photodiode the ranging and display circuit to start the time interval counter. The reflected light from the target is collected by telescopic optics after stray radiation is eliminated by an interference filter. A range gating circuit helps to avoid unwanted echoes The reflected pulse from the target is intensified by the image intensifier and the output is fed to image orthicon, which gives the display of the object. In this way, both the range and the image of the target are obtained. With high power release of several megawatts power, underwater ranging is possible up to 500 m in clear water.

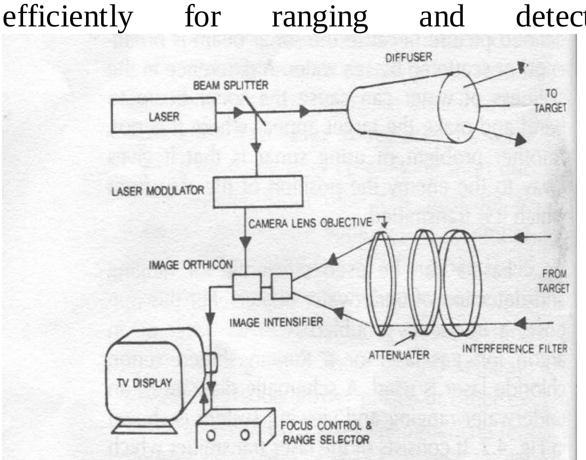

Fig. 4.2 Schematic diagram of underwater ranging.

Lasers can also be used for communication between submarines ensuring absolute privacy and in guidance systems for torpedoes and other unmanned underwater vehicles. Recent underwater laser communication has been established via satellite, i.e., from ground-to-satellite and then to underwater station.

Laser-Guided Anti-Tank Missile (ATM)

A missile can be guided and controlled by an infrared beam emitted from a laser, with extremely small divergence. This can be achieved in four ways:

(i) The laser beam is used to illuminate the target tank; the anti-tank missile (ATM) then homes on to the target,as the latter has .become a source of back-scattered radiation.

(ii) The laser beam is used to provide guidance instructions to the missile, i.e., it provides the command link.
(iii) The missile rides the laser beam which is kept pointing along the collision course to the target.
(iv) The missile itself carries a laser scanner and seeker for active homing on to the target

In the first case, the laser target designator is a pulsed *Nd:YAG* laser. The laser beam is so modulated that the receiver, a four quadrant detector in the missile, is able to calculate any divergence of the missile trajectory from the beam axis and correct the deviation by altering the fins of the missile. The guidance unit consists of both optical and electronic equipment. This enables the gunner to aim the infrared guidance beam for firing the missiles.

The system in which the missile is a beam rider designed to ride the laser pointing in the direction of the target, is more attractive. n missile can carry four detectors at the wing tips looking towards the rear of the missile. The detectors determine the central axis of the laser beam and keep the flight path of the missile along it. The wavelength of the laser should be such that is the least absorbed by the plume of the sustainer motor. Thus in a laser designator, the laser by virtue of its narrow beam illuminates a chosen target. A receiver in a bomb or a missile seeks the target illuminated from the scattered laser radiation and homes on to it. In the Vietnam war an in the recent Iraqi war, the Americans used laser guided missiles with pinpoint accuracy to destroy the enemy targets.

Laser Radar (Radar)

When the laser beam is used for a radar application, it is called lidar. The details, which could not be achieved earlier with microwave radars, can now be obtained with lidar. Besides, the laser beam can be focused with lenses an mirrors easily whereas microwaves need huge antenna for focusing. As a beacon or a radar, the advantages of utilising small antenna and components are obvious. With a lidar, the dimension and the distance of the target can be obtained with higher accuracy, which is not possible wit! the conventional microwave radar. The lasers used in lidars are of carbon dioxide, Q-switched neodymium, or gallium arsenide semiconductor type.

The great advantage of the use of carbon dioxide lasers for radar application is their capacity to produce high power output with requisite The spectral purity. The coherent carbon dioxide laser tips radar functions essentia1 like a coherent microwave radar except for the fact that the carbon dioxide laser beam has a frequency of a few thousand times more than that of the X-band radar and at it a sharp beam width of a few microradians. The high frequency of the carbon dioxide laser also produces high *Doppler shift* even from slow-moving targets. The fine beam width and high *Doppler* the *shift* give the carbon dioxide laser an unparalleled imaging capability. This radar system is used for and measuring radial velocities to track low-flying aircraft and slow-moving objects. Since the laser beam is very much attenuated by rain, fog, or snow, the lidar can perform well only in good weather conditions.

Anti-Missile Defence System (Star Wars)

In an antimissile defence system, laser is used to dispose the energy of warhead, not by vaporising or melting it, but by partially damaging the missile, say by drilling a hole. Tremendous energy is required to completely burn the missile, which is not practicable. If a guided vane of a missile is fractured, several vibrations will be developed in the air frame thereby disintegrating major sensitive portion of the missile. Two types

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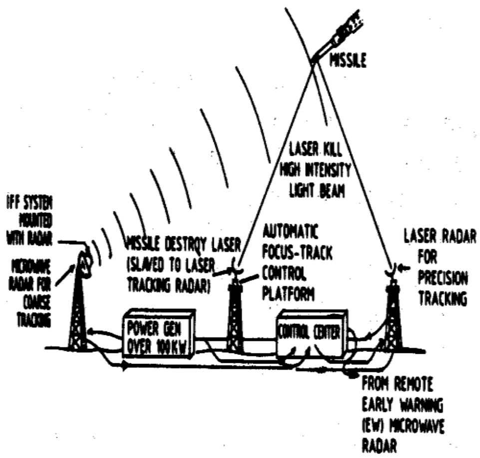
of anti-missile defence systems have been visualised. One such system, laser kill system is completely earthbound (Fig. 9). Here, an early warning microwave radar gives a rough position of the approaching missile. Then a lidar aligned to the target by the tracking radar gives the precise position of the missile. This data is fed on to another high intensity laser beam which actually does the killing. To exploit the laser's killing capability, a high speed servo system and a complex focusing system are essential.



The other anti-missile defence system is the orbiting space station, equipped with detecting, tracking and killing laser devices. An infrared homing system on the laser weapon is used to close on an enemy vehicle and then fire a high energy laser beam. Firing by laser weapons would not change the positional or altitude stability of the space station. It is predicted that the lasers would ultimately make inter-continental ballistic missiles (ICBM's) obsolete. There are, however, many limitations in the utilisation of laser in its anti-missile role. The power required is very prohibitive and as a result huge power stations are required for the operation. At present, huge power of more than 100 kW in the continuous mode is being obtained from the gas dynamic carbon dioxide lasers and some other chemical lasers, developed in the US and Russia. This amount of laser power is sufficient to destroy an enemy vehicle or a missile.

The SDI or Star Wars is the US programme aimed at defending itself and its allies against the ICBM strikes through space. The concept of strategic defence is concentrated at a three-layered defence system in which the enemy missile can be destroyed in the boost, or the mid-course, or terminal phase. Each layer of defence employs several alternatives of weapon systems. Laser is one such important system.

For detecting and destroying missiles, different types of high power lasers, such as gas dynamic carbon dioxide, excimer, x-ray, free-electron, and chemical lasers can be used. In one such programme, the us scientists are developing 5 to 10 MW deuterium fluoride lasers for destroying the ICBM. In the ground-based laser systems, laser beams will be directed towards a large mirror in geosynchronous orbit. From there, the beams will be directed towards a moving mirror in low orbit which will reflect the beams on to the missile to destroy it. The nuclear-pumped x-ray lasers are also being considered for destroying missiles in the boost phase.

Status of Laser Development in India

The research and development work in the field of lasers started in our country 28 years back on a very small scale at a few research laboratories of the Defence Research & Development Organisation, Bhabha Atomic Research Centre, National Physical Laboratory, IIT, Kanpur, and IISc, Bangalore. Later, a number of research laboratories and teaching institutions also entered into this area. A Study Group on Lasers, constituted in 1971 by .DRDO, and INSA Laser Committee constituted under the Chairmanship of Prof. P Venkateswarlu in 1976 (the author was a member of the two committees) made detailed studies to assess the status of R&D work on laser at both international and national levels and gave suitable recommendations for development of lasers and laser systems in the country. In 1988, Dr DD Bhawalkar, Director, Centre for Advanced Technology (CAT), Indore, gave a status report on lasers to the Science Advisory Council to the Prime Minister. Very briefly the current status of the laser work in the country is outlined below:

Ruby, Nd:YAG and Nd:Glass Lasers

Laser rods of ruby, Nd:glass, flash lamps and hard coated laser mirrors, have been developed indigenously at the Defence Science Centre (DSC), Delhi, and the solid sate lasers giving peak power output of a few megawatts have been developed for Defence applications. BARC has also developed these lasers with mainly imported components, Laser range finders with Nd:YAG or Nd:glass as the active element have been developed at Instruments Research Development Establishment(IRDE), Dehradun and DSC. CAT, is developing a high power Nd:glass laser for atomic energy application,

Helium-Neon Laser

Helium-Neon lasers of low power output (2- 5 mW) with lifetimes of a few thousand hours have been developed at IISc, NPL, and Bharat Electronics Ltd., Bangalore. The technology has been transferred by NPL to M/s Laser Instruments, New Delhi and by BARC, Bombay to ECIL, Hyderabad. they started production of these lasers commercially about 20 years back but stopped production since their performance is far from satisfactory. BEL also made an attempt about 10 years back and stopped production due to lack of sufficient technology

Carbon Dioxide Laser

Carbon dioxide lasers giving an output power in the range 10-100 W have been developed at BARC IIT, Kanpur, IRDE and DSC, Central Electronics Ltd. (CEL) and Jyoti Ltd. have started commercial production of these lasers around 1975 but have stopped production by 1982. CAT has developed transverse carbon dioxide laser with 3.5 kW power.

7Semiconductor Laser

BARC and Solid State Physics Laboratory (SPL), Delhi have developed low power gallium-arsenide lasers with a view to use them for applications in communication and ranging. BARC demonstrated communication over 20 Km distance using laser. Further work is necessary to develop these lasers with heterostructures and to improve their efficiency.

Materials

Basic laser materials like ruby, Nd:phosphate glass and lithium niobate are being developed at DSC for Defence applications, Central Glass and Ceramics Research Institute, Calcutta(CGCRI), has also developed good quality Nd:silicate glass for commercial applications. The development of gallium-arsenide and Nd:YAG crystals is under process at SPL. Several establishments and institutes like DSC, IRDE, IISc, NPL, BARC, IIT, Kanpur and BEL have established optical workshops including coating facilities to fabricate laser components. Good experience has been gained to fabricate laser rods and hard coated laser morrors at DSC

Fibre-Optic Communication

In 1980, a panel on Optical Fibre Communication System constituted by the Electronics Commission recommended the introduction of optical fibre communication in India. With this in view, CGCRI took up an R&D project on indigenous development of optical communication fibre. In1982, a System Appraisal Group for Optical Fibre and Cables comprising representatives of the Department of Electronics, Ministry of Defence, IIT, De/hi, Telecommunication Research Centre (TRC) and Hindustan Cables Ltd. recommended setting up of R&D and manufacturing facilities of optical fibres and cables at HCL through collaborative arrangement. It was decided to manufacture at HCL the multimode graded index fibre with' 3 to 5 db/km loss and bandwidth up to 100 MHz. Similarly, the production of optical fibre has been started at OPTEL, Bhopal with foreign collaboration. In 1983, a Committee on Optical Fibres and Cables (COFC) was constituted by the Ministry of Communication to finalise the technical specifications for optical fibres and cables required not only for communications, but also for Defence and other sectors.

The Department of Communications has Successfully installed the optical fibre cable and an 8 Mb system to provide junctions between two exchanges in the Pune Telephone system. TRC has taken up a design of an indigenous 34 Mb .system to be installed between Thana and Powai in the Bombay Telephone system. Efforts are on1e way to introduce optical fibre communication several trunk routes in the country. Facilities for 93 characterisation of optical fibres have been set up at HCL and IIT, Delhi.

Conclusion

There are large gaps in the development of laser technology and its production between our country and other developed countries. Efforts in this area have been so limited in our country that they are not even equal to the efforts made at one major institution in the USA. Not a single reliable laser system is commercially available in the country. Though some institutions in our country have fabricated some experimental lasers on a laboratory scale, reliable operation of these lasers has still been a problem. As an outcome of status report of SAC to PM, a National laser Programme has been started recently. Advantages of lasers for various applications in our country are well known and laser research has been recognised as one of the frontier areas to be developed in the 8th Five Year Plan. It is high time for our country to intensify the R&D efforts in the identified areas with time bound pro- Grammies and start the production of lasers for mass applications.

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