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Lasers in Defence

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Abstract: The development and usage of laser technology in fields such as defence, law enforcement, communication, and defence have had a major impact on the law enforcement sector. The idea of Light Amplification by Stimulated Emission of Radiation (LASER) was conceived in 1957, but it wasn't until 1960 that Theodore H. Maiman built the first practical application of the technology. In addition to its high coherence and intensity, laser illumination is also distinguished by its spatial coherence, enabling light pulses on the femtosecond timescale. It finds use in various disciplines, including holography, the space sciences, spectroscopy, medicine, microelectronics, power electronics, industrial engineering, and even directed energy weaponry. Laser target markers and beam riders are the most common methods for accurately controlling LGW towards ground objects. Recent advances in laser technology are intensively investigated for their potential use in target indicators and range finders. There has been an increase in the usage of lasers in recent years, with several new services in fields as diverse as commerce, industry, medicine, science, technology, and even the military. Applications like range finders, target designators, power beamers, LIDARs, and long-range, high-speed, secure communication systems have the potential to completely alter the face of combat. India's laser R&D centres are working on various laser systems and their supporting components and materials for use in directed energy applications. Laser crosslinks are a technology that can maintain data speeds in the tens of gigabits, and they give higher bit rates with decreased bit error rates owing to their small wavelengths.
Keywords: LASER, LIDARs, Defence, Quantum Cascade Lasers, holography

I. INTRODUCTION

In 1960, Theodore H. Maiman at Hughes Laboratories constructed the first practical implementation of the Light Amplification by Stimulated Emission of Radiations (LASER) theory, developed in 1957. It's distinct from other kinds of illumination because of its great coherence and intensity. In addition to collimation, which travels in a straight line, it has spatial coherence, which enables it to be focused on a small area. Time coherence allows for the generation of femtosecond-scale light pulses. Barcode scanners, laser printers, fibre optics, free-space optical communications, laser surgery, laser metal cutting and welding, and laser light shows are examples of how lasers are employed in modern business.

Defence and law enforcement devices used by the military for a variety of reasons have benefited from this developing technology over the last several decades (Vishwakarma, 2017). Recent decades have seen remarkable advancements in laser technology, which is now used in many different fields, including holography, space sciences, spectroscopy, medicine, microelectronics, power electronics, industrial engineering, and most notably, directed energy weapons. The most popular tools for guiding Laser Guided Weapons (LGW) precisely to ground targets are laser target markers and beam riders. Drones and other unmanned aerial applications benefit from the laser-based systems' small size and high angular resolution. Furthermore, the low risk of intercept provided by laser emissions' narrow-beam divergence makes them a competitive option for secure communications and safety-critical procedures. Recent developments in laser technology for target indicators and range-finders are extensively analysed, and this article surveys laser uses and initiatives for strategic defence activities on the ground or in space.

The essay focuses mostly on the defence and military uses of laser technology. After 60 years of development, lasers are widely used in military and defence applications. It is used in various defence-related technologies, including MIRACL, ABL, THEL, LGW, LiDAR, and other similar systems. Its wide-ranging use of laser technology, including LiDAR, ABL, TheL, etc., has significantly influenced the Law Enforcement industry. The development of the PHaSR Rifle will make it possible to stave off many potential future catastrophes.

New scientific and technological frontiers have been opened up by lasers, which have made many formerly difficult operations simpler and more efficient. When used for defence, lasers shorten the time and effort required to complete any mission while reducing casualties. Researchers continually work on perfecting the prototype designs of cheaper and more effective weapons and defence systems. Several universities in India are researching laser technology and its potential uses. (Vishwakarma, 2017)

Lasers have been influencing every conceivable application area in the last few decades, with an explosion in commercial, industrial, medical, scientific, technological and military usage.

The expansion of the non-military application spectrum of lasers is driven by the emergence of a large number of laser wavelengths followed by ever-increasing power levels and reduced price tags. The military applications of lasers and related electro-optic devices have grown mainly due to the technological maturity of the lasers that were born in the late 60's, and early 70's. The 21st century will witness a large proliferation of laser systems in the armed forces around the globe, with expansion in the already established defence applications of lasers and the development and subsequent use of low-energy laser weapons.

II. TYPES OF LASERS

- Gas
- Liquid
- Semiconductor
- Solid-State
- Fiber
- Quantum Cascade Lasers (QCLs)

A. Gas Lasers

By placing a voltage across a glass or ceramic tube filled with a low-pressure gas or gas mixture, gas lasers can accomplish population inversion. An electric field is generated within the tube, inducing an electric current that collides with gas atoms, causing a population inversion. Excimer lasers operate in the ultraviolet (UV) range, whereas argon ion lasers and HeNe lasers operate in the visible (VIS) range, and carbon dioxide (CO_2) lasers work in the mid-infrared (MIR) region. Although gas lasers were formerly widely used, DPSS lasers and laser diodes have now mostly replaced them, with the exception of a few niche applications. Laser processing and medical eye surgery are two areas where CO_2 and excimer lasers continue to play important roles. (Laflamme, 1970)

B. Liquid Lasers

Since organic dye molecules have relatively long lives, they may be used as radiating species for lasing. Dye molecules are diluted to a concentration of one part per ten thousand in a solvent to create the desired concentration of radiating species. A liquid dye laser is an optically pumped device that flashlamps or other lasers may power. Each molecule of dye has a gain spectrum that is 30-50 nm in width and is uniformly widened. The laser's wavelength may be adjusted over the visible- and near-infrared (NIR) spectrum because of the use of many different dye molecules. However, due to the dye's breakdown when dissolved in its solvent, dye lasers need extensive upkeep. Dye lasers are being phased out in favour of DPSS lasers with nonlinear frequency conversion for various uses.

C. Semiconductor Lasers

Semiconductor lasers are commonly referred to as laser diodes because their operation is similar to that of diodes, with current flowing across the junction. Recombination radiation may occur when charge carriers are injected into the space delineated by the intersection. The high refractive index difference between the semiconductor and air makes the crystal surface reflective enough to function as a resonator cavity. High power and efficiency, small size, and compatibility with electronic components are just some of the benefits that laser diodes have gained over other types of lasers due to their electrical pumping and compact laser design, as well as the maturity of the semiconductor manufacturing process. Applications such as optical data storage, optical fibre transmission, and pumping sources for solid-state lasers make them one of the most significant kinds of lasers in use today. (Najda et al., 2014)

D. Solid-State Lasers

The active ion species in a solid-state laser are imperfections in an otherwise clear host material, making the laser invisible to the eye. To function as a laser, a material must have large yet spectrally narrow transition cross sections, large absorption bands for pumping, and a metastable state with a long lifetime. To preserve their desirable properties, ions with optical transitions between states of inner, incomplete electron shells must be isolated or sheltered from other ions. Optical pumping can achieve population inversion in solid-state lasers, which may be gained through a flashlamp or direct pumping from another laser source.

The advanced manufacturing, defence, and security (D&S) industries have benefited greatly from low-cost semiconductor laser diode pump sources. Thales UK is a sensor system company with products for use on land, sea, air, and in the hands of individuals. Low-cost pump diodes are allowing new approaches in D&S sensors, and this session will provide an overview of the industry trends and issues in the area. One is the development of cutting-edge Laser Target Designators (LTD) for safe munitions guidance. The LTD's tiny footprint (125x70x55mm) belies its powerful output (more than 50mJ per pulse at up to 20Hz).

The second is a solid-state laser range finder (LRF) that is smaller, lighter and uses less energy than comparable items on the market. It is also safe for use around the eyes. Range-finders, target designators, and active-lit imagers are just some of the next-gen laser sensors made possible by these ground-breaking devices. (Silver et al., 2015)

E. *Fiber Lasers*

A fibre laser is a laser that is created when an optical fibre with a solid-state gain medium and a resonator is built. Due to its distinct light-guiding qualities, this category of lasers is often handled independently from the "bulk" solid-state lasers. The active ions for the laser are generally doped into the glass core of the optical fibre. Optical pumping from laser diodes or other fibre lasers is used in almost all fibre lasers. A resonator may be included in a fibre laser geometry in several ways, having by reflecting light from an external source, creating a fibre loop mirror, or using fibre Bragg gratings (FBGs).

Fibre lasers can operate throughout a large portion of the NIR and MIR spectral area, produce high-quality output beams, and reach high output powers in both pulsed and continuous-wave (CW) modes. The market for high-power CW materials processing is likewise dominated by fibre lasers. (Hemming et al., 2013)

F. *Quantum Cascade Lasers (QCLs)*

In recent years, QCLs have supplanted conventional solid-state lasers as the go-to light source for various defence and security applications, including countermeasures, remote sensing, in-situ sensing, and through-barrier sensing. QCLs have a higher quantum efficiency than diode-pumped solid-state lasers with optical parametric oscillators (OPOs), providing direct mid-IR laser output for electrical input. Their usable frequency range is quite large, starting in the terahertz and going to the near-infrared. Countermeasures, Remote Sensing, Through-the-Wall Sensing, and Explosive Detection are just a few examples of how QCLs are used in defence and security. Because of their low cost, versatility, and ability to solve a broad variety of challenges across several spectral regimes, QCLs have sparked a revolution in the laser industry.

Device technology has been developed and used for remote sensing, countermeasures, and security issues thanks to years of support from national and international sources and university-level research. To better defend aeroplanes against heat-seeking missiles, a new generation of laser-based DIRCM systems has been developed, made possible by QCLs. QCL systems should be able to compete with proven mid-IR technologies thanks to the economics of the semiconductor industry, which reduce costs as volume increases. In addition, QCLs have the unique ability to create lines not often produced by conventional lasers.

High-energy laser weapons (DEWs) might pave the way for a brand-new mission that combines Theatre Missile Defence and National Missile Defence in today's battlefields. Within the next quarter-century, advancements in this field will allow these weapons to render obsolete more conventional ones, such as ballistic missiles and aeroplanes. There will be no effective or dependable carriers for nuclear bombs if intercontinental ballistic missiles can be shot down during their boost phase or if planes can be targeted soon after takeoff. If these nuclear weapons and other nuclear deterrents were eliminated by 2025, the world would be much safer and more peaceful.

Laser	Type	Wavelength	CW or Pulsed	Output Power	Applications
CO2	Gas	10600 nm	CW, µs	kW	Material processing, surgery, dental laser, military lasers
Nd:YAG	Solid-state	1060 nm	CW-ps	W-kW	Material processing, rangefinding, surgery, tattoo/hair removal, pumping other solid-state lasers
ArF, Krf, XeCl, Xef	Gas (excimer)	193 nm, 248 nm, 308 nm, 353 nm	ns	10 W	UV lithography, laser surgery, LASIK, laser annealing
Dye	Liquid	400-1000 nm	CW-fs	1 W	Spectroscopy, laser medicine

AlGaInP, AlGaAs	Semiconductor	630-900 nm	CW, ms	10 mW, 10 W	Optical disc (CD, DVD) reading/recording, laser pointers, solid-state laser pumping, machining
Yb-glass	Fiber	1030 nm	CW-fs	W-kW	Materials processing, ultrashort pulse research, LIDAR
Cr: ZnSe	Solid-state	2200-2800 nm	CW, fs	10 W	MWIR laser radar, missile countermeasures, ultrafast and high-resolution spectroscopy, frequency metrology

Table.1: Characteristics and properties of common lasers, with wavelength. Only normal values are represented by output powers.

1) Carbon Dioxide Laser

Properties of Carbon Dioxide Laser is mostly around 10.6 µm with other lines at 9-11 µm.
Range. The CO2 laser operates at a mid-infrared wavelength ranging from 9,300 to 10,600 nm.
Construction of 5m-long, 2cm-diameter tube. DC excitation causes discharge. Aluminum-coated confocal silicon mirrors create the resonant cavity. Pressured He is 7 Torr, P(N2)~1.2 Torr, and P(CO2)~0.33 Torr. Laser oscillator at 10.6 µm due to E(0,0,1) – E (1,0,0) transition gain.Working of CO2 laser is a gas discharge tube is filled with a combination of Co2 and N2 at a ratio of around 0.8:1 to produce a CO2 laser.
Applications used in defence It is absorbed by glasses and hence is used as a deterrence mesasure. is used for soft tissue surgery.It is used in fabricating.Resurfacing using CO2 lasers. Carbon dioxide lasers accurately remove small skin layers without heating nearby structures. Laser light vaporises the skin.
Nature of Output (Pulse or Continuous) of CO2 Laser The nature of output may be continuous wave or pulsed wave. The output from this laser is about 10kW.Advantage of CO2 lasers are straightforward to put together. This laser has a constant output. It is quite effective. It can send forth a lot of energy. Disadvantages of CO2 laser Carbon monoxide's contamination of oxygen will hinder the laser's performance to some degree. The laser's output power is significantly affected by its operating temperature. The reflecting plates might be the source of the deterioration.

2) Deuterium Fluoride Laser

Deuterium Fluoride Laser is a Chemical, ~3800 nm The deuterium fluoride laser at the wavelength of about 3.8 µm.Rocket engines resemble deuterium fluoride lasers. Nitrogen trifluoride burns ethylene. This reaction releases excited fluorine radicals.After the nozzle, the exhaust stream receives helium and hydrogen or deuterium gas, which interacts with fluorine radicals to produce excited molecules of deuterium fluoride or hydrogen fluoride.The MIRACL, Pulsed Energy Projectile, and Tactical High Energy Laser use deuterium fluoride lasers. Continuous output power in the Megawatt range 3.8 µm Gas balloons provide a practical way to store the energy source. Extremely potent output.The reactivity of fluorine gas is high.Hydrogen gas has a low ignition threshold.

3) Nd: YAG Laser

Nd3+:YAG, except for the 946-nm transition, is a four-level gain medium that provides significant laser gain even at modest excitation levels and pump intensities. Wavelength of 1064 nm. The active medium, energy source, and optical resonator are the three main components of a Nd:YAG laser.Nd: YAG lasers use four energy levels. Flashtubes and laser diodes power the active medium.
To produce population inversion in Nd:YAG lasers, lower energy electrons in neodymium ions are stimulated to higher energy states. It is possible to utilise a laser rangefinder or laser designator with a Nd:YAG laser. A laser designator is a laser light source used to zero in on and attack specific targets. The distance to an item may be measured with the use of a laser rangefinder. The output is either a continuous or pulsing beam of light. The output power is around 70 watts. Low energy needs

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The gain of a Nd:YAG laser is very high. The thermal characteristics of Nd:YAG lasers are excellent. The mechanical qualities of a Nd:YAG laser are excellent.
In YAG, Nd^{3+} has a complex electron energy level structure.

4) Krypton Fluoride Laser

Gas, High Voltage Electric Discharge, 248nm. wavelength of 248nm. Electrical discharge, photoionization, a hot wire, or even proton bombardment are just some of the ways that may be used to synthesise krypton difluoride. The lasing medium is krypton and fluorine. The laser works because krypton absorbs energy from the power source and interacts with fluorine gas to form a transient compound, krypton fluoride. Irradiating plasma with short pulses of this laser light produces soft X-rays. Manipulating plastic, glass, crystal, composite materials, and living tissue are also significant. pulsed power Krypton-fluoride lasers have a wavelength of 248 nm.These lasers are now only commercially accessible in large quantities in the visible and near-infrared spectrum. CNTs may be shortened due to oxidation processes, which is a drawback.

5) FEL

Currently, wavelengths range from microwaves through terahertz radiation and infrared to the visible spectrum and ultraviolet. Length is over 100 m. Free-electron lasers are distinguished from conventional lasers by their electron accelerator, magnetic undulator, and optical resonator components. The tube flashes electricity into the ruby crystal. Photons from its flashes power the crystal. The electrons of ruby crystal atoms absorb this energy and rise in energy. The FEL INP programme will increase the power of a 14-kilowatt free-electron laser to 100-kilowatts, making it suitable for use in weapons.A pulse duration of less than 100 fs, and a dazzlingly bright light. A wavelength of less than 0.05 nm. Free-electron lasers are tunable and have a broad frequency range, from microwaves to terahertz radiation to infrared to the visible spectrum, ultraviolet, and X-ray. The free electron laser's size and cost are drawbacks.

6) Excimer Laser

Excimer lasers are pulsed gas lasers that produce ultraviolet light at pulse repetition rates up to a few kilohertz and pulse energy of a few millijoules to hundreds of millijoules. The vacuum ultraviolet (VUV) has a wavelength of just 157 nm, whereas the near UV has a range of 351 nm.Excimer lasers are currently built using stainless steel, polyvinyl, and teflon components due to the corrosive nature of the gases employed. Two electrodes are linked to the discharge voltage source to produce a tube. Between these two electrodes is where the active medium resides. Photolithography, which is used extensively in the production of semiconductors Laser-pulsed depositionGlass and plastics may be laser-marked.Treatment of the eyes and skin using lasersLasers that pump other lasers Excimer lasers produce 10 mJ–1 J pulses. Some pulse repetition rates are 10 Hz, while others are 1 kHz or more. Power output is typically between 1 W and several hundred Watts on average. It is a rapid and risk-free procedure. There is absolutely nothing to be scared about. Astigmatism, myopia, and hyperopia are all corrected. The surgery will eliminate the need for corrective lenses, such as glasses or contacts. This is where an excimer laser really shines.The use of an excimer laser in a procedure raises the cost significantly. Poor execution increases the risk of glare and impairs night vision.

Lasers	Properties	Application in defence	Nature of Output (Pulse or Continuous)	Output Range	Advantages	Disadvantages
Carbon Dioxide Laser	mostly around 10.6 µm with other lines at 9-11 µm	It is used as a deterrence measure as it only gets absorbed by glass and shatters it in aircrafts.	The nature of output may be continuous wave or pulsed wave.	The power output from this laser is about 10kW.	CO2 lasers are straightforward to put together. This laser has a constant output. It is quite effective. It can send forth a lot of energy.	Carbon monoxide's contamination of oxygen will hinder the laser's performance to some degree. The laser's output power is significantly affected by its operating temperature. The reflecting plates might be the source of the deterioration.

Deuterium Fluoride Laser	Chemical, ~3800 nm	The MIRACL, Pulsed Energy Projectile, and Tactical High Energy Laser use deuterium fluoride lasers.	Continuous output power in the Megawatt range	3.8 µm	Gas balloons provide a practical way to store the energy source. Extremely potent output.	The reactivity of fluorine gas is high. Hydrogen gas has a low ignition threshold.
Nd: YAG Laser	Nd3+:YAG, except for the 946-nm transition, is a four-level gain medium that provides significant laser gain even at modest excitation levels and pump intensities.	It is possible to utilise a laser rangefinder or laser designator with a Nd:YAG laser. A laser designator is a laser light source used to zero in on and attack specific targets. The distance to an item may be measured with the use of a laser rangefinder.	The output is either a continuous or pulsing beam of light.	The output power is around 70 watts.	Low energy needs The gain of a Nd:YAG laser is very high. The thermal characteristics of Nd:YAG lasers are excellent. The mechanical qualities of a Nd:YAG laser are excellent.	In YAG, Nd3+ has a complex electron energy level structure.
Krypton Fluoride Laser	Gas, High Voltage Electric Discharge, 248nm.	Irradiating plasma with short pulses of this laser light produces soft X-rays. Manipulating plastic, glass, crystal, composite materials, and living tissue are also significant.	pulsed power	Krypton-fluoride lasers have a wavelength of 248 nm.	These lasers are now only commercially accessible in large quantities in the visible and near-infrared spectrum.	CNTs may be shortened due to oxidation processes, which is a drawback.
FEL	Currently, wavelengths range from microwaves through terahertz radiation and infrared to the visible spectrum and ultraviolet.	The FEL INP programme will increase the power of a 14-kilowatt free-electron laser to 100-kilowatts, making it suitable for use in weapons.	A pulse duration of less than 100 fs, and a dazzlingly bright light.	A wavelength of less than 0.05 nm.	Free-electron lasers are tunable and have a broad frequency range, from microwaves to terahertz radiation to infrared to the visible spectrum, ultraviolet, and X-ray.	The free electron laser's size and cost are drawbacks.
Excimer Laser	Excimer lasers are pulsed gas lasers that produce ultraviolet light at pulse repetition rates up to a few kilohertz and pulse energy of a few millijoules to hundreds of millijoules.	Photolithography, which is used extensively in the production of semiconductors Laser-pulsed deposition Glass and plastics may be laser-marked. Treatment of the eyes and skin using lasers Lasers that pump other lasers	Excimer lasers produce 10 mJ–1 J pulses. Some pulse repetition rates are 10 Hz, while others are 1 kHz or more.	Power output is typically between 1 W and several hundred Watts on average.	It is a rapid and risk-free procedure. There is absolutely nothing to be scared about. Astigmatism, myopia, and hyperopia are all corrected. The surgery will eliminate the need for corrective lenses, such as glasses or contacts. This is where an excimer laser really shines.	The use of an excimer laser in a procedure raises the cost significantly. Poor execution increases the risk of glare and impairs night vision.

III. PROPERTIES AND CHARACTERISTICS OF A LASER BEAM

Because of its distinct monochromaticity, directionality, coherence, and intensity, laser light has found several applications. The radiation's monochromaticity, or single frequency or wavelength, makes it useful for spectroscopic studies, light scattering, and medical diagnostics. With a divergence specification of only milliradians, directionality is very precise. All photons in a coherent light source have the same phase, and this phase connection is maintained as a function of time, making coherence the most distinctive feature of laser light compared to regular light from conventional sources. Laser range finders and laser target designators owe their effectiveness to the narrow beams of light they emit. Last but not least, intensity's low divergence makes it a flexible resource in material processing technology. (Maini & Jindal, 2003)

The laser's components allow for fine-tuning the beam's qualities, allowing for a wide range of applications. The laser beam's characteristics are affected by several factors, including the gain medium's size, the position, spacing, and reflectivity of the optical cavity's mirrors, and the existence of losses along the beam path. Since Maiman's 1960 demonstration of laser activity in a ruby crystal, several more materials have been discovered that provide laser action at visible, ultraviolet, and infrared wavelengths. Rare earth ion-doped crystals have also been found to produce a powerful laser. Solid-state lasers that are pumped optically, liquid lasers (Dye lasers), semiconductor gas lasers, free electron lasers, X-ray lasers, and chemical lasers are the most common types.

A. India's Laser Development Status

The article's primary focus is on India's laser research and development facilities. One such facility is the Centre for Advanced Technology (CAT), while others include the Laser Science and Technology Centre (LASTEC) and the Instrument Research and Development Establishment (IRDE). While IRDE has created a wide range of optical, electro-optical, and laser-based instruments for use on the battlefield, LASTEC is working on various lasers, laser-related components, and laser-based tools. Focusing on laser systems for directed energy applications, including electro-optic countermeasures (EOCM) and high-power lasers, LASTEC is actively developing a wide range of laser systems and associated components and materials.

Several Indian institutions, including the Defence Research and Development Organization's Bhabha Atomic Research Centre, the National Physical Laboratory, the Indian Institute of Technology in Kanpur, and the Indian Institute of Science in Bangalore, began conducting ground-breaking laser research and development 31 years ago. In 1971, the DRDO and the INSA Laser Committee formed a Study Group on Lasers to evaluate the current state of laser research and development worldwide and in the United States. Dr DD Bhawalkar, Director of the Centre for Advanced Technology (CAT) in Indore, updated the Prime Minister's Science Advisory Council on the progress of laser research in 1988. With help from the city's Instrument Research and Development Establishment (IRDE), India has created its first Laser Guided Bomb (LGB), a weapon with increased precision. Part of IRDE's ongoing research towards reaching self-dependency in the defence field is the development of technologies for generating LGB. (Bahadur, 2018)

B. Advantages—Throughput, Power, Information Protection

There is a minimal possibility of detection, interception, and exploitation with laser crosslinks, although they provide data speeds that are ten to one hundred times greater than those of conventional radio frequency. Programmers prefer laser crosslink systems because of their cheap cost per bit and ease of installation. The fundamental benefit of employing laser crosslinks is the orders-of-magnitude improvement in throughput; laser crosslinks provide faster bit rates with reduced bit error rates due to their narrow wavelengths. Compared to a microwave connection in geosynchronous orbit, a laser crosslink can sustain data speeds in the tens of gigabits per second. Supporting in the Tbps range, or the equivalent of streaming 200,000 HD-grade movies concurrently, is possible using laser crosslinks.

Laser crosslinks make full duplex operations possible, which also have the added benefits of reduced power consumption and increased efficiency. They can transmit 10 times as much information as conventional radio waves while consuming just one-tenth as much energy. In addition, because less signal power is needed, collecting antennas may be made smaller. Laser crosslinks guarantee that the message reaches its intended recipient and that the recipient may have faith that the message has not been tampered with in transit.

The incredibly low beam divergence reduces signal loss and boosts security by making jamming difficult, making it an ideal solution for protecting sensitive information during military operations. In addition to preventing electromagnetic interference, carefully chosen optical communications may be sent securely utilising quantum key distribution.

C. Disadvantages—Acquisition, Tracking, and Pointing; and the Atmosphere

Acquisition, tracking, and pointing between a stationary ground station and a slow-moving' geosynchronous orbiting satellite are challenging in the best circumstances. Attempting to hit a target with a smaller bullet while blindfolded and riding a horse requires highly accurate ephemeris data, the point-ahead angle, pointing within an error budget, and the decision not to use a guidance beacon (pointing aid). Since most satellites use solar panels to produce electrical power, laser crosslinks employing optical links provide relief from acquisition, tracking, and meaning. Beam bending, scattering, and, if the atmospheric nonuniformity is great enough, beam break-up owing to loss of coherence is all side consequences of transmitting optical communications across the environment. US Department of Defence laser crosslinks face several challenges before becoming a reality, but a group of dogged engineers and a persistent defence funding programmer will see this project through.(Dmytryszyn et al., 2020)

IV. VARIOUS APPLICATIONS IN DEFENCE

Due to its great intensity and minimal divergence, the laser range finder is a regular component of artillery and tanks. Based on radar theory, it uses the laser beam's unique qualities—its monochromaticity, high intensity, coherence, and directionality—to achieve its goals. An optical system detects the reflected light from the target after a collimated pulse of the laser beam has been directed at it. Measured in terms of the time it takes the laser beam to travel to and from the transmitter and the target, the range is then calculated by multiplying this value by the speed of light. The size of the emitting system may be drastically decreased while providing the benefits of increased radiant brightness and the fact that this brightness remains highly directed even after traversing long distances.

The four main components of a laser range finder are the transmitter, the receiver, the readout and display, and the sighting telescope. The transmitter fires out a single, collimated, and brief pulse of laser light from a Q-switched Nd: YAG laser to hit its target. A photo-detector receives little light from the transmitter pulse, which is then amplified and sent to the counter through a scattering wire grid. After passing it via an interference filter, the telescope takes the reflected pulse and focuses it onto a second photo-detector. A digital system takes the time difference and outputs the distance on the screen.

Most cutting-edge laser range-finders use either a carbon dioxide laser with a range gating device or a high-repetition pulsed Nd: YAG laser. An accuracy of 5 m may be readily reached when employing these devices to range a target at a distance of 10 km. Medium-range (up to 10 km) laser range finders find applications throughout the Defence sector, from tank-mounted artillery fire control systems to portable laser range finders used in the field. The Air Force even uses airborne laser range finders that are pod-mounted and servo-positioned. (Bahadur, 2018)

A. MIRACLE

The United States Navy developed the Mid-Infrared Advanced Chemical Laser (MIRACL) in 1980 as a kind of Directed Energy weaponry. Over a megawatt output is produced for up to 70 seconds using Deuterium Fluoride as the chemical media. Developed to locate and destroy anti-ship cruise missiles, MIRACL underwent testing in California at a contractor site and afterwards in New Mexico at the white sands missile range. The echoed beam was 21cm in height and 3cm in width, and it was put to the test at a distance of 432km from MSIT-3, a decommissioned US Air Force satellite. Unfortunately, MIRACL failed the test and was destroyed in the process. During the trial, a second, weaker laser was able to briefly blind the MSIT-3 detectors. (Vishwakarma, 2017)

Figure 2: *MIRACL*

B. PHaSR Rifle

The PHaSR is cutting-edge technology designed specifically for use by the police. The US Department of Defense's Directed Energy Directorate at the Air Force Research Laboratory created this prototype nonlethal laser dazzler. The PHaSR is designed to briefly confuse and disengage an adversary. There were trials of blinding laser weapons before the UN Protocol on Blinding Laser Weapons was passed in 1995 and outlawed them. The PHaSR was field-tested in New Mexico's Kirtland Air Force Base, home of the Air Force Research Laboratory's Directed Energy Directorate, and it is a two-wavelength laser. (Vishwakarma, 2017)

C. Tactical High Energy Laser THEL

The physics behind directed energy laser weaponry was borrowed from science fiction and is now being used in actual conflicts. High Energy Lasers (HEL), High Power Microwave (HPM) weaponry, Particle Beam Weapons, and Laser Induced Plasma Channels (LIPC) are all examples of Directed Energy Technologies' arsenal of weaponry. With its strong electric field and laser-induced ionisation channel, LIPC is a hybrid that ionises molecules en route to a target. High-intensity light of a certain colour and wavelength is emitted through lasers and Masers, which serve as amplifiers of electromagnetic radiation. Early High Energy systems used rapid heating and cooling of gases; later studies found that cooling may be produced by expanding hot gases.

Hydrogen fluoride (HF) and iodine-oxygen lasers were the next generations to be developed. The US Navy and the IDF have worked together since 1996 to form the Tactical High Energy Laser (THEL), a military-grade laser system. Thel was conceived as a point defence weapon capable of intercepting and destroying rockets, artillery projectiles, and tiny, far-off aircraft. The 3.8-micron chemical laser based on deuterium fluoride was used. To create an excited Deuterium Fluoride Lasing Medium, ethylene is burned in an environment of poisonous Nitrogen Trifluoride, and the resulting gas is then combined with deuterium and helium before being pumped through expansion nozzles.

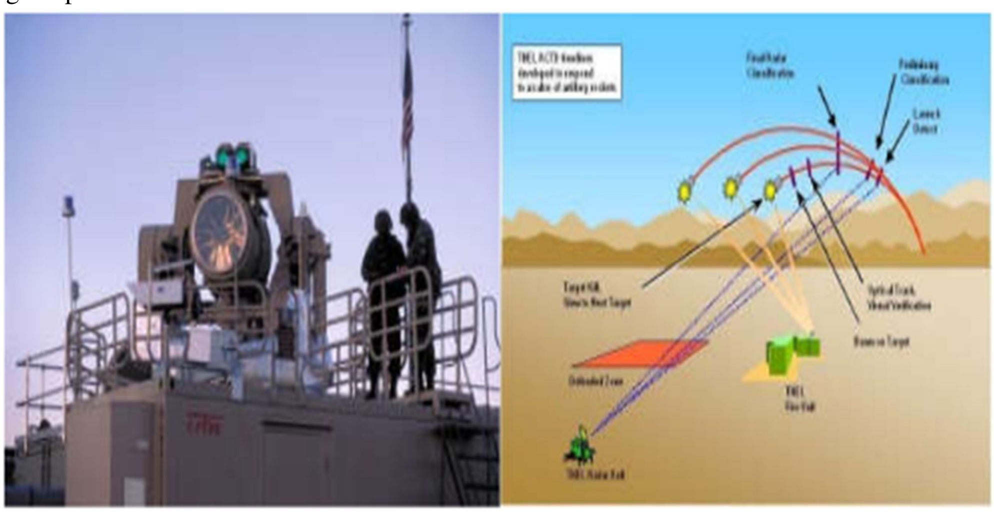

Figure 3: Tactical High-Energy Laser

A neutralisation step to soak up the extremely corrosive and hazardous deuterium fluoride exhaust efflux gas is part of the diffusion and pressure equalisation technologies needed to solve this issue. The US Navy's MIRACL (Mid Infrared Advanced Chemical Laser) successfully tested the first DF laser, opening the door to developing directed energy weapons. Phased array radar was used here, which pinpoints the exact locations of inbound targets. Unlike ABL, SAM, and AAA, the Thel has a limited range and is utilised for local defence instead. (Vishwakarma, 2017)

D. LOC

There is 3000 km between India and Pakistan, with 182 kilometres of the border left unsecured owing to terrain features like hills and swamps. BSF has decided to use the KVI-101S equipment to construct laser barriers over this unprotected km. This system is very sophisticated in detecting capabilities, is hackproof, and needs little human involvement. It can distinguish between humans and animals and employs cutting-edge infrared optics for early detection. India wants to put up laser barriers along its eastern border as well.

E. Laser Guided Bomb

The United States pioneered using a Laser Guided Bomb (LGB) during the Vietnam War. To hit a target with pinpoint precision, it employs semi-active laser pathways and a tracking electronic board that identifies where each laser is pointed. Half as often as unguided bombs made direct strikes, the LGB did not. These bombs are now widely deployed by a variety of air forces throughout the world and are considered a standard kind of guide bomb. The United States and the United Kingdom created these weapons originally in the early 1960s, and in October 2010, with the help of IRDE, a lab of the Defence Research and Development Organisation of India (DRDO), constructed India's first Sudarshan laser-guided bomb. This is part of our continuing investigation into how to become militarily independent.

F. Anti-Ballistic Missile

Anti-Ballistic Missiles were developed after World War II's German V1 and V2 rocket programmes introduced the concept of destroying rockets before they can reach their objectives. The Indian government has begun work on a programme to defend against ballistic missile strikes by creating and deploying a sophisticated missile defence system. High-altitude intercepts are handled by the Prithvi Air Defence (PAD), while low-altitude intercepts are handled by the Advanced Air Defence (AAD). In November 2006, we ran our first test of PAD, and in 2007, we ran our first test of AAD. With the success of PAD, India joined the ranks of the United States, Russia, and Israel as the fourth nation to develop an anti-ballistic missile defence system. Despite passing a testing battery, it has not yet been formally commissioned.

G. LiDAR

Light detection and ranging (LiDAR) systems employ pulsed lasers to estimate distances to targets and other objects on the ground. It is used in many different scientific disciplines, including Geology, Geodesy, Archaeology, Geometry, Atmospheric Physics, etc. It has a fascinating history, having found use only a short time after the invention of the laser in the early 1960s. Using suitable sensors and data-gathering devices, it combines laser technology with focused imagery to determine distances. The Airborne Multi Laser System and the Airborne Laser Mine Detection System are examples of LiDAR's use in the military. The enemy's land may be mapped with the help of LiDAR.

H. Space Defence

Asteroids headed in earth's direction will be destroyed as part of Project De-Star. This is crucial because the devastation wrought by asteroids on earth is fatal to all life forms. The extinction of the dinosaurs and the formation of the 118-mile-wide (190-kilometre-wide) Vredefort Dome are both examples of the devastation that asteroids may cause. If an asteroid only a few kilometres across crashes into earth, it would do more damage than the atomic bombs dropped on Hiroshima and Nagasaki combined.

De Star is an acronym for "Directed Energy System for Targeting of Asteroids" and is an exploration system designed to divert potentially hazardous asteroids, comets, and other near-Earth objects. DE-STAR is a solar-powered, modular, phased array of lasers with outputs in the kilowatt range. Large "stand-off" DE-STAR arrays stay in Earth orbit and deflect the target from afar, while small "stand-on" DE-STARLITE systems travel to & deflect from beside the mark. The modular layout promotes iterative development and testing, reducing costs, lessening risk, and opening the door to technical collaboration. Both methods involve directing a laser beam onto a specific place on an asteroid or comet, where the intense heat generated will vaporise the material instantaneously and cause it to be ejected in a new direction, thereby changing the orbital path of the object. Multiple targets should be able to be engaged at once by an ideal DE-STAR system.

I. Project DEEP-IN

NASA's DEEP-IN (focused Energy Propulsion for Interstellar Exploration) programme aims to propel tiny spacecraft to relativistic speeds using huge focused energy, allowing for the first human interstellar voyages. The NASA Innovative Advanced Concepts (NIAC) programme provided money for this initiative beginning in 2009 thanks to a proposal submitted in 2014 by UC Santa Barbara and the NASA Space Research Consortium. The first round of money was allotted in April 2015, and the second round was assigned in May 2016. NASA's DEEP-IN (Direct Energy Propulsion for Interstellar Exploration) programme aims to propel tiny spacecraft to relativistic speeds using huge focused energy, allowing for the first human interstellar voyages. The NASA Innovative Advanced Concepts (NIAC) programme provided money for this initiative in 2009 thanks to a proposal submitted in 2014 by UC Santa Barbara and the NASA Space Research Consortium.

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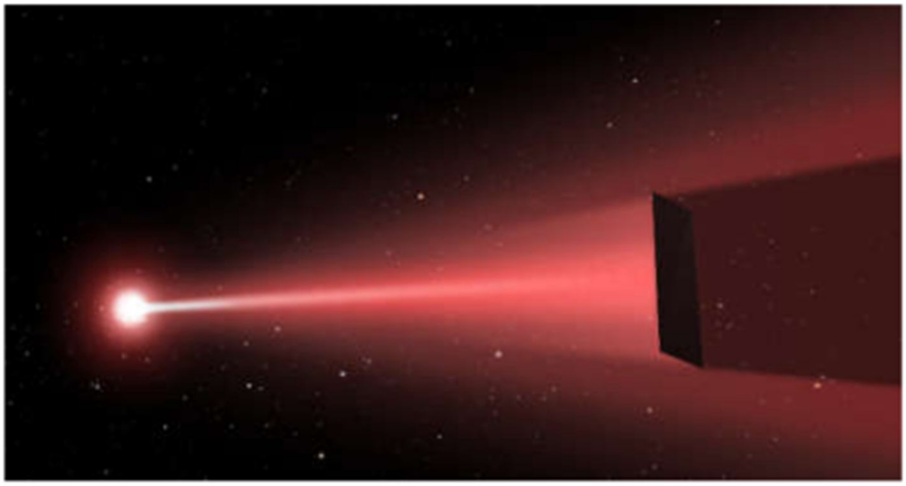


Figure 4: *Project DEEP-IN*

V. FUTURE SCOPES

High-energy laser weapon development and testing need sufficient power to inflict significant damage on distant targets, ideally measured in megawatts. Evaluating such systems' performance in a controlled laboratory or field setting presents significant safety difficulties. There is a growing need to design and implement secure, cost-effective, and all-encompassing testing facilities for high-energy laser experiments. Effective cooling techniques are also required for high-energy laser generating systems, which improves laser systems' precision in the face of purposeful (jamming) or naturally occurring unfavourable weather. To assure the highest level of functionality and dependability, researchers in this field investigate effective approaches to harden environmentally friendly electronics.

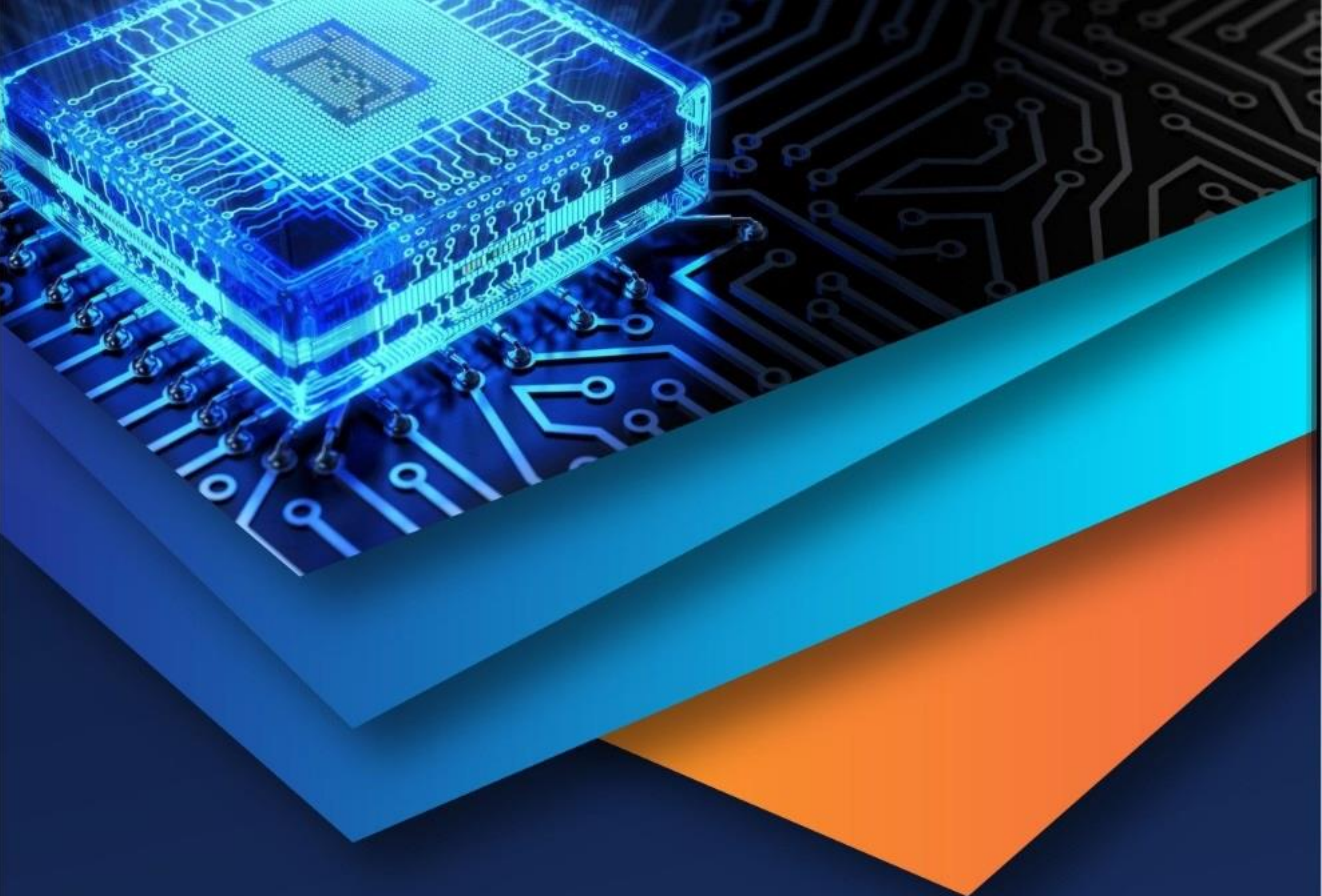
The main active initiatives with significant research and development in laser technology are briefly summarised in Table 2. Space laser deployments, such as laser-propelled interstellar detectors, space communications, and space wreckage cleanup, are becoming an important study area.

Title	Area	Purpose
Long-Range Research & Development Program Plan	Water, Space and Land Technology	This program aims to focus on developing water, space and land technologies to improve military capabilities between 2025 and 2030.
Japanese Experiment Module Extreme Universe Space Observatory	Space Wreckage Cleaning	The project is scheduled to begin by the end of 2018 but is delayed with plans to install lasers on the International Space Station to remove space wreckage.
Quantum Experiments at Space Scale	Communication	After successfully launching the quantum satellite in 2016, China plans to launch QUESS by 2020 and global QUESS by 2030.
Project-Dragonfly	Space travel	The project is initiated to investigate the feasibility of interplanetary travel by laser-propelled interstellar detectors.
Megawatt-class Laser Weapon	Ballistic Missile Defense System	This project aims to develop a lightweight and megawatt-class laser Ballistic Missile Defense System. All the components of this system will not weigh more than 4 tons. The project is estimated to be completed by 2026.

Table. 2: Future Laser-based Projects

VI. CONCLUSION

The advent of strong laser range finders, target designators, power beamers, LIDARs, and long-distance, high-speed, secure communication systems has the potential to completely alter the face of combat. It has offensive and defensive uses and may counterattack using its bandwidth and high angular resolution. For example, spectroscopic research, light scattering, and medical diagnostics may all benefit from laser light's unique combination of monochromaticity, directionality, coherence, and intensity. Several laser R&D centres in India are working on various laser systems and related components and materials for directed energy applications. These include the Centre for Advanced Technology (CAT), Laser Science and Technology Centre (LASTEC), and Instrument Research and Development Establishment (IRDE). As part of its efforts to become militarily independent, India has produced its first Laser Guided Bomb (LGB), a weapon with greater accuracy via the actions of the Indian Research and Development Establishment (IRDE). Because of their low per-bit cost and simple setup, software developers often favour laser crosslinks. Their Tbps range, low power requirements, and high efficiency make them ideal for transmitting large amounts of data quickly and accurately. The development of laser crosslinks for the United States Department of Military faces many obstacles, but the project will be completed with the help of dedicated engineers and a reliable military financing coder. First and foremost, a laser range finder uses a carbon dioxide laser or another kind of ranged laser.



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