

LASERS IN DEFENCE

Nitin Vishwakarma, Harshal Tanwade, Aditya More, Priyanshu Tiwari, Yash Shah, Krishnakant Mishra

Department Of Humanities & Sciences
Thakur College of Engineering & Technology
Kandivali (East), Mumbai-400101, India.

nitivishwakarma007@gmail.com

harshal.tanwade17@gmail.com

aaditya.s.more@outlook.com

priyanshutiwari450@gmail.com

planetsky1999@hotmail.com

kkmishra372@gmail.com

Abstract: *In today's world, there is rarely any scientific field which is not influenced by laser technology. In our paper, we will be particularly focusing on the applications of laser in defense & military. After 60 years of regressive research & experimentation on lasers, it has finally found its place in the field of defense & military. It is used in various defense applications like Mid-Infrared Advance Chemical Laser (MIRACL), Air Borne Laser (ABL), Tactical High Energy Laser (THEL), Laser Guided Weapons, LiDAR, etc. It has conclude to be very useful where safety & Security are top priorities. Although there are quite many limitations for using Laser Technology in the area of Military & Defense, still there is high scope of future development in this field. So, the scientists are developing new Defense System, which will increase the security of nations against foreign threat.*

Keywords: LASER, MIRACL (Mid-Infrared Advance Chemical Laser), PHaSR (Personal Halting & Stimulation Response) THEL (Tactical High Energy Laser), LiDAR (Light Detection & Ranging), LOC (Line of Control), De-STAR (Directed Energy System for Targeting of Asteroids & exploration system)

1. Introduction

Light Amplification by Stimulated Emission of Radiations which is also written in short as "LASER", was theoretically discovered in 1957, but the first laser was built in 1960 by Theodore H. Maiman at Hughes Laboratory, which was used the theoretical work of Charles Hard Townes & Arthur Leonard Schawlow. A Laser has properties like high coherency & high intensity which makes it different from other sources of light the property of laser like spatial coherence allows laser to be focused onto a very tight spot, which is useful in laser cutting & lithography where accuracy is a top priority. While it also allows collimation of a laser beam due to which it follows rectilinear path. This can be useful in laser pointers. As they emits light of single wavelength i.e. single color, they also have temporal coherence, which can be used to produce pulses of light of the order of femtoseconds. Due to these properties of laser, they are widely used in today's industry, with varieties of application like Barcode Scanner, Laser Printers, Fiber Optics & Free Space Optical Communications, Laser Surgery & Cutting & Welding of Metals, Laser Lighting Displays, which are used for entertainment purpose. But, in the past few decades, it has been emerging as a modern technology used in Defense & Law Enforcement Devices used by Military for various purposes.

2. MIRACL

MIRACL which stands for Mid-Infrared Advanced Chemical Laser. MIRACL is a type of Directed Energy weapon, which is collaborated by the US Navy



Figure 1: MIRACL

The MIRACL is a type of Chemical Laser which uses Deuterium Fluoride as a chemical medium to produce high intensity laser. The MIRACL Laser first commenced in 1980. It can generate over a megawatt of output for up to 70 seconds, which is the most powerful unceasing wave laser in US. The main mission of MIRACL was to be able to track & destroy anti-ship cruise missiles, but after some years it was first tested at a contractor facility in California, later during 1990-2000, it was located at a facility in the white sands missile range in New Mexico. The size of the beam in the reverberated is 21cm high & 3cm wide, which is the reshaped to a 14×14cm square. During the mid of October 1997, It was tested Against MSIT-3, which is US Air-Force Satellite at the end of its original mission in orbit at a distance of 432km But, MIRACL undergone failure during the test & was damaged. The Pentagon claimed mixed results for other portions of the test. Whereas, a second laser, which was a low powered one was successful in temporarily blinding the MSIT-3 sensors during the test.

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3. PHaSR Rifle

The PHaSR which stands for Personal Halting & Stimulation Response Rifle is a new type of technology developed for law Enforcement



Figure 2: PHaSR

PHaSR rifle is prototype nonlethal laser dazzler developed by the Air Force Research Laboratory's Directed Energy Directorate US Department of Defence. The main purpose of PHaSR Rifle is to temporarily perplex & dis-engage a target. Blinding laser weapons have been trailed in the past, but in 1995 was banned under UN Protocol on Blinding Laser Weapons, which United States Acceded to on 21st January 2009. The PHaSR is a two-wavelength laser. PHaSR was tested at Kirtland Air Force Base, part of Air Force Research Laboratory Directed Energy Directorate in New Mexico.

4. Tactical High Energy Laser THEL

Directed energy laser weapons has been derived from science fiction movies which is now being applied to the real war world, ever since H.G. Well, the famous fiction writer wrote "The war of world". This uses conception producing a deadly ray which can effectively destroy the enemy target causing blisters & holes in their body. Now, it has been a century, since Well's put forth the "deadly ray", & now in this highly agile & sophisticated era, laser technology is maturing to point of soon becoming deployable.



Figure 3: Tactical High Energy Laser

It was not just a development of a laser weapon, but its discovery was marked by several scientific breakthroughs & important engineering millstones. There is variety of weapons in the Directed Energy Technologies: High Energy Lasers (HEL) Weapons, High Power Microwave (HPM) Weapons, Particle beam weapons, Laser induced plasma channel (LIPC). The first two are common

Directed Energy weapons while Particle weapons use atomic or subatomic particles as projectiles accelerated to relativistic speeds. LIPC is a hybrid which induces laser to ionize a channel of molecules to the target which carries high electric field which can purge the electronic equipment & devices. There is deep connection between lasers & Masers (Mission of Radiation). Both Lasers & Maser act as amplifiers of electromagnetic radiation, if somehow we reflect these radiations through mirrors we can create an oscillator which can act as producer of Electromagnetic radiation.

In practical terms the energy used to excite the atoms & molecules is given out in the form of high intensity light of a particular color & wavelength. The process of exciting the device is called pumping. Early High Energy system made use of rapid heating & cooling of gases, further research showed that cooling can be obtained by expansion of heated gases. This concept was used to make the first Gas Device Laser (GDL) using mixture of CO_2 & NO_2 , which delivered 400KW for 4 millisecond. The ambiguity was cleared that now High Energy Laser are feasible. The next class of laser which was invented involved Hydrogen Fluorine (HF) Laser & Oxygen Iodine Laser.

Tactical High Energy Laser (THEL) is a Military based laser system also known Nautical Laser system. This Powerful laser Demonstrator was jointly constructed by US Navy & Israel, starting this program in 1996. The design of THEL system aimed to provide point defense weapon by engaging & destroying the rockets, artillery shells & small distant aircraft. The THEL demonstrator was trailed successively between 2000 & 2004 hampering Katyusha rockets, multiple artillery shells & motor rounds including salvo attack by motor. It makes use of Deuterium Fluoride chemical laser working at wavelength of 3.8microns. Ethylene is burnt in the atmosphere of toxic Nitrogen Trifluoride to produce excited Deuterium Fluoride Lasing Medium which is mixed in deuterium & helium & fed into expansion nozzles as same as CO_2 laser in GDL. Now it might be fatal if the exhaust components of deuterium fluoride is released in atmosphere. To avoid this problem, diffusion & pressure equalization technologies must be used, including a neutralization stage to soak up the highly corrosive & toxic deuterium fluoride exhaust efflux gas.

The first DF laser was tested by the US Navy's MIRACL (Mid Infrared Advanced Chemical Laser) & it was a great success in producing a directed energy weapon. Its test was done extensively since 1983 in White Sands Missile Range in New Mexico. This device produced output in order of megawatts.

The radar used was phased array radar which locates the coordinates of incoming targets & accordingly the beam was directed. THEL is short range weapon used to defend local area unlike ABL (Air Borne Laser), SAM (-----), AAA (-----). Its disadvantage can be looked through weather conditions & propagation limitations. This type of device cannot be used in humid tropical environments or northern temperate environment where moist, fog & low level clouds & similar propagation obstruction are common. The expenditure in fuel is about several

thousand dollars per shot hence it becomes problematic to use the DF in large quantity. The impact is still to be determined in strategic terms unlike ABL which changes the game completely. The present MTHEL technology is prominent to become the feature of ground to air defense in the upcoming decades. But the physicists are shifting in making a new laser technology i.e. electrically pumped Solid State Laser Technology.

5. LOC

The border between India & Pakistan is about 3000 kilometers long. About which 182 kilometers of border is unguarded due to Hilly area, Marshy land, etc. So, The infiltration of Pakistan is more in these sites. So, BSF had taken a decision of installing laser walls across these odd kilometers of border.



Figure 4: LOC

KVI-101s system is used for these laser walls. The system KVI-101S requires very little human intervention, has advanced detection capabilities & the encryption are hack proof. The new technology uses next generation IR optics to provide all weather & harsh terrain early detection capabilities. With the help of infra-red rays & laser beam, the laser walls cannot just detect when there is a breach but can also tell differentiate between man & beast. Hence using this virtual border India will able to solve the issues of terrorism in those areas & also will able to stop infiltration of Pakistan.

A further integration of laser wall with a system called miCRON, has enabled encrypted communication for five layer fencing, complete automation of border holding, is being designed & manufactured in India. The walls will be fully upgraded in western (Indo-Pak) border in Feb. or Mar. 2017. Furthermore India is also planning to install these laser walls in eastern border as well.

6. Laser Guided Bomb

A Laser Guided Bomb was first developed by United States during Vietnam War. This LGB is a guided bomb that they uses semi-active laser path to strikes a accurate target with high accuracy than any other unguided bomb. They have quickly proved their aim in precision strikes of difficult point targets. These weapons uses an electronic board to track the targets by designated laser. The laser guided bombs achieved directly hits approximately 50% of time v/s just 5.5% for undesignated bomb, that is shown

from Vietnam data laser guided ammunitions carry less explosive & cause less collateral damage than unguided ammunitions. Nowadays, these bombs are one of the most common & widespread guide bombs. These are used by the large number of World's Air Forces. These weapons, first developed in United States & United Kingdom in early 1960s, where United States Air Force issued the first development contract in 1964. With the support of IRDE a lab of DRDO India built its first Sudarshan laser guided bomb in October 2010. This is the part of ongoing research to achieve self-dependency in defense area.

7. Anti-Ballistic Missile

The thought of destroying rockets prior they can hit their targets was first made by Germans in their V1 & V2 program of worldwar-2, which provoked the idea of Anti-Ballistic Missile. It is a surface to air Missile which is designated to destroy Ballistic missile. A Ballistic missile is kind of a missile that follows ballistic trajectory. Basically these missiles are used to deliver nuclear, chemical & biological or conventional war heads in a ballistic flight trajectory. The "Anti-Ballistic Missile" is layman term depicting a system devised to intercept & destroy any type of ballistic threat.

The Indian Ballistic Missile Defense Program is an initiative to develop & deploy a multi-layered ballistic missile defense system to protect from ballistic missile attacks. Prithvi Air Defense (PAD) belonging to the class of missile is a high altitude interceptor & The Advanced Air Defense (AAD) used for low altitude interceptor. The first test of PAD was carried out in November 2006, followed by AAD in 2007. The positive results of PAD made India the fourth country in making an anti-ballistic missile defense system after United States, Russia & Israel. It is yet to be officially commissioned although it has undergone several tests

8. LiDAR

LiDAR known as the light detection & ranging system which adopts remote sensing method, that transmit light energy in the form of a pulsed laser to measure the distance of the target or variable distances on the earth. It sends a beam of laser which illuminates the target & by measuring the time interval of the reflected laser, the distance of the target is calculated. It can be also called as laser scanning or 3-D scanning. It has many uses in the field of Geology, Geodesy, archaeology, geometrics, atmospheric physics, etc. It has a very interesting history, LiDAR came into applications in early 1960s just after laser was invented. It is a combination of laser & focused imaging with an ability to calculate the distances by measuring the time for a signal to return using appropriate sensors & data acquisition electronics. Most importantly it was used in Apollo-15 Mission when the astronauts used the laser altimeter to map the landscape of the moon. Examples of military application of LiDAR are Air Borne Laser Mine Detection System. Airborne multi laser

LiDAR is used to map the territory of the enemy i.e. to locate their tanks & warheads.

9. Space Defence

Project De-Star, a project given by scientist to destroy asteroids which are aiming towards Earth. This project is important as asteroids / space debris especially rocks are a few kilometers big but the destruction made by them on earth is deadly for all human as well as animal species. Example of asteroid destruction are 1: destruction or end of whole dinosaur species. & 2: The Vredefort Dome, the Vredefort crater has an estimated radius of 118 miles (190 kilometers), making it the world's largest known impact structure. One asteroid, if few km big falls on earth creates destruction more than Hiroshima Nagasaki attack or even more than energetic weapon on earth.

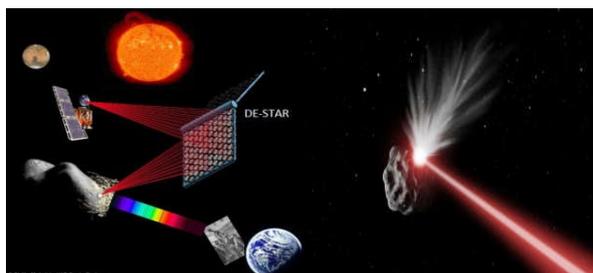


Figure 5: Project De star

De Star stands for Directed Energy System for Targeting of Asteroids & exploration system to deflect asteroids, comets, & other near-Earth objects that pose a credible risk of impact. As we see above the object that cross the earth's orbits even a tiny one, has a very destroying effect on Earth. So NASA has introduced orbital planetary defense system which is capable of melting or vaporizing the object by heat produced by laser. Laser will just vaporize or cut down it into fine pieces. DE-STAR is a modular phased array of kilowatt class lasers powered by photovoltaic. We consider two classes of systems, Large "stand-off" DE-STAR arrays, which remain in Earth orbit & deflect the target from a far. Much smaller "stand-on" DE-STARLITE systems which travel to & deflect from alongside the target. The modular design allows for incremental development & test, lowering cost, minimizing risk, & allowing for technological co-development. DE-STAR is designed as stand-off that can accomplish task from far. While comparing DE-STAR & DE-STARLITE, DE-STARLITE is small & it can be deployed on a single launcher but still powerful i.e. capable of diverting large asteroids in given sufficient warning time.

In both the systems a highly focused laser light beam is targeted on an asteroid at a spot, the temperature at that spot rises up to ~3000K which will instantly vaporize the material in that spot & material gets ejected which alters the direction of asteroids or comet's orbit. Ideal DE-STAR systems can simultaneously engage multiple targets.

Project DEEP-IN

As we know that we don't have such a technology that can go up to 2-3% the speed of light. But NASA have studied & invented an idea that make us travel at approx. or greater than 25% speed of light & that project is named DEEP-IN. As we know, we humans have sent a voyager space satellite in 1977 & now it has crossed our solar system.

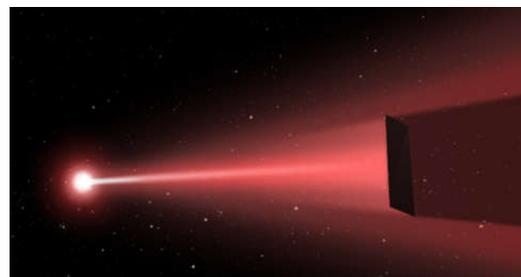


Figure 6: Project DEEP-IN

See it's how many years it would take to reach to reach our nearest star Alpha Centurai, just imagine very big drawback of our used propulsion is weight of propellant (fuel). It weighs half the space shuttle load or even more. So this system takes very less fuel & also less costly. But it can carry fewer loads. So we can send "wafer sats", wafer-scale systems weighing no more than a gram. The wafer sats would include integrated optical communications, optical systems & sensors. As these weigh less they can travel as fast as possible. So, with the help of this propulsion we can reach our closest star in few years.

DEEP-IN (Directed Energy Propulsion for Interstellar Exploration) is a NASA program to use massive directed energy to thrust small spacecraft to relativistic speeds to enable humanity's first interstellar missions. This program was started in 2009 with initial funding from UC Santa Barbara & the NASA Space grant Consortium with funding from the NASA Innovative Advanced Concepts (NIAC) program from a 2014 proposal. NIAC Phase I funding began in April 2015 with Phase II funding started in May 2016.

10. Conclusion & Future Scope

Due to the properties of laser like high intensity high coherency its use for military & defense application makes it a perfect choice. It has made huge impact on Law Enforcement sector due to its various ranging application of laser technology like LiDAR, ABL, THEL, etc. Many major threats can be averted in the future. Because of the invention of the PHaSR Rifle, there will be improvement in the Law Enforcement, as it will be bullet free & the damage effects would be temporary. Scientists are still trying to improve the prototypes design of weapons & defense system which will reduce the cost & increase the efficiency. The Applications of laser technology are also been studied in India at various institutions & they are being researched for improvements.

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