Lasers: Future of Military Defence Systems

SURYA KIRAN SHARMA

US President Ronald Reagan proposed an ambitious project in 1983, the Strategic Defence Initiative (SDI) that aimed to use land-based and space-based systems to protect the country from strategic nuclear ballistic missiles.[1]The programme was dubbed "Star Wars" for its expansive approach and application of space-based assets. The SDI intended to intersect Soviet ballistic missiles at various phases of their flight and direct laser beams from earth-based and space-based stations. Project Excalibur, part of SDI, was the research programme that conceived the development of a nuclear pumped x-ray laser as a directed energy weapon for ballistic missile defence. The objective was to direct x-rays towards the enemy missiles to heat their surface, causing them to vapourise explosively, destroying them or changing their course.

Though the SDI was technologically infeasible for the time and critics questioned its military and political implications, the programme and, in particular, its Project Excalibur component, laid the groundwork for the application of lasers for military purposes. SDI was christened the Ballistic Missile Defence Organisation (BMDO) in 1993 and was later renamed the Missile Defence Agency in 2002. Three decades after its inception, SDI has become a reality with lasers being used as deterrents against ballistic missiles and other military targets.

Laser, which stands for Light Amplification by Stimulated Emission of Radiation, emits light coherently that allows it to focus to a tight spot and stay narrow over long distances (called collimation). Compared to conventional weaponry, lasers or directed-energy weapons have the under-mentioned advantages.

Laser based weapon system can have limitless ammunition.

- Laser beams travel at the speed of light. Consequently, evading an accurately aimed laser after it has been fired is impossible.
- Light is only slightly affected by gravity; hence, long-range projection requires little compensation.
- Given a sufficient power source, laser weapons can essentially have limitless ammunition.
- Because light has a practically zero ratio of momentum to energy, lasers produce negligible recoil.
- Laser beams do not generate sound or light that would be detected by human senses when emitted, so the weapon would not betray its user's position when fired.
- Cost per shot is negligible, often less than a US dollar, which makes the weapon system very cost-effective.

A number of experiments carried out in the last two decades, have led to the development of lasers as the next generation weapon system. A number of defence companies are carrying out research in this field and have achieved varying degrees of progress in constructing a high energy weapon. The challenge is to achieve generation of high power while keeping in mind the mobility and cost factors.

Two systems, the Tactical High Energy Laser (THEL) and Airborne Laser (ABL) were the early successful weapon systems which were able to demonstrate the effectiveness of a laser weapon platform. The THEL was designed, developed and produced by a Northrop Grumman-led team of US and Israeli contractors for the US Space & Missile Defence Command, and the Israeli Ministry of Defence.[2] The THEL was designed and built in only four years – from 1996 to 2000. Field tests began in 2000 and ended in 2005, during which time it destroyed 46 rockets, artillery and mortar rounds in flight. These included:

- 28 Katyusha rockets, including salvos and a surprise attack.
- 5 artillery projectiles.
- 3 large calibre rockets.
- 10 mortars, including a salvo of three.
- 7 medium, 2 heavy and 1 light rockets / missiles.

The ABL, designated YAL-1A, was among the largest and most complex of the Missile Defence Agency's high-energy laser projects. Conceived in 1996 by the US Department of Defence (DoD), the ABL was a high-energy laser weapon system intended for the destruction of tactical theatre ballistic missiles, which was carried on a modified Boeing 747-400F freighter aircraft.[3] It was controlled by a four-man team, that operated at altitudes of 40,000 ft or higher. Six infrared sensors positioned on the outside of the 747 (one each on the front and rear and two on each side) gave the ABL the ability to scan the horizon for threats. The ABL fired its high-energy Chemical Oxygen Iodine Laser (COIL) from a turret located in the 747's nose. The COIL combined common industrial chemicals (hydrogen peroxide, potassium hydroxide, chlorine gas, water) to create its lethal beam. A three- to five-second burst heated the missile's metal skin until it cracked. Since the missile's interior is pressurised during launch, the crack expands rapidly into a tear, resulting in fuel explosion and disintegration of the missile.[4] The ABL weapon system was successful in destroying a test ballistic missile in 2010[5] but the programme was shut down in 2012 due to significant affordability and technology problems.[6]

Significant developments have taken place in the last decade in the development of a weapon system based on solid-state lasers. Raytheon successfully tested a prototype solid-state laser weapon in 2007 that combined the proven capabilities of the Phalanx weapon system with the power and effectiveness of the laser. The prototype solid-state Laser Area Defence System (LADS) successfully detonated 60 mm mortars at a range of 550 yards.[7] Northrop Grumman fielded the FIRESTRIKE(tm) laser, a ruggedised, high-energy, solid-state laser in 2008 which was dubbed as the first weaponised solid state laser with 15KW output for battlefield applications.[8]In a demonstration for the US DoD in 2013, Boeing tested its Thin Disk Laser System with a 30 KW output and achieved greater beam quality, a result that would pave the way towards a practical tactical laser weapon.[9]

The US armed forces have been testing solid-state lasers, the Army's High-Energy Laser Mobile Demonstrator (HEL MD) and the Navy's Laser Weapon System (LaWS) being the notable programmes in this field. These weapons systems are designed to fire over relatively short distances, at targets much slower and less durable than a ballistic missile, such as small drones, fast-attack boats, precision-guided mortar rounds, tactical rockets, or — at the high end — anti-ship cruise missiles.[10]

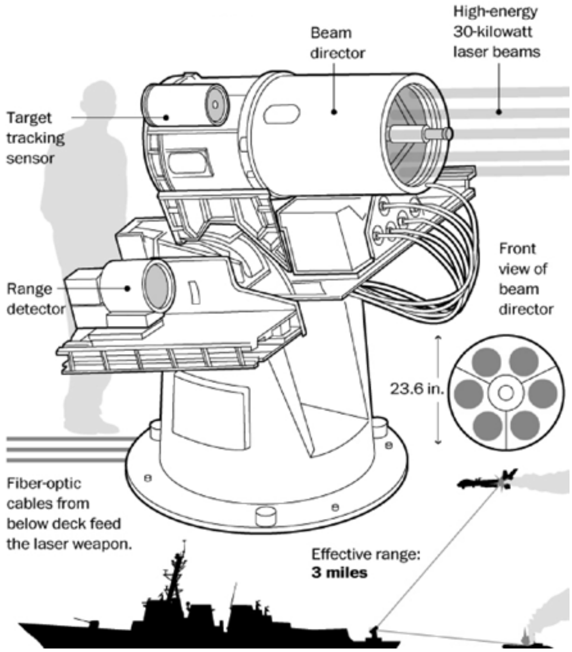
The United States Army's HEL MD is the first mobile high-energy solid-state laser platform. When completed, HEL MD will consist of a ruggedised and supportable high energy laser and sub-systems installed on a tactical military vehicle that will be capable of demonstrating area joint force protection to forward operating bases, naval installations, air bases and other facilities. The HEL MD beam director rotates 360 degrees to provide full sky coverage and extends above the roof of the vehicle to engage below-the-horizon targets. The thermal management and electrical power systems provide a deep magazine of continuous target engagements.[11]

New laser weapon systems are aimed at destroying targets, slower than ballistic missiles.

Lockheed Martin demonstrated a 30-kilowatt fibre laser in January 2014 that pushes the technology closer to military deployment.[12] Described as a "weapons grade" laser, it combined a large number of sources operating at slightly different wavelengths, and is said to retain beam quality while consuming half the electrical power of a more conventional solid-state laser. The company successfully tested a prototype laser system that disabled two boats at a range of approximately 1.6 km. These were the first tests of the Area Defence Anti-Munitions (ADAM) system against maritime targets.[13] The system can precisely track moving targets at a range of more than 5 km and its 10-kilowatt fibre laser can engage targets up to 2 km away while providing a virtually unlimited "magazine" at a low cost per engagement.

Another notable development has been the operationalisation of the Laser Weapon System (LaWS), a directed-energy weapon developed by the US Navy. The system was fitted aboard the warship USS *Ponce* and was deployed in the Persian Gulf where it successfully fired a laser weapon in December 2014. The laser hit and destroyed targets mounted atop a small boat, blasted a six-foot drone from the sky, and destroyed other moving targets. The US Navy spent about $40 million over the past seven years developing LaWS, which consists of six commercial welding lasers lashed together and aimed at the same point. A major advantage of the directed-energy weapon system is its cheap cost: the energy required to fire the *Ponce*'s laser costs 59 cents a shot, compared to a shell or missile, which can cost $1 million or more.[14]

Fig 1: Laser Weapon System



Along with the Army and Navy applications, the solid-state laser has also found its way to being integrated with F-35 Joint Strike Fighter (JSF). Lockheed Martin has since 2002 been developing variants of the solid-state laser, powered by a drive shaft from an aircraft's engine instead of batteries for F-35 and AC-130 gunships.[15] A first-generation laser weapon would be able to engage aerial targets such as cruise missiles and enemy aircraft, as well as ground targets such as anti-aircraft missile sites and ground vehicles. These capabilities would likely require laser power of 100 KW.

Israel has also been developing lasers for battlefield use. Rafael Advanced Defence Systems unveiled its Iron Beam High-Energy Laser (HEL) system designed to defeat rockets, mortars, and Unmanned Aerial Vehicles (UAVs) at short ranges, at the Singapore Air Show in February 2014.[16] The land-based system uses a pair of multi-kilowatt solid-state lasers to defeat incoming projectiles out to a range of about 7 km. The Iron Beam is set to become the world's first active duty combat laser with Israel planning to deploy the system with the armed forces in 2015.[17] The Iron Beam will constitute the fifth element of Israel's integrated air defence system designed to destroy short-range rockets, artillery, and mortars considered too small for the Iron Dome system to intercept effectively. The Iron Dome system has intercepted over 1,000 rockets fired into Israel since 2011. The Iron Beam system will lead to major cost savings as a laser shot costs less than a dollar compared to $50,000 per Tamir interceptor missile of the Iron Dome system.

In the Indian context, Headquarters Integrated Defence Staff (HQ IDS) has identified Direct Energy Weapons (DEW) as the key thrust area until 2025 in its Technology Perspective and Capability Roadmap.[18] The Defence Research and Development Organisation's (DRDO's) Laser Science and Technology Centre (LASTEC) is working to develop laser-based weapons, deployed on airborne as well as seaborne platforms, which can intercept missiles soon after they are launched towards India in the boost phase itself. LASTEC is developing a 25-KW laser system to hit a missile during its terminal phase at a distance of 5-7 km. LASTEC is also working on a vehicle-mounted "gas dynamic laser-based DEW system", under Project Aditya, which remains under development.[19]

Ironically, lasers make poor offensive weapons. The power requirements to burn through a bunker or an armoured vehicle, as opposed to a relatively thin-skinned missile, are still well out of reach. And, as lasers can only fire in a straight line, they're actually an inferior form of artillery to old-fashioned howitzers, which can fire in a ballistic arc over a hill or over the horizon at targets not in their line-of-sight.

Despite all their shortcomings, lasers make excellent deterrents against missiles and given their advantages of speed, cost and scalability in terms of power output, laser weapon systems are the future of missile defence systems.

Surya Kiran Sharma is a Research Assistant at CLAWS.

Notes

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