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DIRECTED ENERGY WEAPONS

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Introduction

Directed energy weapons (DEW) are what we describe as high-power laser-based weapons. As the name suggests, they use high-powered lasers to inflict damage on targets. Compared to traditional weapons, which mainly rely on physical impact and kinetic energy, DEW uses directed energy to heat up and destroy or damage the target. It has diverse military applications, offering rapid and precision strikes against threats such as UAVs, missiles, and small vehicles. The most important aspect of DEW is that it can be used in all warfighting environments; therefore, it can be deployed by the army, navy and air force.

How it Works:

1. Photon Generation: Electrical energy is supplied to an active optical medium (like a crystal in a solid-state laser).

2. Photon Cascade: This energy excites the medium, causing it to emit photons (light particles).

3. Amplification: The photons are reflected back and forth between two mirrors inside an optical cavity, creating a cascade and increasing their numbers exponentially.

4. Beam Formation: A portion of these concentrated photons escapes through a partially reflective mirror, forming a powerful, narrow beam of light.

5. Targeting: The beam is directed at a target, where the intense light energy can cut through it or ignite it, causing it to burst into flames.

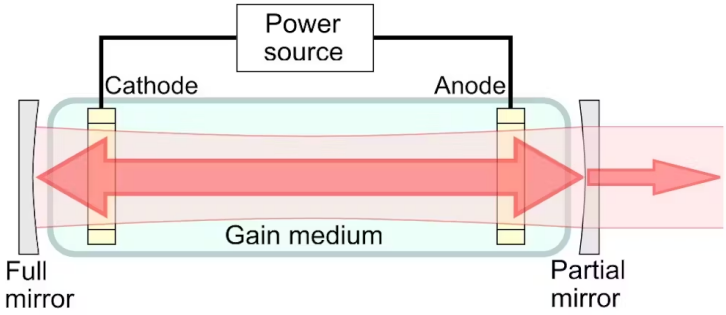

Fig. 1: *Lasers work by turning electricity into photons and bouncing them back and forth between two mirrors through a special gain material that creates a cascade of many more photons*[1].

Applications and Capabilities

- Precision and Low Collateral Damage: DEWs can target specific weak spots of enemy systems, motors, electronics, or wings, minimising collateral damage or debris[2].
- Rapid Response: DEWs engage with targets at the speed of light, eliminating fast-moving threats in real time.
- Cost and Logistics: DEWs have low operational costs, only requiring a continuous supply of electricity to work indefinitely. This also reduces resources needed for logistics and transportation of conventional ammunition, making it a highly cost-effective weapon.
- Counter-Drone and Stealth Technology: DEWs are uniquely positioned to tackle swarm drones while ensuring there are no sounds or explosions, giving them stealth capabilities.

India’s leap towards DEW

Integrated Air Defence Weapon System (IADWS) is a multi-layered air defence system developed by India, designed to protect against various aerial threats. The system combines three major indigenous components - Quick Reaction Surface to Air Missiles (QRSAM), Advanced Very Short-Range Air Defence System (VSHORADS) missiles and a high-power laser-based Directed Energy Weapon (DEW), forming a robust shield against aircraft, drones, cruise missiles, and other aerial threats[3]. The integrated operation of all weapon system components is managed by a Centralised Command and Control Centre developed by Defence Research & Development Laboratory, ensuring coordinated surveillance, detection, engagement, and destruction of incoming threats.

India has recently developed its own indigenous DEW systems under the project ‘Sahastra Shakti’. It first started with the DEW model - Mk1 in 2024, then came into existence Mk2, and in April 2025, India successfully demonstrated Mk2A at the National Open-Air Range (NOAR), Kurnool, Andhra Pradesh. This demonstration marks a huge milestone in the nation's technological defence systems. Mk2A is a vehicle-mounted system which uses six 5kW laser beams totalling 30kW power output, and has a range of 4 km. It is currently being developed indigenously by the Centre for High Energy Systems & Sciences (CHESS), Defence Research and Development Organisation (DRDO), Hyderabad.

Fig. 2: *Mk-II(A) Laser- Directed Energy Weapon (DEW) system*[4].

The Mk2A has been equipped with state-of-the-art electronic warfare systems, including a Command and Control (C2) unit, a Beam Control Unit, a cooling system, and 360-degree Electro-Optical/Infrared (EO/IR) sensors, providing precision targeting and tracking capabilities[5]. In the recent demonstrations, Mk2A successfully tracked and neutralised aerial targets, including UAVs, Swarm drones in a simulated coordinated drone attack, a Radiating panel of an antenna, and blinded an EO System. Mk2A's automated kill assessment algorithms with fully integrated artificial intelligence (AI) capabilities demonstrate a weapon system capable of defending critical infrastructure[6]. DRDO is also working on developing different variants for this project, ranging from 50 to 100 kW power output values.

In a press statement, DRDO's chairman, Dr Samir V Kamat, told:
"This is just the beginning of the journey. The synergy that this lab has achieved with other DRDO labs, industry and academia, I am sure we will reach our destination soon… We are also working on other high energy systems like high energy microwaves, electromagnetic pulse. So, we are working on a number of technologies that will give us Star Wars capability. What you saw today was one of the components of Star Wars technologies."[7]

Therefore, moving forward, several projects are being developed by DRDO in the field of directed energy weapon systems, including:

- **DURGA II:** Directionally Unrestricted Ray-Gun Array (DURGA) is a lightweight DEW project with a 100-kW capability. According to media reports, in March 2021, the Ministry of Defence allocated USD 100 million to the DRDO for this project to accelerate its development[8]. This indigenous DEW will be used to counter swarm drones, artillery shells, and other aerial threats or terrestrial threats.

- **Surya:** This is a high-powered laser power system capable of 300 kW power output and can work at an effective range of 20 kilometres. It is being developed specifically to neutralise supersonic missiles, high-speed fighter jets, unmanned aerial vehicles, and other aerial attacks with high accuracy. It is designed to be deployed aboard air defense systems and border based mobile vehicles, thus enhancing the rapid response capabilities of India. This cutting-edge, high-power laser system is built to be operational in 2027.

- **KALI:** The Kilo Ampere Linear Injector (KALI) is being co-developed by the Bhabha Atomic Research Centre (BARC) and the DRDO. KALI has a linear electron accelerator, which generates powerful pulses of electrons. These electrons are converted into intense beams, known as Relativistic Electron Beams (REBs), or into high-frequency electromagnetic radiation. The resulting high-energy pulses and electromagnetic radiation are designed to overload and disable

the electronic circuits of incoming aircraft and missiles with a “soft-kill” mechanism. Initially developed for industrial purposes, but due to its ability to generate high energy electron pulse led to its research as a weapon system[9].

Global Rise of DEW

There is an increasing demand for DEW globally, but not many countries have been able to develop it successfully. According to DRDO’s chairman, currently we are the fifth country to demonstrate DEW system capabilities after America, Russia, China and Israel[10]. Globally, the US is taking the lead in DEWs development with a 41.6% market share followed by China and Russia. The US Navy has installed LAWS and HELIOS DEW systems on its warships. The 30kW laser weapon system, LAWS, may incapacitate unmanned aerial vehicles and remove boat propulsion systems, as well as destroy IEDs remotely. The HELIOS weapons system is unique in that it can intercept drones, fast-attack boats, and missiles with 300 kilowatts of power[11]. Russia’s Peresvet laser weapon system can work as an anti-satellite as well as CUAS. The laser defense system covers 360 degrees of azimuth and targets satellites at altitudes ranging from 200 to 1,100 kilometres. The Russian military has recently upgraded its Pantsir air defence system with laser technology. The Chinese are also creating a high-powered microwave laser weapon capable of disabling or dazzling satellites.

The laser defence system targets satellites from 200 to 1,100 kilometres altitude through 360 degrees of azimuth coverage. The Russian military has also enhanced its Pantsir air defence system with laser technology. Recently, Russia showcased a laser rifle designed to counter small drones, specifically first-person view [FPV] models, at a defence conference near St Petersburg.

Limitations and Challenges

- **Atmospheric Interference**: Harsh weather conditions, such as rain, dust, and fog, may cause phenomena such as atmospheric absorption, turbulence and scattering, resulting in significant power reduction and effectiveness of DEWs[12].
- **Range:** The effectiveness of DEWs diminishes with distance, limiting their operational flexibility in attacking over the horizon targets. Therefore, maintaining a clear line of sight is crucial for successful engagement.
- **High Power:** Directed Energy Weapons require high, sustainable power sources. Thus, generators, distribution and energy storage units must be integrated into mobile or static systems[13].
- **Cooling System**: DEWs produce high heat and typically cannot be maintained continuously, having to be shut down periodically. A powerful cooling system is required for its use.
- **Cost:** Though the cost per shot is very low, its production, development, integration and repair costs are particularly high.

Conclusion

India's proactive investment in cutting-edge military technologies ensures its prominent position as one of the key players in the global defense landscape. Directed Energy Weapons are one of the latest technologies being researched and developed by DRDO, proving the increasing capabilities of India's high ambitions. Project 'Sahastra Shakti', 30kW Mk2 laser weapon system, was successfully developed and tested, and there is continuous research and development ongoing with projects like 'Surya', a 300kW laser weapon system, and 'KALI', a pulse-powered laser weapon system. These projects are developed in cooperation with private and public research centres. Prominent private companies with increasing involvement in indigenous development of defense technologies, particularly directed energy weapons, are Bharat Electronics Limited, Adani Defence & Aerospace, Big Bang Boom Solutions, Paras Defence, and Tonbo Imaging[14]. Directed Energy Weapons must be enhanced in terms of mobility, reliability, and

affordability to establish a comprehensive military capacity, encompassing infrastructure, logistics, doctrine, and training. DEWs must be included in conjunction with existing air and missile defense systems within a cohesive joint service framework to address all aerial threats across diverse altitudes, velocities, and ranges[15].

DISCLAIMER

The paper is author's individual scholastic articulation and does not necessarily reflect the views of CENJOWS. The author certifies that the article is original in content, unpublished and it has not been submitted for publication/ web upload elsewhere and that the facts and figures quoted are duly referenced, as needed and are believed to be correct.

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