Role of Directed Energy Weapons (DEWs) in Shaping the Future of Warfare in South Asia

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Abstract

As modern warfare gradually integrates advanced technology, the advent of cost-effective, user-friendly technologies has altered its landscape. Directed Energy Weapons (DEWs) exemplify this transformation, possessing distinct features that major global powers actively develop for both offensive and defensive purposes. At the regional level, India's prioritization of DEWs development has prompted Pakistan to concentrate on enhancing its capabilities in this domain. The primary research question in this study addresses how states are developing DEWs internationally and in South Asia, along with its potential implications? This study adopts the conceptual framework of a force multiplier, and employs qualitative research methodology. It concludes that DEWs hold significant potential to be leveraged at both operational and strategic levels. These advanced technologies can augment existing defense systems, disrupt command and control infrastructures, and provide critical capabilities for countering drones and missiles with precision. Furthermore, their application in targeted strikes underscores their transformative role in modern warfare. The study emphasizes the importance of Pakistan prioritizing investment in DEWs to enhance its defense architecture and maintain strategic balance.

Key Words: Directed Energy Weapons, High Energy Lasers, High Powered Microwaves, Pakistan, India

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Introduction

Directed Energy Weapons (DEWs)[1] encompass various technologies that utilize electromagnetic energy across different ranges, designed for both offensive and defensive military operations. These technologies include[2] High-Powered Microwaves (HPM), High-Energy Lasers (HEL), Charged Particle Beams (CPB), Neutral Particle Beams (NPB), among others. DEWs possess distinct characteristics[3] that make them highly advantageous in modern warfare scenarios. Following table explains these characteristics in details with description and their profound impact.

Table 1.1 Characteristics of DEWs[4]

Characteristic	Description	Impact
Speed of Light Operation	DEWs operate at the speed of light, ensuring rapid response and precise interception.	Superior tracking and accuracy in targeting.
Stealth-Like Properties	Difficult to detect and intercept, enhancing strategic and tactical advantages.	Ideal for strategic defense and battlefield applications.
Cost-Effectiveness	Provides a high return on investment with relatively low financial outlay.	Affordable force multipliers, enhancing military capabilities.
Compact Size & Versatility	Easily integrates across various platforms (land, air, sea, space).	Operational flexibility and diverse deployment options.
Simultaneous Target Engagement	Capable of engaging and neutralizing multiple targets at once.	Increased effectiveness in complex and dynamic environments.

These attributes underscore the pivotal role DEWs play in modern military strategy, warranting further research into their optimal deployment and strategic implications. There are several studies which discusses the potential use of DEWs.

[1] Henry Obering, "Directed Energy Weapons Are Real . . . And Disruptive," *PRISM* 8, no. 3 (2020): 10. https://ndupress.ndu.edu/Portals/68/Documents/prism/prism_8-3/prism_8-3_Obering_36-46.pdf
[2] D. Curtis Schleher, *Electronic Warfare in the Information Age* (Boston: Artech House Publishers, 1999).
[3] Ibid.
[4] The table is made by the author based on her understanding of the subject.

The article "Directed Energy Weapons Are Real and Disruptive"[5] by Henry "Trey" Obering, III explores the growing reality of DEWs including the HELs and HPMs, which are advancing rapidly by examining their key characteristics, potential applications, and disruptive impact, particularly in countering emerging threats like hypersonic weapons. The book, "Effects of Directed Energy Weapons"[6] by Philip E Neilsen offers an in-depth exploration of how DEWs propagate and interact with targets. The authors Mark Gunzinger and Chris Dougherty in "Changing the game: The Promise of Directed Energy Weapons"[7] argues that directed energy technologies have reached a level of maturity where they could offer significant advantages throughout the targeting process, including enhanced defense of forward bases and forces against a wide range of threats.

In the article "War at the Speed of Light: Directed-Energy Weapons and the Future of Twenty-First Century Warfare"[8], author Louis A. Del Monte discusses how DEWs offer significant advantages to competing nations, especially the United States, Russia, and China. The author Mohit Vashisth argues in his article titled, "Directed Energy Weapons-International research and country specific developments"[9] that governance mechanism for DEWs is a crucial issue.

Despite extensive studies, a research gap exists regarding the development of DEWs internationally, particularly in the context of South Asia. The study aims to fill this gap by conducting research about DEWs and their potential applications in modern warfare by analysing the role of DEWs in shaping offensive and defensive military strategies. The study emphasizes the development of DEWs in India and how these weapons could potentially be used against Pakistan in various scenarios.

This study is significant for several reasons. First, it offers a South Asian perspective on DEWs while touching upon the DEWs development at global level. Second, it explores how these

[5] Henry Obering, "Directed Energy Weapons Are Real . . . And Disruptive," *PRISM* 8, no. 3 (2020): 10. https://ndupress.ndu.edu/Portals/68/Documents/prism/prism_8-3/prism_8-3_Obering_36-46.pdf
[6] Philip E. Neilsen, *Effects of Directed Energy Weapons,* (Washington DC, 1994).
[7] Mark Gunzinger, Chris Dogherty, "Changing the game: The Promise of Directed Energy Weapons", *Centre for Strategic and Budgetry Assessments* (2012), https://csbaonline.org/uploads/documents/CSBA_ChangingTheGame_ereader.pdf
[8] Louis A. Del Monte, *Directed-Energy Weapons and the Future of Twenty-First-Century Warfare*. University of Nebraska Press, 2021. https://doi.org/10.2307/j.ctv1f70m1m.,
[9] Mohit Vashisth, "Directed Energy Weapons-International research and country specific developments", *Cescube,* February 21, 2021, https://www.cescube.com/vp-directed-energy-weapons-international-research-and-country-specific-developments.

technologies could impact future conflicts between Pakistan and India. Third, it analyses the strategic options available to Pakistan in response to India's potential deployment of DEWs, considering various countermeasures.

The study adopts qualitative methodology to explore DEWs from various perspectives such as their characteristics, utility in modern warfare and strategic implications. Research is primarily based on secondary sources to analyse and review the strategic environment and use of DEWs in future warfare in South Asia. Case study approach is used to study the current status and advancements in DEWs, especially in countries like India, and analysing how this might influence Pakistan's approach to enhancing its own capabilities.

This paper is divided into several sections; the first section provides a conceptual framework for study, the second section discusses the development of DEWs, and the third section provides detail about the applications of these weapons. The Fourth section provides policy options for Pakistan, and the last section provides the conclusion.

Conceptual Framework

The concept of a force multiplier, defined as, "the effect produced by a capability that, when added to and employed by a combat force, significantly increases the combat potential of that force and thus enhances the probability of successful mission accomplishment, is integral to understanding modern military and strategic operations".[10] Originating from military operational art, this concept now broadly describes factors that amplify the effectiveness of various endeavors, including security and strategic operations.[11]

At its core, the force multiplier concept assumes several key principles. First, it enhances the capability of military units, enabling them to perform tasks with greater efficiency and effectiveness. This enhancement could be through advanced weaponry, superior training, or innovative tactics that boost combat effectiveness.[12] Secondly, technological superiority is a significant force multiplier, providing qualitative advantages that can shift the balance in favor of the force employing them.[13] For instance, technologies such as precision-guided munitions, cyber

[10] John F. Bradford, "Force Multiplier," *Asian Survey* 62, no. 4 (August 1, 2022): 666–94, doi:10.1525/as.2022.1651914.
[11] W. J. Hurley, "A Clarification of the Concepts of Force Multiplier and Returns to Force Scale," *Defence and Peace Economics* 16, no. 6 (January 1, 2005): 463–65, doi:10.1080/10242690500167817.
[12] B. Menon, "Understanding Force Multipliers," News and Analysis, *SP Aviation*, (September 10, 2023), https://www.sps-aviation.com/story/?id=1307.
[13] William J. Perry, "Information Technology as a Force Multiplier," News and Analysis, *Hoover Institution*, (October 30, 1998), https://www.hoover.org/research/information-technology-force-multiplier.

capabilities, and intelligence, surveillance, and reconnaissance (ISR) systems dramatically enhance operational effectiveness.[14] Moreover, force multipliers offer greater operational flexibility, allowing forces to adapt and respond to various threats more effectively.[15] Enhanced mobility, advanced communication systems, and improved logistical support enable forces to maneuver efficiently and sustain prolonged operations.[16] The use of force multipliers has a substantial psychological impact, boosting the morale of friendly forces while deterring or demoralizing adversaries through the perception of superior capability.

Furthermore, the effectiveness of force multipliers is maximized when integrated into a cohesive strategy. The combined use of various multipliers, such as air power, electronic warfare, and special operations forces, creates a synergistic effect that amplifies overall combat effectiveness.[17]

Global Development of DEWs

Advancements in DEWs have been underway for several decades. In the United States, research into microwave physics began in the 1930s, while laser technology development started in the 1960s.[18] One of the major challenges due to which laser weapons could not be used in warfare is their huge size, weight and power (SWaP). The early laser weapons were significantly bigger and heavy. They were transported through separate aircraft to hold the equipment. For instance, the megawatt-class airborne laser weapons developed in the late 1990s required 747 aircraft to transport their equipment.[19]

However, recently, developed laser weapons are lighter in weight and smaller in size. With reduced SWaP, the use of laser weapons in warfare will be increased for two reasons; first, due to technological advancements, the use of low-cost and precision weapons with minimum causality rate is a preferred choice on the battlefield. Second, due to the advent of threats and the introduction of emerging technologies in warfare, DEWs can achieve desired results for warfare. One such

[14] Daniel C. Billing et al., "The Implications of Emerging Technology on Military Human Performance Research Priorities," *Journal of Science and Medicine in Sport* 24, no. 10 (October 1, 2021): 947–53, doi: 10.1016/j.jsams.2020.10.007.
[15] Perry, "Information Technology as a Force Multiplier."
[16] M. Cucinotta et al., "Integrating Adaptive Smart Technology for 40mm Weapon Platforms," *2012 IEEE Systems and Information Engineering Design Symposium*, 2012, 79–84, doi:10.1109/SIEDS.2012.6215121.
[17] Benjamin M. Jensen, "Small Forces and Crisis Management," *The US Army War College Quarterly: Parameters* 45, no. 1 (March 1, 2015), doi:10.55540/0031-1723.2813.
[18] John P. Geis, *Directed Energy Weapons on the Battlefield: A New Vision for 2025*, report* (Alabama: Center for Strategy and Technology, 2003). https://apps.dtic.mil/sti/pdfs/ADA463429.pdf
[19] Obering, "Directed Energy Weapons Are Real . . . And Disruptive."

technological advancement and popping threat is hypersonic missile technology, for which no defence system proved to be effective yet, and in this respect directed energy countermeasures are said to be an effective countermeasure to hypersonic missiles than other kinetic solutions.[20]

According to a report, due to high demand and utility, the global DEWs market in 2029 is projected at $17.4 billion and the market share in 2022 was $ 9.24 billion.[21] The factors contributing to high demand include increasing operational requirements by the militaries across the world particularly after the Russia-Ukraine war, effectiveness against small drones and multiple targets, rise in research and development, etc.

- ***United States***

The United States manages its DEWs programs through the Army, Navy, and Air Force, with oversight by the Office of the Under Secretary of Defense for Research and Engineering (OUSD[R&E]) and coordination by the Principal Director for Directed Energy (DE). The Directed Energy roadmap prioritizes developing DEWs for military and other strategic uses, aiming to boost the power of HEL weapons from 150 kilowatts to 1 megawatt by 2030.[22]

The US currently deploys several DE systems, including the Navy's ODIN (Optical Dazzling Interdictor), HELIOS (High-Energy Laser with Integrated Optical-Dazzler and Surveillance), and the Solid-State Laser – Technology Maturation program. The Marine Corps uses CLaWS (Compact Laser Weapon System), while the Air Force has the HELWS (High Energy Laser Weapon System) and THOR (Tactical High Power Microwave Operational Responder).[23]

In January 2023, US Army's Rapid Capabilities and Critical Technologies Office (RCCTO) was funding an HPM prototype project worth $66.1 million to counter swarm drones in a single shot.[24] In February 2022, the U.S. Navy successfully tested the Laser Layered Defense (LLD) system, intercepting multiple aerial targets, including simulated cruise missiles, at the White Sands Missile Range. The system, designed for use across various domains and platforms,

[20] Obering, "Directed Energy Weapons Are Real . . . And Disruptive."
[21] Fortune Business Insights, "Directed Energy Weapons Market to Reach USD 17.43 Billion by 2029 | Fortune Business Insights™," December 06, 2022, https://www.globenewswire.com/news-release/2022/12/06/2568330/0/en/Directed-Energy-Weapons-Market-to-Reach-USD-17-43-Billion-by-2029-Fortune-Business-Insights.html
[22] Sayler et al, *Department of Defense Directed Energy Weapons.*
[23] Stew Magnuson, "Directed Energy Weapons: Here Now? Or 5 Years Off?", *National Defense*, February 29, 2024, https://www.nationaldefensemagazine.org/articles/2024/2/29/editors-notes-directed-energy-weapons-here-now-or-5-years-off
[24] David Szondy, "US Army awards contract for microwave weapon to counter drone swarms," *New Atlas*, January 24, 2023. https://newatlas.com/military/us-army-awards-contract-microwave-weapon-counter-drone-swarms/

is expected to enhance future naval operations.[25] In 2020, Admiral Michael Gilday, then commander of the US Sea services, identified lasers, hypersonic, and networking as his top three technological priorities. The increasing threat posed by precision weapons, including hypersonic missiles from Russia and China, has raised significant concerns for the U.S. In this context, laser weapons are seen as a promising solution for countering hypersonic threats.[26]

In 2019, the Air Force Research Laboratory (AFRL) successfully tested a laser weapon system that intercepted and destroyed air-launched missiles in flight. As part of the Self-Protect High Energy Laser Demonstrator (SHiELD) program, this technology aims to develop a laser system that can be mounted on an aircraft pod, enhancing its defensive capabilities against surface-to-air (SAM) and air-to-air (AAM) missiles.[27]

The Director of AFRL's Directed Energy Directorate stated that this advancement is expected to be a game-changer for war fighters in the future.[28] Similarly, the Counter-electronics High-powered Microwave Advanced Missile Project (CHAMP) is a directed energy weapon that, as an air-launched cruise missile equipped with a high-power microwave payload, can disable electronic and data systems while minimizing or eliminating collateral damage.[29]

One of the directed energy weapons deployed in Afghanistan was the US Active Denial System, which uses millimetre-wave technology to address potential threats without causing loss of life. Developed by the AFRL, the system was ultimately withdrawn due to non-technical issues, including concerns about human rights and the ethical implications of using the weapon.[30]

Since 2014, the US Navy has equipped a naval ship with a prototype solid-state Laser (SSL) designed to target surface vessels and unmanned aerial vehicles (UAVs). Enhanced versions currently in development aim to counter anti-ship cruise missiles (ASCMs). Ongoing

[25] Warren Duffie Jr., "U.S. Navy Conducts Historic Test of New Laser Weapon System," *Naval News,* April 14, 2022, Ahttps://www.navalnews.com/naval-news/2022/04/u-s-navy-conducts-historic-test-of-new-laser-weapon-system/
[26] John M. Doyle, "Navy/Marine Corps Wish List: Subs, Hypersonics, Training and Education," *Seapower*, December 3, 2020, https://seapowermagazine.org/navy-marine-corps-wish-list-subs-hypersonics-training-and-education/
[27] 88th Air Base Wing Office of Public Affairs, "AFRL Completes Successful Shoot down of Air-Launched Missiles," *The Air Force Research Laboratory*, May 3, 2019, https://afresearchlab.com/news/air-force-research-laboratory-completes-successful-shoot-down-of-air-launched-missiles/
[28] 88th Air Base Wing Office of Public Affairs, "AFRL Completes Successful Shoot down of Air-Launched Missiles."
[29] "CHAMP - Lights Out," *Boeing*, October 22, 2012, https://www.boeing.com/features/2012/10/bds-champ-10-22-12.page
[30] Benjamin Buch, Katherine Mitchell, "The Active Denial System: Obstacles and Promise." https://www.wm.edu/offices/global-research/research-labs/pips/_documents/pips/2011-2012/active_denial_system.pdf

advancements are focused on expanding the use of laser technology for weapon systems, surveillance, and ASCM defense.[31]

The United States Air Force is actively researching and developing various laser technologies to explore their potential for both offensive and defensive operations. The AFRL has conducted war games to showcase how these weapons could be employed to protect U.S. airbases from missile attacks.[32] During the war games, pilots were trained using virtual reality simulations to tackle contemporary warfare challenges, including encounters with DEWs.

- ***Russia***

Since 2010, Russia is actively involved in developing new weapons with potentially disruptive effects i.e., 'weapons based on new physical principles such as radiological, genetic and DEWs.[33] Russia is developing a variety of directed energy weapons to safeguard its use of the Electromagnetic Spectrum (EMS) and to counteract the EMS activities of Western nations and NATO. This involves employing various techniques such as surveillance, jamming, and protective measures. In 2018, President Vladimir Putin highlighted several new technologies that Russia has either developed or about to complete, including laser weapons. He stated that the country has reached significant milestones in laser weapon development, which will be integrated into the military to enhance Russia's overall defense capabilities.[34]

Russia claimed to have deployed laser weapons against a Ukrainian drone in 2022. Deputy Prime Minister Yuri Borisov stated that following the successful use of the Zadira laser weapon in Ukraine, the country is now moving towards mass production of these systems. However, both the US and Ukraine have denied any reports of laser or DEW usage by Russia during the conflict.[35]

One of the land-based systems, Peresvet, is a truck-mounted laser cannon deployed near ICBM bases for protection. While it lacks the power to destroy incoming targets, it can blind or

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[31] "*Navy Lasers, Railgun, and Gun-Launched Guided Projectile: Background and Issues for Congress*," report*(Congressional Research Service, 2022), https://sgp.fas.org/crs/weapons/R44175.pdf

[32] Shelley K. Mesch, "AFRL Wargames Simulation Focuses on Directed, Kinetic Energy Capabilities," *Inside Defense*, February 14, 2022, https://insidedefense.com/daily-news/afrl-wargames-simulation-focuses-directed-kinetic-energy-capabilities

[33] Samuel Bendett et al., "Advanced Military Technology in Russia," *Chatham House*, 2021. https://www.chathamhouse.org/sites/default/files/2021-09/2021-09-23-advanced-military-technology-in-russia-bendett-et-al.pdf

[34] Bart Hendrickx, "Peresvet: a Russian mobile laser system to dazzle enemy satellites," *The Space Review*, June 15, 2020, https://www.thespacereview.com/article/3967/1

[35] Defense News, "Russia claims its Zadira laser weapon destroyed a drone in Ukraine," May 19, 2022, https://www.defensenews.com/global/europe/2022/05/19/russia-claims-its-zadira-laser-weapon-destroyed-a-drone-in-ukraine/

disrupt their optical sensors and is also designed to counter small drones.[36] The main difference between Peresvet and Zadira is that Peresvet can blind or disrupt targets, whereas Zadira has the capability to destroy them. To address future challenges in space, Russia is developing directed energy weapons designed to disrupt and dazzle the optical sensors of surveillance satellites in low Earth orbit. [37]

- ***China***

China is another major player when it comes to the development of DEWs. From the 863 plans,[38] China's Hi-tech innovation and development program, it is evident that China is focusing more on the development of new technologies including DEWs. During the Sino-Indian border clashes in 2020, reports suggest that China employed microwave weapons to incapacitate Indian soldiers. The high-energy electromagnetic radiation caused Indian troops to experience vomiting and loss of stability for about 15 minutes. This temporary disadvantage allowed Chinese forces to capture two strategically significant hilltops.[39]

Furthermore, China has been utilizing DEWs, including its HPM anti-missile system and laser weapons, since 2010. One notable HPM weapon system, which received the National Science and Technology Progress Award in 2017, is portable and capable of disrupting electronic systems. Another microwave weapon, known as Poly WB-1, has broader applications beyond perimeter security and is intended for use by the Chinese Navy.[40]

Portable Laser systems, which can be mounted on vehicles, are designed for crowd control and dispersal by law enforcement agencies. Another truck-mounted laser weapon system, known as Silent Hunter, is specifically designed to target small drones and has an effective range of approximately 200 meters to 4 kilometres.[41] Besides developing new types of DEWs, China is also developing countermeasures to such weapons. In January 2023, China claimed that the military

[36] Hendrickx, "Peresvet: A Russian mobile laser system to dazzle enemy satellites.".
[37] Iain Boyd, "Russians reportedly building a satellite-blinding laser – an expert explains the technology," *The Conversation,* July 26, 2022, https://theconversation.com/russians-reportedly-building-a-satellite-blinding-laser-an-expert-explains-the-technology-186890
[38] "National High-Tech R&D Program (863 Program)," accessed April 13, 2024, https://www.mfa.gov.cn/web/system/index_17321.shtml
[39] Joe Evans, "China uses microwave weapons to blast Indian troops in disputed border region," *The Week,* 17 NOV 2020, https://www.theweek.co.uk/108688/china-deploys-microwave-weapons-against-indian-troops
[40] Andrew Griffin, "China reveals long-range heat ray gun," *The Independent*, December 15, 2014, https://www.independent.co.uk/tech/china-reveals-longrange-heat-ray-gun-9925713.html
[41] Jeff Martin, "Check out What China Brought to One of the World's Largest Defense Exhibitions," *Defense News*, February 17, 2019, https://www.defensenews.com/digital-show-dailies/idex/2019/02/17/check-out-what-china-brought-to-one-of-the-worlds-largest-defense-exhibitions/

has invented a shield meant to protect missiles and other military hardware from being dazzled by laser weapons.[42]

In the context of the technological race with the US, China is making notable advancements in new technologies, including DEWs. The Chinese recognize the potential of DEWs to disrupt enemy satellites in space, drones in the air, and small boats at sea, and have accordingly developed weapons to address these capabilities.[43]

China has also been accused of using microwave weapons against US diplomats in Havana, leading to what is referred to as the "Havana syndrome." The evidence suggesting that microwave weapons can cause harmful effects on humans is undeniable,[44] however, the involvement of China in Havana syndrome is still a mystery.

Development of DEWs in South Asian Context

- ***Indian DEWs Programme***

In March 2022, the Indian Ministry of Defence outlined eighteen key platforms for industry-led design and development. Within the "Make I" categories, DEWs are prioritized second, following hypersonic glide vehicles. India aims to achieve self-reliance in these technologies by engaging the domestic industry.[45]

The Indian Defence Research and Development Organization (DRDO) has indicated its commitment to a national program focused on DEWs. To achieve this, it plans to establish short, medium, and long-term objectives for developing various DEW variants with power levels of up to 100 kilowatts, collaborating with the domestic private sector.[46] The Head of DRDO stated that the world is increasingly shifting towards DEWs due to their importance, and India has also been conducting experiments in this field over the past few years.[47] The DRDO has established two

[42] Stephen Chen, "Chinese military invents smart shield designed to make laser weapons useless," *South China Morning Post*, January 12, 2023. https://www.scmp.com/news/china/science/article/3206540/chinese-military-invents-smart-shield-designed-make-laser-weapons-useless

[43] Anastasios Giannakis, Ethan Wacaster, "Directed Energy Weapons: Recent Developments and Utilization," *The Counter Terrorism Group*, May 31, 2021. https://www.counterterrorismgroup.com/post/executive-summary-directed-energy-weapons-recent-developments-and-utilization.

[44] Etfa Khurshid Mirza, "Microwave Weapons and Impact on Human Beings.".

[45] Press Information Bureau Delhi, "Ministry of Defence identifies 18 major platforms for industry led Design and Development" March 11, 2022, https://www.pib.gov.in/PressReleasePage.aspx?PRID=1805135

[46] Rajeswari Pillai Rajagopalan, "What Are India's Plans for Directed Energy Weapons?," *The Diplomat*, September 24, 2020, https://thediplomat.com/2020/09/what-are-indias-plans-for-directed-energy-weapons/

[47] Rajagopalan, "What Are India's Plans for Directed Energy Weapons?"

laboratories, the Centre for High Energy Systems and Sciences and Laser Science & Technology Centre to work exclusively on DEWs.[48]

As described in previous sections, regarding the claims of Chinese use of microwave weapons during recent tensions with India, the development of DEWs has become a priority for India. The country has already created two anti-drone DEW systems capable of engaging aerial targets at a range of 2 kilometers.[49] One of the systems, the Kilo Ampere Linear Injector (KALI), was developed by DRDO in collaboration with the Bhabha Atomic Research Centre (BARC) to target long-range missiles. The Indian Defense Minister refrained from providing additional details about the weapon system, citing national security concerns, which highlights its strategic importance for India.[50]

According to the 10-year roadmap, the first phase will require the development of 20 tactical HEL systems with a range of 6 to 8 km. In the second phase, the range of these systems will be extended to 20 km, along with the addition of 20 high-power electromagnetic weapon systems that will have a range of 15 km.[51]

- ***Pakistan's DEWs Development***

Given India's ambitious plans to develop eighteen technologies, including DEWs, and their active pursuit of these initiatives, Pakistan feels compelled to respond in this area. Former Chief of Naval Staff Admiral Zafar Mehmood indicated Pakistan's intention to develop DEWs to counter Indian offensive capabilities. He mentioned that laser-based DEWs will be deployed on warships ordered from China. In 2022, Pakistan inducted two Type 054A/P frigates into its navy. These Chinese frigates are capable of operating DEWs, and once they are in service, they will enhance Pakistan's naval capabilities to address future regional challenges.[52] Considering the emerging challenges in the South Asian environment, where India has prioritized DEWs, it is essential for Pakistan to

[48] Rajagopalan, "What Are India's Plans for Directed Energy Weapons?"
[49] Rajat Pandit,"DRDO Plans Star Wars-Style Weapons for Battles of Future," *Times of India,* April 14, 2022, https://timesofindia.indiatimes.com/india/drdo-plans-star-wars-style-weapons-for-battles-of-future/articleshow/78096712.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst%25252C.
[50] The Economic Times, "Government refuses information on KALI 5000 citing national security", Jul 14, 2018. https://economictimes.indiatimes.com/news/defence/government-refuses-information-on-kali-5000-citing-national-security/articleshow/50234073.cms.
[51] The Economic Times, "Government refuses information on KALI 5000 citing national security."
[52] Usman Ansari, "Outgoing Pakistan Navy Chief Reveals Details of Modernization Programs," *Defense News*, October 15, 2020, https://www.defensenews.com/naval/2020/10/14/outgoing-pakistan-navy-chief-reveals-details-of-modernization-programs/.

develop its capabilities in this area to enhance its technological edge, particularly in DEWs. These weapons offer several advantages over kinetic options.

Applications and Implications of DEWs

As discussed earlier, the paper focuses on HPMs and HELs as the two main types of DEWs. HPM primarily utilize radiofrequency (RF) energy, operating with electromagnetic pulse (EMP) peak power measured in the frequency range from megahertz to gigahertz. These microwave-based weapons can disrupt electronic systems by targeting antennas or penetrating through cracks, wires, or metal conduits.[53]

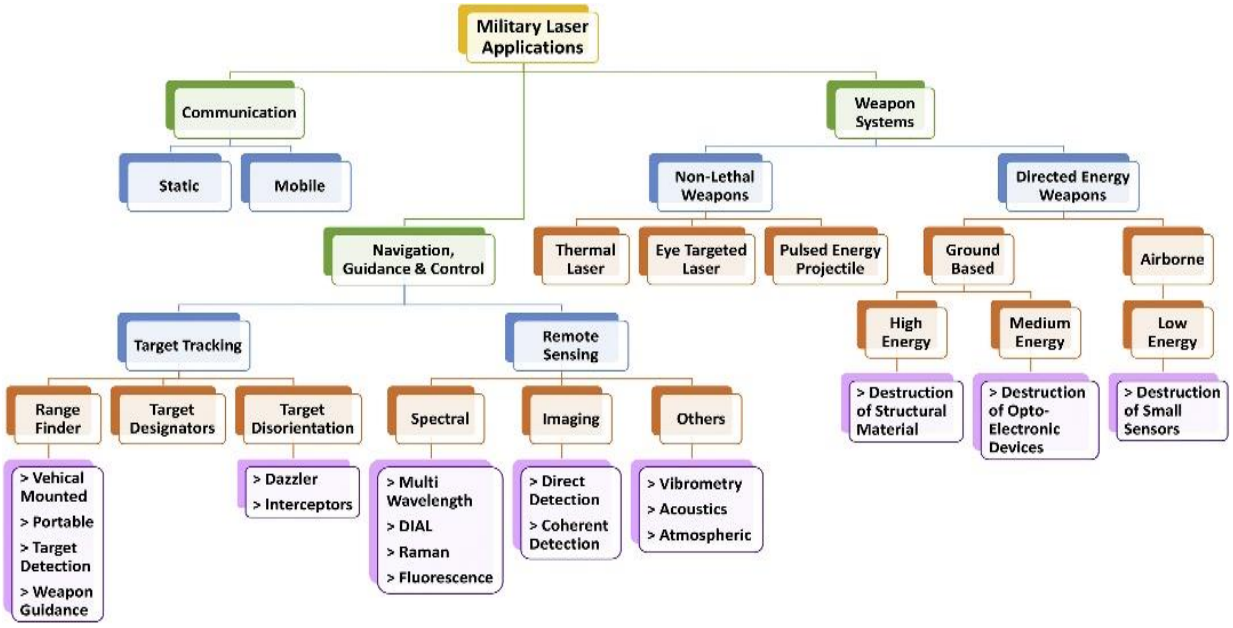
In contrast, HEL generates energy in the form of continuous waves or pulses, varying in power from kilowatts to megawatts. Lasers can effectively cut through various materials, rupture pressurized vessels, and disable or blind sensor and electronic systems.[54] HEL and HPM operate within the electromagnetic spectrum, yet they differ significantly in operation and effect. HEL utilizes light energy and can be deployed from ground or aerial platforms, offering a wide range of military applications.[55]

Laser Communication, also referred to as Free-Space Optics (FSO), plays a critical role in both civilian and military contexts due to its low power consumption, robust signal strength, and reliable transmission capabilities. It facilitates communication links across various domains, including terrestrial, aerial, and maritime environments.[56] Other applications of HELs include employment in the battlefield for safety measures, such as navigation, guidance, and threat detection systems. HELs are also pivotal in remote sensing applications like Light Detection and Ranging (LIDAR), enhancing air force capabilities for precise data collection and damage assessment. These technologies underscore the diverse and vital roles of lasers in modern military operations.

In offensive operations, laser weapons are employed to incapacitate or render targets immobile. They are effective in intercepting aerial threats such as rockets, small drones, aircraft, and cruise missiles. Laser weapons serve dual roles as target designators and range finders, ensuring precise engagement with pinpoint accuracy. One of their key advantages is their ability

[53] John A. Brunderman, "High Power Radio Frequency Weapons: A Potential Counter to U.S. Stealth and Cruise Missile Technology," *Center for Strategy and Technology* (1999), Air War College, https://apps.dtic.mil/sti/tr/pdf/ADA393362.pdf.
[54] Ibid.
[55] Obering, "Directed Energy Weapons Are Real . . . And Disruptive, 10.
[56] Obering, "Directed Energy Weapons Are Real . . . And Disruptive, 10.

to minimize casualties during warfare.[57] Furthermore, they find application in non-lethal crowd control scenarios, where they can temporarily disorient individuals or groups through inflicted pain or induced blindness, effectively managing riots and disturbances.



Military Applications of High-Energy Lasers[58]

HPM find extensive military applications spanning tactical and operational levels. Unlike conventional methods that destroy entire equipment or components, HPMs infiltrate targets through vulnerabilities such as cracks, antennas, wires, metal conduits, or seals. Once inside, they disrupt, damage, or destroy specific parts of the equipment. The effects produced by HPMs vary depending on the amount of energy directed at the target, leading to graduated impacts on electronic systems and equipment. This variability in lethality underscores the versatility and strategic value of HPM technology in military operations.[59]

[57] Ahmed, Mohsin & Ali, "Survey and technological analysis of laser and its defense applications,".
[58] Ahmed, Mohsin & Ali, "Survey and technological analysis of laser and its defense applications,".
[59] Eileen M. Walling, "High Power Microwaves: Strategic and Operational Implications for Warfare", *Center for Strategy and Technology*, no.11(2000): 4 https://apps.dtic.mil/sti/pdfs/ADA425472.pdf

Characteristics of HPM

Serial No.	How HPM Disable Enemy's Potential to Operate the System	Level of Harm to the System	Example	Effect
1	**Deny**	No Harm	Circuit, minor distortions in radio etc.	Temporary; the system may get back to normal when it leaves the area
2	**Degrade**	Minimal Damage,	Electronic hardware systems; malfunctioning power buttons	Temporary; may require minor repairs
3	**Damage**	Moderate	Communication Jamming, distorting signals	Permanent effects; depending on the level of attack
4	**Destroy**	Lethal	Affects the entire System; electrical grids, defence systems	Permanent, replace the entire system

The Author has developed the chart and presented the characteristics of HPM obtained from the cited article in a simplified manner for better understanding.[60]

Implications of DEWs

DEWs by major global powers like the US, China, Russia, as well as regional players such as India and Pakistan, it is crucial to examine the implications of DEWs at various levels of warfare. This examination establishes the rationale behind these nations' substantial investments in DEW technology for military applications.

- ***Operational Effects***

States are increasingly turning to technologies capable of causing significant harm to adversaries without physical impact, with DEWs emerging as viable options for future conflicts. These

[60] Obering, "Directed Energy Weapons Are Real . . . And Disruptive,"

weapons utilize different intensities of light and the electromagnetic spectrum, resulting in a spectrum of effects that can range from lethal to non-lethal. The severity of these effects depends on the intensity and duration of exposure to the weapon.[61]

Once DEWs are operational and deployed, they are poised to play a crucial role during wartime or crisis scenarios by delivering non-kinetic effects. These include penetrating adversary air defense systems, disrupting command and control networks, and incapacitating communication systems. DEWs can also disperse or dazzle enemy troops and engage targets across air, sea, and land domains. As a result, these weapons are anticipated to be employed in anti-access and area-denial operations.[62]

An EMP has the capability to disrupt electrical systems and high-technology microcircuits. Given the increasing dependence of critical civilian infrastructure on electric systems and network-based technology, an EMP device, such as an E-bomb, can significantly impact these systems by denying, degrading, damaging, or even destroying them.[63]

The HELs, renowned for their exceptional precision, serve as potent strike weapons capable of effectively targeting small drones. Their lightweight nature enables deployment across various platforms including mobile, land, air, sea, and space, thereby offering a strategic advantage early in conflicts.[64] Due to their precise targeting capabilities, HELs can function effectively as strike weapons against small drones. Their lightweight design allows them to be deployed on diverse platforms such as mobile units, land vehicles, aircraft, naval vessels, and space assets, providing a strategic edge in the initial stages of conflict.[65]

- ***Strategic Effects***

When it comes to strategic effects, DEWs wield significant strategic effects across modern military operations. One of them is the disruption of adversary's communication systems. For instance, targeting communication satellites has the potential to induce extensive communication blackouts,

[61] Jürgen Altmann, "Millimetre waves, lasers, acoustics for non-lethal weapons? Physics analyses and inferences," *Physics analyses and inferences* 16, (2008), https://www.ssoar.info/ssoar/bitstream/handle/document/26039/ssoar-2008-altmann-millimetre_waves.pdf

[62] Jason D Ellis, "Directed-Energy Weapons: Promise and Prospects," report* (Centre for New American Studies, 2015). https://www.files.ethz.ch/isn/190363/CNAS_Directed_Energy_Weapons_April-2015.pdf

[63] David P. Fidler, "The Meaning of Moscow: 'Non-Lethal' Weapons and International Law in the Early 21st Century," *International Review of the Red Cross* 87, no. 859 (2005): 525–52, https://doi.org/10.1017/S1816383100184371.

[64] Ellis, "Directed-Energy Weapons: Promise and Prospects."

[65] Wheeler and Brehm, "Directed Energy Weapons."

impacting communications and critical infrastructure alike. Similarly, disabling GPS or other navigation satellites could severely disrupt logistical operations, transportation networks, and precision-dependent activities, leading to widespread strategic implications. Furthermore, damaging satellites used for earth observation purposes, such as weather forecasting and disaster response, threatens to undermine crucial decision-making capabilities and resilience efforts in the face of natural disasters and climate events.[66]

DEWs also support anti-access and area denial strategies by neutralizing enemy platforms and defenses, thereby limiting their operational reach and influence in specific regions. With precise targeting capabilities, DEWs can selectively engage critical enemy assets such as drones, missiles, and aircraft while minimizing collateral damage. DEWs can be used to control crowds in non-lethal way. They can be effective in confusing crowds without harming them permanently. With it, they can be useful in strategic signaling, as they can showcase a state readiness and technological advancement inface of emerging threats. Furthermore, they can play role of force multipliers. They can also be used as low-cost solution for emerging threats such as autonomous drones and drone swarm. DEWs technology is likely to matured and their cost as compared to missile and other kinetic weapons will be less. They will also provide precision, flexibility and strategic advantage.

Potential Use of DEWs in South Asian Conflicts

As technology continues to transform warfare in the modern era, the role of emerging disruptive technologies is increasingly vital. With innovation, the strategies for employing these technologies are equally important. In the context of evolving threats in South Asia, particularly between India and Pakistan, how these technologies are utilized in future conflicts will be critical. The nation that can develop superior employment strategies in both offensive and defensive operations will likely gain the upper hand.

Given the prominence of DEWs in contemporary warfare, their potential use in future conflicts is highly probable. Pakistan must prepare for any challenges arising from India's deployment of DEWs. Possible applications of these weapons in the South Asian context include:

[66] "Directed Energy Weapons: Disruptors and Safeguards in the Space Economy", *New Space Economy*, https://newspaceeconomy.ca/2024/03/18/directed-energy-weapons-disruptors-and-safeguards-in-the-space-economy/#:~:text=DEWs%20harness%20focused%20beams%20of,disable%20sensors%2C%20or%20disrupt%20communications.

- First, combining with other weapons systems, DEWs have the potential to Disrupt command, control, and communication (C3) systems. It can interfere with the communication networks that military forces rely on for coordination and operational effectiveness. By disrupting these systems, a military can create confusion, hinder decision-making, and reduce the enemy's situational awareness.
- Furthermore, it can be utilized in targeting air defense systems or their components. DEWs can specifically target the components of air defense systems, such as radars and missiles, rendering them inoperable. For instance, DEWs can significantly multiply India and Pakistan's existing defense capabilities by complementing its advanced missile systems, with precise and scalable energy-based attacks. They can play a role in India's air defense by countering swarm drone threats and intercepting ballistic missiles, thereby strengthening its multi-layered defense network.
- DEWs have the potential to offer Pakistan cost-efficient and rapid-response capabilities to neutralize threats, reducing reliance on traditional kinetic systems. Analyzing the February 2019 Balakot strikes, where Indian fighter aircraft violated Pakistani airspace, highlights that similar incident could occur in the future. Moreover, there have been numerous sightings of small drones and quadcopters used for surveillance along the Line of Control from the Indian side. With DEWs, Pakistan would be capable of precisely targeting any intruding aerial objects, using laser systems to disrupt the electronic components or dazzle the optical systems of these drones.
- By integrating DEWs with its existing nuclear and conventional deterrence architecture, Pakistan can enhance strategic stability and maintain a credible defense posture in South Asia. Moreover, DEWs integrate seamlessly with India's space and cyber capabilities, creating a synergistic effect that boosts overall strategic dominance in the region.
- In addition, DEWs can emit energy that disrupts radar signals, effectively blinding the enemy's surveillance and targeting capabilities. This jamming can prevent detection of friendly forces and enable stealthy movements or surprise attacks.
- Laser-based weapons can be used for highly accurate aerial strikes, minimizing collateral damage. This precision allows military forces to eliminate specific targets while protecting surrounding infrastructure and civilians.

- DEWs can be employed to incapacitate soldiers or deter hostile actions without causing lethal damage. Their use in this context raises ethical considerations, as they may affect civilian populations inadvertently.
- DEWs can effectively target drones, which are increasingly used for surveillance and attacks. By disabling or destroying these systems, military forces can protect their airspace from unwanted intrusions. DEWs can target the electronic systems of enemy military hardware, rendering them inoperable. This capability can cripple an opponent's operational effectiveness by targeting key technologies like communication devices and weapon systems.
- Furthermore, DEWs offer stealth capabilities that can help mitigate threats from incoming missiles and enhance the protection of fighter aircraft. During a crisis, these weapons could defend against swarm drones and unmanned combat aerial vehicles, as well as safeguard forward-deployed troops and infrastructure near the border.
- The situation along the Line of Control remains tense, with frequent ceasefire violations by India resulting in civilian casualties. DEWs could be employed to dazzle Indian soldiers without crossing the border, neutralizing threats while maintaining a strategic advantage. A similar technique was utilized by China during the Sino-Indian standoff in 2020.

Options for Pakistan

Considering India's ambitions in space, the potential deployment of DEWs on space-based platforms to target long-range missiles poses a significant risk to Pakistan's critical infrastructure. If India achieves this capability, Pakistan's vulnerable assets could be exposed to laser attacks, which could inflict damage on soft targets, including electronic systems and personnel. Therefore, Pakistan must implement measures to protect these soft targets.

- To counter the effects of laser weapons with electro-optical capabilities, several defensive strategies can be considered: Using artillery or mortars to suppress known or suspected DEW locations. Smoke rounds can also effectively obscure laser devices.
- Minimizing or blocking the exposure of glass surfaces to enemy lines of sight by placing them in covered positions or using smoke to reduce effectiveness. Equipment with glass components should be kept shielded until needed. Limiting the number of soldiers in vulnerable areas can decrease the likelihood of injury, and employing night vision goggles

during night operations can further protect against harm. Covering optical lenses with tubular extensions can help mitigate vulnerability.

- Defending against EMP attacks poses a significant challenge, as they can cause varying degrees of damage depending on proximity to the source and exposure levels. Such attacks may last only seconds but can impact large areas, resulting in irreparable damage to unprotected systems. The best defense against EMP attacks is to store equipment within metallic shields, as other measures, like sandbags or terrain masking, may prove ineffective.
- Pakistan must consider these emerging threats related to DEWs in its policymaking and force structuring to avoid being unprepared on the battlefield. Because DEWs are difficult to intercept or detect, their use by either side may not be immediately identifiable, allowing for the disruption of electronic components or sensors without total destruction of the equipment.

Conclusion

In light of emerging challenges, nations are increasingly investing in advanced technologies to enhance their military capabilities and secure a strategic advantage at the onset of conflict. The demand for non-kinetic weapons, particularly DEWs, is on the rise due to their precision, cost-effectiveness, portability, operational flexibility, and resilience against interception. As these weapons become operational, they are expected to counter leading offensive technologies, driving major powers like the U.S., Russia, and China to develop robust DEW programs. These weapons can significantly enhance the capabilities of existing defensive and offensive systems and can play role of force multiplier. In the context of Indo-Pak tensions, the potential for future conflicts may see the deployment of DEWs, particularly following India's military modernization efforts and its recent experiences with the Chinese DEW use. This underlines the urgency for Pakistan to enhance its research and development in DEWs to effectively counter any Indian advancements. By doing so, Pakistan can maintain strategic equilibrium in the region, ensuring it is well-prepared to respond to any threats that arise from the evolving landscape of modern warfare.