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INDIA'S DEFENCE INNOVATION: POWERING SELF-RELIANCE WITH LASER WEAPONS

WHY IN THE NEWS?

India made headlines on April 13, 2025, with the successful demonstration of the indigenously developed Mk-II(A) Laser-Directed Energy Weapon (DEW) system by the Defence Research and Development Organisation (DRDO). Conducted at the National Open Air Range in Kurnool, Andhra Pradesh, the trial showcased India's advanced capabilities in non-kinetic warfare by neutralising multiple aerial threats, including fixed-wing drones and surveillance equipment, with lightning-speed precision. With this achievement, India joins an elite group of nations possessing high-power Laser-DEW systems, marking a significant milestone in its pursuit of self-reliance under the Atmanirbhar Bharat mission. The development strengthens India's defence preparedness in the era of modern asymmetric and non-contact warfare.

WHAT IS LASER?

A laser is a device that emits light through a process called stimulated emission of radiation, producing a highly focused and coherent beam of light. The term "laser" is an acronym for Light Amplification by Stimulated Emission of Radiation. Lasers generate powerful, focused beams that are monochromatic (single-wavelength), collimated (travel in a parallel direction), and coherent (waves in phase).

WHAT IS LASER WEAPON TECHNOLOGY?

General Atomics Electromagnetic Systems (GA-EMS) is at the forefront of developing next-generation electric weapon systems, especially High Energy Laser (HEL) systems, designed for multi-domain deployment – land, air, and sea.

High Energy Laser (HEL) Weapon System

The advanced solid-state HEL weapon system provides proven laser technologies to enable the detection and defeat of an expanding range of targets, including unmanned aerial systems (UAS), missile threats, ISR systems, rockets, artillery, and mortars. The HEL's modular and scalable nature allows simple power scaling to increase the total laser output power. The system's large optical aperture and efficient cooling offer significant reductions in size and weight to suit air, land and sea-based platforms.

1. 25 kW-class laser scalable to 300 kw and larger

2. Pulsed and continuous wave systems
3. Proven technology for high-energy solid-state laser systems
4. Designed for all warfighting environments
5. Extended target engagement ranges

Adaptive Optics

When a laser beam is propagated a long distance through the atmosphere, it becomes distorted. For high-energy laser weapons, this reduces the effective kill range of the weapon. Backed with cutting-edge advancements in Adaptive Optics technology, GA-EMS mitigates these distortions, making the HEL a more effective end-to-end weapon system.

1. HEL beam quality enhancement and atmospheric turbulence mitigation
2. Phased array beam control and distributed aperture tracking
3. Coherent imaging for target identification and characterization
4. Optical weather modelling and forecasting

KEY FEATURES OF LASER

- 1. High Intensity:** Lasers deliver extremely concentrated energy in a small area. Enabled by stimulated emission, where light photons are amplified within the laser cavity. Useful in metal cutting, surgery, and weapon systems.
- 2. Directionality (Collimation):** Laser beams are highly collimated—they travel as a narrow, focused beam with minimal divergence. This allows the beam to stay sharp even over long distances. Crucial in targeting systems, laser communication, and astronomy.
- 3. Coherence:** Laser light is coherent, meaning all light waves are in phase (aligned peaks and troughs). Enables interference patterns, precise holography, and optical measurements.
- 4. Monochromaticity:** Lasers emit light of a single wavelength (colour). This narrow spectral purity makes lasers ideal for spectroscopy, fibre-optic communication, and barcode scanning.
- 5. Precision and Focusability:** Due to coherence and collimation, laser beams can be focused to a pinpoint for delicate operations. Widely used in eye surgeries, microelectronics, and material processing.
- 6. Non-Contact Operation:** Lasers do not require physical contact with the target. Ideal for remote sensing, laser engraving, cutting, and defence applications like Directed Energy Weapons (DEWS).
- 7. Energy Efficiency and Reusability:** Many modern lasers are energy-efficient and require minimal maintenance. Solid-state and semiconductor lasers are increasingly used for their durability and compactness.
- 8. Wide Range of Applications:** Medicine (surgery, diagnostics), Defence (targeting, counter-drone systems), Telecommunications (fibre optics), Manufacturing (cutting, welding, 3d printing), Research and Space Technology

SIGNIFICANCE OF LASER WEAPON TECHNOLOGY

- 1. Precision and Accuracy:** Lasers are renowned for their ability to focus on specific targets with high accuracy, minimising collateral damage, especially in urban or sensitive areas.
- 2. Speed and Response Time:** Laser weapons can engage targets at the speed of light, making them effective against fast-moving threats like drones and missiles, according to HowStuffWorks.
- 3. Countering Emerging Threats:** Laser weapons are particularly valuable in countering threats like swarm drones and other emerging aerial and ground-based hazards, according to Idrow.org.
- 4. Cost-Effectiveness:** Lasers offer a potentially more cost-effective alternative to traditional munitions, as they can be fired repeatedly without needing to be reloaded, according to EurAsian Times.
- 5. Reduced Environmental Impact:** Compared to traditional weapons, laser weapons produce less pollution and have a smaller environmental footprint.

6. Versatility: Laser systems can be adapted for various platforms, including ground-based, shipborne, and even aircraft-based applications, according to the Times of India.

7. Enhanced Military Readiness: The ability to rapidly deploy and utilise laser weapons across different domains strengthens military readiness and enhances defence capabilities, according to EurAsian Times.

8. Stealth Advantage: Lasers are stealthy, as their presence is only revealed through target damage, making them useful in certain tactical scenarios.

CONCLUSION

The successful demonstration of the indigenously developed Mk-II(A) Laser-Directed Energy Weapon (DEW) system by DRDO marks a pivotal moment in India's defence advancement and self-reliance goals. Laser weapon technology, with its high precision, rapid response, and cost-effectiveness, represents the future of modern warfare, especially in dealing with asymmetric and non-contact threats like drones, missiles, and surveillance systems. As India joins the elite group of nations possessing high-power laser systems, it not only boosts its strategic deterrence but also showcases the country's growing prowess in cutting-edge defence R&D. Moving forward, the deployment of laser-based systems across land, sea, air, and space platforms will play a vital role in shaping India's 21st-century security architecture.

PRELIMS QUESTIONS

Q. With reference to Laser-Directed Energy Weapons (DEWs), consider the following statements:

1. Laser-DEWS are kinetic weapons that destroy targets through physical impact.
2. They use monochromatic, coherent, and collimated beams of light to neutralise threats.
3. India recently tested an indigenous Laser-DEW system with anti-drone capabilities.

Which of the statements given above is/are correct?

- (a) 1 and 2 only
- (b) 2 and 3 only
- (c) 1 and 3 only
- (d) 1, 2 and 3

Answer: B

MAINS QUESTIONS

Q. Discuss the significance of laser weapon technology for India's defence preparedness, along with its advantages and challenges.

(250 words, 15 marks)

6G NETWORK: THE NEXT FRONTIER IN WIRELESS COMMUNICATION

WHY IN THE NEWS?

India is making significant strides in the development of 6G technology. The government has released the "Bharat 6G Vision" document, aiming to position India as a leading contributor in the design, development, and deployment of 6G technologies by 2030. This initiative is part of a broader effort to enhance digital infrastructure and ensure technological leadership in the next generation of wireless communication. Additionally, the launch of over 100 5G labs across the country is expected to foster innovation and prepare

the groundwork for a seamless transition to 6G. With global competitors accelerating their 6G roadmaps, India’s early push is both strategic and timely.

WHAT IS 6G?

6G, or sixth-generation wireless technology, is the successor to 5G. It is expected to offer significantly higher data rates, ultra-low latency, and enhanced reliability. 6G aims to integrate advanced technologies such as artificial intelligence (AI), machine learning, and the Internet of Things (IoT) to provide seamless connectivity and support a wide range of applications, from immersive virtual reality experiences to autonomous vehicles. It will leverage higher frequency bands, including terahertz waves, to achieve these performance benchmarks. The technology is also expected to enable real-time digital interactions, paving the way for smart cities, precision healthcare, and advanced robotics.

FEATURES OF 6G

- 1. Ultra-High Data Rates:** Expected to reach up to 1 Tbps, enabling faster downloads and real-time data processing. This will allow for instantaneous communication across multiple platforms simultaneously. For example, high-resolution 3D holograms could be transmitted in real-time without lag.
- 2. Ultra-Low Latency:** Targeting latency as low as 1 microsecond, facilitating instantaneous communication. This will benefit time-sensitive applications like remote surgeries and industrial automation. Gaming and VR/AR applications will become highly immersive and seamless.
- 3. Enhanced Connectivity:** Supporting a massive number of connected devices per square kilometer, crucial for IoT expansion. 6G networks will accommodate the exponential growth of smart devices in homes and industries. For instance, smart cities could manage traffic, pollution, and energy use in real-time.
- 4. Advanced AI Integration:** Incorporating AI for network optimization, predictive maintenance, and efficient resource management. AI will play a key role in automating and personalizing user experiences. AI-based decision-making in network management could reduce human intervention and errors.
- 5. Energy Efficiency:** Focusing on sustainable and energy-efficient network operations. Green technologies and power-efficient hardware will be at the core of 6G development. Dynamic power control and energy harvesting methods are being explored to minimize carbon footprint.

COMPARISON: 4G VS. 5G VS. 6G

Feature	4G LTE	5G NR	6G (Projected)
Peak Data Rate	1 Gbps	10 Gbps	1 Tbps
Latency	~50 ms	~1 ms	~1 µs
Bandwidth	Up to 20 MHz	Up to 100 MHz	Up to 1 GHz
Frequency Bands	2-8 GHz	24-86 GHz	95 GHz–3 THz
Use Cases	Mobile internet	IoT, AR/VR	AI, holography
Deployment Year	2010s	2020s	2030s

The evolution from 4G to 6G represents a leap not only in speed but also in network intelligence and capability. 6G is designed to support future innovations that current networks are not equipped to handle

GOVERNMENT POLICIES AND GLOBAL INITIATIVE

1. Bharat 6G Vision: A strategic roadmap to develop and deploy 6G technologies by 2030, focusing on affordability, sustainability, and ubiquity. This vision also includes enabling indigenous technology and promoting domestic manufacturing.

2. 6G Testbeds: Establishment of advanced research facilities to foster innovation in 6G technologies. These testbeds aim to simulate real-world conditions and accelerate product development.

3. Collaborations: Partnerships with global research institutions and industry leaders to align with international standards. These alliances will ensure that India's 6G advancements are in harmony with global frameworks.

4. National 6G Mission: Launched to spearhead the technological roadmap and provide funding for 6G R&D. It brings together academia, startups, and major industry players to create an ecosystem of innovation.

5. PM-WANI Scheme Integration: Exploring how public Wi-Fi under PM-WANI can be upgraded for future 6G connectivity in rural and underserved areas, thereby ensuring inclusive growth.

6. 6G Academic Support Programs: Indian Institutes of Technology (IITs) and other research bodies are receiving increased grants to conduct applied research in AI, edge computing, and terahertz communications.

7. International Forums and Leadership: India is actively participating in international forums like ITU and 6G Global Summit to ensure its interests are represented in the global 6G standards-making process.

Global Efforts:

1. United States: Investing in research and development to maintain technological leadership in 6G. Federal programs are supporting innovation hubs and public-private research partnerships. The Next G Alliance, a coalition of private and academic entities, is shaping the future of North American 6G roadmap.

2. China: Conducting extensive research and trials to pioneer 6G technologies. It aims to deploy 6G by the early 2030s and dominate the global telecom market. China launched the world's first 6G test satellite in 2020 and has been leading patent applications in 6G.

3. European Union: Initiating projects like Hexa-X to explore 6G use cases and develop a unified framework. EU efforts emphasize sustainability and interoperability across member nations. Horizon Europe, the EU's key funding program for research, supports cross-border 6G collaborations.

4. South Korea: Announced a 6G roadmap targeting commercial launch by 2028, focusing on smart cities and digital twins. Korea is investing over \$190 million in 6G R&D and has begun working on core technologies like terahertz antennas.

5. Japan: Promoting 6G development through initiatives led by NICT and major telecom firms. Japan's "Beyond 5G" strategy includes \$450 million funding for next-gen wireless infrastructure and global partnerships.

6. International Collaboration: Multiple countries are aligning efforts via global forums like ITU and 6G Flagship to ensure harmonization of standards and accelerate innovation across borders.

CHALLENGES IN IMPLEMENTATION

1. Spectrum Allocation: Identifying and regulating new frequency bands, especially in the terahertz range, for 6G deployment. These frequencies require new hardware and regulatory frameworks.

2. Infrastructure Development: Building a dense network of base stations and integrating advanced technologies into existing systems. It also demands heavy investments in fiber-optic and cloud infrastructure.

- 3. Energy Consumption:** Ensuring energy-efficient operations to support the massive data processing requirements. The use of renewable energy and energy-harvesting technologies will be crucial.
- 4. Security and Privacy:** Addressing potential vulnerabilities and ensuring robust cybersecurity measures. With increased connectivity comes a higher risk of cyber threats and data breaches.
- 5. Standardization:** Achieving global consensus on 6G standards to ensure interoperability and seamless integration. A unified standard is essential for global adoption and mass deployment.

WAY FORWARD

- 1. Research and Development:** Continued investment in R&D to innovate and overcome technical challenges. This includes funding for academia, startups, and incubators working on futuristic tech. There is also a need for establishing innovation hubs focused specifically on 6G applications. Long-term funding cycles and international academic exchanges can enhance the scope and quality of research. Stronger IP frameworks and cross-border tech transfer agreements can further stimulate innovation.
- 2. Policy Framework:** Developing comprehensive policies to facilitate spectrum management, infrastructure development, and international collaboration. Clear and adaptive policies will streamline implementation. Incentivizing domestic manufacturing of 6G components and creating regulatory sandboxes can also support agile policy testing and iteration. Encouraging open-source collaboration and aligning national standards with international norms can prevent fragmentation.
- 3. Public-Private Partnerships:** Encouraging collaboration between government bodies, academia, and industry stakeholders to drive innovation. These partnerships can reduce the financial burden and expedite technological readiness. Examples include government-backed consortiums for 6G innovation and shared infrastructure ventures among telecom providers. PPPs can also be used to extend coverage to remote areas and ensure inclusive technology access.
- 4. Skill Development:** Fostering a skilled workforce equipped to handle the complexities of 6G technologies. Educational institutions need to update curricula to include 6G-related competencies. National-level reskilling programs and global fellowships can be launched to ensure talent availability and global exposure. Online learning platforms could also play a significant role in democratizing 6G education. Public coding bootcamps, industry mentorships, and certification programs can further bridge the talent gap.
- 5. International Collaboration and Standardization:** Strengthening bilateral and multilateral collaborations with countries leading in 6G R&D. Participation in global 6G forums ensures India's voice in shaping standards and policies. Developing open standards in coordination with international bodies like ITU and ETSI can help ensure interoperability. Hosting international 6G summits and joint research programs can enhance global presence and influence.
- 6. Inclusion and Accessibility:** Ensuring that the benefits of 6G reach all segments of society. Developing low-cost 6G-enabled devices and services for underserved regions is essential. Focus on bridging the digital divide through subsidized infrastructure and digital literacy programs. Integrating 6G in public service delivery, such as education and healthcare, can promote inclusive growth.

CONCLUSION

6G represents a significant leap in wireless communication, promising unprecedented speed, connectivity, and integration of advanced technologies. While challenges exist, strategic planning, investment in research, and international collaboration can pave the way for successful implementation. India's proactive approach through the Bharat 6G Vision positions it to be a key player in shaping the future of global telecommunications. As nations race toward 6G, inclusive and equitable deployment will be key to ensuring technology benefits reach every corner of society.

PRELIMS QUESTIONS

Q. The “Bharat 6G Vision” document primarily aims to:

- (a) Launch commercial 6G services by 2025
- (b) Promote foreign telecom investment
- (c) Position India as a leader in 6G technology by 2030
- (d) Subsidize 5G smartphones

Answer: C

MAINS QUESTIONS

Q. Discuss the potential of 6G technology in transforming India’s digital infrastructure. In your view, what should be the key focus areas in India’s roadmap toward 6G deployment?

(250 words, 15marks)

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