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Perspective Article

Laser Weapons on the March in China

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Introduction

As a preamble, Chinese President Xi Jinping, at a meeting with delegates of the People's Liberation Army of China (PLA) during the last session of the National People's Congress (NPC), demanded the introduction of scientific discoveries and innovative technologies in the army. Xi Jinping noted that new technologies are the key to modernizing the Armed Forces. The Chinese leader discussed with the military ways to achieve the goals set in the field of state defense and army construction, and the implementation of the 13th five-year plan for the development of the armed forces. Laser Weapons (LW) have become a key priority in China's defense agenda. Chinese scientists and technologists have been thinking and working on the LW problem for a long time. Since the 1970s, industry and the military have laid the groundwork for seriously figuring out how to achieve practical power levels, how to control the beam, and how to deliver laser radiation over significant distances. The Ministry of Defense officially recognized lasers as a likely weapon of the future back in that century, marking the beginning of official research and development. China, following the United States, Japan, Germany, France, and Britain, plans to equip the country's fighter aircraft with light and compact laser systems for aircraft. Two tender announcements for the development of suitable equipment and software were posted on the official PLA procurement website. According to the terms of the first tender announced by the PLA, applicants for the contract must develop an outboard aircraft container for LW. The second tender included requirements for the creation of software for managing this LO. The combat laser must protect PLA Air Force aircraft from enemy missiles and engage a range of targets, including airborne, ground, and surface threats. The Chinese military plans to receive a universal laser module, which in the future will be able to become a tactical naval, land-based and air-based missile defense system. The air defense will be able to intercept incoming missiles and engage and neutralize enemy aircraft during aerial combat. The significant advantages of LW systems over missiles and firearms make them indispensable tools for aerial combat. Aviation LW will be able to provide not only protection from missile attacks from the ground and from the air, but also air superiority for Chinese aviation during aerial engagements.

Over the past few years, China has been very actively engaged in the development of LW. At the Airshow China 2018 in Zhuhai, the China Aerospace Science and Technology Corporation (CASIC) demonstrated the LW-30 self-propelled laser combat system designed to protect facilities from unmanned aerial vehicles, light aircraft and helicopters. The 30 kilowatt laser installed on the LW-30 is capable of hitting targets at a range of up to 25 kilometers in functional mode. The installation has reportedly been adopted by the PLA. Simultaneously, China Central Television showcased a new development, the LW mobile installation. Although the technical specifications were not disclosed, a local source indicates that the system is designed to instantly destroy targets near the coastline, and its main targets will be small boats and unmanned aerial vehicles. When installed on aircraft, this missile defense system could potentially intercept incoming missile attacks and provide superiority in close-range aerial engagements, the Global Times said in a statement. Chinese media noted that the created LW module is tactical. If it were a laser designator for targeting smart bombs, then it would be called a laser targeting module. A Chinese television program recently also claimed that China has already developed a prototype of a 100-kilowatt aircraft LW. It pointed to a document entitled "A study of energy storage and a power source for airborne weapons", prepared by the AVIC State Institute of Production Technologies and the Military Representative Office of Special Equipment of the PLA Missile Forces. It is important to note here that many other countries are working on the problem of creating missile defense. For instance, Russia recently announced that a next-generation

fighter jet could be armed with a missile defense system, and a project announced by the United States called the "Self-protection High Energy Laser Demonstrator" would consist of a laser, a power and cooling unit, and a beam control system to focus the missile defense system on a target. In February, at the International Defense Exhibition and Conference in the United Arab Emirates, China demonstrated its Silent Hunter laser system, which is capable of disabling vehicle engines at a distance of one mile and has a power of up to 70 kW. This information raises a reasonable question, what is in China's arsenal in the field of law, if they openly show such complexes at international exhibitions. For comparison, the current LW complex on the American ship "Ponce" has a capacity of 33 kilowatts. Earlier, China presented at the exhibition in South Africa and another ground-based mobile complex "Low Altitude Guard II" based on a conventional military truck and with a 30kW laser installation for destroying drones and helicopters. Recently, foreign and Russian media have again begun quoting material from the Chinese Optics magazine, where leading Chinese scientists in the field of military lasers proposed putting a five-ton chemical laser into orbit by 2023, which would disable US satellites. The same scientists said that back in 2005, China conducted successful tests to disable its own orbiting satellites using a ground-based laser with a power of up to 100 kW. For the Chinese army, air-launched lasers are more than a potentially useful weapon for destroying enemy aircraft or protecting their aircraft from anti-aircraft missiles. LW can also be a key component of ballistic missile defense. Chinese media acknowledge the difficulty of creating LW air complexes. "This type of weapon has not yet become widespread due to the remaining technical difficulties, including problems with power sources and insufficient power output of the lasers themselves due to their large weights and dimensions." A striking example of how an on-board laser does not need to be developed for China is the test bench for on-board lasers "YAL" of the US Missile Defense Agency. This ambitious attempt to turn a Boeing 747 airliner into a flying LW has ended in failure. Armed with a giant chemical laser powered by an environmentally hazardous working fluid, the YAL was designed to destroy ballistic missiles. However, it turned out to be so expensive and the tactical ranges so short that then-Secretary of Defense Robert Gates abandoned the project in 2009. However, the YAL concept originated in the 1980s, alongside ambitious initiatives such as Ronald Reagan's 'Star Wars' missile defense program. Currently, Chinese military efforts focus on a more compact and more practical air defense system that can be mounted on a land or sea vehicle, as well as on a suspension carried by an airplane. According to the Chinese military, the tactical air defense based on modern solid-state technology is approaching its final reasonable appearance. Currently, the leadership of the PLA Armed Forces is actively exploring how to integrate laser systems into existing weapons systems. Although lasers have existed nearly as long as rocket technology, it takes a sufficient amount of time for modern armed forces to deploy nuclear weapons effectively. The problem in previous years was that these laser systems were too bulky and heavy. They were physically too large to be used effectively for tactical purposes, or on a truck, or in an airplane, or even on a ship, without taking up large carrier spaces. Naturally, certain limitations exist regarding the compatibility of systems with different delivery platforms. Not all media can support 100 kW - 150 kW class systems. Since solid-state lasers are powered by electricity, they can function continuously until energy depletion. Solid-state lasers can effectively track and engage fast-moving targets with high precision and offer the necessary variability that can be used for various types of impacts, from simply observing targets to causing serious or unacceptable damage [1-6].

From laser monsters to compactness

Contemporary threats make high-energy defense systems more practical than during earlier periods in the days of creating laser monsters based on gas-dynamic, electric discharge, chemical and alkaline vapor bases. Currently, the Chinese Ministry of Defense and other advanced militaries are ordering high-energy defense systems for field testing in order to determine the most effective designs of complexes and ways to protect against high-tech enemy objects of military equipment. Modern solid-state missile defense systems should be capable of tracking, striking, and neutralizing a target in order to completely neutralize it. The systems now possess tactically viable size, weight, and power characteristics. Earlier, integration of these systems with existing weapons was ineffective. But three key components of LW complexes have evolved. First, the development of fiber and disk laser technologies has allowed the systems to be "most efficient at converting electricity into a high-power beam, which means that the weights and dimensions of power supply and heat exchange systems are minimized because efficiency is high. Secondly, the beam has improved in terms of uniformity in the beam cross-section and its divergence. Thirdly, the commercial industrial base is now becoming much cheaper and is able to provide many of the basic components of the LW complexes faster. China, similar to other countries with advanced laser technologies, is developing strategies of combining the output power of a large number of individual lasers instead of trying to create a single beam by a larger size disk active media. However, this approach is suitable for creating modern tactical air defense systems with an output power of 500 kW, which is determined by the physical and technical limitations of the technology used.

The impact of the market on the development of technology in China

Commercial laser technologies have significantly influenced the development and powerful acceleration of military law technology. Fiber optics have been extensively utilized in communication systems, and a wide range of fiber laser-based machines have made it possible to produce

industrial cutting, welding and drilling much more efficiently. To create smart phones and other small electronic devices, very high-quality fiber "scalpels" were required, allowing the laser beam to be focused very precisely and in extremely small sizes. The development of fiber lasers for defense purposes led in turn to the development of the idea of combining the radiation of individual fiber lasers with each other using highly efficient spectral elements. In addition to precise beam focusing, LW systems must enable effective long-distance radiation propagation. Therefore, the creation of optical telescopes based on silicon carbide, not only for laser physics, should be considered another positive outcome of the LW technology. The advancement of high-quality fiber production technologies for communication purposes has been important for a wide range of technologies. The manufacture of a large range of fibers, the purity of the material, the technique of alloying fiber with rare earth elements, the creation of waveguides and the ability to pull fibers of large sizes and high quality - all this has been successfully developed by the industry of developed countries, and hence China, which appeared to the world as a huge technological platform with cheap labor.. The technology of producing semiconductor rulers and arrays of laser diodes for pumping lasers is also the essence of military lasers. As for industrial laser cutting and welding, these laser applications use highly efficient electrical circuits, power switching circuits, and the fiber itself, which is capable of withstanding high power density. As for tracking targets using GPS, it requires fast and simultaneous processing of video information from several high-speed cameras. These fast-processing technologies are based on developments widely utilized in the video game industry. Using all these high-speed gaming processors capable of rapidly processing incoming data and supporting visualization algorithms, it enables the execution of algorithms developed in the interests of creating truly effective LW systems. Simultaneously, advancements in civilian sectors reciprocally influence defense laser technology. Advances in Artificial Intelligence (AI) through the gaming industry and machine learning technologies, which already help in the development of target search algorithms, significantly enhance targeting accuracy. At the same time, the rapid development of high-energy electric vehicles can benefit from the modern electric vehicle market. Energy storage processes at high power, the processes of controlling the temperature regime of circuit elements, the important ability to efficiently transfer high power to the radiator, and therefore cable and electrical connection technologies, switching circuits, and other energy redistribution technologies in the engine are common to electric power and electric vehicle technologies. On the other hand, lasers are widely used in many industries, and their market covers the defense, industrial and medical sectors. Gas lasers, traditional solid-state lasers, electric discharge lasers, and excimer lasers are employed in major industries, including materials processing and automotive manufacturing. Currently, lasers with significantly lower power are playing an increasingly important role in the development of many new technologies, including targeting ammunition, communications, surgical and diagnostic applications. Thus, China's rapidly expanding market forms a critical foundation not only for economic prosperity, but also for the rapid growth of defense technologies and, in particular, the improvement of LW.

What does China and the world expect tomorrow?

Recent global discourse has emphasized the need to enhance the power output of LW systems. The world's current power level of compact and lightweight solid-state fiber laser systems does not exceed 300 kW. The fundamental competitor to the fiber laser is a disk laser, a single module of which has already reached an output power level of 50 kW - 75 kW. In China, both laser designs are actively being developed, and their element base is also developing. China has long been a supplier to the global market of a wide range of components for solid-state laser systems and beyond. Chinese scientists and technologists recognize that the future of defense technologies lies in compact, lightweight, and reliable solid-state systems for the development of a new class of technologies and the creation of the entire line of tactical and strategic missile defense systems. As the output power of such equipment increases in the world, the trade of low-power laser equipment, by analogy with laser metalworking machines, will become more possible and economically efficient. Therefore, we should expect a further increase in the output power of technological laser equipment and control systems manufactured in China, which integrate cutting-edge Artificial Intelligence (AI) technologies that control them.

The high-energy laser market

According to SIPRI, the global high-energy laser market will reach $14.74 billion by 2026, representing an average growth rate of 12.4% from 2021 to 2026. This industry was significantly impacted by the COVID-19 pandemic. Currently, the market is recovering in response to renewed demand for laser systems and laser processing equipment: High-energy lasers play an increasingly crucial role in modern technological applications in manufacturing, communications, and defense. Amid growing defense budgets and research grants, militaries, including that of China, are introducing high-energy laser equipment and investing heavily in research and development. For example, In May 2021, the U.S. Army initiated testing of a prototype short-range air defense system; this sample is a 50 kW radar connected to the Stryker A1 vehicle, which can detect, detect, track and destroy aerial threats. Countries with substantial military budgets are actively developing and implementing laser technologies. According to the Stockholm International Peace Research Institute ("SIPRI" since 1966 provides data, analysis and recommendations for armed conflict, military expenditure and arms trade as well as disarmament and arms control), global defense spending has reached a record high of $1.98 trillion. In 2020,

an increase of 2.6% compared to the previous year. Defense developments, including laser technology, are expected to pave the way for new technologies and modernization. China's defense industry, like that of other countries, provides a significant share of R&D and laser technology applications. The proliferation of unmanned aerial vehicles (UAVs) in the defense sector has significantly increased demand for laser-based defense solutions. For example, in March 2021, the European missile manufacturer MBDA (UK) and the French firm CILAS (France) agreed to cooperate with a specialist in electronic warfare and intelligence to explore the possibilities of jointly developing high-energy missile defense systems for the destruction of unmanned aerial vehicles. Projections indicate that, in the coming years the number of such associations in the military sphere will increase. The use of high-energy lasers in missile defense systems is expected to expand, including in China, as major global defense contractors increasingly deploy and invest in these solutions in developing such solutions. In March 2021, the Israeli Ministry of Defense expressed interest by requesting U.S. funding and expertise for its air defense and missile defense lasers. Israel's current LW prototypes have achieved an output radiation of almost 100 kW, while The United States has developed prototypes of 300-kW LW systems capable of destroying cruise missiles. The demand for air defense systems in naval forces around the world is growing rapidly to combat aerial threats such as missiles and unmanned aerial vehicles. LW has proven its effectiveness against missiles and is used as the first line of the HVAC security network. For example, a high-energy LW complex with an integrated blinding system and a Lockheed Martin HELIOS surveillance system is planned to be placed on board the DDG Flight IIA destroyer Arleigh Burke in 2021. The US Navy has officially accepted the LW complex into the Aegis combat system. Additionally, laser weapon systems are being tested for their effectiveness in disabling unmanned aerial vehicles by integrating such weapons aboard naval vessels. For example, in May 2020, the USS Portland successfully disabled an uncontrolled aircraft during a test of a new high-energy propulsion system. Northrop Grumman developed the system, and the test was conducted after the incident with the Chinese destroyer, where a US Navy P-8A Poseidon patrol aircraft fired a weapon-grade laser. Additionally, numerous countries are actively expanding their naval defense capabilities to deter and neutralize possible enemy threats. China is among the countries that intend to fight for their security, and therefore for parity in the field of creating modern law. The PLA Navy has tested its tactical laser system, which, according to foreign experts, bears a striking resemblance to the samples of the US Navy, which today are approaching achieving absolute accuracy of hitting targets at the already achieved power level.

Ethical, legal, and humanitarian considerations in the deployment of laser weapon systems

The advancement of Laser Weapon (LW) systems presents not only technological and strategic opportunities but also significant ethical, legal, and humanitarian challenges. The potential deployment of high-energy laser systems raises concerns regarding collateral damage, proportionality in the use of force, and adherence to international treaties governing the conduct of armed conflict.

One major ethical concern involves the principle of distinction under international humanitarian law, which obliges armed forces to differentiate between combatants and civilians. The deployment of powerful laser systems, especially in densely populated or urban environments, increases the risk of unintended harm to civilians and civilian infrastructure. While the precision targeting capabilities of LW systems may theoretically reduce such risks, operational errors, power miscalculations, or system failures could lead to violations of humanitarian norms.

In addition, the principle of proportionality, which prohibits attacks causing excessive civilian damage relative to the anticipated military advantage, must be carefully considered. High-energy laser weapons, capable of inflicting catastrophic localized damage, necessitate strict operational guidelines and command oversight to ensure compliance with these standards.

From a legal perspective, the use of certain types of laser weapons is restricted under international agreements. The Protocol IV of the 1980 Convention on Certain Conventional Weapons (CCW) prohibits the use of laser weapons specifically designed to cause permanent blindness. Although current Chinese developments focus on anti-aircraft, anti-missile, and anti-drone applications, future enhancements must remain compliant with these regulations to avoid legal violations and international condemnation.

Furthermore, the prospect of space-based or high-orbit laser systems targeting satellites raises questions under the Outer Space Treaty (1967), which mandates the peaceful use of outer space and prohibits the placement of weapons of mass destruction in orbit. While high-energy lasers may not meet the traditional definition of WMDs, their deployment in space could spark legal disputes and necessitate new international agreements.

Humanitarian considerations also extend to the potential escalation of conflicts through the deployment of directed-energy weapons. The introduction of laser-based defense or offensive systems could lower the threshold for engagement and destabilize existing deterrence frameworks, potentially leading to a more rapid onset of hostilities in contested regions.

In light of these concerns, it is imperative that the development and deployment of laser weapon systems incorporate robust ethical review processes, legal compliance checks, and humanitarian risk assessments. Transparent international dialogue and confidence-building measures

could mitigate the risks associated with these emerging technologies, ensuring that their integration into modern military arsenals does not undermine international peace and security.

Conclusion

China has contributed significantly to the industrial development of the Western world in recent decades. Chinese industries had to develop environmentally hazardous sectors, put up with low pay for the hard work of performers and many other things. In that case, why not take advantage of your position as a world workshop and do something for your own defense! Moreover, the regional geopolitical situation surrounding China has become increasingly complex. China's skilled scientific and technological workforce is capable of solving complex tasks and effectively introducing new modern technologies into the country's industry, which, as Chinese President Xi Jinping said, are the key to modernizing China's Armed Forces.

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