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WEAPONS AT HOME AND ABROAD: AN OUTLINE

by

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Development of Tactical Air Defense Laser Weapons at Home and Abroad: an Outline

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Abstract

This article describes tactical missile defense as an important task of modern air defense and tactical air defense laser weapons as effective weapons. It also details the history and present condition of laser weapons developed by the three branches of the U.S. Armed Forces and briefs the research and development of laser weapons in the Soviet Union, Germany, France and the People's Republic of China.

Key Words: Laser device, Laser confrontation, Antimissile system

It has been over 20 years since research on laser weapons started, but the only laser weapon that was used on the battlefield is a simple laser blinding weapon. As far as the more sophisticated laser blinding weapons (capable of blinding both human eyes and optical sensors) are concerned, their research and development have been finalized and replaced by the system development phase in some developed countries. Among other laser weapons under development are: ground-based antimissile laser weapons, air-based antimissile laser weapons, and tactical air defense laser weapons.

Tactical air defense laser weapons refer to weapons that can directly kill attacking tactical air targets with intensive laser beams. In terms of present tactical applications, these tactical targets are basically tactical ballistic missiles, cruise missiles, antiradiation missiles, other ground-to-air precision guided missiles, bombs and aircraft.

This paper discusses tactical air defense laser weapon development in and outside our country.

I. Objective Demand for Tactical Air Defense Laser Weapons in Modern Warfare

1. Tactical Missile Defense As a Vital Mission of Modern Air Defense

Taking the Gulf War as an example, we can see how modern warfare operates. During the Gulf War, over 100 ship-launched Tomahawk cruise missiles were the first to be employed to attack the Iraqi air force, the ground air defense forces, the C^3I system, etc., as major targets, temporarily or partly paralyzing them. Then the following operations were air raids, during which vanguard aircraft carrying AGM-88A Harm antiradiation missiles or Phoenix antiradiation missiles attacked Iraqi air defense radars. The surviving targets were struck with precision guided bombs or air to ground missiles that were dropped or launched from high altitude or from long distances, including laser-guided bombs, AGM-65 Bullpup, and Helfa air-to-ground missiles. Related department statistics show that in the first phase of the air raids, the Iraqi ground-to-air missile systems were mostly destroyed, and ground air defense forces suffered great losses such that they could perform only very weak counterattacks.

During the Gulf War, the Iraqi side launched a total of more than 80 tactical ground-to-ground missiles such as Scout and its modified versions Houssan and Abas, aimed at important political and military targets in Israel and Saudi Arabia. The Iraqi attacks, though not so powerful, did pose a threat to Israel and the Allied Forces.

The Gulf War shows that in modern warfare, ground targets are under threat coming not only from various kinds of aircraft, but also from diversified tactical missiles (including cruise missiles, antiradiation missiles, air-to-ground missiles, precision-guided bombs and tactical ground-to-ground missiles). How to defend against tactical missiles has become an urgent task of modern air defense. Obviously, without an antiaircraft and anti-tactical missile air defense system, a nation's safety would not be guaranteed.

To solve the tactical missile defense problem, a combination of various means are generally adopted in different countries, including antimissile missiles, antimissile antiaircraft guns and laser weapons. Among them, laser weapons appear to be a quite effective interception means. Some overseas laser weapon experts believe that air defense laser weapons are the nemesis of diversified precision guided weapons.

2. Tactical Air Defense Laser Weapons As Effective Anti-Tactical Missile Weapons

(1) High-power lasers have the capability of destroying air targets

Tactical air defense laser weapons kill targets through several destructive effects as follows:

Heating destruction of target body. Upon irradiation with an intensive laser beam, the target body undergoes a temperature rise, with which the body material shows a linear decrease in tensile and compressive strength. When the temperature rises to a certain degree, the designed rigidity of the material can be depleted and the material may even become plastic. Under this scenario, the aircraft or missile structure will explode or lose destabilize due to internal stresses.

Intensive laser beam-excited seeker head dome. Any precision guided missile is equipped with a seeker head dome including radio-frequency dome and optical hood, or a fused optical window. Both dome and window are made of brittle material. The laser beam irradiation can heat the surface of this type of material and then cause an explosion. And under the action of aerodynamic forces, the dome or window may be completely destroyed, affecting missile flight.

Blinding the sensor. Technically, more than 50% of the precision guided missiles are based on optical guidance. The key component of an optical seeker head is its optical sensor. Given its extremely small geometric size, and with the optical receiver of larger bore in the front, the optical sensor becomes the component most vulnerable to laser radiation destruction. Once the optical sensor is destroyed, the seeker head will fail and the missile will miss the target.

Other destructive effects. Apart from the foregoing destructive effects, intensive laser beams can also produce other destructive effects such as ablative destruction, combat sector burning, laminar cracks and so on, but those destructive effects appear rather difficult to realize.

Owing to all the above mentioned destructive effects, intensive laser beams are capable of effectively destroying aircraft, cruise missiles, tactical ground-to-ground missiles and various precision-guided weapons.

(2) Principal characteristics of laser weapons

Attacking targets at the speed of light. Laser weapons, ready to operate in no time at short distances, can be used to deal with high-speed targets and abrupt targets, i.e. can win time for target acquisition, identification and pointing.

Quick to shift fire. Laser weapons can easily shift their fire from one target to another in several fractions of a second and therefore, have the capability of hitting multiple targets.

High cost-effectiveness ratio. The cost for firing one tactical air defense laser weapon is cheap, i.e. it basically equals the cost of the fuel for the laser device; for example, $800,000 for a Patriot missile; $20,000 for a Stinger short-range missile; $1,000-2,000 for one transmission of a DF chemical laser, and only several hundred dollars for a CO_2 laser. Obviously, the cost-effectiveness ratio of laser weapons in shooting air targets turns out to be extremely high.

High kill effect. An intensive laser beam, capable of blinding the sensors of optically guided weapons over long distances, breaking seeker head domes at medium distances and destroying aircraft and missile bodies at short distances, can fire at a threat target repeatedly over different distances and thereby increase the target interception probability.

II. Development of Laser Weapons in Several Countries

1. The United States

(1) Air Force

In 1968, with the appearance of 60kW output CO_2 aerodynamic laser devices in the United States, the military was greatly encouraged to use high power lasers as a weapon. The first response was by the Air Force, which worked on a project called "The 8th Card", intended for intensive laser development. Under this project, the Weapons Laboratory at Kirtland Air Force Base was selected as the major intensive laser development center and major ground test site.

In June 1971, a laser device was used to ignite a wooden board 3.2km away. In spring of 1973, again a laser was employed to shoot down a MQM-61A Cardinal target drone at a speed of 300km per hour. Then in April of the same year, the Air Force began implementing the Defense Ministry PE63605F Program by modifying a

Boeing NKC-135 air-refueling plane into an "Air Laser Laboratory". The major task of this laboratory was to carry out, through basic research and unit technology research, demonstrative verification of the feasibility of this airborne laser device so as to provide data necessary for airborne laser weapon development.

The foregoing task was scheduled to be completed in three phases. The first phase test was begun in 1973, during which the pointing-tracking system and the fairing were successfully evaluated during 90 hours of flight.

The second phase, covering 230 hours of flight from 1975 through March 1976, was basically devoted to testing laser device performance in a dynamic flight environment and laser beam atmospheric propagation properties. Test results showed that the laser device proved adaptable to airborne flight environments and could tolerate vibrations and other perturbation effects; the aircraft-emitted laser beam did not display serious distortion and energy dissipation while passing through the ambient aerodynamic flowfield, and the airborne laser device transmitted beam could maintain stable and accurate collimation.

The third phase completed 450 flight hours from July 1977 through 1984, to perform major missions such as: demonstration of dynamic target firing from the airborne laser system; assessing its technical performance and its capability of acquiring, tracking and killing flight targets; checking the feasibility of the airborne laser weapon system arrangement; providing overall proof of cost effectiveness of the airborne laser weapon and judging its prospects for tactical applications.

To meet test requirements, a 400kW CO_2 aerodynamic laser device developed by United Technologies Company, a modified version of the tracking and pointing system developed by Hughes Corporation as well as a beam control transmission system with an aperture of approximately 1m were installed in the test craft. In June 1981, a ground static test indicated that the airborne laser device could operate at full power and emit a beam strong enough to destroy a missile. This test paved the way for the following test on air dynamic target firing. During a flight test made in May 1983 the "airborne laser laboratory" successfully intercepted, at about 10km in height, five AIM-9 Sidewinder air-to-air missiles at flight speeds of M2.5, causing all of them to fly off course and crash onto the ground. This successful test was the last one to finalize the "airborne laser laboratory" test mission. The U.S. Air Force believed that it served as a "significant milestone" in the research on intensive laser weapon technology feasibility and promoted its development.

(2) Navy

In 1973, major U.S. Navy laser weapon research institutions, such as the Naval Research Institute, the Naval Military Equipment Laboratory, etc., began to carry out PE63754N, a research and development program sponsored by the Department of Defense. This program was aimed to provide vessels with various means for defense against low altitude antiship missiles, cruise missiles and aircraft with an emphasis on development of chemical laser devices.

To implement this program, the Navy first conducted an analysis and experiment on laser destructive effects and atmospheric propagation under laboratory conditions, as well as many field tests at sea. In 1977, they acquired, using aerodynamic simulation, quantitative data necessary for chemical laser beams to effectively disrupt missile components, structure and material. During a test completed in early 1978, a DF chemical laser device with output power of hundreds of kilowatts and 3.8 micrometer wavelength, as well as an infrared imaging aiming-tracking system, were applied to destroy BGM-71A Tao antitank missiles. The test proved to be perfect.

Based on the foregoing test, the Navy formulated the SEALITE program, which was designed to test the ability of laser weapons to kill real targets (aircraft and missiles); to test and verify their capability of amplifying power to a required level, and to test pointing and tracking precision and kill effect--all these factors were necessary for determining the cost effectiveness of ship-borne air defense laser weapons. For this purpose, the large-power DF chemical laser device MIRACL was developed, which provided 2.2 megawatts of power and operated by using a 1.8-in bore transmission optics system. In 1985, the U.S. Defense Department placed the Navy's SEALITE/MIRACL project under the Strategic Defense Initiative Organization (SDIO).

(3) Army

U.S. Army laser weapons are managed by the High Energy Laser Administration under Missile Command, which began to implement the Defense Department PE62621A Laser Weapon Program in 1974. Following this program, the Redstone Arsenal in Alabama modified a LVTP-7 amphibious vehicle into a laser weapon mobile test setup. The major laser device tested, an electrically excited CO_2 laser device, had earlier undergone a feasibility experiment on uneven roads and under different military application conditions.

According to the report issued in August, 1975, a few target planes had been shot down by using this equipment. For instance, in July 1975, two MQM-61A target planes, 4.5m in length, with a flight speed of 480km/h, were shot down from 8200m away, and two remote control target helicopters were hit in October of that year. Soon after this test, Army research interest shifted to a vehicle-borne photoelectric confrontation system called Stingray, which was designed to destroy the optical system and sensors of modern guided weapons. In 1986, a demonstration test was carried out on the Stingray tactical laser weapon, which, mounted in a Bradley fighting infantry vehicle, proved to be capable of damaging the photoelectric sensor within the distance of 8km. Upon completion of this demonstration test, the engineering development phase of this weapon was immediately started.

(4) Balanced Development

With the implementation of the Strategic Defense Initiative (SDI) after 1983, the United States laser weapon research was directed at the development of strategic laser weapons, with a substantial rise in annual funding. These weapons included air-based laser weapons, ground-based laser weapons and nuclear blast-pumped x-ray lasers.

However, the U. S. Congress began worrying about the nation's conventional warfare capability since the government was stressing strategic missions. Subsequently in 1987, three projects were successively worked out, namely the Balanced Technology Initiative (BTI), Conventional Defense Initiative (CDI) and Air Defense Initiative (ADI). All the foregoing three projects were designed in favor of balanced development of strategic and tactical laser weapons so that technological achievements of the SDI Program could be fully applied to ground-to-air defense missions, including interception of cruise missiles. With funds allocated to the three projects, a series of research and air target firing tests were undertaken. All these facts indicated that the United States laser weapon research was virtually centered on the development of the strategic laser weapons included in the SDI Program, while tactical laser weapons research and development were just kept on as a midcourse achievement.

From September 18, 1987 through March 1988, a number of tests were conducted on the capability of tactical laser weapons to intercept cruise missiles at the White Sand missile test range. During a test, a deuterium fluoride medium-infrared laser device with 2.2 megawatt output power was tested under conditions close to actual combat. Without any advance information concerning the time of appearance and azimuth of a flying target plane, the device, through acquisition, tracking, pointing and locking on, accurately hit the target and destroyed its key components, making it spin and eventually crash into the ground. Tests demonstrated that this high-power laser weapon system realized its performance as expected. Experts already believed by then that there was no technical obstacle to research on tactical air defense laser weapons. The foregoing successful test proved that the United States tactical air defense laser weapon research had completed its advanced development phase and from then on, progressed into the classified engineering development phase.

2. Soviet Union

The Soviet Union commenced its laser weapon development from the mid sixties, which was carried out in accordance with an extremely ambitious research program and involved more than six research institutions and approximately ten thousand technical personnel. Soviet laser weapon research and development covered both strategic and tactical laser weapons. Among the well-known large scale installation facilities in this country are a center on a mountain peak near Dushanbe and another with laser test equipment at the Semipalatinsk Test Firing Range. In addition, related sources revealed that a small vehicle-borne blinding laser weapon, well advanced, was tested in Afghanistan. A group of experts from the United States, who visited the Soviet laser test equipment in Semipalatinsk, commented that this equipment could only provide defense against low-orbiting satellites. Undoubtedly, however, what the Soviets showed to Americans by no means represented their highest research level in this area.

The Soviet tactical air defense laser weapon development program, which is currently under implementation, includes three major areas as follows:

Ground air defense-oriented laser weapons. These weapons, deployed together with air defense missile weapons, are planned for point-defense missions. So far, they remain at prototype development phase.

Ship-borne air defense-oriented laser weapons. A megawatt level DF laser weapon system, mounted in the second nuclear powered cruiser of the Kirov class, can provide a firing range of 11-16km.

Airborne laser weapons. A modified Ilyushin II-76 is used as a launch aircraft, which carries this laser weapon for air defense and as a self-defense weapon in bombers.

3. Germany

In 1970, the MBB Company advanced a research mission on how to use lasers to destroy missiles, for which the company's defense technology department was responsible. In 1978, they developed a 10 kilowatt CO_2 laser device and conducted a series of tests its destructive mechanism and others. In 1982, research went into the advanced development phase, in which the MBB Company took the responsibility for developing the laser device itself, while the Diehl Company worked on the laser beam control system. They applied a megawatt level liquid-fuel CO_2

aerodynamic laser device and an adaptive deformation reflector. The reflector was controlled by 19 operators to compensate for the effect of atmospheric perturbation on laser propagation. With adaptive compensation, the laser weapon doubled its operating distance. A transmission telescope and a pointing-tracking setup were erected on top of a tank with the help of an 11.5-m foldable telescopic frame, reaching a height of 15m at full extent. This system, mounted on a Puma-2 tank chassis, can be transported as a whole with a total weight about 20t. It could shoot 60 times on a single fuel load. Its components underwent testing in 1990. The research mission was scheduled to be completed in three phases: when the component test phase was finished, the system test phase immediately started.

Germany invited related experts to discuss and revise the arrangement of this air defense laser weapon system in the United States and in this way, by deriving from American experience and lessons in developing similar systems, this system has become a high-tech device with the most sophisticated technology ever and the most perfect equipment, and has been accepted as one of the laser air defense system projects under the European Defense Initiative (UDI).

4. France

The French LATEX Air Defense Laser Weapon Program was proposed by the Research and Technology Bureau in 1984 and implemented by the Weaponry Agency (DGA) under its Ministry of Defense. According to this program, a test would be made on the tracking and pointing ability of a 1-kilowatt laser device constructed by the Cilas Company, and 400-kilowatt and 40-kilowatt laser devices would be developed. Also, a laser weapon test center was established at Londe, with firing range test equipment designed by the industrial department.

To accelerate laser weapon development and translate its possibilities into reality and develop laser weapon systems for military applications as soon as possible, France set up the Unilaser Company in 1989. As a branch of the Aerospace Company, this firm is located in Marcoussis near Paris and boosts a strong staff of 450 qualified experts. So far, it has developed a 300-kilowatt laser device, which was already tested on its pointing and light velocity focusing system. There was a briefing on the device's target firing given in the corporation's Marcoussis laboratory on November 3, 1989. It was reported that a 40-kilowatt laser device and a huge transmission telescope were installed, and the first target firing test fully displayed the device's capability of tracking mobile targets while, during another test, the device destroyed the target. In addition, a new laser system test is scheduled at the Londe Test Center in 1991, during which the device is likely to be fired at a 250m/sec in flight target from 2000m away.

5. China

Under the guideline of "Stressing Foundation, Stressing Improvement", China has long been engaged in some probing research on high power laser technology. As far as high power laser devices are concerned, research is focused on CO_2 laser (electrically-excited, aerodynamic) devices, chemical laser devices, free-electron laser devices, x-ray laser devices, etc. Among these devices, CO_2 and chemical laser devices developed can provide an output power 10,000 watts and more. In research on intensive laser destruction effects, China has done relatively extensive and in-depth experimental and theoretical research on laser thermal and dynamic effects and acquired desired results. Based on these results, a certain understanding has been obtained of laser destructive capability. In the area of laser atmospheric propagation properties, widespread research was conducted, both experimentally and theoretically, on atmospheric refraction, atmospheric attenuation, turbulence effect, nonlinear effect, and so on. Advances were made in improving the atmospheric propagation effect with adaptive optics. For instance, a transverse-shear interferometer was used as a wavefront detector which, by driving a 21-unit deformable reflector with a 300Hz bandwidth, compensated for atmospheric turbulence effects on the laser beacon beam. Through correction, the peak value energy increased by a factor of 3.5, compared with the value before correction, and its distribution approached diffraction limit.

In short, with an adequate foundation in high-power laser technology, China is capable of advanced development phase research on tactical air defense laser weapons if needed.

III. Prospects

Currently, some countries including the United States, the Soviet Union, Germany and France are involved in burgeoning research on tactical air defense laser weapons. The United States and Soviet Union have already completed demonstrative verification of their advanced development phase, and have progressed to the engineering development phase for classified development.

It is reported that apart from SDIO and Defense Advanced Research Project Agency (DARPA) projects, U. S. laser weapon research still includes Navy, Army and Air Force confidential research and development.

In 1984, West Germany, while developing tactical air defense laser weapons, believed that West Germany, located at the frontiers of western Europe, was particularly apt to be attacked by low-altitude aircraft as well as cruise missiles and air-to-ground missiles launched from long distances, that conventional air defense weapons could hardly deal with. Therefore, to defend against those weapons, they planned to develop air defense laser weapons featuring attacking at the speed of light, hemispheric operating aspect, flexibility and mobility in dealing with multiple targets. In addition, the Germans were also convinced that air defense laser weapons would surely become one of the vital air defense weapons in the 21st century. And furthermore, to meet the air raid challenge at the turn of the century, it was necessary to produce an air defense system that was difficult to break through, by combining tactical air defense laser weapons with antiaircraft guns and ground-to-air missiles.

Based on an analysis of the long years research and development carried out in the United States, Soviet Union, Germany, and France, it is not impossible that the United States and Soviet Union will develop tactical air defense laser weapon systems available for use by the end of the nineties. Similarly, Germany and France, though a little behind the United States and Soviet Union, are also likely to produce practical air defense laser weapon systems by the end of the nineties or in the early 21st century.

To summarize, after over 20 years' research and testing in several countries, many key technical problems were solved, and tactical air defense weapon systems are now moving toward practicability. It can be predicted, therefore, that tactical air defense laser weapons are certain to appear in not-too-distant future. When the time comes, they will join the air defense weapon group, and, together with ground-to-air missiles and antiaircraft guns, will play their part in air defense missions.