High Power Lasers in Military Applications

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***Abstract*—This paper presents briefly a piece of military equipment designed to detect and destroy different targets such as missiles using a laser beam for detection and another for deactivation. The general name for this equipment is Laser Weapon System (LaWS). The LaWS is a ship-defense system that has so far publicly engaged different targets like drones, small ships or missiles. LaWS uses an infrared beam from a solid-state laser array which can be tuned to high output to destroy the target or low output to warn or cripple the sensors of a target. The low cost per shot it is an advantage, as each firing of the weapon requires only the minimal cost of generating the energetic pulse.**

***Index Terms*—Amplification, anti-missile, army, energy, LASER, sources, weapon.**

I. INTRODUCTION

Department of Defense (DOD) development work on high-energy military lasers, which has been underway for decades, has reached the point where lasers capable of countering certain surface and air targets at ranges of about a mile could be made ready for installation on Navy surface ships over the next few years. More powerful shipboard lasers, which could become ready for installation in subsequent years, could provide Navy surface ships with an ability to counter a wider range of surface and air targets at ranges of up to about 10 miles [1].

Potential targets for shipboard lasers include the following:

• electro-optical (EO) sensors, including those on anti-ship missiles;

• small boats (including so-called “swarm boats”) 14 and other watercraft (such as jet skis);

• rockets, artillery shells, mortars (sometimes collectively referred to as RAM);

• UAVs;

• manned aircraft;

•ASCMs;

• ballistic missiles, including ASBMs [1].

Directed energy systems, including solid-state and fiber optic lasers and the electromagnetic projectile required Laser Power Levels for Countering Targets. A laser’s ability to disable a target depends mainly on the power and beam quality of its light beam. The power of the light beam is measured in kilowatts (kW) or megawatts (MW). Additional factors affecting a laser’s ability to disable a target include:

• atmospheric absorption, scattering, and turbulence;

• jitter – the degree to which the spot of laser light jumps around on the surface of the target due to vibration or other movement of the laser system;

• target design features, which can affect a target’s susceptibility to laser damage [1].

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The launcher, have the potential to help address these threats as well as perform additional high value missions. The inherent characteristics of laser weapons, speed of light engagement, precision targeting, rapid shot generation and tunability, offer the opportunity for expanded engagement options against a range of threats. These features can enhance the ability of naval units to defeat large raids and to counter short time-of-flight threats such as rockets, mortars and artillery shells. Equally important, laser weapons could bend the cost-exchange curve between offensive and defensive systems that appears at present to favor the former over the latter. When not employed as a weapon system, the inherent electro-optical/infrared properties of laser weapons could be used as a high fidelity intelligence, surveillance and reconnaissance sensor. Maritime laser weapons (MLW) have the potential to help counter the range of threats the Navy will have to confront [2].

The realization is setting in that the military superiority enjoyed by the United States over the two decades following the collapse of the Soviet Union and the end of the Cold War is eroding. Adversaries of all types have “gone to school” on the so-called American Way of War in order to identify weaknesses that could be exploited. In some instances this meant selective investment in advanced capabilities. In other cases, prospective adversaries have sought to create leverage by deploying large numbers of relatively simple and low-cost platforms and systems in order to overwhelm their more technologically-sophisticated opponents or just create an unfavorable cost-exchange ratio [2].

Directed energy weapons have been said to offer the potential to transform warfare for decades, with their combination of deep magazines, long range, precision engagement at the speed of light and relatively low cost per shot. Past efforts to develop a militarily-effective and affordable laser weapon system had limited success. Over the past several years, however, research and development (R&D) demonstrations have proceeded to a point that suggests a solid-state maritime laser weapon could have a significant impact on future naval operations [2].

China also is working on advanced weapons technologies that could negate current U.S. capabilities and require development of entirely new offensive and defensive capabilities. On January 9, 2013, China tested a hypersonic vehicle atop an intercontinental ballistic missile. A hypersonic weapon travels at more than five times the speed of sound. Once launched into space, this vehicle separates from its booster and then maneuvers at the edge of the atmosphere at speeds up to a dozen times that of sound. Hypersonic weapons, like the first long-range ballistic missile, will totally transform conventional warfare making sitting ducks of aircraft and surface ships. The U.S. Navy is already having trouble defending against slower supersonic

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anti-ship missiles; it has no defense against a hypersonic weapon [2].

As guided munitions and battle networks proliferate, legacy power projection platforms and bases will be vulnerable to saturation attack from large numbers of long-range guided weapons, such as ballistic and cruise missiles, unless defenders can find interception methods with favorable cost-exchange ratios. As previously discussed, the guided munitions-battle network regime is offensive dominant, which imposes both great burdens and costs on a defender. Shooting two $10 million to $15 million interceptors against a single inbound ballistic missile to ensure a successful engagement is a losing proposition over the long run in a guided munitions salvo competition. This will be even truer when defending against future arming attacks by unmanned systems. Electric weapons, such as electromagnetic rail guns and high-energy lasers, with high rates of fire and low cost per shot, could help redress both near-term and far-term problems. As such, military planners are aggressively pursuing them. High-powered microwave weapons that disrupt electronics likewise have tremendous potential. Such weapons could disable enemy weapons and electronic systems through nonlethal means and could potentially be employed with a greater degree of autonomy in unmanned systems. With the development of smaller, high density power generation systems, these systems could be made much more compact, making them available on future battlefields in increasing numbers [2].

Maritime laser weapons (MLW) have the potential to help counter the range of threats the Navy will have to confront. The inherent characteristics of laser weapons, speed of light engagement, precision targeting, rapid shot generation and tunability, offer the opportunity for expanded engagement options. These features can enhance the ability of naval units to defeat large raids and to counter short time-of-flight threats such as rockets, mortars and artillery shells. Speed of light engagement allows the MLW to address maneuvering platforms and weapons [2].

Because laser power is adjustable this allows options beyond a kill, such as the ability to warn, distract and disable. Even a relatively low-power laser can be effective against electro-optical sensors. Unmanned threats can be disabled by destroying their cameras or optics vice shooting down the vehicle; again, providing the Strike Group Commander options in a sensitive diplomatic environment. This is of particular value in a highly cluttered environment or in the presence of small, maneuvering targets (e.g., small boats and UAVs). In addition, the MLW has the potential to be employed as a non-lethal disabling device against certain target classes [2].

The introduction of an effective MLW would offer the potential to change the Navy's CONOPS (Concept of Operations) for A2/AD (Anti-Access/Area Denial) environments. Laser weapons would provide an additional layer of defense with the potential to address "trash targets", thereby saving kinetic weapons for more severe threats. U.S. forces could engage these threats while holding back high cost, highly capable long range (over the horizon) weapons for a potential second or third wave assault by the enemy using their more advanced weaponry. Without a low cost weapon such as lasers, U.S. forces will waste their highly capable and costly advanced weapons against low cost threats early in a campaign placing themselves at a significant disadvantage due to requirements to resupply, which leads into the area denial issue [2].

A 250-500 kW MLW is what appears to be required in order to engage cruise missiles, aircraft and even ballistic missiles. At these higher power levels, MLWs would support a modified shot doctrine and missile load flexibility. Taken together, these features would support the ability of naval platforms to operate in severe A2/AD environments, such as that being created by the People's Republic of China, for longer periods of time and address larger sizes of attack weapons [2].

Given the surface fleet's ability to overcome the technical challenges associated with the military exploitation of high power, long range DEW [Directed Energy Weapons] -- including power, cooling, weight, and volume requirements -- it is the logical vanguard for demonstrating the potential of first-generation weapons. Across the spectrum of DEWs, early applications will focus on supporting forward deployed forces to defeat Improvised Explosive Devices (IEDs); artillery, mortars, and rockets; intelligence, surveillance and reconnaissance systems; fast-attack craft; fixed and rotary-wing aviation; and subsonic anti-ship cruise missiles. The longer term objective is to field higher power systems capable of defeating supersonic cruise missiles and selected ballistic missiles [2].

It is clear that directed energy weapons are no longer just science experiments. They have been successfully demonstrated and tested repeatedly. It is time to move towards actual weaponization and deployment. The go-slow, take-small-steps, wait-and-see approach works okay for research organizations and government labs in general, but it is not adequate for the creation of a new generation of military capabilities. Nor is the current approach likely to entice industry to invest scarce corporate resources in this area [2].

The requirement for a transformational capability such as the MLW is clear. Progress on technology has been significant; with the completion of the prototype MLW system the technology readiness level for the critical technologies will be of seven out of ten. The Ponce deployment and the simulation exercise should help to resolve many of the outstanding employment, operational and policy issues. Given the Navy's clear need for directed energy weapons and anticipating continuing progress across all these fronts, should the ongoing technology development efforts mature, the Navy needs to be prepared to make rapid transition to a program of record [2].

II. About Lasers

The laser has revolutionized many areas of science and society, offering new research opportunities in various fields. A second laser revolution is currently underway by studying petawatt pulsed laser lasers that offer very high power concentrated in a pulse in the femtosecond range and even below that value. Such light sources create unique, extreme laboratory conditions that can accelerate the collision of elementary particles, or trigger nuclear reactions. These powerful lasers come largely from the US and Europe, and the scientific and technological

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opportunities that they have allowed, and especially those not yet explored, are discussed in several reports by renowned Academy of Sciences.

Laser applications in the military are an area of interest nowadays. Due to its high spectral intensity and very low divergence, the laser is ideal for these applications. Laser devices have become a standard feature for land, air, and naval forces. Devices using lasers have some advantages over conventional light sources, including low weight, high reliability, and superior performance and operating stability.

An example in this regard is the laser rangefinder. This device exploits the characteristic properties of the laser beam, namely monochromaticity, high spectral intensity, coherence and directionality. A collimated pulse of the laser beam is directed towards a target, and the reflection is detected by a reception system. The length of the beam from the target beam transmitter is measured by the laser beam, then multiplied by the speed of light, the product divided by two representing the target emitting distance. In an anti-missile defense system, for example, the laser is used to inactivate the impactor by partially destroying the rocket fuselage, for example by drilling a hole. If a guided palette of a rocket is fractured, vibrations that will develop in the nearby air will disintegrate the most sensitive portion of the rocket. An early microwave warning radar reveals the position of the approaching missile, then a LIDAR (Laser Detection and Ranging) directed to the target by the tracking radar gives the exact position of the rocket. These data are transmitted to another high-intensity laser beam (laser effector), which effectively destroys the target. In order to exploit the ability to destroy the laser, a high-speed servo system and a complex focusing system are essential (Fig. 1). [5]

Figure 1. Inactivating a missile with a LASER beam [4]

III. Laser Weapon System

By building a fire control system (combining a remote sensing system with an attacking system), we will try to get an effective weapon in fighting various targets in the air, on water or on the ground. Such equipment has been developed in the US, and is labeled as LaWS (Laser Weapon System) (Fig. 2).

It is a complete laser detection and elimination of targets of various sizes, such as ballistic missiles, drones, craft and small aircraft, etc.

Figure 2. Laser Weapon System [1]

IV. Power Supply Problem

The essential issue of this military system that aimed at being mobile is the power supply, as the required power is quite high, in the 30 kW - 150 kW range. For power supply, use will be made of a special cell system used to power the Tesla Model S P85D electric machines (Fig. 3), whose power ranges around 100 kWh. The configuration of these cells will be specifically designed for the laser equipment in question.

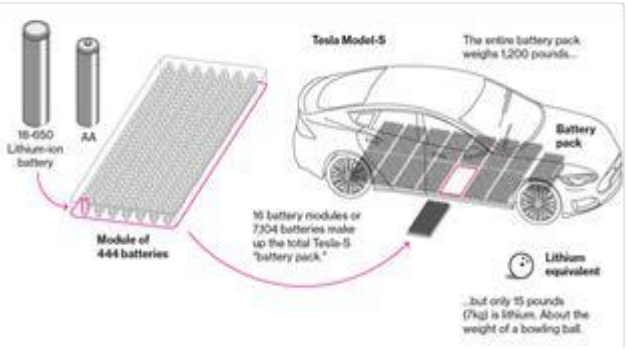

Figure 3. Power Cells for the Tesla Model S P85D Electric Car [3]

In order to increase the effectiveness of the equipment in the field of attack and destruction, detailed research will be carried out on the interaction of LASER radiation with different materials from which the fuselage of flying objects can be made.

This will investigate the behavior of irradiation of various materials such as metals (copper, iron, duralumin, inox), composite materials, as well as fuselage pieces taken from old equipment, and determine to what extent the radiation needs to be modeled for to achieve the desired effect.

V. Advantages

The speed of operation of the equipment is very high due to the high speed of light propagation.

The apparatus has high spectral accuracy, being also useful in combating small targets at great distances.

The beam is hard to detect, the equipment being quiet, optimal for use in almost any situation.

Although production costs are very high, the cost for one shot is low.

The size of the appliance is relatively small and can be adapted for small craft, off-road vehicles, aircraft, etc., so it can be easily moved to many areas of interest.

VI. DISADVANTAGES

A main disadvantage would be low efficiency in case of misty atmosphere, rain or smoke in the range of the equipment.

The main function of the system is defensive, detection and not offensive. Without kinetic energy, it is ineffective in the case of targets made of hard materials, or those absorbs or completely reflect laser radiation, the time required to destroy them is great, and there is even the risk that destruction may not occur.

The cost of building this appliance is high.

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