Wave Front

DEPS News Letter - - Winter 2000 : Vol 1 Issue 1

Director's Forum

As the President of the Directed Energy Professional Society (DEPS), it is my great pleasure to welcome you all to *Wave Front* , the first DEPS newsletter. It is our intent to use this newsletter in a format that not only allows us to keep our members informed, but to energize the exchange of that information. By posting the *Wave Front* on our web page we will be able to accommodate quick updates and also allow our readers to readily disseminate that information via electronic means. We are confident this forum will continue to grow and provide a useful tool.

Even though our society is only a little over one year old, and it has already had many success stories—including the Directed Energy (DE) Symposia and multiple workshops. These get-togethers have provided platforms for exchange of ideas and solutions between hundreds of people involved in directed energy from bench level scientists up to the highest policy makers within government, academia and industry. During our short history we have seen the adoption of congressional language that has led to the creation of the High Energy Laser Joint Technology Office and the subsequent addition of about $21 million of new money in this year alone. We also continue to witness technological successes in this nations premiere laser programs like the Army Tactical High Energy Laser (THEL), the Air Borne Laser (ABL), the Space Based Laser (SBL), and the Ground Based Laser (GBL) program that is supported by the Starfire Optical Range (SOR). We have seen growing support from military commanders as they begin to identify the applications and threats from directed energy devices that include new high power microwave technology. All-and-all, it has been an excellent start.

As with any new organization, we have had our growing pains…and we will most likely see more. But, we have overcome the hardest part—the beginning! With the continuing support from our wonderful sponsors and outstanding members I am convinced that the DEPS will indeed be able to meet the challenges it has accepted in its mission and vision. We invite suggestions from all members.

Welcome to the DEPS family.

Donald L Lamberson, President

Featured Technology

The 10-Mile Laser

by Don Slater, Lasers & Electro Optical Systems of The Boeing Company

Lasers in space, lasers in the stratosphere, lasers on and over the battlefield - we're at the beginning of an evolutionary new wave of weaponry. Highly precise, long range and primarily defensive in application, high energy lasers are emerging as key components in the military planner's options for defense against intercontinental ballistic missiles, theater ballistic missiles, overland and anti-ship cruise missiles and short-range rockets.

One of the newest concepts is the Airborne Tactical Laser (ATL), which is seeking to join the Space Based Laser (SBL) and the high altitude Airborne Laser (ABL) in moving from laboratory technology validation to government-sponsored concept demonstration and ultimately to operational capability.

The ATL places a high-energy laser of moderate power in a highly maneuverable tactical aircraft. Looking out and down from altitudes of 10,000 feet and less, the laser can engage and destroy a variety of airborne threats, such as cruise missiles, artillery-type rockets and unmanned aerial vehicles at horizontal ranges from five to 15 miles. We selected the V-22 for a point design study.

The technology that allows a weapons-capable laser to fit inside a small aircraft is also adaptable to ground vehicles for use in short-range air defense roles. A small tactical air defense laser on the ground could be extremely mobile, or a larger version could be transportable between temporary fixed locations.

High-energy lasers have two characteristics that make them viable as weapons: They're extremely fast and extremely precise. Whether the beams cross thousands of miles in space, hundreds of miles in the upper atmosphere or tens of miles in the lower atmosphere, the laser begins its attack within seconds of detecting its target and completes its destruction a few seconds later. This means the defender has time for multiple shots if needed to "kill" the target or engage multiple targets. For long-range engagements, early kill means the debris from the attacking missile falls far short of its target.

The laser beam delivers its energy to a relatively small spot on the target - from a few inches in diameter to a few feet, depending on the range. The incident intensity is sufficient (similar to a welding torch) to melt steel, even if the surface is shiny. Typical melt-through times for missile bodies are about 10 seconds. But if the heated area is under stress from aerodynamic or static pressure loads, catastrophic failure can occur even sooner. Laser weapons don't deliver as much "killing power" as guns or missiles, but they are effective against many targets. And, precision delivery makes up for limited delivered power.

The beam can attack specific aimpoints on a missile that are known to be vulnerable; for example, pressurized fuel tanks or aerodynamic control surfaces. The laser weapon design, therefore, must include the ability to "see" and identify specific aimpoints, and then put the beam on that aimpoint and hold it for a few seconds, and finally, to determine when the target has been destroyed.

Over the past two years, *several ATL concepts* been explored--they all rely on the same basic laser capability to generate 100 to 300 kW of optical power and deliver it precisely to a small, pre-defined spot.

Anti-ship cruise missile defense was the mission we used to establish some general requirements for an ATL point design concept. In open seas, Navy ships are well protected by their own air cover and missile systems which prevent enemy launchers (ships or planes) from getting too close, but in certain circumstances the risk of attack at relatively close range can't be avoided. The risk is compounded if the threat includes supersonic cruise missiles whose speed reduces the time available for defensive actions.

One valid scenario is the protection of ships entering the Arabian Gulf through the Straits of Hormuz.

Warships are required to pass through a "choke point" where they are relatively close to land-based attack from a potentially hostile country. Three ATLs are deployed in a defensive screen between the ships and the threat, which is about 30 km away from the ships in the assumed threat direction. The screen moves with the ships as they enter the gulf, repositioning in response to intelligence estimates of likely launcher locations.

Suddenly, a hostile raid of multiple cruise missiles is launched at Mach 2 velocity from the hostile coast, with a total assumed flight time of about two minutes.

The ATLs detect the incoming raid about 65 seconds before impact. The outermost engagements occur at 20 km, where laser dwell times of five seconds are required for each kill. At shorter ranges, the dwell times are reduced. One target is destroyed for each dwell period, and a few seconds are allocated for re-targeting between shots. As many as eight incoming threats are destroyed in about a minute, with the last engagement overlapping the defended ship's own self-defense zone.

This scenario highlights the advantages of the ATL in situations where timelines are compressed by short distances and high-speed attackers. The combination of mobile air platforms and instantaneous engagements offered by the ATL provides a much stronger defense than ship- or air-launched defensive missiles alone, or even a ship-based laser weapon.

A potential second mission area is called "ultra-precision strike," and refers to uses of the ATL in operations other than a full-fledged war, an operation where military action is required, but rules of engagement are strictly controlled and collateral damage must be limited.

In recent years, U.S. and U.N. forces have been involved in many of these kinds of actions. These situations frequently place friendly, hostile and noncombatant personnel in close proximity. They can also involve operations in built-up areas where buildings and urban infrastructure interfere with freedom of movement and may be off-limits to damaging weaponry.

In these circumstances, the ATL offers the mobility of a small aircraft, high-resolution imagery for target identification and the ability to localize damage to a small area of less than a foot in diameter. In addition, from a standoff distance of a few miles, the ATL is not subject to direct attack by small arms or shoulder-launched anti-aircraft missiles. In fact, it can be far enough away that its action is almost covert. The laser beam makes no sound and is not visible. The effect of the beam may not be easily associated with a presence of an aircraft several miles away!

In these situations an ATL could have surprising effect. It could disable communications lines, disable radio and TV broadcast antennas, disable satellite or radar dishes, break electrical power lines and transformers, disable individual vehicles, and create various forms of distractions by setting small fires. These actions would serve to isolate and control hostile individuals and groups without casualties and with minimal, repairable damage.

But what about operating conditions? Laser light can't penetrate clouds. The SBL and ABL are immune to most weather because they operate at very high altitudes. Is ATL only useful on sunny days?

That's a fair question, because an ATL flies where clouds are common. And it's not just clouds - dust, sea spray, rain and fog can all interfere with beam propagation.

One way ATL responds to bad weather is to move away from it. An ATL will generally operate below most of the clouds. For missile defense, the ATL works best at altitudes around 10,000 feet. But it can operate down to about 2,500 feet; below that, the operational range becomes too short to be useful. Localized weather cells and fronts, however, may be avoided by maneuvering around them, a flexibility that goes a long way to keeping the availability of the ATL high, even in less than ideal weather.

Another approach is the use of good analytical models of laser beam propagation anchored to actual weather data collected in specific locations of interest. Using weather databases collected over many years, we can predict statistically what levels of performance to expect from the ATL.

For example, in the Arabian Gulf, temperatures are high, humidity moderate, cloud ceilings high, and visibility limited by blowing sand and dust much of the time. In the Korean peninsula, conditions vary greatly between summer and winter. Winters are cold and clear. Summers are hot, humid and frequently overcast.

In both areas, the baseline ATL design achieves > 20 km kill range 50 percent of the time. In the Arabian Gulf location, for 10 percent of the time the range will exceed 24 km, and at 10 percent of the time it will be less than 16 km. In the Korean coastal climate, the variation is greater. The "best" 10 percent of the time the range exceeds 30 km, but the worst 10 percent limits the range to less than 8 km.

Using the Straits of Hormuz scenario as a guideline, we established a set of top-level requirements for the ATL and then produced a system concept design and layout that fit the V-22 rotorcraft.

Some of the key parameters are:

- Laser power to meet 20 km lethal range goal
- Weapon system weight to allow 4 hr loiter in V-22
- Laser run time to allow at least 8 shots before refueling
- Primary mirror diameter largest that fits existing V-22 floor hatch
- Detection field-of-regard = full hemisphere
- Detection range matched to 20 km kill range
- Detect-to-shoot time allows first shot at max range for Mach 2 target

The Boeing packaging approach is to assemble the entire weapon system on four pallets that can be loaded into any available V-22.

The first pallet contains the surveillance sensors and mounts over the forward hatch in the V-22 floor. The sensors are mounted in a small, rotatable turret that extends through the floor after take-off. The second pallet contains the operator's workstation and electronics rack. The third pallet contains the laser device; its large turret is positioned directly over the main floor hatch in the V-22 and is also retracted for take-off and landing. The fourth pallet contains the laser exhaust management hardware and some of the fluid supply tanks.

The primary aircraft interfaces are to its computer data bus and electrical power and the mechanical tie-down points. At this point, we have not identified a need for any substantial modifications to the V-22. A roll-on, roll-off package could also de designed for the CH-47 Chinook helicopter. Airplanes like the C-130 have plenty of weight and volume capability, but would probably require a structural modification to accommodate the external turret.

The ABL was the starting point for assessing the technology readiness for the ATL. Boeing, TRW and Lockheed-Martin are teamed on the billion-dollar ABL effort to build a large laser weapon that flies in a modified 747 aircraft. It is designed to engage theater-class ballistic missiles from ranges over a hundred miles, while operating at altitudes around 40,000 feet.

Some of the technology in the ABL, however, goes well beyond the requirements for the ATL and is being adapted for use in smaller aircraft. In particular, the ABL requirements on beam pointing accuracy are much stricter, so the technologies for vibration stabilization and jitter correction are at the limits of the state-of-the-art. For ATL, the requirements are relaxed because the targets are closer, and the vibration and jitter control systems are less complex.

The ABL laser is much larger and more powerful than that required for the ATL mission, which is smaller and lighter, mostly because it doesn't produce - or need - the power to engage targets at the extreme range of the ABL.

Another difference is in how the laser exhaust gas is managed. The ABL uses a large ejector system to pump the gases through the laser and then exhaust them out the bottom of the airplane into the ambient atmosphere. At sea level, however, the external ambient air pressure is about five times higher, and the ABL ejector system can't exhaust the laser gases against this pressure.

Because of this, the ATL *[using the V-22 and COIL as point design]* manages the laser gases differently.

Instead of pushing them overboard, the ATL captures them internally in a "sealed exhaust system," which is basically a box full of cold zeolite. Zeolites are a family of commercially available materials that can be used in a wide variety of applications to trap impurities in process flows. In our application, zeolite adsorbs the laser gases in its internal microstructures, up to 20 percent of its own weight. At liquid nitrogen temperatures, the vapor pressure over the zeolite bed is low enough to pump the laser exhaust. The zeolite is recycled by warming it up to drive off the absorbed gases. It can then be cooled and reused.

The system impact of the sealed exhaust system is dramatic. It means the entire laser can be made compact and self-contained--essential attributes for a mobile weapon adaptable to various air and land vehicles. It is the enabling technology for tactical applications of COIL lasers.

This approach had never been used to pump a chemical laser, so we established an internal development program to obtain the data necessary to design a practical sealed exhaust system and to demonstrate it on a subscale laser. The core laser for the ATL is also rather different from the ABL COIL, because it can't use helium as the carrier gas for the reactants, and the ABL laser requires significant quantities of helium. (Zeolite can't pump helium.) For ATL, we also had to learn how to make a helium-free COIL. So the IR&D task included building a new laser as well as the sealed exhaust.

The next goal is to build an integrated, flyable ATL demonstrator, large enough to perform actual target kills in flight, but scaled down in power. That will require a moderate cost combination of capabilities that can prove the ATL's utility in all of the mission roles we've considered. If that can be accomplished, the look of the battlefield will be changed forever.

[This issue's featured article is submitted by Boeing, a DEPS Gold Sponsor. The contents are solely the input of the author and are not in anyway the product of the DEPS. The WaveFront *staff is looking for support for future articles. If you are a DEPS member or sponsor, and would like to submit an article, please forward your input to Terry Franks at* tfranks@deps.org *--Thank You.]*

Programmatic Update

On 6 June 2000 the High Energy Laser (HEL) Joint Technology Office (JTO) was formed to assist the community, and focus on the technology ready for near term pay-off. [See the JTO News Letter for additional information]

The new management structure called for in the HEL master plan has been implemented. Senior level policy oversight is carried out by a Board of Directors which is chaired by the Under Secretary of Defense (Acquisition, Technology and Logistics), Dr. Jacques Gansler and consist of the Military Service Senior Acquisition Executives and the Directors of the Defense Agencies. Operational oversight is carried out through the High Energy Laser Technology Council, which is chaired by Dr. Etter and consists of senior Military Service and Defense Agency leaders

The JTO is the focal point of the new management structure recommended by the HEL Master Plan. The JTO is responsible for developing a Department-wide, coordinated investment and execution strategy to take advantage of opportunities presented by HEL weapons technology. It is also responsible for the development and day to day management of a joint program for revitalizing HEL S&T and serving as a clearinghouse for new S&T initiatives proposed by DoD components. In the future the JTO plans to establish and maintain a technology alliance to foster information exchange and cooperative activities with other government organizations, universities and industry.

Cooperation Highlights

PAPA – PHASED ARRAY OF PHASED ARRAYS

Traditional methods of steering laser beams, and correcting wavefront aberrations, rely on mechanically actuated tip/tilt and deformable mirrors. These systems are often limited in performance and are costly. Rapid steering of large aperture laser beams to sub-micron precision may not even be attainable without prohibitively large power expenditures. A promising alternative approach is the Optical Phased Array (OPA).

Similar to the microwave phased array, an OPA is composed of multiple liquid crystal elements that modify the optical phase of an incident optical signal in transmission or reflection. Modification of the phase results in beam steering and/or aberration correction. The liquid crystal elements, called writeable gratings, are solid-state devices that are manufactured using semiconductor fabrication techniques. A grating modifies the phase of an incident optical signal via a voltage-controlled index of refraction. Creation of a linear gradient of optical path delay tilts the phase front and steers the optical beam. The realized linear gradient is actually folded similar to a blazed grating. Current devices are just over 4 cm square.

The OPA can be flood illuminated by a single high power laser source or each element of the array can be fed by its own unique laser. It is this last approach that is the focus of the Phased Array of Phased Arrays (PAPA) research program being managed by Dr. Paul McManamon, AFRL/SNJ, Wright-Patterson AFB, Ohio.

In the PAPA concept, each element of the OPA is flood illuminated by a fiber laser, driven by a Master Oscillator. The MOPA approach ensures that the phase of each fiber laser is consistent. With proper OPA phasing a rapidly steerable high power laser beam can be synthesized.

PAPA technology is scalable to high power by coupling multiple fiber lasers and increasing the power per fiber. High power optical systems can be simplified by eliminating expensive and fallible gimbals, and by reducing the number of optical elements. The OPA can steer active and passive sensors to acquire a target, provide multiple laser beams when needed, and focus and cleanup laser output. The possibility of phased array, or subaperture, imaging is apparent whereby an incoming signal is also modified by the writeable grating.

The OPA concept facilitates the idea of conformal apertures for aircraft-based lasers. These lasers would be used for self-defense, sensing, and force application. In Space OPAs are scalable to large apertures and high powers for SBLs while keeping the power-area ratio low. The OPA represents a distributed architecture that provides a graceful degradation.

The soon-to-kickoff research effort will award a number of small contracts to stimulate private investment and explore promising technologies in preparation for an eventual large-scale research effort.

Wave Packets

1. The following is an extract from the **ENACTMENT OF PROVISIONS OF H.R. 5408, THE FLOYD D. SPENCE NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2001**. It describes the level of funding for the new JTO and the congressional expectations

………..SEC. 241. FUNDING.

(a) FUNDING FOR FISCAL YEAR 2001- (1) of the amount authorized to be appropriated by section 201(4), $30,000,000 is authorized for high energy laser development.

(2) Funds available under this subsection are available to supplement the high energy laser programs of the military departments and Defense Agencies, as determined by the official designated under section 243.

(b) SENSE OF CONGRESS- It is the sense of Congress that--

(1) the Department of Defense should establish funding for high energy laser programs within the science and technology programs of each of the military departments and the Ballistic Missile Defense Organization; and

(2) the Secretary of Defense should establish a goal that basic, applied, and advanced research in high energy laser technology should constitute at least 4.5 percent of the total science and technology budget of the Department of Defense by fiscal year 2004.

SEC. 242. IMPLEMENTATION OF HIGH ENERGY LASER MASTER PLAN.

The Secretary of Defense shall implement the management and organizational structure specified in the Department of Defense High Energy Laser Master Plan of March 24, 2000.

SEC. 243. DESIGNATION OF SENIOR OFFICIAL FOR HIGH ENERGY LASER PROGRAMS.

(a) DESIGNATION- The Secretary of Defense shall designate a single senior civilian official in the Office of the Secretary of Defense (in this subtitle referred to as the `designated official') to chair the High Energy Laser Technology Council called for in the master plan referred to in section 242 and to carry out responsibilities for the programs for which funds are provided under this subtitle. The designated official shall report directly to the Under Secretary of Defense for Acquisition, Technology, and Logistics for matters concerning the responsibilities specified in subsection (b).

(b) RESPONSIBILITIES- The primary responsibilities of the designated official shall include the following:

(1) Establishment of priorities for the high energy laser programs of the military departments and the Defense Agencies.

(2) Coordination of high energy laser programs among the military departments and the Defense Agencies.

(3) Identification of promising high energy laser technologies for which funding should be a high priority for the Department of Defense and establishment of priority for funding among those technologies.

(4) Preparation, in coordination with the Secretaries of the military departments and the Directors of the Defense Agencies, of a detailed technology plan to develop and mature high energy laser technologies.

(5) Planning and programming appropriate to rapid evolution of high energy laser technology.

(6) Ensuring that high energy laser programs of each military department and the Defense Agencies are initiated and managed effectively and are complementary with programs managed by the other military departments and Defense Agencies and by the Office of the Secretary of Defense.

(7) Ensuring that the high energy laser programs of the military departments and the Defense Agencies comply with the requirements specified in subsection (c).

(c) COORDINATION AND FUNDING BALANCE- In carrying out the responsibilities specified in subsection (b), the designated official shall ensure that--

(1) high energy laser programs of each military department and of the Defense Agencies are consistent with the priorities identified in the designated official's planning and programming activities;

(2) funding provided by the Office of the Secretary of Defense for high energy laser research and development complements high energy laser programs for which funds are provided by the military departments and the Defense Agencies;

(3) programs, projects, and activities to be carried out by the recipients of such funds are selected on the basis of appropriate competitive procedures or Department of Defense peer review process;

(4) beginning with fiscal year 2002, funding from the Office of the Secretary of Defense in applied research and advanced technology development program elements is not applied to technology efforts in support of high energy laser programs that are not funded by a military department or the Defense Agencies; and

(5) funding from the Office of the Secretary of Defense to complement an applied research or advanced technology development high energy laser program for which funds are provided by one of the military departments or the Defense Agencies do not exceed the amount provided by the military department or the Defense Agencies for that program.

Calendar

1. The 3rd Annual DE Symposium was held during the week of 30 Oct 00 through 3 Nov 00 and was a huge success. The Army has already started planning for next year's symposium which will be held around the same timeframe, but at a location yet to be determined…please make a note on your calendar to check the DEPS website for further information.

2. Spring 2001 Workshop - - Watch for news on http://www.deps.org/.

Did You Know…?

That according to the Army FM 42-414; TACTICS TECHNIQUES AND PROCEDURES FOR QUARTERMASTER FIELD SERVICE COMPANY DIRECT SUPPORT defines

Directed energy mission-kill is the use of electromagnetic energy, such as visible light, infrared, millimeter waves, microwaves, or x-rays, to disable susceptible military targets by damaging or destroying a critical component of the military target.

Antimateriel Effects

Mission-kill effects to materiel include inducement of mechanical damage, overheating of components, inducement of electrical currents, or inducement of other effects to cause a variety of types of damage or system malfunction.

Antipersonnel Effects

Directed energy mission-kill antipersonnel effects cover a very wide range.

Sources of Directed Energy Mission-Kill Effects

Directed energy mission-kill effects can occur in training or combat. Effects in training or combat can occur when susceptible personnel or equipment are accidentally exposed by getting too close to nonweapons-directed energy sources such as radio transmitters, radars, electronic warfare jamming devices, television transmitters, television or communications microwave relays, laser range finders, laser designators, laser jammers, and similar devices. Some of these mission-kill effects are also sometimes technically categorized as electromagnetic interference or electromagnetic effects. Directed energy warfare is the use of and defense against directed energy weapons and devices in combat. Mission kill is one of a very large continuum of DEW effects on targets. The large variety of DEW target effects are used to provide a very wide range of combat functions including the following: detection of targets, illumination of targets to supplement night-viewing systems, identification and classification of targets, disruption of target function or mission, damage of targets, and destruction of targets. Examples of directed energy mission-kill devices include hand-held, crew-served, or vehicular-mounted laser devices and vehicular-mounted or artillery-delivered radio frequency devices.

The End….