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Navy's new laser weapon: Hype or reality?

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In December 2014, the US Navy made a great show of their test of a laser weapon in what it called the "realistic threat environment" of the Persian Gulf. Video from the test, made available to the press, showed the *USS Ponce* firing the Laser Weapon System to burn some holes through the sides of some speedboats, causing the boats' contents to explode. Other tests apparently shot some drone replicas out of the sky.

To an old hand in the laser research industry such as myself (as a graduate student I worked at the Avco Everett Research Laboratory in Everett, Massachusetts, a pioneer in gas dynamic lasers, and later as a member of its senior staff), the tests were underwhelming. They reminded me of an old cartoon in which someone shot an arrow at the side of a barn, then painted a bulls-eye around the spot where the arrow landed. Similarly, after years of false promises, boondoggles, and an enormous waste of taxpayer money going back to the early years of the Reagan era, the military laser lobby came up with these tests. When they couldn't get a laser lightweight enough to fit on a ship while still being powerful enough to burn through the metal skin of an incoming nuclear missile, they simply changed their goal to something akin to puncturing the side of an Iranian rubber dinghy.

In the *USS Ponce* tests, the distance of engagement appeared to be short—less than a mile. The sides of their speedboat target were thin, and the target drone aircraft appeared to be small. So, it was possible to accomplish a so-called "successful" test with a relatively low power, in the 10 to 20 kilowatt range. In addition, the short distances meant that a low-quality beam could be used, which tipped the scales because high-quality has long been the Achilles heel of high-power lasers.

To add to the questionability of the December tests, they look like they were conjured up in a hurry—perhaps to impress those in charge of the purse strings. The laser they used was deployed two years ahead of schedule, which is rare for a defense system; the device itself was thrown together using pre-existing, commercial-off-the-shelf components. In other words, there was nothing new here, and the weapon was certainly not custom-made from scratch for naval use. (A little-known company called Kratos built the laser in question, known as a fiber laser because it uses fiber optic cables as the medium in which particles are excited from a low- to a high- energy state. Not much else is known: Its power is strangely classified, but the laser likely operates in the 15 to 50 kilowatt range, according to an article in *Optics and Photonics*, the journal of the Optical Society of America.)

Proponents do not seem to be dismayed, however, citing the same old supposed benefits of a military laser, if one could ever work under battlefield conditions: A military laser would be a lightweight, effective high-energy device, that could hit an enemy target at the speed of light (186,000 miles per *second*) as opposed to the speed of the fastest hypersonic missiles (about 3,800 miles per *hour*). And they claim that each individual firing of a laser would be dirt-cheap, at less than a dollar per shot—if one excludes the billions of dollars spent in research and development. It also presumably excludes the cost of shipboard electrical power, likely in the thousands of watts, that would be needed.

But there are many obstacles to getting a powerful laser out of the lab and onto the battlefield, where it must be small and rugged enough to operate in a hostile environment while still packing enough punch to be effective. Big, gas-powered lasers generate plenty of oomph to do damage, but they need vast amounts of power to operate, and are far too bulky to fit on a tank or a plane. Chemical-based lasers offer the benefits of being very efficient while not needing electrical power, but they are almost as hefty as gas-powered ones—one of the reasons for the demise of the airborne laser system that the Air Force had been pursuing. Solid-state lasers are small and compact, but produce only low power and cannot fire very far.

There are many other hitches as well. Any weapon that relies upon light traveling through the atmosphere runs into the problems of dust, humidity, and fog—features which absorb and scatter the laser energy. In addition, atmospheric distortions such as turbulence can deflect a beam of light. And at the same time that the photons in a laser's beam must overcome all of these obstacles, they must also stay focused in a tight column and keep advancing forward without diminishing in power. Meanwhile, the user of the laser weapon must account for the movement of the target, the movement of the firing platform, and any decoys, dummies, or multiple war warheads that the enemy throws up.

The latest generation of lasers, based on fiber optics, promises to solve many of these problems, but at this time, fiber-based lasers consume about ten times as much power as their older brothers—and reliably generating that huge amount of energy under battlefield conditions is a challenge.

All told, while lasers, or "directed energy weapons," offer the tantalizing possibility of being game changers, they will not likely be ready for prime time anytime soon. Like a mirage, battlefield lasers are always just over the horizon. If the history of military lasers is any guide, caution is warranted.

The path to laser weapons is littered with dead lasers. Not long after the carbon dioxide laser was demonstrated at Bell Labs in 1960 (the acronym "laser" stands for "light amplification through the stimulated emission of radiation"), the Navy began funding research to bring the new technology to the battlefield. The military influence showed in the choice of names for the devices—Thumper, Humdinger, and Scaleup—which I became familiar with when gas-powered, carbon-dioxide lasers showed a lot of promise. Regardless of whether they are powered by gases, chemicals, solid fibers, or wafer-thin diodes, all lasers operate under the same general principle: They get a bunch of atoms, molecules, or ions in a given lasing medium pumped up in unison to the next energy level so that they emit light (photons) while giving up their energy. A laser resonator (much like a telescope) makes the unruly photons march in step, and stay in a narrow column. The resulting beam of light contains a powerful concentration of energy, all at precisely the same wavelength, that can be used for everything from eye surgery to cutting metal. And, possibly, for warfare.

The trick, however, is to get the required laser energy device within the size, weight, and power (SWAP in Pentagon parlance) limitations of a mobile weapons platform—which could be a ship, airplane, tank, or any other large vehicle that can house a laser weapon. And it must do so at a wavelength that enables the laser energy to travel some distance to the target without being absorbed in the atmosphere, while still retaining its focus (qualities sometimes referred to as "good beam quality"). Generally speaking, wavelengths of less than 10.6 microns seem to fit the bill.

After much experimentation, along came lasers that used toxic gases such as fluorine for the lasing medium. These laser weapons demonstrated high power, but were so big that they and all their ancillary equipment—coolers, generators, etcetera—could barely fit on a football field, let alone on the deck of a destroyer.

The miracle that wasn't. Then, in 1980, the Navy began pursuing a megawatt-class chemical laser that employed deuterium fluoride gas for the laser action. It was called the MIRACL, short for Mid-Infrared Advanced Chemical Laser, and built by a predecessor of Northrop Grumman. The laser beam had a wavelength greater than 3 microns, which allowed it to propagate well in the atmosphere, along with an aiming device, or "director," whose purpose was to direct the high-power laser beam toward the target.

But as is usually the case with high-energy lasers, the whole system was still too big to fit on a Navy ship. Ironically, it ended up at an army base at White Sands Missile Range in New Mexico, which was about as far from the high seas as possible. So, while the MIRACL had plenty of punch and good beam quality, and fulfilled the power requirement portion of the SWAP parameters, it still didn't meet the other two: size and weight.

Chastened, the Navy got out of the laser business. But during the salad days of Reagan's Star Wars, when vast amounts of government dollars became available, the US Army and Air Force took up the cause, funding ever-more fantastic laser projects that ultimately came to a similar fate. From Livermore National Laboratory's science-fiction-like space-based missile-killer X-ray laser to the Army's ground-based ultraviolet lasers, the prototypes just kept coming.

Billions were spent on outlandish schemes. Every Pentagon briefing that I saw seemed to indicate that the technology was ready now. Nothing could have been further from the truth, but true believers kept harping upon the virtues of a weapon system that could fire shots at the speed of light using a near-infinite supply of ammunition. Not to mention that the fuel to operate an airborne chemical laser consisted of extremely cheap materials: everyday household chemicals like hydrogen peroxide, potassium hydroxide, iodine, and chlorine gas.

But by 2009, the Air Force finally faced facts, realizing that its Airborne Laser still wouldn't fit into a Boeing 747. Nor could it produce anywhere near the required power to destroy ballistic missiles.

Enter the solid-state laser. But not to worry. While most of these efforts employed either a gas or a chemical as the lasing medium, other scientists had been busily pushing lasers that used substances based upon media that were in a solid state, as opposed to gases or liquids. After the spectacular failure of the Air Borne Laser project, the funding for solid state lasers gained momentum and brought the Navy's Office of Naval Research back into the game.

It appears that the progress in solid-state laser technology in recent years has sufficiently encouraged the Navy brass that it launched a so-called "technology maturation program" whose goal is to produce a prototypical weapon system for use on surface Navy combat ships. It is pursuing a number of solid-state technologies, the laser weapon system demonstrated in the Gulf among them.

The military seems eager to field a tactical laser weapon that requires about an entire order of magnitude less power than the earlier ones—which were envisioned for shooting down ballistic missiles. (Their power numbers are always classified. But the original goal was mostly for missile defense, which required a megawatt-class laser to burn through the thick skins of incoming intercontinental ballistic missiles. When that didn't work, the mission shifted to the stopping of smaller, shorter range missiles, which likely could be destroyed with devices whose power measured in the hundreds, instead of thousands, of kilowatts. But again, no precise numbers are available.)

The ultimate goal for a tactical weapons-grade laser finally became 100 kilowatts, or the amount of power needed to destroy small boats and drones. But cooling limitations and power demands have continued to stymie the deployment of even this, scaled-down high-energy laser weapon system. (The need to cool the device that fires the laser beam is often overlooked, but just imagine the heat generated by a 100-watt incandescent light bulb. Now multiply that by a thousand, and you get the heat from a 100-kilowatt laser light—and a 1-megawatt-class weapon is ten times above that. Similarly, the input power they need is many times more, although there is not a strict one-to-one correspondence; the exact amount depends on the individual laser's efficiency.)

And supplying the power for a laser weapon continues to be a problem. The vast majority of older ships have only 6 megawatts of power available. Meanwhile, a 1-megawatt laser system will have at best an overall electrical to optical efficiency of about 10 percent, which means it would require 10 megawatts or more from the ship's power system. So, you would need much more power than the ship could possibly produce at any given moment—another reason for going with the punier, 100-kilowatt version. To overcome this obstacle would most likely require huge batteries to store the electrical energy for later use by the laser, but eat up scarce real estate in the already tight confines of a ship. And batteries aren't exactly light-weight.

A new savior: the fiber-based laser. Now, however, comes the latest new thing from the lab: the fiber laser, which uses optical fibers as a lasing medium, and which seems to produce much better beam quality while being easier to cool. Most encouragingly, the beam quality is reportedly not dependent on output power, which means that the small lab version could theoretically be scaled up to the higher powers needed by the military while still maintaining good beam quality.

Yet, many hurdles remain; in particular, some issues related to the structure of the fiber itself and the efficiency with which the photons are pumped up could be show stoppers. We will have to wait and see.

So, despite the present euphoria emanating from the tests conducted by the *USS Ponce*, caution is warranted. The tests were clearly conducted with a thumb pressed firmly on the scale. Most high power lasers still fail because they cannot get high power and good beam quality at the same time, while being within usable dimensions.

At the end of the day, good beam quality and good SWAP-size, weight and power - still determine the success or failure of a given laser weapon, and we're just not anywhere near meeting all those requirements simultaneously.