

# Half a Century of Laser Weapons

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The laser concept emerged at an ideal time to stimulate the emission of military research contracts. In early 1958, President Dwight Eisenhower established the Advanced Research Projects Agency (ARPA) to handle the high-risk, high-payoff projects that cautious military bureaucrats had been avoiding. That May, ARPA director Roy Johnson told Congress that his agency's work "might lead to a death ray. That would be the weapon of tomorrow," a step beyond the hydrogen bomb, able to destroy nuclear-armed ballistic missiles before they reached their targets.

Thus it was no wonder that ARPA welcomed Gordon Gould and Lawrence Goldmuntz with open arms when they came bearing a proposal to build a laser in early 1959. As Gould told the author many years later, "Ray guns and so on were part of science fiction, but somebody actually proposing to build this thing? And he has theoretical grounds for believing it's going to work? Wow! That set them off, and, those colonels, they were just too eager to believe." (See Fig. 1.)

Charles Townes and Arthur Schawlow were the first to propose the laser publicly, but their vision was a modest-power oscillator. Gould had realized that the amplification of stimulated emission in an oscillator might allow a laser to generate high power and concentrate light to a high intensity. His pitch to ARPA was laden with bold ideas. He said a laser pulse could mark military targets and measure their ranges for other weapons. He predicted that laser beams could be focused to be 10,000 times brighter than the Sun, enough to trigger chemical reactions. Ultimately, he suggested, lasers might be powerful enough to destroy targets or ignite nuclear fusion.

Paul Adams, who handled ARPA's optics projects, loved the plan, and a review panel thought prospects for laser communications, target designation, and range finding were good enough to justify the \$300,000 grant requested. Adams was so enthusiastic that he pushed through a \$999,000 contract for a bigger program at TRG Inc., the company Goldmuntz headed. Then the Pentagon tossed a monkey wrench into the works by classifying the laser project and denying Gould a security clearance because of his youthful dalliance with communism. He could not work on the project he had created.

The press also focused on the idea of laser weapons. When Ted Maiman announced he had made the first laser, reporters asked if the laser was a "death ray." After trying to duck the question, he finally admitted he could not rule out the possibility. When he returned to California, he found the *Los Angeles Herald* carrying a headline in two-inch red type: "L.A. Man Discovers Science Fiction Death Ray."

After Maiman's success, ARPA expanded its program to study laser mechanisms, materials, and beam interactions with targets. The Air Force gave Maiman a contract to develop ruby lasers, and other military labs started their own laser projects. The armed services focused on near-term applications in missile guidance and communications; ARPA focused on high-energy laser weapons.

Although many physicists were skeptical, they also hesitated to oppose Pentagon plans. After weapon scientists said nuclear re-entry vehicles were so sensitive to thermal shock that laser heating might shatter them, ARPA's laser-weapon budget was boosted to \$5 million. Air Force Chief of Staff General Curtis LeMay jumped on the laser bandwagon, saying on 28 March 1962 that "beam directed energy weapons would be able to transmit energy across space with the

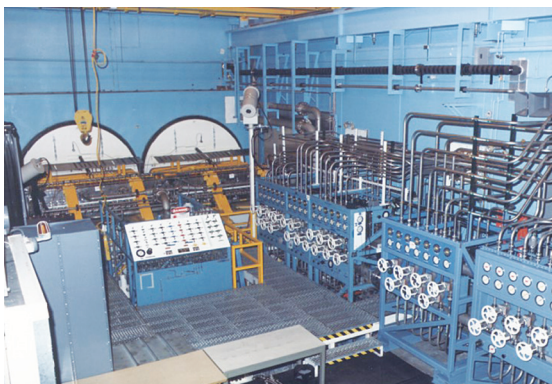


▲ Fig. 1. Gordon Gould. Courtesy of Geoffrey Gould, 1940.

continuous wave from CO<sub>2</sub> at 10 μm in mid-1965. That was enough to satisfy his research needs, but it only whet the appetites of military labs, which began scaling CO<sub>2</sub> lasers to impractical sizes. Hughes reached 1.5 kW using a 10-m oscillator followed by a 54-m amplifier.

The real breakthrough to high-energy lasers was the gasdynamic laser, developed by Arthur Kantrowitz and Ed Gerry at the Avco Everett Research Laboratory near Boston. They knew that sustained laser power would have to reach a megawatt to damage a military target—and figured they might reach that level by drawing 0.1% of the energy from a rocket engine, which could generate a gigawatt by burning chemical fuel to generate hot CO<sub>2</sub>. Expanding the gas through special nozzles at supersonic speed produced a population inversion. “It was a very simple thing, but not a very efficient laser,” recalled Gerry. First demonstrated in 1966, the gasdynamic laser was kept classified until 1970. By then Avco had exceeded 100 kW, although Gerry was only allowed to report 50 kW at the time.

That power level attracted interest from the armed forces, and Avco built three 150-kW gasdynamic lasers, one for each of them. Moving targets proved a challenge. When the Air Force tried to hit a drone flying figure-eight patterns, the beam locked onto a weather tower and melted it. In 1973, the laser finally shot down a weakened drone. The next step was squeezing a 400-kW gasdynamic laser into a military version of a Boeing 707 to make the Airborne Laser Laboratory. Two years after an embarrassingly public failure in 1981, it finally shot down an air-to-air missile over the Naval Weapons Center in China Lake, California. That was the end of the line for the gasdynamic laser, a monster of such size and complexity that critics called it a ten-ton watch.



▲ Fig. 2. MIRACL. Courtesy of U.S. Army Space and Missile Defense Command.

speed of light and bring about the technological disarmament of nuclear weapons.” The Air Force Systems Command budgeted \$27 million for a five-year “Project Blackeye” to develop ground-based anti-satellite lasers and perhaps a space-based laser weapon.

But early laser technology was not up to the task. American Optical pushed neodymium-glass lasers to generate 35-J pulses, but thermal effects shattered the rods. The same happened to ruby rods when Westinghouse pushed Q-switched pulse energy to 60 to 80 J. Discouraged, ARPA scaled down its solid-state laser weapon program around 1965.

By that time, the carbon-dioxide laser was showing hints that gas lasers could reach high powers—and could conduct away troublesome heat. C. Kumar N. Patel generated 200 watts

After the Big Demonstration Laser built by TRW exceeded 100 kW, the Navy focused its attention on chemical lasers because moist air transmits better at the 3.6- to 4.0-μm band of deuterium fluoride. In 1978, the 400-kW Navy ARPA Chemical Laser (NACL) became the first chemical laser to shoot down a missile in flight. TRW then built the first megawatt-class laser, the Mid-Infrared Advanced Chemical Laser (MIRACL) (Fig. 2). The giant laser, finished in 1980, could emit 2 MW, but only for seconds at a time. Focusing that tremendous power through the air to a moving target proved an overwhelming challenge, and by the early 1980s the armed services

had lost their enthusiasm for deploying laser weapons.

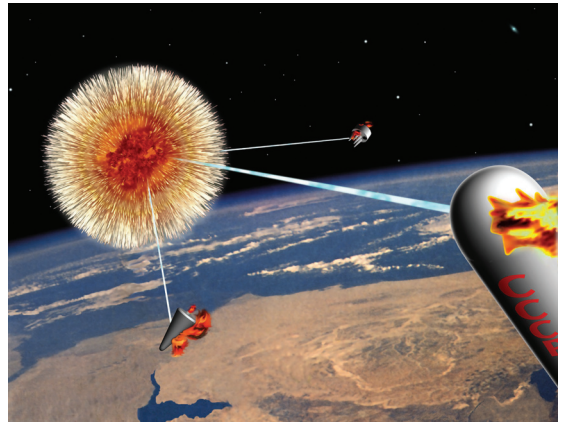
DARPA, renamed the Defense Advanced Research Projects Agency in 1972, had spent the 1970s trying to develop high-energy lasers at short wavelengths. Projects included x-ray, free-electron, and excimer lasers. At the end of the decade, DARPA proposed building three testbeds for testing space-based defense against a nuclear missile attack: a high-frequency laser called Alpha emitting 5 MW at 2.7  $\mu\text{m}$ , a 4-m high-power space mirror called the Large Optics Demonstration Experiment (LODE), and a pointing and tracking system called Talon Gold.

Then Lockheed engineer Max Hunter proposed an even bolder plan, using that technology to build a fleet of 18 orbiting chemical laser battle stations to block a Soviet nuclear attack. He claimed that 17,000-kg satellites could carry the laser, the optics, and enough fuel to fire 1000 shots at targets up to 5000 km away, and proposed launching them on the space shuttle. Senator Malcolm Wallop embraced the plan and in 1979 claimed it could be built for \$10 billion.

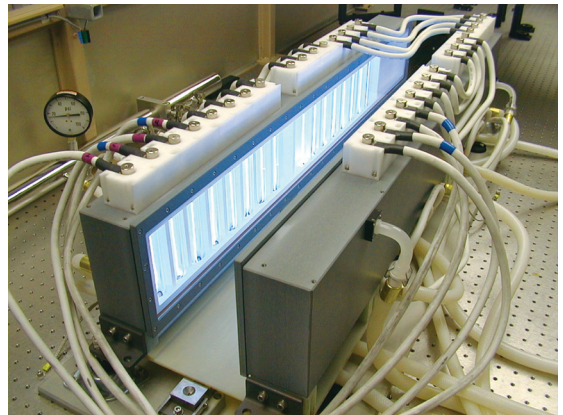
Ronald Reagan's Strategic Defense Initiative took over the DARPA space laser projects in 1983, envisioning them as part of a multi-layer defense system designed to block a Soviet nuclear attack. SDI also poured money into plans for space-based x-ray lasers (Fig. 3) and massive ground-based free-electron lasers to be paired with orbiting relay mirrors. Most of the laser community was skeptical—to say the least—but SDI spending on optics peaked around \$1 billion a year in the mid-1980s, including optics for beam direction, target tracking and other purposes, as well as high-energy lasers.

A ground-based demonstration of the Alpha laser achieved megawatt-class output in 1991, but after the end of the Cold War, most of the big high-energy laser missile defense programs faded away. They were replaced by a missile defense program that at the time seemed more realistic than orbiting laser battle stations: the Airborne Laser. The plan called for installing a megawatt-class chemical oxygen-iodine laser (COIL) in a modified Boeing 747 to defend against a few missiles launched by a “rogue state” such as North Korea. Emitting at 1.3  $\mu\text{m}$ , the COIL included an adaptive optics system designed to deliver lethal power to missiles rising through the atmosphere up to a few hundred kilometers away. After falling several years behind schedule, it destroyed two test missiles in February 2010, but results fell far short of operational requirements, and the program was canceled.

Ironically, as the Airborne Laser faltered in the 2000s, dramatic advances in diode-pumped solid-state lasers opened the door to a new class of laser weapons, vehicle-mounted systems powered electrically rather than by special chemical fuels. They are designed to stop rocket, artillery, and mortar attacks by detonating the munitions in the air at ranges to a few kilometers. A key demonstration was the Joint High Power Solid State Laser (JHPSSL) (Fig. 4), a diode-pumped neodymium-slab laser built by Northrop Grumman, which fired 100 kW continuous wave for five minutes in March 2009. More recently, the multi-kilowatt beams from several industrial fiber lasers have been combined and used to shoot down rockets.



▲ Fig. 3. Space-based x-ray laser art. Courtesy of Lawrence Livermore National Laboratory.



▲ Fig. 4. Inside view of Joint High Power Solid State Laser (JHPSSL). Courtesy of U.S. Army Space and Missile Defense Command.

Big challenges remain in making high-energy lasers that can fire reliably on the battlefield, with key issues including keeping the optics clean, avoiding optical damage, building durable cooling systems, and making the lasers reliable and affordable. But the task is also vastly easier than SDI's goal of building orbiting battle stations capable of blocking a massive Soviet nuclear attack.

Note: This article was adapted from [1].

## Reference

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1. J. Hecht, "A half century of laser weapons," *Opt. Photon. News* 20(2), 14–21 (2009).