# World's Most Powerful Solid-State Laser

START with a 6-second shot of laser light. End up with a 1-centimeter hole in a 2-centimeter-thick slice of steel.

In the past, this sort of fire power was only available from large gas or chemical laser systems. But thanks to a new technology developed at Livermore, this feat was accomplished by a refrigerator-size laser system using about 30 cents worth of electrical current from a wall socket. Dubbed the solid-state heat-capacity laser (SSHCL), this system garnered one of 100 awards presented annually by *R&D Magazine* to honor the most technically innovative products for the year. The SSHCL can produce up to 13,000 watts in a single, high-quality beam with output-pulse energies of more than 600 joules, making it the most powerful solid-state laser in the world.

The system's solid-state heat-capacity design paves the way for a laser, now under development, that will produce 100,000 watts in a single beam and opens up a range of applications for industrial materials processing and military defense. (See *S&TR*, April 2002, pp. 19–21.)

## New Operation Mode Means More Power

According to Brent Dane, who led the SSHCL team in Livermore's Laser Science and Technology program, the breakthrough that made this laser possible involves a revolutionary, yet seemingly straightforward solution to dealing with the high temperature gradients that occur while operating a solid-state laser system.

Before the SSHCL, solid-state lasers operating with high-energy pulses have been limited to power outputs of less than 1,000 watts. The stumbling block to increasing the power involved the heat generated during laser operations. "Any laser creates waste heat in the system," explains Dane. "For a solid-state laser, this heat is deposited inside the optics—the glass or crystal—that provide the gain for lasing. If not removed, the heat can damage the optics."

Most solid-state laser systems are continuously cooled while operating to avoid such damage. Waste heat is conducted from inside the glass to the surface where it can be carried away by coolant, such as water. This cooling process occurs at the same time as the lasing, creating a large difference in temperature between the optical material's relatively cool surface and its heated interior. These large temperature gradients lead to mechanical stress, physical deformation, optical distortion, and ultimately, to the fracture of the optic.

Dane and his team have demonstrated a different operating mode, in which the laser's cooling cycle is completely separate from its high power bursts. During a burst, the waste heat accumulates evenly throughout the glass or crystal material of the optic. At the end of the burst—which typically lasts 10 to 20 seconds—the laser is shut off, and the optical material is aggressively cooled over a period of from 30 seconds to several minutes. Operating the system in this pulsed manner—separating lasing cycles from cooling cycles—means that there are no significant thermal stresses on the optical material during lasing. The average power emitted by the laser is now limited only by the power capacity of the laser pump source, which for the SSHCL is flashlamps or another Livermore-developed technology, the high-average-power diode array (see the article on diode arrays, p. 6). "This pulsed operation means that the average power cap is removed for solid-state lasers, allowing us to scale up the output to hundreds of thousands of watts," says Dane.

Members of the solid-state heat-capacity laser development team are, from left, Balbir Bhachu, William Manning, Scott Fochs, Bruce Roy, James Wintemute, Steve Sutton, Georg Albrecht, Brent Dane, and Mark Rotter.

## Many Advantages to SSHCL

This unique pulsed operating mode makes the SSHCL the most powerful solid-state laser around. When compared with other pulsed-format solid-state lasers, the average power of the SSHCL during a burst is better than that of the competition by more than tenfold. And when compared with the most powerful nonpulsed solid-state lasers, the SSHCL exceeds their average power by up to two times.

But what about other lasers that are not solid-state based? According to Dane, the realm of truly high-average-power laser systems has been historically dominated by chemical and gas lasers. Because these lasers, by their very nature, can flush out the waste heat from their systems along with the expended (and often toxic and corrosive) combustion products, it has been possible to scale their output powers to the highest values ever obtained for any laser system. However, says Dane, the SSHCL is now prepared to scale up to and challenge the highest powers obtained from these lasers as well. SSHCL has other advantages over these giants of the laser power world, including the ability to operate at a shorter wavelength of laser light. A shorter wavelength allows a laser beam to propagate longer distances through the atmosphere with less beam spread. (The greater the beam spread, the lower the power density—that is, watts per unit area—delivered to the target.) For example, given the same size beam, the smallest theoretically achievable beam area spread for the powerful deuterium fluoride chemical laser is 12 times greater than the beam spread for the SSHCL, and for the carbon dioxide laser, it is 100 times greater.

The SSCHL also has the advantage when it comes to operational logistics. It can be installed and operated on a mobile vehicle the size of a jeep and powered by electrical generating equipment that consumes conventional fuels such as diesel or gasoline. In practice, says Dane, advanced versions of the SSHCL will also be able to use high-storage-capacity, rechargeable batteries that are part of a vehicle. A subscale prototype SSHCL amplifier, capable of 15,000 watts of output power using advanced lithium-ion batteries, is being constructed and will be demonstrated at Livermore next year.

## Bright Future Foreseen

From military to industry, organizations and companies foresee a bright future for the world's most powerful solid-state laser system.

One interesting possibility, notes Dane, is using the large pulse energies of the SSHCL to clear orbital space debris from the paths of satellites and manned shuttle flights. Precisely targeted laser pulses could cause the orbits of space trash to decay, allowing the trash to harmlessly burn up during reentry into the atmosphere. Other more down-to-earth applications for the future include heat treatment of metals and thick-section metal cutting and drilling.

Laser technician Balbir Bhachu monitors the performance of the 13,000-watt solid-state heat-capacity laser during a low-power test. The prototype uses an electrical source to power flashlamps, which in turn pump nine neodymium-doped glass laser disks that release energy in pulses of laser light.

Because the project is sponsored by the U.S. Army Space and Missile Defense Command, the first application is a military one: to defend against rockets, artillery, mortars, and other tactical threats at close range (1 to 10 kilometers). There is, Dane notes, currently no effective protection against these weapons in the battlefield. Michael W. Booen, vice president of Directed Energy Systems for Raytheon Electronic Systems, said, "Tests of this laser to melt metals and damage other materials are convincing many audiences that the era of tactical, solid-state weapons may be fairly close at hand."

The Livermore team and its industrial partners (including Raytheon, General Atomics, PEI Electronics, Northrop Grumman, Goodrich Corporation, Armstrong Laser Technology, and SAFT America) are already working on a version of the SSHCL capable of being transported and powered on the modern version of the Humvee military jeep. This final laboratory demonstration version of the SSHCL, which will have an output power of 100,000 watts under burst mode for up to 10 seconds, could be ready to demonstrate to the Army by 2007.

*—Ann Parker*

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