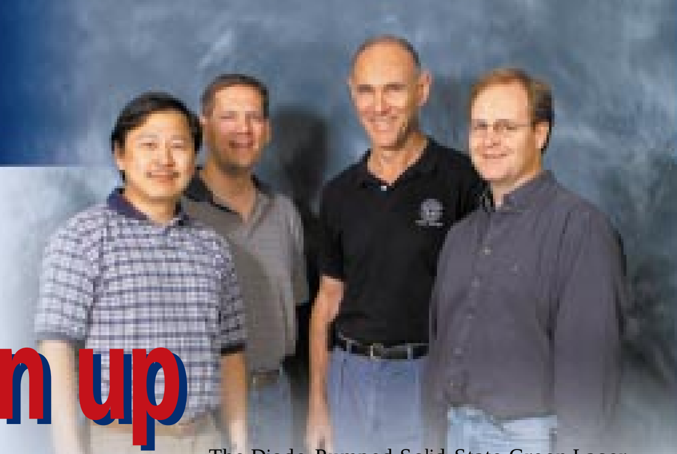
High-Power Green Lasers Open up Precision Machining



The Diode-Pumped Solid-State Green Laser (DPSSGL) development team includes, from left to right, Jim Chang, Christopher Ebbers, Isaac Bass, and Curt Cochran. Not pictured is Ernest Dragon.

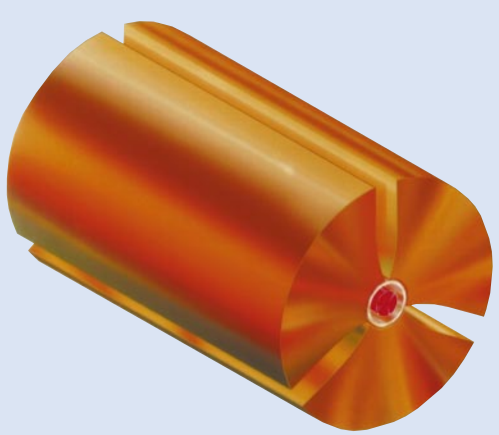
THE power of green light is requisite to the world of precision laser machining. During the past decade, pulses of green light have come from copper-vapor lasers and lamp-pumped solid-state green lasers, but ever-growing demand for higher performance and reliability have pushed these laser systems beyond their capacity. Now, an R&D 100 Award–winning system based on a Diode-Pumped Solid-State Green Laser (DPSSGL) looks to be a natural contender for meeting these demands. In addition to its use for precision machining, the high-power pulsed green laser can be used to pump ultrashort-pulse lasers, create laser displays, and treat disfiguring skin conditions such as port-wine stains.

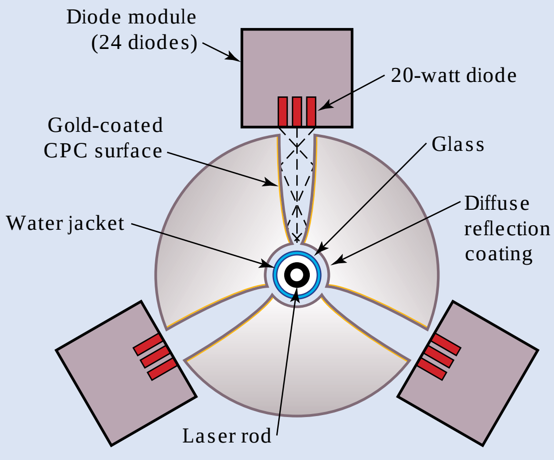
The DPSSGL—developed by physicist Jim Chang and others from Lawrence Livermore's Laser Programs Directorate and from the United States Enrichment Corporation—provides more than 300 watts of pulsed green output at 10 to 20 kilohertz. This is a world record for green-light generation and far outshines the capabilities of commercial copper-vapor lasers, which provide up to about 120 watts, and lamp-pumped solid-state green lasers, which provide about 50 to 100 watts.

The DPSSGL is also much more reliable than current systems. For instance, a lamp-pumped system or a copper-laser system used in an industrial setting lasts only about a month, at which time the lamps must be replaced or the copper reloaded. This maintenance requirement not only increases the operational cost of these systems but also prevents them from being used in applications that require long-duration continuous operation (such as in machining for the automotive industry). Because of its innovative design, the new laser can be run around the clock for more than one year without major maintenance. Moreover, its electrical efficiency ranges from 7 to 8 percent, in contrast to electrical efficiencies hovering around 1 percent for both the lamp-pumped green laser and copper-vapor laser.

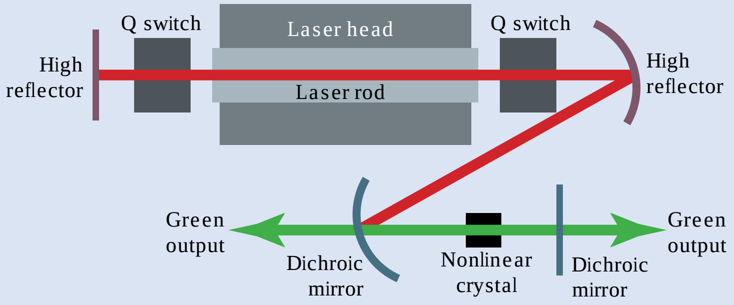
Innovative Design Halves Costs

Although diode-pumped green lasers gradually have been replacing many lamp systems for low-power applications such as laser marking and titanium–sapphire laser pumping, their use in high-power applications has been hindered by their complexity and cost, because of the large number of diodes they use. Chang and his team developed an innovative design that greatly simplifies laser construction and cuts the system's cost by 30 to 50 percent, making it a viable replacement for high-power lamp-pumped systems.





Schematic of the diode-pumped solid-state green laser (DPSSGL) pumping concept. Light from a diode is compressed by the compound parabolic concentrator (CPC) through a small slit into the chamber surrounding the laser rod. There, the rod absorbs the diode light and converts it into infrared laser light.



Above, a schematic of the optical system shows how infrared light emerging from the compound parabolic concentrator (CPC) laser head is converted into pulsed green light. At right, a technician is shown working with the laser.

The DPSSGL uses light from high-power laser diodes to optically excite a solid-state laser rod. The radiation from the diodes normally diverges rapidly; in this case, the light is concentrated by two parabolic surfaces, called a compound parabolic concentrator (CPC). The CPC compresses the diode light through a small slit into a chamber surrounding the laser rod. The light is trapped in the chamber, where the rod can then efficiently absorb it.

Chang notes that the CPC's efficiency in compressing the light is better by a factor of 3 to 5 over conventional optics. This compression efficiency permitted the team to design a fully enclosed pump chamber that more effectively traps light for exciting the rod. Furthermore, because the CPC's parabolic surface works like a convergent waveguide to direct the light into the pump chamber, no lens is needed to focus the light through the narrow slit. This feature both simplifies laser-head assembly and improves system reliability. The resultant laser head greatly simplifies light delivery to the laser rod and provides a compact and robust package.

The CPC laser head converts more than 40 percent of the diode radiation into infrared laser light, a rate that is 30 to 40 percent higher than that of other commercially available high-power designs. A well-designed high-power optical system then converts 75 to 80 percent of this infrared laser light to pulsed green output via carefully configured nonlinear crystal and acousto-optic Q switches. The rack-mountable, efficient system design enabled the laser to generate a record amount of pulsed green light and to log more than 40,000 unit hours of around-the-clock operations.

Lean and Green for Machining

Over the past few years, the use of pulsed green laser systems has increased. Such systems are proving to be effective tools for high-quality machining because of their small laser spots and good laser–material coupling. Originally developed for the enrichment of nuclear fuels through the Livermore-developed atomic vapor laser isotope separation (AVLIS) process, the DPSSGL looks to be especially useful in precision laser-machining applications. This emerging technology is finding a place in the automotive and aerospace industries for drilling fuel injectors and turbine engines as well as for other precision machining tasks. Such lasers also show promise in certain laser micromachining tasks performed in the electronics industries—for example, to scribe wafers, trim resistors, and drill microscopic holes.

As noted by one of the major suppliers of high-power industrial laser systems, "This type of laser system will lead the push toward the use of diode-pumped lasers in industrial applications that require reliability, power, and good beam quality. There are many industrial applications that may well be opened up by the availability of green power at this level." Another laser company also noted, "The reliable operation record of the Livermore laser has convinced us that high-power diode-pumped lasers have finally emerged as a mature technology." Apparently, the DPSSGL will radically change the business strategy of many industrial laser manufacturers.

—Ann Parker

Key Words: compound parabolic concentrator (CPC), Diode-Pumped Solid-State Green Laser (DPSSGL), industrial lasers, precision laser machining.

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