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## Abstract

The average power performance capability of semiconductor laser diode arrays has improved dramatically over the past several years. Additionally, optical conditioning technologies have been developed that increase the effective radiance of stacked two-dimensional arrays by nearly two orders of magnitude. These performance improvements have been accompanied by cost reductions that now make feasible the replacement of flashlamp pump sources by laser diode arrays in a large variety of military and commercial solid state laser systems.

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The type of packaging technology applied to semiconductor laser diode arrays is key to enabling the high average power performance of these devices. Not only must the laser diode package be capable of efficiently shedding the large heat intensities generated at the laser diode array with only a small temperature rise at the device, it must also be low cost to implement if it is to be attractive to commercial users. In designing the Lawrence Livermore National Laboratory (LLNL) laser diode package these points were seriously addressed and a systems level approach was used in carrying out the design. The laser diode packaging group worked closely with the solid state laser design groups at LLNL to develop a package that would be suitable for applications involving the diode pumping of high average power solid state laser systems. In addition to the requirements of aggressive heatsinking and low cost, the package was also required to be modular and to minimize the number of external hydraulic and electrical connections to large two-dimensional arrays constructed by stacking many of the modules. The modularity was required to ensure the maintainability of such large two-dimensional arrays. It was desired to hold the level of diode array integration to several linear centimeters of diode array bar length per package so that if it became necessary to service a large array, small sections could be replaced cheaply and easily. Minimizing the number of external hydraulic connections to large arrays constructed from the LLNL package was necessary to ensure the simple and flexible implementation of these arrays into diode pumped solid state laser (DPSSL) systems in which the number of external hydraulic connections to the diode pumps impacts system complexity as well as the overall system size and weight. In many of the military systems LLNL is involved in, weight and volume envelopes are often the deciding factor as to a system's viability for its intended mission. In commercial systems; it is the simplicity, improved maintainability, and cost savings that can be realized when the hydraulic circuits are simplified that is attractive. To ensure the package manufacturing technology was low cost in terms of its implementation and consumed materials a silicon based construction technique was chosen. Aggressive thermal performance of these silicon modules is obtained through a series of microscopic water channels fabricated to allow cooling water to flow in close proximity to the laser diode heat source. Thermal paths are simple and kept to a minimum length and only a single solder bond is required between the laser diode heat source and the cooling water. No exotic, expensive, high thermal conductivity materials (such as synthetic diamond) are used in the package; it is fabricated entirely from low cost silicon and borosilicate glass.

One of the chief advantages of using laser diode arrays as replacements for flashlamps in the excitation of solid state lasers is the ability to focus their outputs to small spot sizes and high intensities. This ability to generate high intensities has significantly expanded the number of ions and transitions that can be exploited for use in practical laser systems. Along with this increase in the number of ions and transitions has come an increase in the number of wavelengths that can be generated by DPSSL's and so an increase in the number of applications that can look toward diode pumped solid state lasers for a solution to their specific problems. One draw back of pumping solid state lasers using laser diodes that are focused to high intensities that has existed until recently has been the limited number of apertures that could be efficiently combined and delivered to a single focused pump spot. This has limited the peak and average power scaling capability of the approach and so limited the number of applications for which it could be usefully implemented. In an effort to address this limitation of laser diode pump arrays, LLNL has developed a microlens conditioning technology which is used to condition the fast axis divergence of the laser diode radiation from 60° FWHM down to 0.6° FWHM. This effectively allows large arrays to be focused in the fast axis direction to a spot size 100 times smaller than would be possible if no optical conditioning had been performed. This ability to perform optical conditioning along with the development of optical lensing ducts has enabled the development of a scalable end-pumping technology at LLNL in which the radiation from large and extended two-dimensional laser diode arrays can be easily and efficiently delivered to the end of a rod laser at very high intensity. To date this technology has been used to build a 100 mJ Q-switched Nd:YLF laser oscillator for use in atmospheric and space-based lidar systems and a wing-pumped Cr:LiSAF laser using 770 nm AlGaAs laser diode pump arrays. Presently, the end-pumping technology is being pursued in the demonstration of a 2 micron Tm:YAG laser for medical applications. One very promising commercial development foreseen to emerge with this technology is in the area of high-average-power DPSSL systems for material-processing applications in which a rod laser technology could be used with Yb:YAG as the gain element. The high intensities that can be generated with the end-pumping technology offer an opportunity to overcome the deleterious effects of ground state absorption in $Yb^{3+}$. At the same time, advantage can be taken of the very small thermal power generation parameter of the $Yb^{3+}$ by using the high-average-power capability of the LLNL developed diode packaging technology to implement a high average DPSSL using a very simple, compact, and inexpensive end-pumped rod laser approach.

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