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Aluminum-Free Diode Lasers

The commercialization of aluminum-free diode lasers opens a new era of high-power semiconductor lasers.

by Geoff Burnham, Semiconductor Laser International

High-power semiconductor lasers emitting at near-infrared wavelengths (typically 780 to 1000 nm) have been found a significant number of applications, such as solid-state laser pumping, printing, imaging, and several military applications. More and more applications will be emerging as the laser diodes become more cost-effective and reliable.

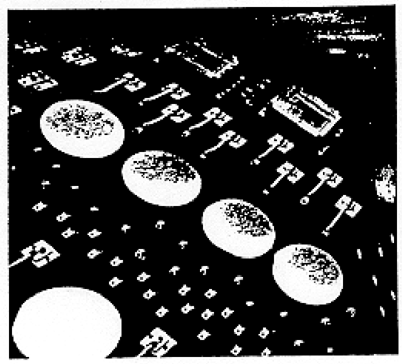
At present, most of the high-power near-infrared diode lasers use AlGaAs/GaAs material as the gain medium to generate laser beams, based on the historical development of diode laser technology. But the use of Al-containing semiconductor material for laser diodes can limit the output power and lifetime of the diode lasers themselves, because of certain material disadvantages, such as a low catastrophic optical damage (COD) threshold,[1] and device degradation caused by the formation of dark-line defects.[2] A low COD level limits the maximum optical power that can be extracted from the laser diode.

Dark-line defects and their growth during laser operation are the major device failure mechanism for AlGaAs-based semiconductor lasers. Furthermore, growth of dark-line defects is accelerated if the laser is operated at high levels of injection current, which is typically the case of high-power laser operation. Another disadvantage of using AlGaAs material is the relative difficulty of material regrowth, which is usually required to make distributed-feedback (DFB) or other advanced laser structures.

The growth of InGaAsP quaternary material, lattice-matched to a GaAs substrate, is very attractive as an aluminum-free alternative to the conventional AlGaAs-based materials for semiconductor laser diodes. By carefully choosing the material composition, the InGaAsP material covers most of the AlGaAs laser wavelengths, from 700 to 1000 nm. Four primary distinguishing features of the InGaAsP Al-free material system for the realization of reliable, high power diode laser sources exist.

First, retardation or even elimination of the growth of dark-line defects considerably improves device reliability and expected operational lifetime. Second, a significant increase of the COD level (due to a reduction in facet heating) raises the limit of the maximum output power and allows direct operation of the laser diodes without special facet coatings. Third, higher electrical and thermal conductivity, as compared with AlGaAs material, reduce the individual laser device's series resistance and thermal resistance, respectively, which significantly improves devices' thermal performances. Fourth, the low reactivity of InGaAsP to oxygen facilitates regrowth for the fabrication of advanced laser structures such as DFB lasers.

The advantages of the Al-free material over conventional AlGaAs material have attracted significant interests of developing high-power Al-free semiconductor lasers for high-reliability operations.



Diode lasers from wafers to finished products.

Results With Al-Free Lasers

Utilizing aluminum-free laser material greatly improves laser performance and dramatically increases the power levels which in turn results in increased power capabilities of light emitted by the diode laser. Recent experimental results have shown extremely high power output and excellent lifetime from these aluminum-free lasers.

The Center for Quantum Devices at Northwestern University (Evanston, Ill.), has achieved operation at 60° C, with 1 W of output power from a 100-µm-emitting aperture, over a device lifetime of 30,000 hours without any degradation in output power or change in wavelength, threshold current, or efficiency.[3] These devices do not have any facet coating. Another research group at University of Wisconsin (Madison, Wisc.) recently reported as high as 8.1 W of cw output power from a single 100-µm, wide-stripe, Al-free laser.[4]

The rapidly improving performances of aluminum-free laser diodes indicate that a new era of high-power semiconductor laser is here. Aluminum-free laser diodes will eventually replace AlGaAs lasers for many high-power, high-reliability applications.

SLI's Al-free laser products

Semiconductor Laser International Corporation (SLI), founded in 1993, is dedicated to the production of high-power semiconductor lasers at low cost, as well as to the research and development of novel semiconductor laser systems. In addition to standard laser diode products in various packaging configurations, SLI supplies custom fiber- pigtailed packages for single-chip, single-bar, and multi-bar arrays. High-power, single-spatial-mode lasers utilizing ridge-waveguide structure have also been developed.

In October 1996 SLI was granted an exclusive license from Northwestern University's Center for Quantum Devices, to develop, manufacture, market and sell aluminum-free, high-power semiconductor lasers worldwide.

Geoff Burnham is president of Semiconductor Laser International, 15 Link Drive, Binghamton, NY 13904. Telephone is 607/722-3800.

Refernces

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3. M. Razeghi, "Temperature sensitivity of long-lived, Al-free diode lasers", Technical Conference Proceedings, Volume 3001, Photonics West, San Jose, Calif., Feb. 1997.
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