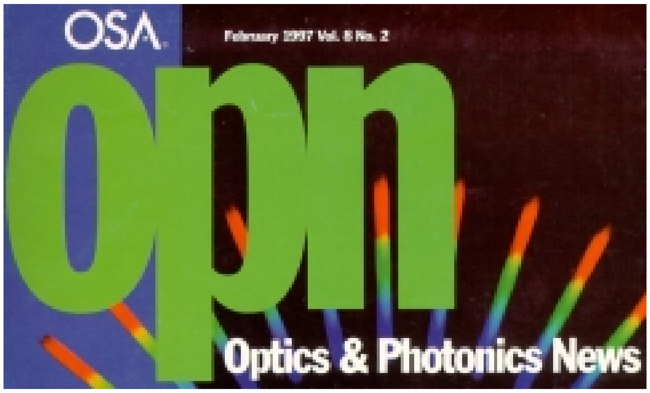

Building a better high-power laser diode

Semiconductor Laser International Corp. (SLI) and Coherent Inc. are removing aluminum from their laser diodes to offer higher power, longer lifetime, and lower cost. The technology replaces AlGaAs quantum wells and cladding layers normally used in high-power diode lasers. Lower emitting facet temperature of aluminum-free diode lasers provides higher output power levels, and resistance to dark-line defects improves reliability. Aluminum-free laser diodes have drawn lots of attention, and more companies have plans to develop the technology. But the semiconductor laser industry has not discounted AlGaAs diodes.

"Aluminum-free devices have been hyped up as the solution for everything, while others have pooh-poohed the technology," says Dan Botez, a professor at the University of Wisconsin/Madison, who works with aluminum-free laser diodes. The key issue is whether there is aluminum in the active region of the diode. "It's a big advantage at 0.81 or 0.78 μm [important laser pumping wavelengths], when you're forced to put aluminum in the active region," he says. Since AlGaAs has poor optical quality and a much lower facet damage level than aluminum-free material, "aluminum-free devices will win out at 0.81 μm and beyond," Botez predicts.

"Aluminum-free [technology] has lots of potential, but it's not going to sweep AlGaAs," says John Tracy, president of Opto Power Corp., a high-power laser diode manufacturer. Tracy compares the situation to GaAs integrated circuits in the 1980s, when the material was highly touted, but did not take over the semiconductor industry. "Great improvements are being made in AlGaAs," Tracy says. "There will be some astounding results."

New lasers

In about six months, SLI plans to launch aluminum-free laser diodes with 4 W per 100 μm with a lifetime on the order of 40,000 hours. "With no aluminum in the structure, you can operate these devices at room temperature without facet coating," says Geoffrey Burnham, SLI president and CEO. "You save about one-third of the cost of the manufacturing process."

SLI's lasers are based on InGaAs(P)/InGaP technology developed by Manijeh Razeghi at Northwestern University (see *OPN*, August 1995, page 16). SLI licensed the Northwestern patent, which covers a metal-organic chemical vapor deposition (MOCVD) method for fabricating aluminum-free wafers.

Coherent, meanwhile, has been buying wafers from Tutcore OY Ltd., a Finnish company, and selling aluminum-free diode lasers for almost a year. "In our diode production, we were missing the growth step," says Vittorio Fossati, Coherent's director for laser diode programs. "[We determined that] having growth in-house was necessary for success, so we acquired Tutcore," buying 80% of the company's outstanding shares in December.

Applications for high-power diodes run the gamut through telecommunications, material processing, printing, medicine, and laser pumping. The 1996 market for high-power laser diodes is over $100 million and likely to grow 25% next year, according to Bob Steele, an analyst with Strategies Unlimited, an optoelectronics industry market research firm. Coherent, however, estimates a $200 million market.

Why aluminum?

Aluminum is added to GaAs semiconductors to achieve wavelengths below about 840 nm. By adding aluminum, GaAs semiconductor laser wavelengths get down to about 780 nm. At that point, the abundance of aluminum degrades the quality of the diode's active region, which severely degrades performance. Researchers have been trying to reduce the problems of aluminum-based GaAs semiconductor laser material for years, using techniques such as putting strain on the quantum well, seeking higher-quality aluminum, and replacing aluminum with indium and phosphorus.

Researchers have approached 9 W cw maximum power levels with aluminum-free material at 980 nm, and 5 W cw at 810 nm. Although some question the correlation, a rule-of-thumb in the laser diode business is that operating power is roughly half that of maximum power. The record power level still belongs to AlGaAs/GaAs diodes, after SDL Inc. announced 11 W cw from an 860 nm diode with a 100 μm emitting output aperture. The operating temperature was 10°C.

SDL maintains that while the record-breaking technology is not ready for commercialization, it shows potential for excellent yields and substantially lower manufacturing costs. AlGaAs/GaAs laser diodes with 1.2 W of power and 100,000-hour lifetimes have been available from SDL since 1990. The new aluminum-free technology "is not going to open up whole new markets," says SDL President Don Scifres. "It's the standard march toward higher power and increased reliability." Aluminum-containing lasers will continue to improve as well, Scifres notes.

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Senior Staff Writer
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Dollars-per-watt

With the same package size, SLI lasers will have two or three times the power of today's commercially available laser diodes, says Burnham. Higher power in smaller packages will reduce the number of lasers in an array for high-power applications, and allows more lasers to be packed together on a semiconductor wafer, which reduces cost. "You'll be able to cut cost in half from current products," Burnham predicts.

Burnham thinks his company can produce 650 nm lasers and address new markets with aluminum-free diodes. "We're not positive how low we can get," Burnham says. A lot of work has gone into achieving shorter semiconductor laser wavelengths, particularly for data storage applications. He points out that optical storage applications are looking toward 635-650 nm wavelengths. A lot of work is being done with GaN to reach into blue wavelengths and beyond. "Gallium nitride has different issues," says Burnham. "With aluminum-free technology, you can use technology that has already been developed" for GaAs, such as metalization schemes and soldering techniques.

Building diodes

While the Northwestern patents cover an MOCVD method for making aluminum-free diodes, Coherent is confident of Tutcore's fabrication technique, which is based on molecular beam epitaxy (MBE). The approach offers higher yields in production and better processing technology than other diodes, according to Coherent's Fossati. The MBE-grown structure allows devices with lower beam divergence and better spectral uniformity and reproducibility, he says.

Coherent acknowledges that they haven't accumulated the lifetimes to substantiate high reliability. "We can do projections, but we like to be more careful," Fossati says. "We don't believe [projections] are fair numbers to give to users," he says. "We're working on protocols—industry needs numbers that are understandable." Coherent is working towards 20,000-hour lifetimes, and reports over 3,000 hours of operation with 1 W devices at 40°C. ◆