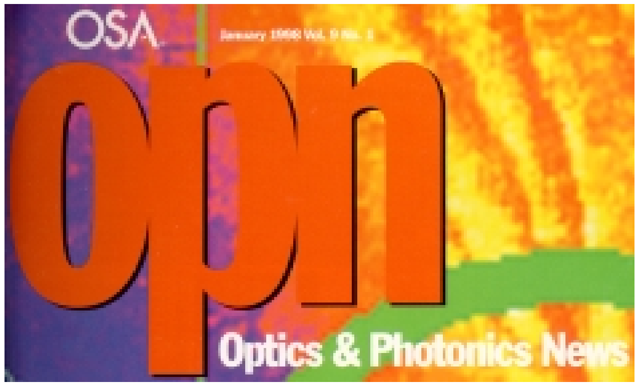


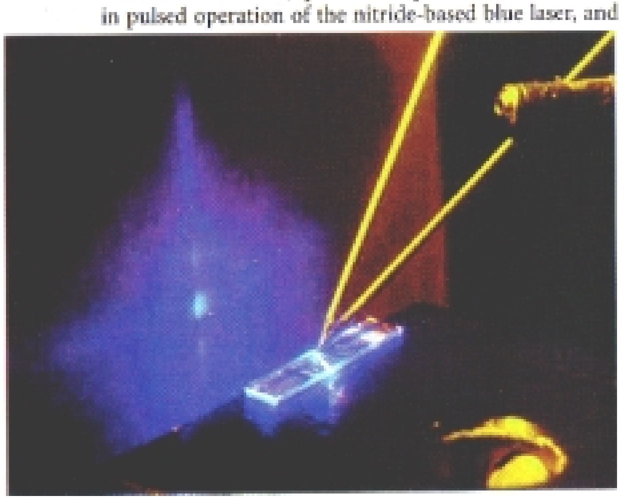
As Companies Race to Develop the Blue Laser, Universities Join the Game

Nichia Chemicals Industry Ltd. is still setting the pace, but more companies and universities are heating up the competition.

On November 18, 1995, Nichia Chemical Industries Ltd. in Japan produced the first nitride-based blue laser diode. The team's leader, Shuji Nakamura, said in a March 1996 *OPN* article (page 8) that they "celebrated by drinking champagne and taking pictures." The researchers were excited because they had finally proven that gallium nitride (GaN) can be used to create a blue laser. While the group reveled, word of their development reverberated around the world, setting off a fierce competition as companies began scrambling to create this GaN laser that has endless commercial applications for lighting, optical data storage, semiconductors, and more. The lasers may also prove useful as a component in military systems.

Now, two years later, Nichia is still in the lead, announcing last November that they have demonstrated a GaN laser with an estimated lifetime of more than 10,000 hours under cw operation at 20°C. No company has even come close to this lifetime estimation. Although the Nichia researchers have a head start on the technology, they are no longer the lone gatekeepers of the elusive blue laser prize. Since Nichia's discovery, a handful of U.S. and Japanese companies have succeeded in pulsed operation of the nitride-based blue laser, and others have achieved blue through additional methods, some using periodically poled lithium niobate (PPLN) doped with magnesium oxide.

However, using gallium nitride to get a blue laser is the preferred method according to T.Y. Fan, assistant group leader in the quantum electronics group at MIT Lincoln Laboratories. "It's the simplest way technologically to achieve blue, and also the cheapest," says Fan. "If you can satisfy your requirements with the gallium nitride laser, it's the best solution."



The UCSB GaN blue laser.

University success

Until recently, primarily only the commercial sector had achieved success in developing GaN lasers. But, Meijo University in Japan has achieved a pulsed blue laser, and universities have been involved with research efforts—about 15 are currently working on developing the lasers. Universities have also collaborated with industry. For example, the U.S. Defense Advanced Research Projects Agency (DARPA) funded a collaboration between Brown Univ., North Carolina State Univ., and Cree Research Inc. (North Carolina). Cree was the first U.S. company to develop a GaN blue laser, announcing it on June 9, 1997. Other universities such as Boston Univ., MIT, the Univ. of New Mexico, the Univ. of Texas at Austin, and the Univ. of Utah teamed up with Xerox Corp., SDL Inc., and the Hewlett Packard Co. in the Blue BAND II Consortium supported by DARPA. From this effort, Xerox Corp. generated a blue diode laser beam in late October 1997.

But on Sept. 15, 1997, the Univ. of California at Santa Barbara (UCSB), became the first U.S. university to successfully grow and fabricate blue GaN laser diodes on its own. Since the university developed the laser without industry influence, the laser will be used primarily for basic research. Many agree that it is important to study the laser from a scientific perspective, and not just for industry's sake. "I think UCSB has done a good job with the blue laser and since they are a university they will be able to concentrate on the academic study of the laser, whereas big companies have to concentrate on the commercialization of the laser," says Nichia's Nakamura.

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Blue laser

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Robert Byer, director of the Center for Nonlinear Optical Materials at Stanford Univ., agrees that having a university make strides in this area is very important. "Development of the blue laser is a very difficult materials research problem," says Byer. "The most sane way to move forward is to have a number of groups solving these problems. Universities are great places to do research. You can have a number of research groups investigating a range of materials problems and when there are breakthroughs, the knowledge is shared widely and adapted by industry for commercialization."

The UCSB researchers were able to grow, fabricate, and test blue laser diodes that operated pulses for up to six hours at room temperature. Sharp lasing spectra in the blue (420 nm), peak output powers to 17 mW, and a narrow coherent output beam were observed.

"From my viewpoint, we're discovering new phenomena that the companies are not publishing," says Steven DenBaars, associate professor of materials at UCSB and co-advisor to Michael Mack and Amber Abare, the graduate students who performed the lab work. Even though DenBaars could not go into specific details due to patent negotiations, he says, "We're developing new techniques to make materials different from what the companies are doing. The way we grow the layers is different from everyone else. Our ultimate goal is to make a device that no one has made—the blue vertical cavity laser." UCSB's work is presented by the *Materials Research Society Nitride Internet Journal* at http://nsr.mij.mrs.org/2/41.

DARPA sponsored the UCSB research. "We need universities to essentially develop the science aspect and make sure we push the limits toward things industry isn't developing," comments Anis Husain, assistant director for the electronic technology office at DARPA and program manager for the gallium-nitride optoelectronics program.

"In UCSB's case, we want to be able to make the blue vertical cavity laser with the same efficiency we have in the infrared. This would be very attractive to the lighting industry, and we may some day be able to use blue/green laser light in lightbulbs," says Husain.

How far ahead is Nichia?

As noted, Nichia is considered to be the leader of this industry. And with their announcement of 10,000 lifetime hours, the company is one step closer to developing the laser for applications in color scanners, data storage, large TV displays, traffic lights, and more. "Nichia is still very far ahead of all the competitors," says DenBaars. "So far nobody has closed the gap."

"Nichia has a 5–10 year head start," agrees Husain. "We in the U.S. largely ignored this area. Nakamura had been working on this 10 years prior to his announcement, and really we had no major effort here. I think the potential was there, but many people just didn't believe it could be done. Once it was, there was a tremendous initiation of activity."

In addition to Xerox and Cree Research, other companies such as Hewlett Packard, Toshiba, Fujitsu, and Sony have also developed the blue laser.

This race is far from over, and one reason may be because the blue laser is such a captivating phenomenon. "It's very exciting," says Husain. "I think before you have the laser, it's like being in a black room with all the doors shut. Once you have the laser, it's a crack in the door and you can see the light." DenBaars agrees and says, "You don't realize how beautiful blue is until you see the color shooting out of a crystal." ◆

This just in . . .

As *OPN* went to press, another university announced a blue laser development. Researchers at Northwestern Univ., under the direction of Manijeh Razeghi, reported a 408-nm stimulated emission from GaInN/GaN multi-quantum well lasers grown by low pressure metalorganic chemical vapor deposition on basal plane sapphire substrates. The stimulated emission was observed from the lasers without high-reflective mirror-coating at threshold current density of 1.5 kA/cm^2 for pulse operation (duty cycle 0.1%) at 78 K. The III-Nitride work at the Center for Quantum Devices is jointly supported by the Office of Naval Research, the Ballistic Missile Defense Organization, and DARPA.