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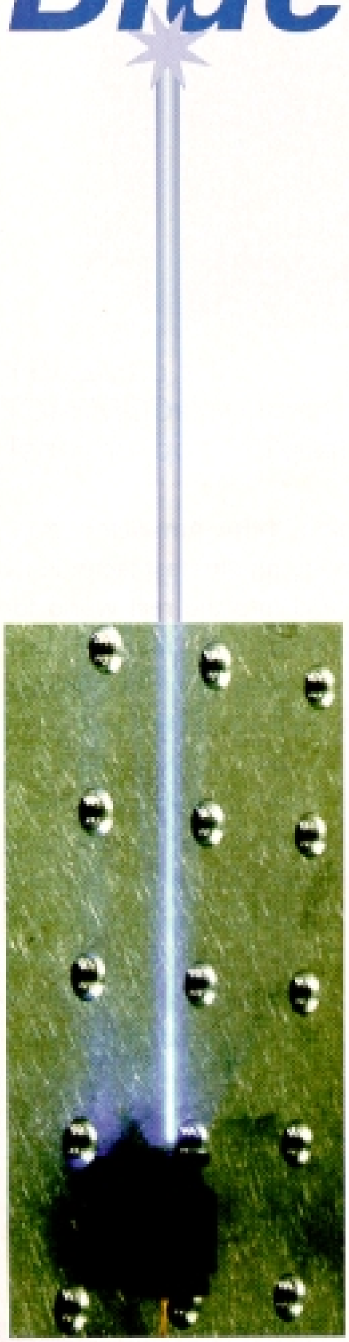
Staff Report:
Blue Lasers

Blue Again



Maybe blue is not coming as quickly as everyone thought.

by Charles T. Whipple
Contributing Editor/Japan

In mid-1998, Curt Fredrickson, then a marketing manager at Spectra-Physics Lasers Inc. in Mountain View, Calif., made a prediction: "If the red diode vs. HeNe wars teach us a lesson, it is that the transition [to blue lasers] will not be as quick as the blue diode advocates would like us to believe."

At that time, there were no blue laser diodes, only wild expectations.

Now Nichia Corp. of Anan, Japan, markets three laser diodes in the blue to violet range with lifetimes of 10,000 hours. And while many companies and research teams hover around the edge of the commercial marketplace, it remains mostly a tangle of wild expectations.

People and patents

A year ago, blue diode inventor Shuji Nakamura was flush with the laser's technical success — and the resulting commercial success for his employer, Nichia. Now a professor at the University of California in Santa Barbara, he declines to discuss it.

"Development of the laser is finished," he said. "And I am no longer an employee of Nichia, so I don't want to talk about their laser."

Nakamura said that he left Nichia because he wanted to be involved in basic research, not applied engineering, and that he chose Santa Barbara because of its expertise in GaN. He has expressed keen interest in the field of alternative light sources, especially for biological applications.

In April 2000, Emcore Corp. of Somerset, N.J., announced that Nakamura and his colleague Steven DenBaars had ordered one of its SpectraBlue GaN production platforms and had started a formal research collaboration to report on the performance of the equipment.

Around October, Nichia rival Cree Inc. of Durham, N.C., mustered Nakamura's services, at least part time. Cree would not divulge the nature of his job, but in November, Cree, its founders and a spin-off gave $2.2 million to the Santa Barbara university to endow a Cree chair in solid-state lighting and devices.

The employment and endowment were a second and third salvo by Cree in a bitter battle against Nichia.

Nichia fired the first shots, filing three lawsuits in Japan alleging that some of Cree's LEDs infringe on Nichia patents. Cree's response came in September: a lawsuit alleging that Nichia's blue laser diodes infringe on US Patent No. 6,051,849, which covers the lateral epitaxial overgrowth technique used in making GaN-based materials. The lawsuit asks the courts to ban Nichia from importing, selling or marketing the devices in the US.

Neither company is talking about the lawsuits. But the Cree suit may have some extra sting because Nichia has been proud of its US and Japanese patent portfolio covering the basic technologies related to making blue or shorter-wavelength lasers and LEDs using GaN. Nakamura describes the company's patents as comprehensive, offering no loopholes through which another company could create GaN-based lasers.

This explains why other companies are slow to enter the market. But it's also why the Cree lawsuit

worries some people who use blue lasers. Because Nichia is the world's sole commercial supplier of blue laser diodes, a courtroom win for Cree would leave US buyers in the dark.

Of course, Cree is not sitting idly by as the case slogs through the courts. Employing Nakamura, even as a part-time consultant, proves that it plans to compete. In October 2000, the company announced that it had achieved continuous-wave blue lasing at 1 to 3 mW for 100 hours at room temperature in the laboratory. Company officials said this achievement shows that Cree has learned how to extend laser lifetimes on silicon carbide. But it's still a long way from being a commercially viable product.

IR × 2 = Compact Blue

While the battle over blue semiconductor lasers rages, a few companies have taken a slightly different tack to produce semiconductor-based blue light sources.

Matsushita Electric Industrial Co. of Osaka, Japan, uses an 830-nm distributed Bragg reflector laser and a second-harmonic generator to create a 415-nm blue beam. Yokogawa Electric Co. Ltd. of Tokyo, a measuring instrument manufacturer, recently introduced a blue laser module based on the Matsushita device. It uses the Matsushita diode at an 852-nm fundamental, then doubles the frequency to 426 nm. Its typical output stands at 1.5 mW.

A device from Coherent Inc. of Santa Clara, Calif., uses 980- and 808-nm diode lasers to optically pump a semiconductor wafer that emits light at 980 nm, which is then frequency-doubled into the blue spectrum at 490 nm.

Other "compact" blue light sources are based on frequency-doubled and -tripled solid-state lasers. Often called microchip lasers, these devices use diode lasers to pump small laser crystals (e.g., Nd:YAG) and create IR light, then use harmonic conversion to reach green, blue and UV wavelengths.

The utility of these alternatives, of course, depends on the application — and the buyer's and seller's definitions of "compact." □

Whither the blue?

Meanwhile, other players continue to plod slowly toward the same goal of a semiconductor diode laser emitting in the blue region.

Sony Corp. has demonstrated a 515-nm blue-green laser that operated for 100 hours at room temperature. It used a II-VI material rather than the III-V GaN-based materials that Nichia employs. Defects in II-VI materials have prevented their reaching short wavelengths in the past, but Sony's engineers said they reduced the defect density in their device from 100,000 per cm^2 to less than 10,000.

Pioneer Corp. of Tokyo also has entered the blue laser melee. It started its blue research program in 1992, producing a pulsed, room-temperature laser in June 1998 and continuous-wave lasing in September 1999. Since then, Pioneer has agreed to collaborate with Rohm Co. Ltd. of Kyoto to develop a GaN blue-violet semiconductor laser. The companies plan to produce a commercial laser within two years.

Also in September 1999, researchers at the Institute of Industrial Science at the University of Tokyo demonstrated a 399-nm vertical-cavity surface-emitting laser (VCSEL) operating at room temperature.

The German, Japanese and Italian researchers, headed by Takao Someya, used InGaN quantum wells that they sandwiched between nitride and oxide-based reflectors. The lasing came as the result of optical pumping.

"An optically pumped laser does not need electrodes to inject the carriers into the active layer," said Susumu Noda, a professor at Kyoto University.

"Also, it does not need to form a PN junction. Thus, optical pumping makes it easy to test whether the structure can work as a laser."

However, he added, electrically pumped lasers are better commercial products than are optically pumped devices because they are compact and need no additional light sources, and their output power can be adjusted simply by changing the injection current.

In the US, however, surface-emitters have taken another step. Researchers from Sandia National Laboratories in Albuquerque, N.M., and Lucent Technologies Inc.'s Bell Labs in Murray Hill, N.J., have produced an optically pumped VCSEL that emits UV light at 380 nm.

Jung Han, the lead scientist at Sandia, said the device requires a large 355-nm laser as a pump source, but he thinks the team will demonstrate an electrically pumped device within a year.

The secret to the new laser, Han said, is a bottom mirror of epitaxial AlGaN with almost 100 percent reflectivity. Sandia has applied for a patent on a set of stress-management procedures that prevent the mirrors from cracking during growth and cooling. Han claimed that the procedures resulted in 100 percent yields.

Nichia's lasers, by the way, are conventional side-emitting types.

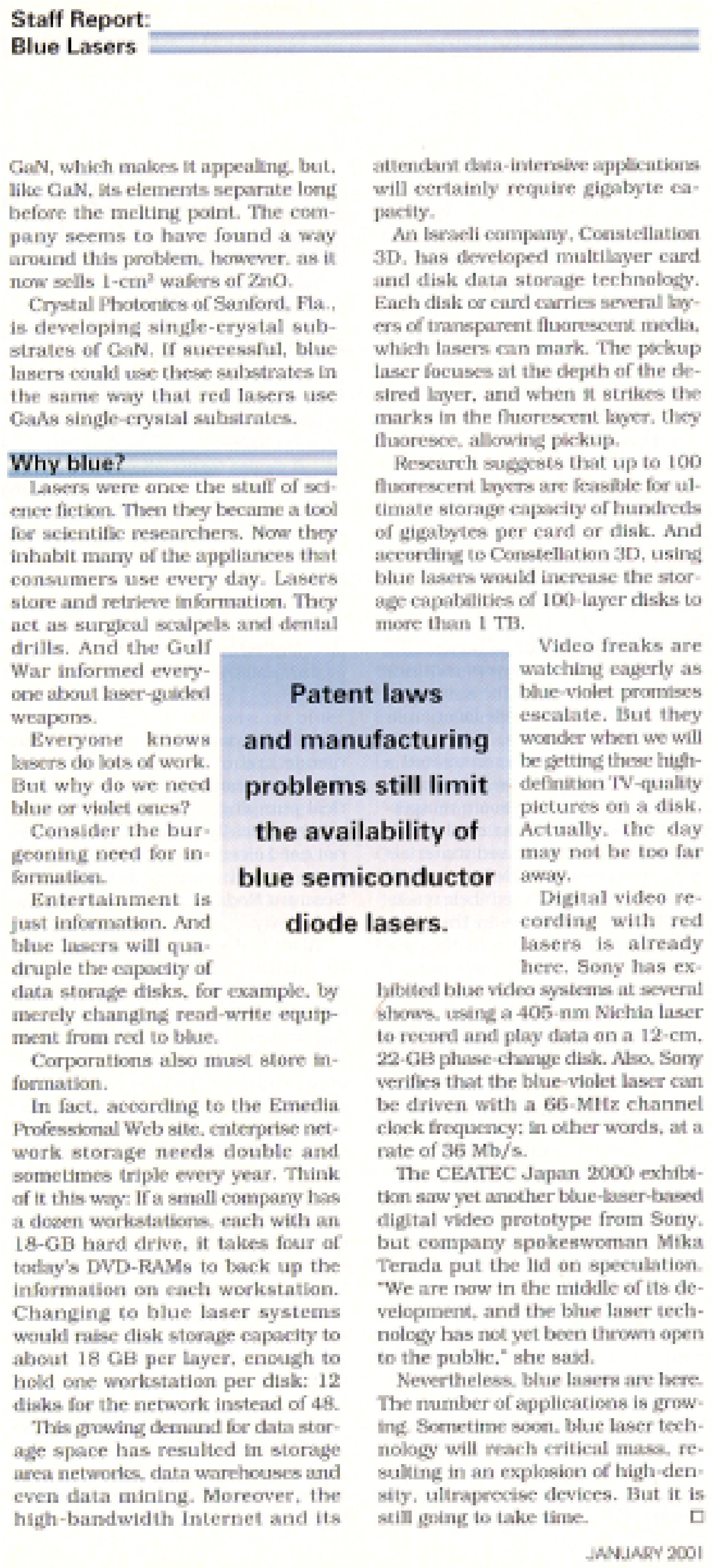
Substrate improvements

Advances also have come in materials.

Sumitomo Electric Industries Ltd. of Osaka, Japan, claims to have developed a single-crystal GaN substrate that is 50 mm across. The company says the new substrate would help reduce laser chip size and manufacturing costs, and would increase laser life. It expects to market the substrate next year.

The US Ballistic Missile Defense Organization lists several blue-laser-linked projects at Northwestern University's Center for Quantum Devices, Cree, Cermet Inc., Crystal Photonics Inc. and others.

Cermet, of Atlanta, is working on ZnO as an alternative substrate to sapphire and silicon carbide. It has only a 2 percent lattice mismatch with



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GaN, which makes it appealing, but, like GaN, its elements separate long before the melting point. The company seems to have found a way around this problem, however, as it now sells 1-cm^2 wafers of ZnO.

Crystal Photonics of Sanford, Fla., is developing single-crystal substrates of GaN. If successful, blue lasers could use these substrates in the same way that red lasers use GaAs single-crystal substrates.

Why blue?

Lasers were once the stuff of science fiction. Then they became a tool for scientific researchers. Now they inhabit many of the appliances that consumers use every day. Lasers store and retrieve information. They act as surgical scalpels and dental drills. And the Gulf War informed everyone about laser-guided weapons.

Patent laws and manufacturing problems still limit the availability of blue semiconductor diode lasers.

Everyone knows lasers do lots of work. But why do we need blue or violet ones?

Consider the burgeoning need for information.

Entertainment is just information. And blue lasers will quadruple the capacity of data storage disks, for example, by merely changing read-write equipment from red to blue.

Corporations also must store information.

In fact, according to the Emedia Professional Web site, enterprise network storage needs double and sometimes triple every year. Think of it this way: If a small company has a dozen workstations, each with an 18-GB hard drive, it takes four of today's DVD-RAMs to back up the information on each workstation. Changing to blue laser systems would raise disk storage capacity to about 18 GB per layer, enough to hold one workstation per disk: 12 disks for the network instead of 48.

This growing demand for data storage space has resulted in storage area networks, data warehouses and even data mining. Moreover, the high-bandwidth Internet and its attendant data-intensive applications will certainly require gigabyte capacity.

An Israeli company, Constellation 3D, has developed multilayer card and disk data storage technology. Each disk or card carries several layers of transparent fluorescent media, which lasers can mark. The pickup laser focuses at the depth of the desired layer, and when it strikes the marks in the fluorescent layer, they fluoresce, allowing pickup.

Research suggests that up to 100 fluorescent layers are feasible for ultimate storage capacity of hundreds of gigabytes per card or disk. And according to Constellation 3D, using blue lasers would increase the storage capabilities of 100-layer disks to more than 1 TB.

Video freaks are watching eagerly as blue-violet promises escalate. But they wonder when we will be getting these high-definition TV-quality pictures on a disk. Actually, the day may not be too far away.

Digital video recording with red lasers is already here. Sony has exhibited blue video systems at several shows, using a 405-nm Nichia laser to record and play data on a 12-cm, 22-GB phase-change disk. Also, Sony verifies that the blue-violet laser can be driven with a 66-MHz channel clock frequency: in other words, at a rate of 36 Mb/s.

The CEATEC Japan 2000 exhibition saw yet another blue-laser-based digital video prototype from Sony, but company spokeswoman Mika Terada put the lid on speculation. "We are now in the middle of its development, and the blue laser technology has not yet been thrown open to the public," she said.

Nevertheless, blue lasers are here. The number of applications is growing. Sometime soon, blue laser technology will reach critical mass, resulting in an explosion of high-density, ultraprecise devices. But it is still going to take time. ☐

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