

COMPOUND SEMICONDUCTOR

Three-Fives and Silicon Heterostructures

June 2004 Volume 10 Number 5



ASIA

**The LED boom continues:
reports on Korea and Taiwan**

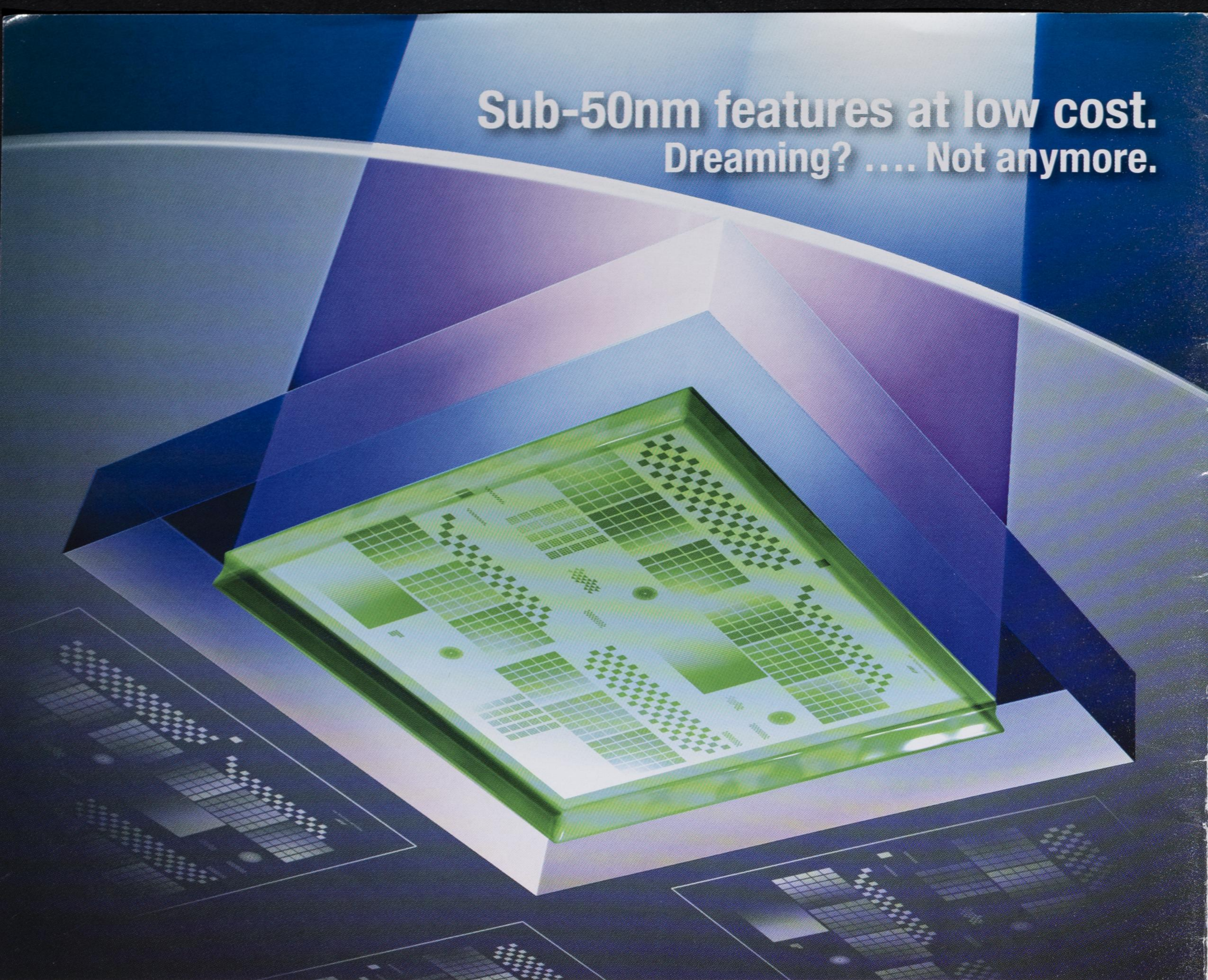
ALSO INSIDE

Infineon sells fiber-optic unit to Finisar

III-V devices and the automotive industry

Latest progress in GaN laser diodes

Sub-50nm features at low cost. Dreaming? Not anymore.



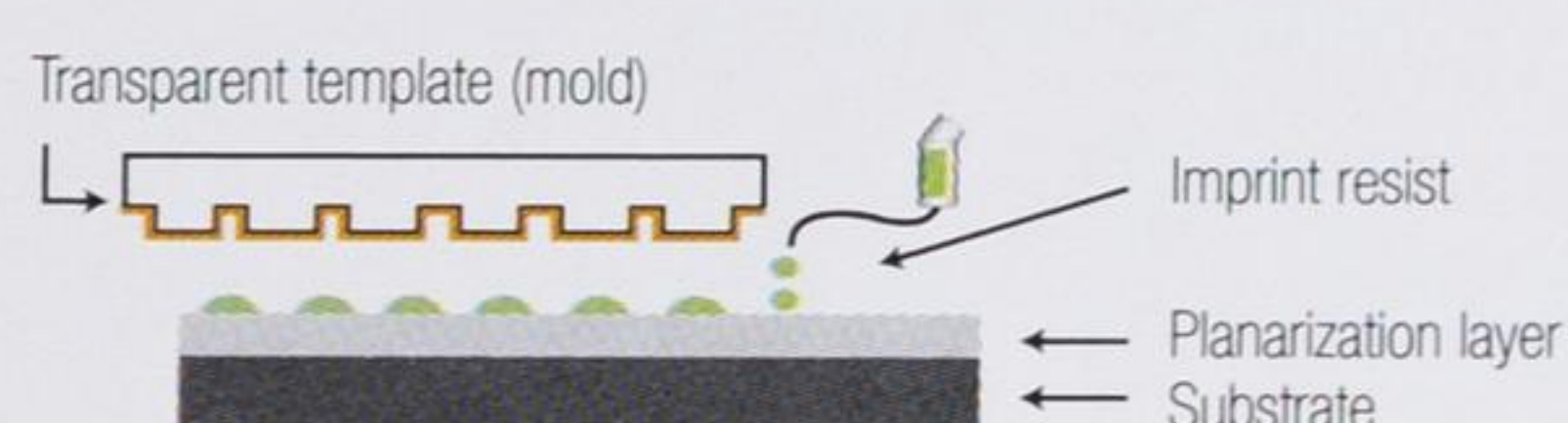
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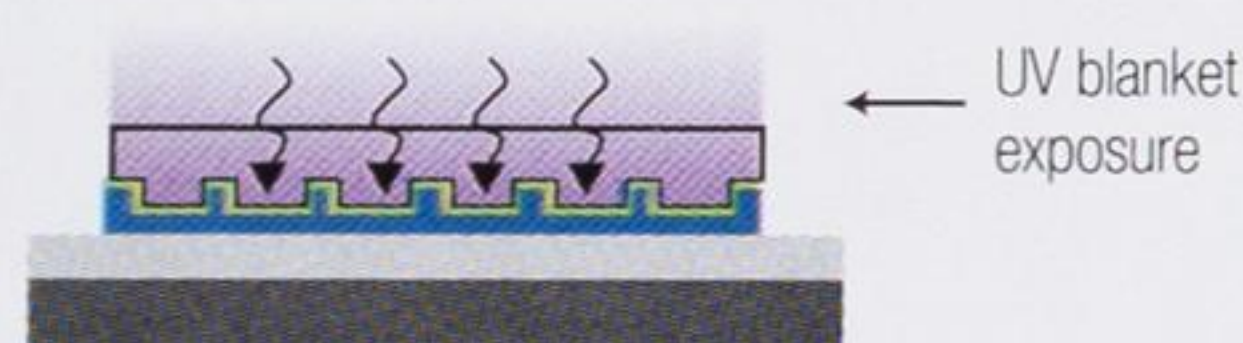
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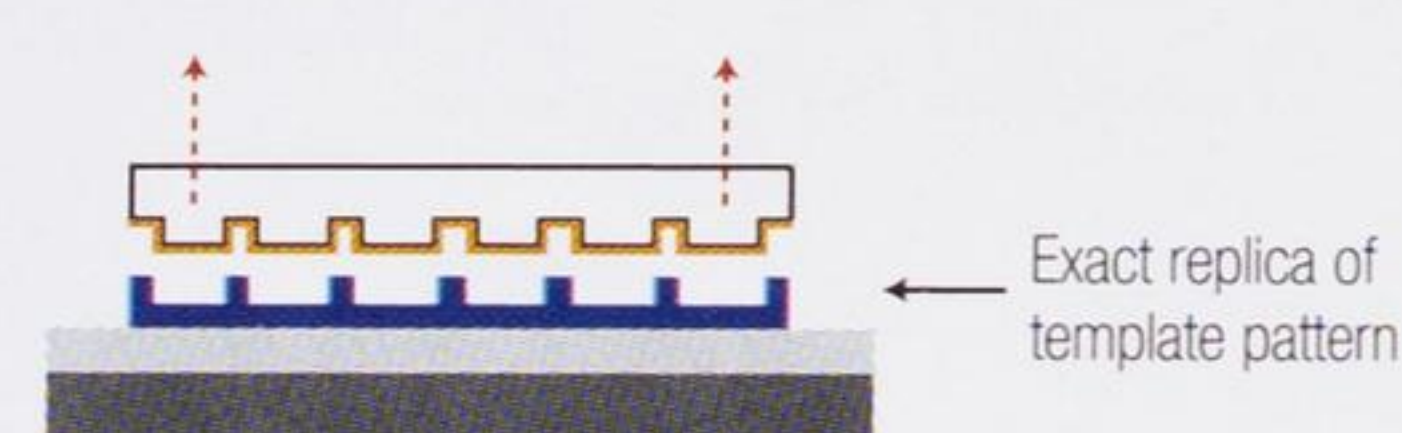
Step 1: Dispense drops of liquid imprint resist



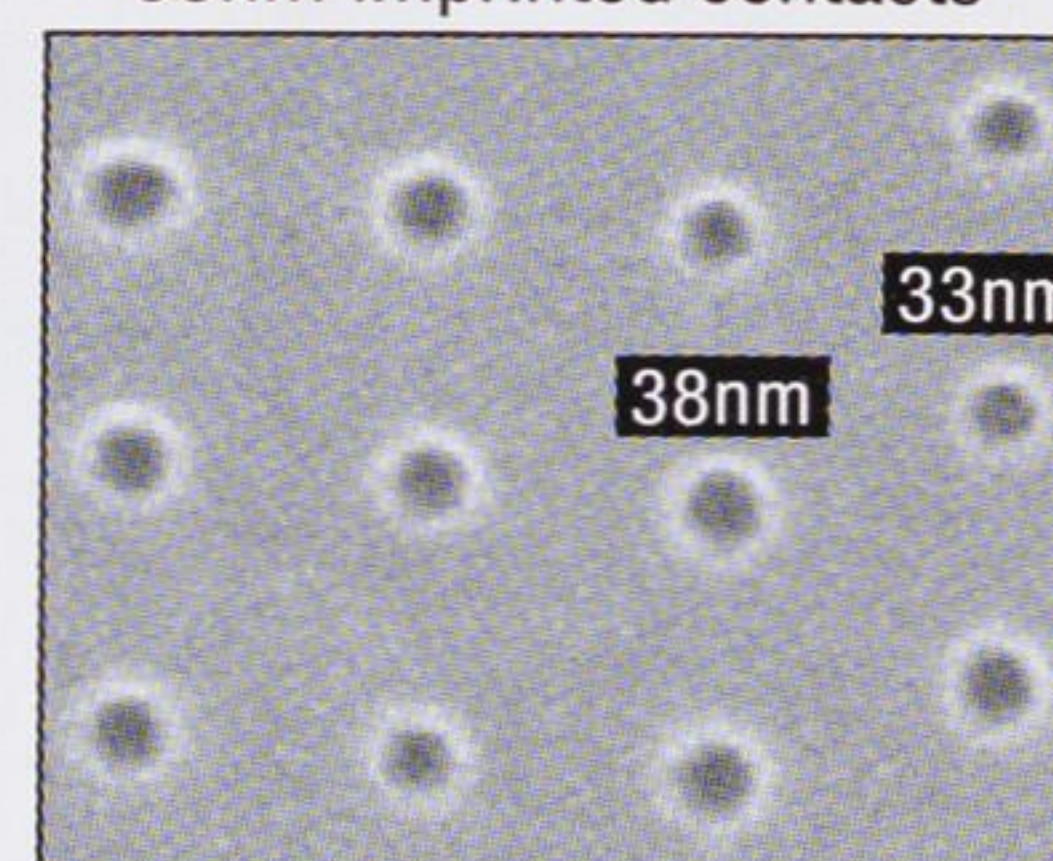
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Three-Fives and Silicon Heterostructures

JUNE 2004 VOLUME 10 NUMBER 5



Vishay is the latest company to have signed a white LED licensing deal with Osram **p11**



We look at the opportunities for III-V devices in automobile electronics **p18**



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On the cover: The Asian boom in LED manufacturing shows no sign of stopping. See pages 21-29. (Photo: David Ball/CORBIS.)

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Editorial

Positive industry mood in evidence at sunny Mantech



Last month, much of the III-V manufacturing industry gathered among the beaches and palm trees of southern Florida. And for the most part, the sunny weather seemed to match the mood of the 300 or so attendees at the annual Compound Semiconductor Mantech event.

Many of those at the industry exhibition were quietly confident, saying that business this year was better than in 2003. Hardly surprising after the severity of the recent slump, but Ralph Quinsey, CEO of top-tier GaAs device manufacturer TriQuint Semiconductor, added to the sunny outlook in his "state of the union" assessment of the GaAs industry.

Quinsey identified a number of application areas that he believes will propel volumes and revenues upwards over the next few years. His vision of "untethered" communications and convergence is a world in which your cell phone, PC, digital camera, TV, DVD recorder and hi-fi communicate through RF interfaces. In the long term, this machine-to-machine communication promises to become the industry's biggest opportunity.

Other opportunities such as automobile radar are on the horizon, but the risk-averse nature and drawn-out development cycle of the automotive industry probably means that this will remain a long-term goal for RF device makers unless governments push the safety aspects of autoradar through legislation.

Quinsey hinted that the nascent recovery of the compound semiconductor industry will require some tough decisions. Although the likes of RFMD might be enjoying 90% GaAs fab utilization, the overall figure is estimated at just 40–50%, and further industry consolidation will continue to be an objective while it is still so difficult for even the larger companies to make money.

Just as the occasional thunderstorm interrupted the Florida sunshine, the industry outlook appears far from settled.

Michael Hatcher

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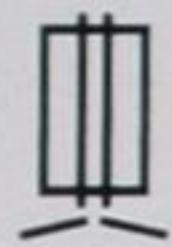
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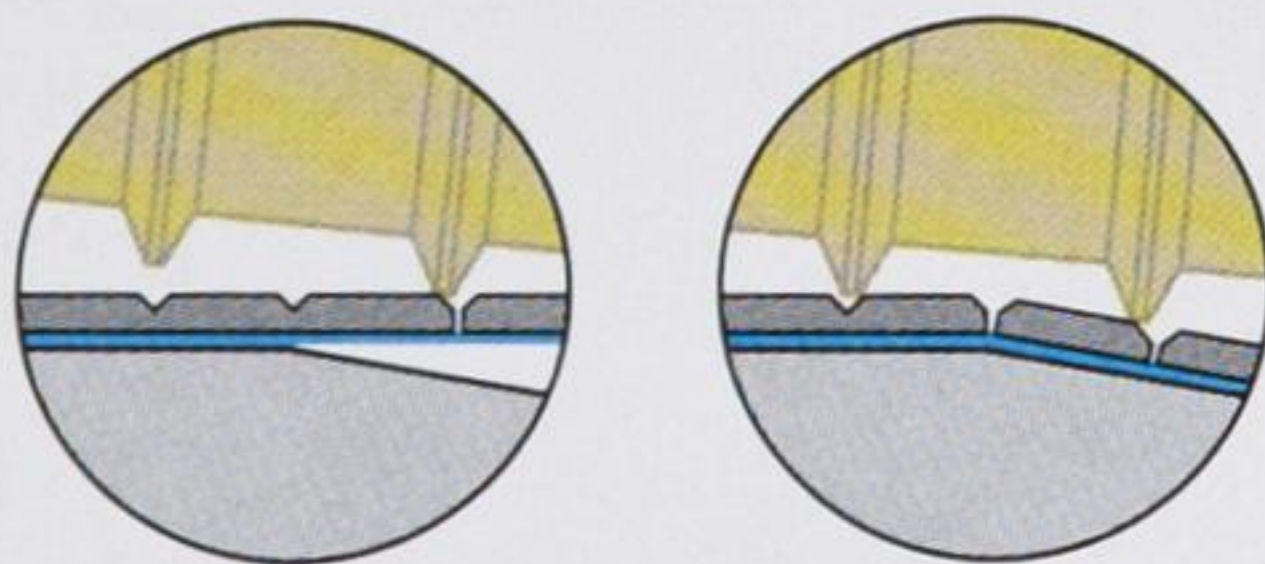
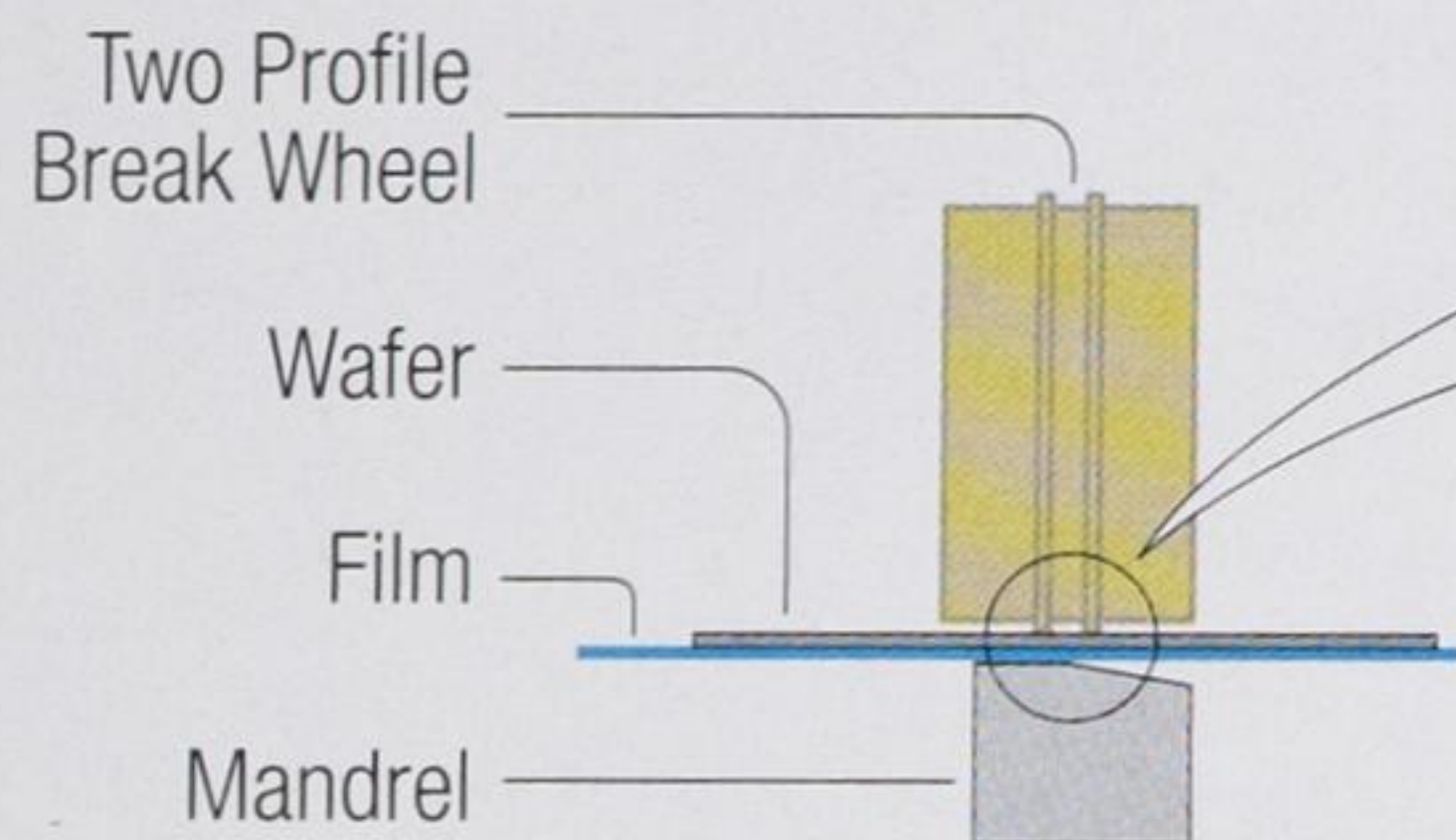
Californians understand the importance of protecting what you've built.

Limited Contact Dicing: Earthquake Insurance for MEMS

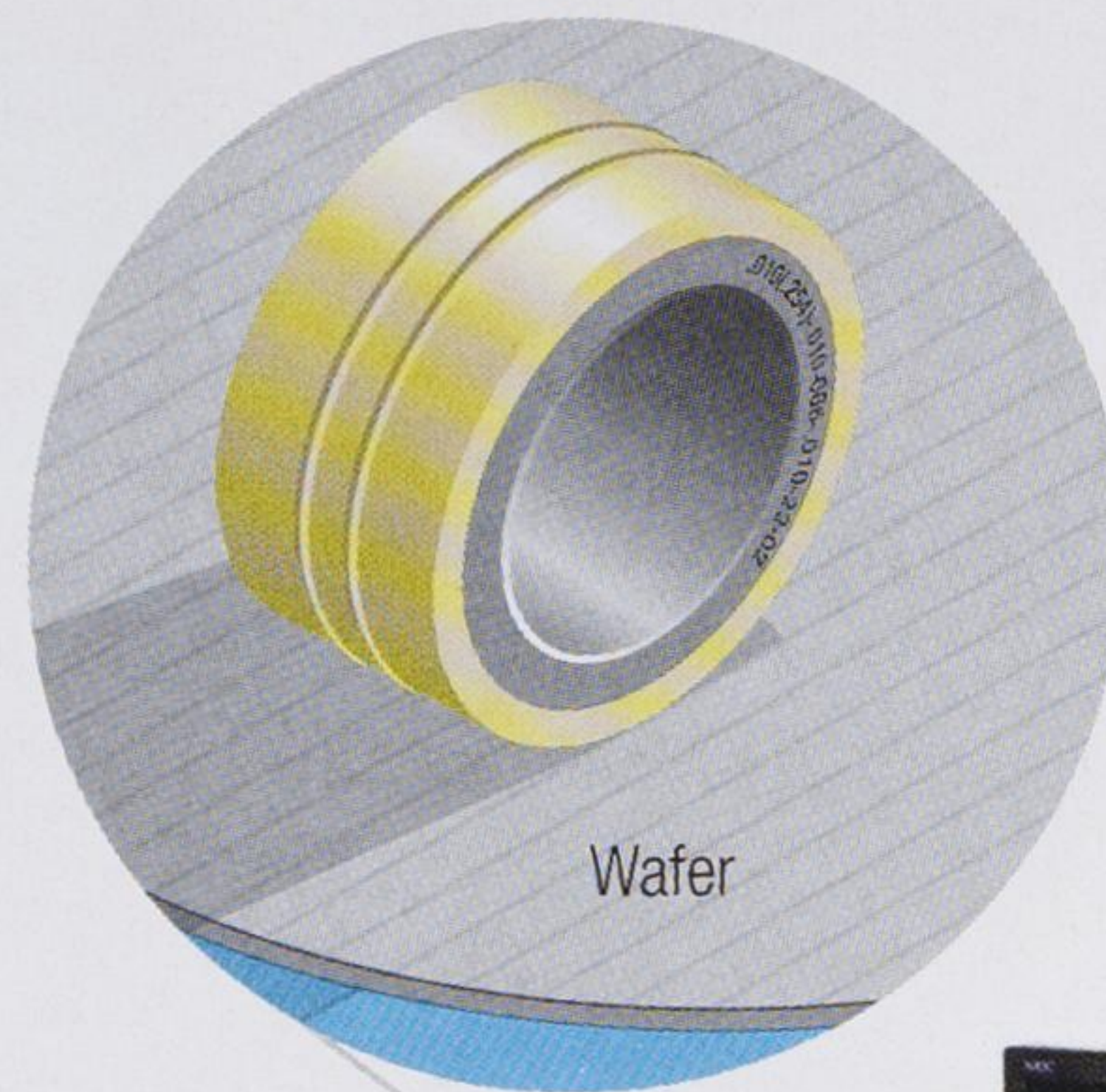
"Limited contact dicing" refers to a scribe and break process where the breaking mechanism applies a force over a limited area of the wafer.

When materials are sensitive to contact pressure, it's necessary to employ limited contact dicing rather than full contact dicing. MEMS, for example, contain delicate structures that can collapse under normal breaking pressures. The LSD-200 Dicing Machine offers breaking mechanisms that can effectively avoid sensitive areas of the wafer.

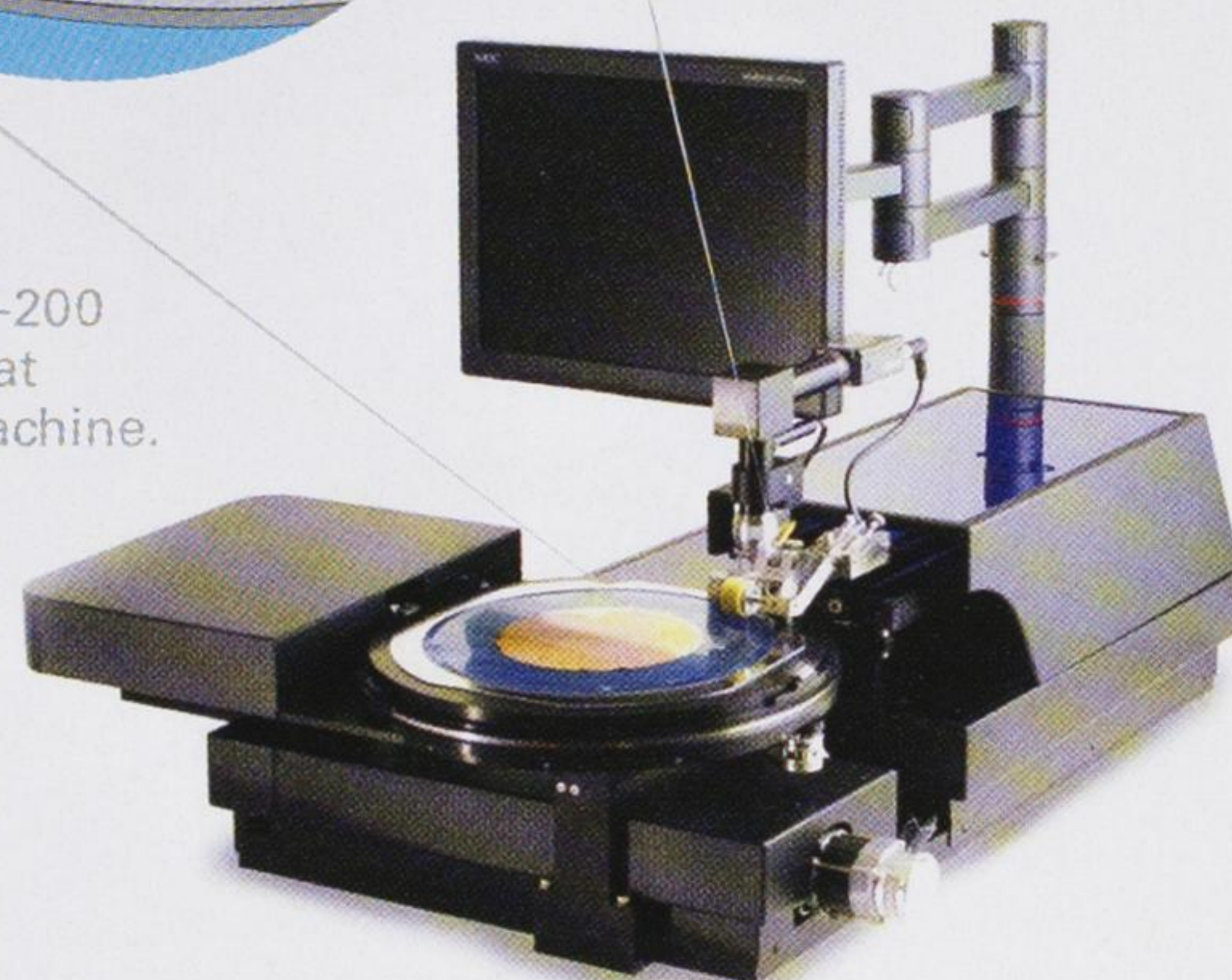
Applications: Micro-electromechanical systems (MEMS), MMIC's with airbridges, vertical lasers (viscels).



A two profile break wheel avoids active structures by applying breaking force to separation grids.



The new LSD-200
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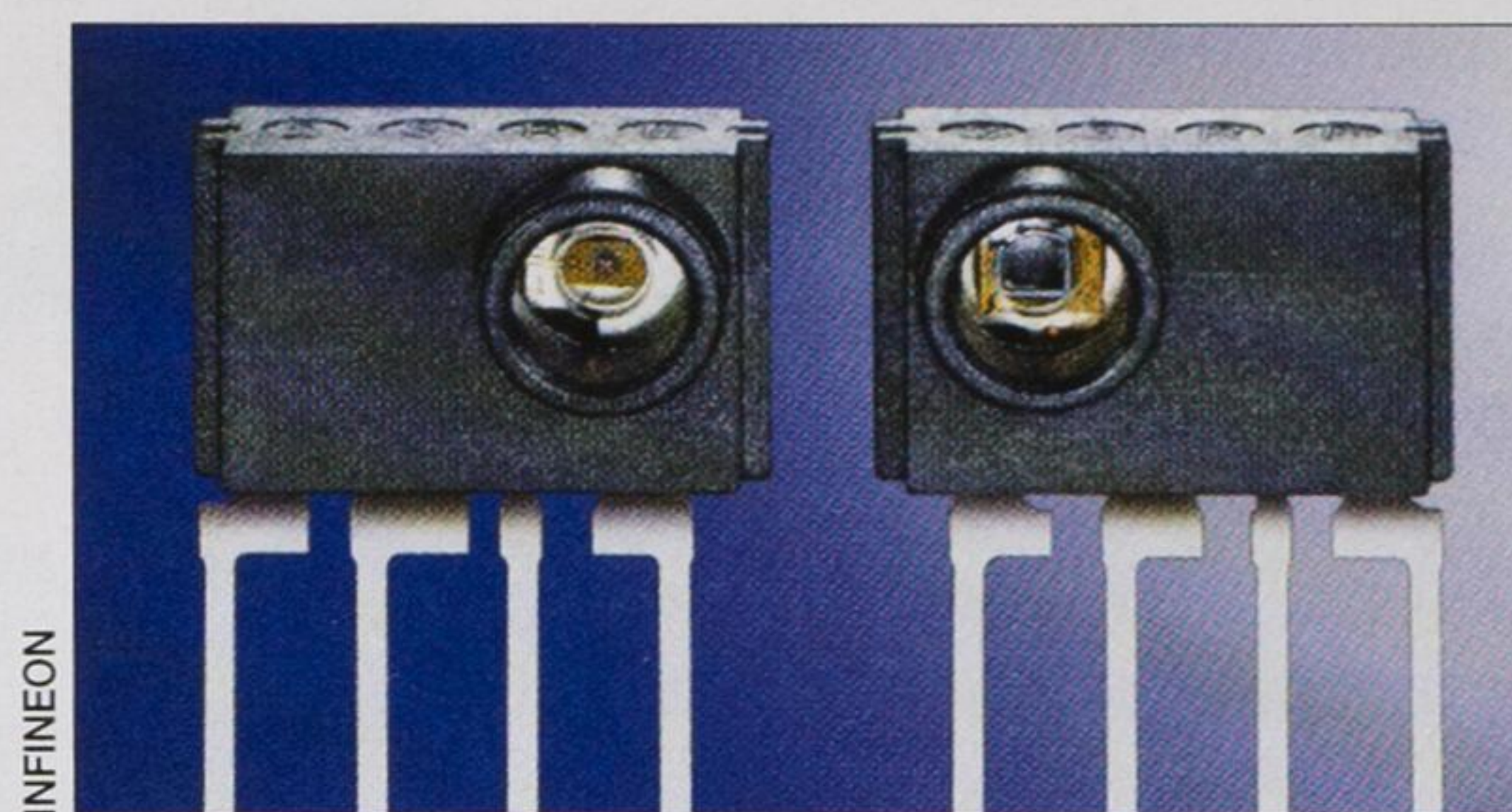


Finisar buys Infineon's fiber-optics unit

Fiber-optic device manufacturing is set to undergo further consolidation, with the US company Finisar planning to buy Germany-based Infineon Technologies' fiber-optic business unit. Infineon indicated earlier this year that the business unit was up for sale.

Finisar, which has also recently acquired Honeywell's VCSEL business, will acquire the Infineon operation by the transfer of 135 million shares, assuming shareholder approval. The value of the deal was estimated at \$263 million initially, although Finisar's share price did drop after details of the acquisition were announced.

After the transaction is closed, which is expected to be in the third calendar quarter of this year, Infineon will hold a 38% share in Finisar. The acquisition involves approximately 1200 Infineon employees, as well as the company's fiber-optic development, manufacturing and certain marketing activities.



Under the terms of the \$263 million deal, Finisar will acquire Infineon's expertise in LED-based in-car communications, such as these components used in media-oriented system transport (MOST) links.

In the quarter ended March 31 this year, Infineon's fiber-optic unit posted \$32 million revenue. Finisar's revenue for its most recent quarter is expected to be \$55–60 million.

Compound semiconductor devices are manufactured at Infineon's Perlach fab in

Munich. This fab, plus Infineon's 56% holding in Taiwan-based Parolink, a joint venture with United Epitaxy Company, will be transferred to Finisar, along with all staff and technology associated with laser development and manufacture. However, Infineon will continue to supply packaging technology and PMD IC components to Finisar.

The companies say that the combined entity would create "the largest pure-play optical components company in the world".

Finisar president and CEO Jerry Rawls said that the combined operation would be a good fit: "About 40% of Infineon's business is in markets where we currently don't compete, including the automotive industry and fiber-to-the-home," he commented.

The acquisition also includes Infineon Fiber Optics' manufacturing facilities in the German city of Berlin, as well as in Trutnov, in the Czech Republic.

TriQuint tips automotive radar

Automotive radar is set to drive most of the growth in the mm-wave GaAs MMIC market over the next few years. That's according to two TriQuint executives speaking at the Compound Semiconductor Mantech conference in Florida, US, last month.

Opening the event's plenary session, TriQuint CEO Ralph Quinsey said that the deployment of GaAs-based collision-avoidance radar operating at 77 GHz will likely be driven by government regulations on car safety. He added that future systems will use 77 GHz technology for both long- and short-range radar. 24 GHz radar is currently used in short-range applications.

According to TriQuint's director of broadband technology, Dan Green, automotive

applications made up 16% of the \$267 million mm-wave GaAs MMIC market in 2003. This proportion is set to increase as automotive radar becomes cheaper and is deployed in vehicles other than the high-end models where it is currently used.

Although the timing of automotive radar being introduced in the mainstream is difficult to predict, the technology will dominate future growth in mm-wave applications, according to Green. He said that the commercial (non-military) mm-wave market for GaAs MMICs is expected to grow from \$163 million last year to \$400 million in 2007.

"Autoradar will be the next high-volume application for mm-wave GaAs MMICs," Green told delegates.

ing CEO and executive chairman, Charles Shalvoy, who was previously at superconductor manufacturer Conductus.

Shalvoy said: "We believe our GaN-on-silicon technology can provide significant performance and cost advantages in a number of markets, and we expect to introduce our first power transistor products for the wireless market later this year."

The GaN-on-silicon technology developed by Nitronex also has applications in LED, military and automotive markets.

Nitronex closes \$6 m funding round

GaN-on-silicon specialist Nitronex, based in Raleigh, NC, has raised a further \$6 million.

The round brings the company's total venture funding to \$50 million. Nitronex says that it plans to use the money to accelerate product development and sales and marketing activities for its power transistors.

The company also announced its new act-

Nichia and Sony cross-license laser patents for Blu-ray

Nichia and Sony have agreed to cross-license patents related to blue-violet laser diodes for optical disc applications. The two Japanese companies have been collaborating on the development and manufacture of GaN laser diodes since December 2002 (*Compound Semiconductor* January/February 2003 p5).

The cross-license agreement will further strengthen the existing collaboration between Nichia and Sony. In a joint statement, the companies said that the agreement would enable the use of "all related patents on blue-violet laser diodes, with no time limit, in the field of optical disc recording/playback".

Collectively, the two companies have filed around 800 patent applications in the field. Both Sony and Nichia will mass-produce the lasers, which they believe will lead to a stable supply for their use in Blu-ray disc consumer applications and professional disc systems.

The technological collaboration is set to continue, with plans to reduce the cost of devices through improvements in production efficiency, and to develop higher-performance and higher-power lasers.

● See our ISBLLED report on p27 for the latest progress in GaN-based lasers.

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Growth continues at Taiwan LED makers

LED manufacture is continuing to ramp up in Asia. Taipei-based Lite-On Technology, which began shipping white LEDs in March 2004, saw 14% growth in LED sales year-on-year, amounting to NT\$594 million (\$17.8 million) during the month. LEDs make up around 5% of the company's overall revenue.

Other Asian companies are also benefiting from the strong mobile handset industry, with

Taiwan's Industrial Technology Intelligence Service expecting monthly capacity of GaN-based LEDs to reach 1.1–1.2 billion chips, double last year's figure.

According to *DigiTimes.com*, Formosa Epitaxy expects to ship 33–36 million blue LED chips in the current quarter, up 10–20% on the previous three months thanks to orders from mobile phone companies in Korea.

Letters

Pure-play GaAs foundry debate rumbles on

Following our article "The pure-play GaAs foundry business: is it a viable model?" in our May 2004 issue, we received the following correspondence:

Sir,

Both pure-play foundries and integrated device manufacturers (IDMs) must continually develop, support and characterize leading-edge processes if they are to survive and prosper. However, I think that pure-play foundries have a number of important advantages over IDMs that were not highlighted in the article.

They do not have to undertake the detailed market research required to choose which standard products they should develop, nor fabricate, evaluate and perform design iterations on their chosen standard products, or indeed market and provide sales and application support for these products.

In addition, pure-play foundries do not incur the costs of employing a permanent IC design team, or find themselves supporting a standard product that is seeing low sales and is not justifying its support costs.

Finally, pure-play foundries can manufacture ICs that become successful high-volume products and make a profit on both the prototype and the production phases. Conversely, if their customers have them fabricate ICs that are commercial or technical failures, the foundry can still make a profit from the activity.

All of these advantages offer financial benefits for the pure-play foundry over the IDM. Rob Christ commented that pure-play foundries "have to sell wafers for about \$2000 to \$2500", and he is right. In

very high volumes they do – but they can afford to do so and still make a profit. These companies can also make a profit from IC development work undertaken on their processes, whereas such activity is an overhead for IDMs.

For a fabless IC supplier the low wafer costs offered by pure-play foundries make them an attractive choice for very-high-volume applications. Of course they will need to have a suitable, well characterized process for any given application, but the same is true of an IDM. While being a pure-play GaAs foundry is no guarantee of commercial success, I believe the business model does stack up.

Liam Devlin, director, RF Integration, Plextek Ltd. E-mail: LMD@plextek.co.uk

Response from Rob Christ:

It is a matter of scale. If the pure-play foundries can garner the wafer volumes that the big IDMs can without investment in product development, then one or two foundries may be viable.

It is a big "if". Foundries still have to invest millions in ongoing process development to stay competitive. There are a small handful of fabless GaAs houses that are financially successful, but none of them are currently big mobile phone chip players.

The collection of them represents less than \$100 million per year, maybe \$20–30 million of which goes to GaAs wafers. I think you would have to knock out a major phone chip supplier and consolidate everything else for the pure-play foundry model to work.

Rob Christ, marketing director, TriQuint Semiconductor, Inc. E-mail: rchrist@tqs.com.

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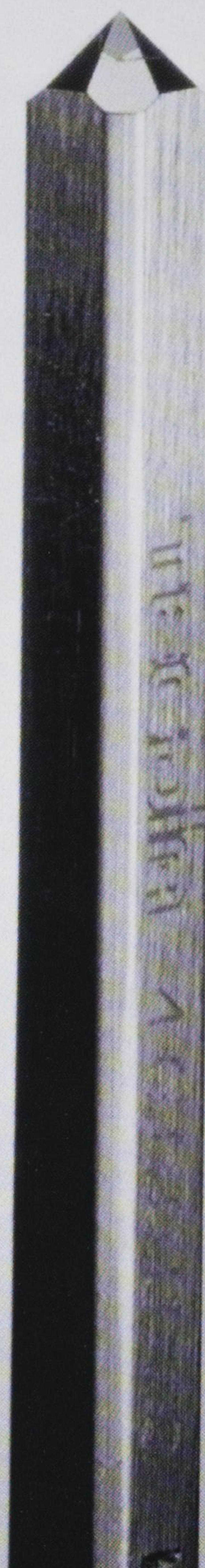
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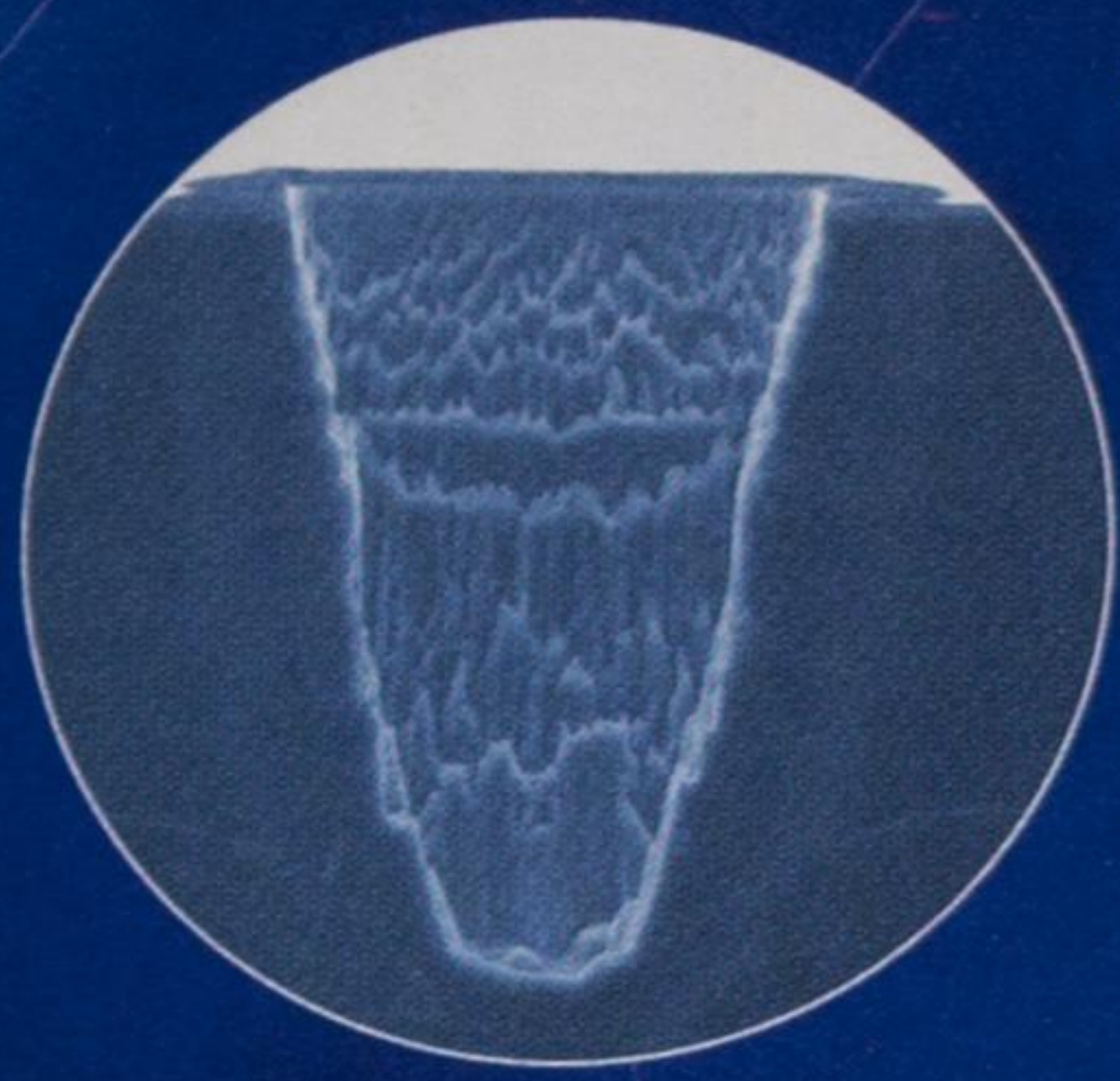
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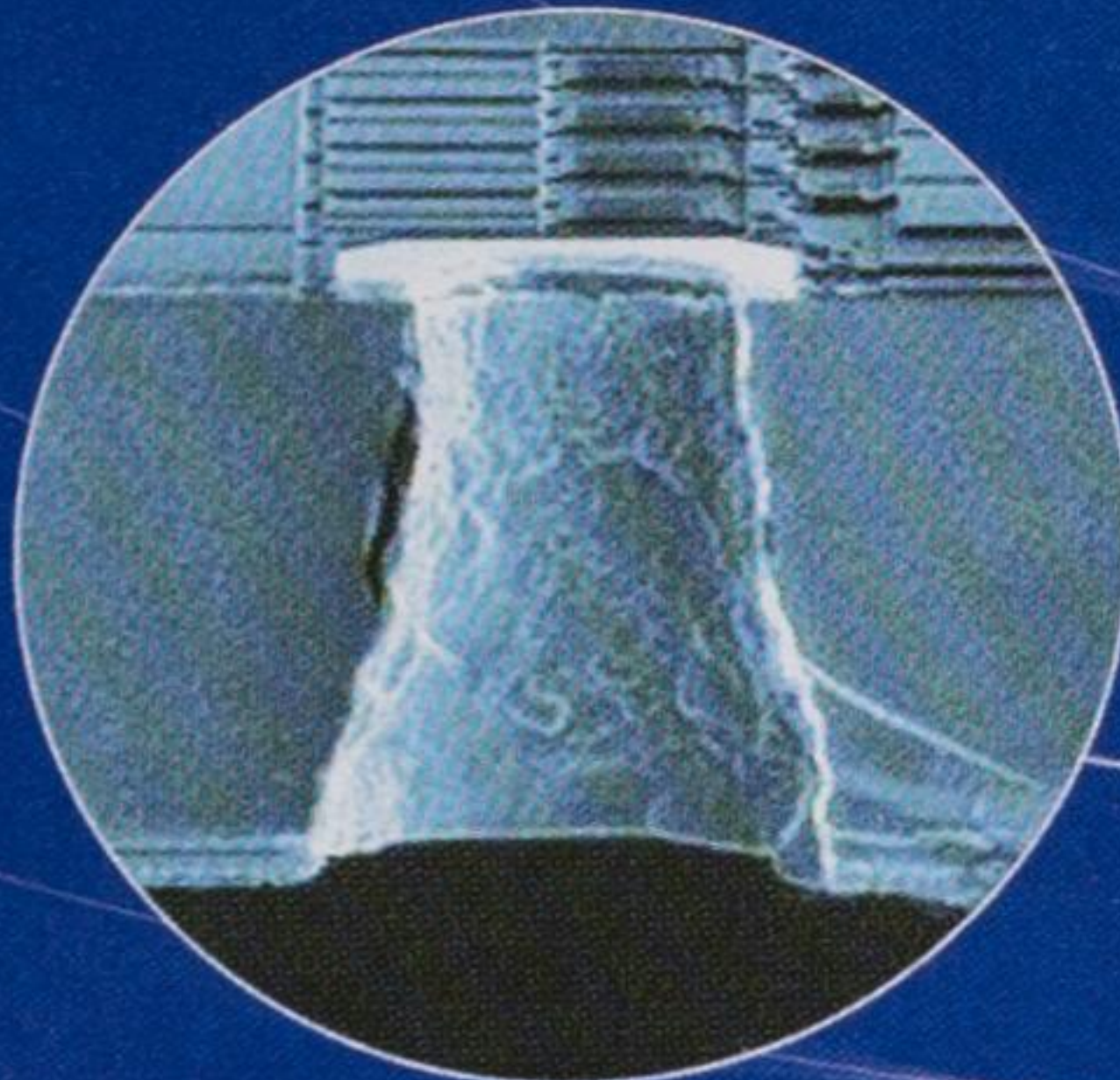
InP via etch

*(Courtesy HRL
Laboratories, LLC)*

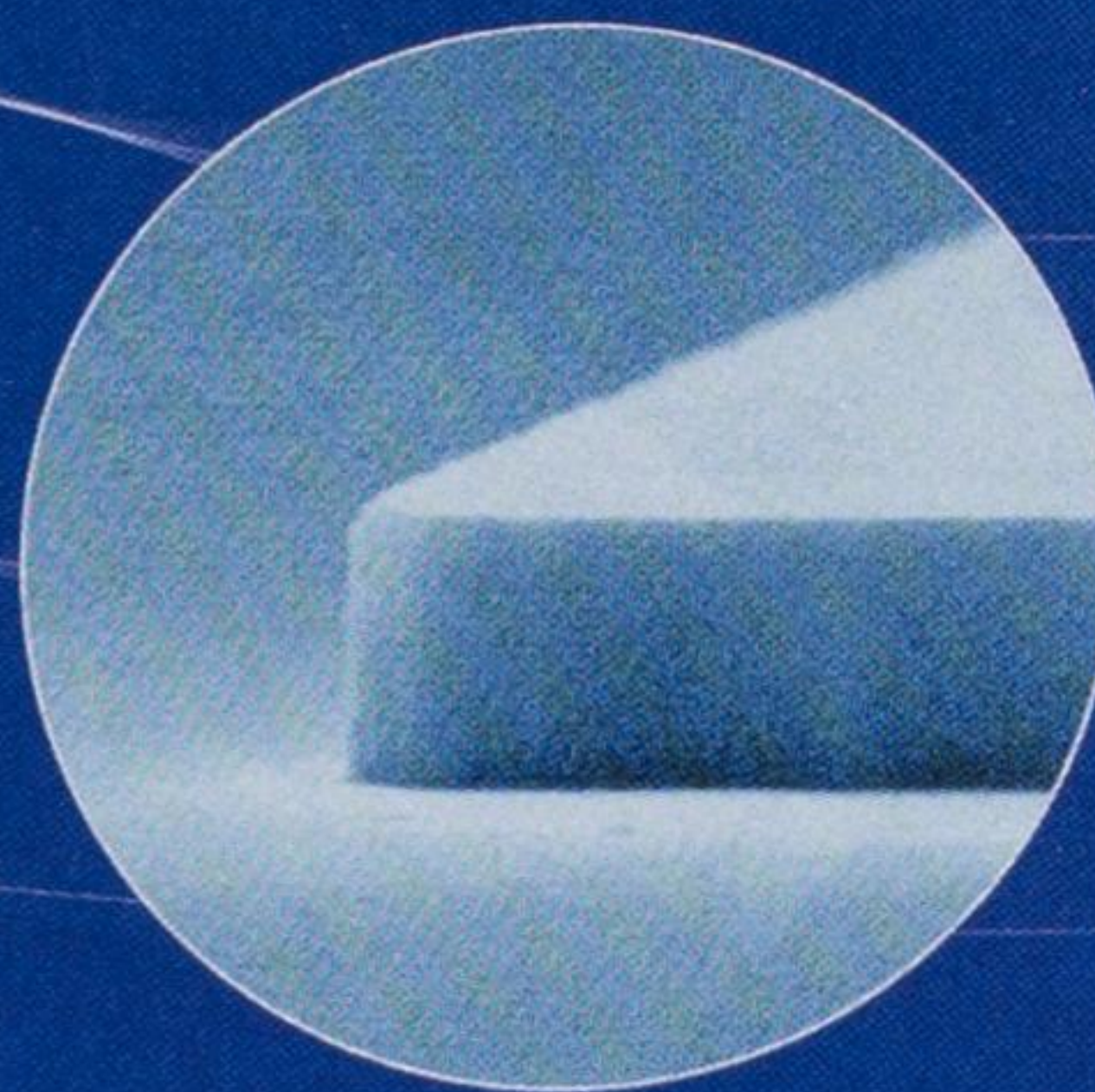


InP-based
VCSEL etch

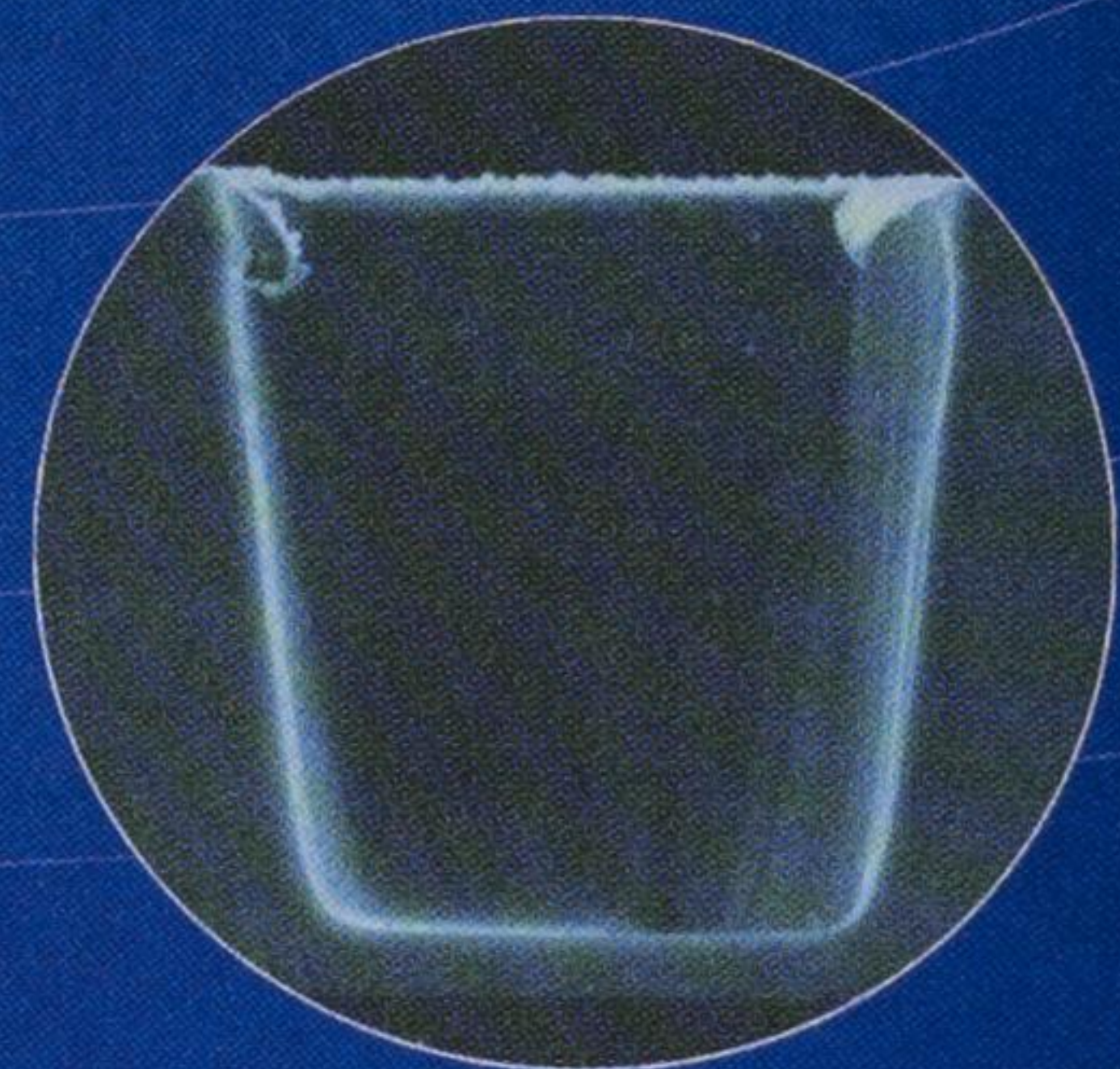
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SURFACE TECHNOLOGY SYSTEMS

Realigned RFMD aims for \$1 bn sales

Top-tier RFIC manufacturer RF Micro Devices (RFMD) believes that its annual revenue will reach the billion-dollar level by 2007. The company has realigned its strategy around three core business units – cellular, wireless connectivity and infrastructure – with a view to exploiting the strong growth it expects in the overall wireless communications market.

RFMD's president and CEO Bob Bruggeworth explained that the new structure would align the company's business more closely with those of its customers. He expects the total market addressed by the three core units to grow to about \$6 billion within three years. "We will continue to invest in the assets and

resources necessary to grow in each of our core markets," said Bruggeworth. "We forecast [that] these investments will enable the company to exceed \$1 billion in revenue within three years."

RFMD's cellular unit will focus on devices and modules for handset applications, including power amplifiers (PAs) and the recently introduced SiGe-based Polaris Total Radio transceiver, which is now ramping into production. The total addressable market for RFMD's cellular division is currently estimated at around \$2.5 billion.

The second business unit is focused on wireless connectivity applications, such as Bluetooth and wireless LAN. This market

covers more GaAs-based PA products, plus RFMD's CMOS radio processors and modems. The third business unit – covering wireless infrastructure – will concentrate on components for wireless base stations. Currently, these include GaAs-based driver amplifiers and PAs.

RFMD is also developing GaN devices for wide-bandwidth base station PAs, which it expects to become a disruptive technology in the wireless industry.

The company capped a successful fiscal 2004 by posting a profit of \$29.7 million in the year ending March 31. It had posted a loss of \$9.3 million this time last year.

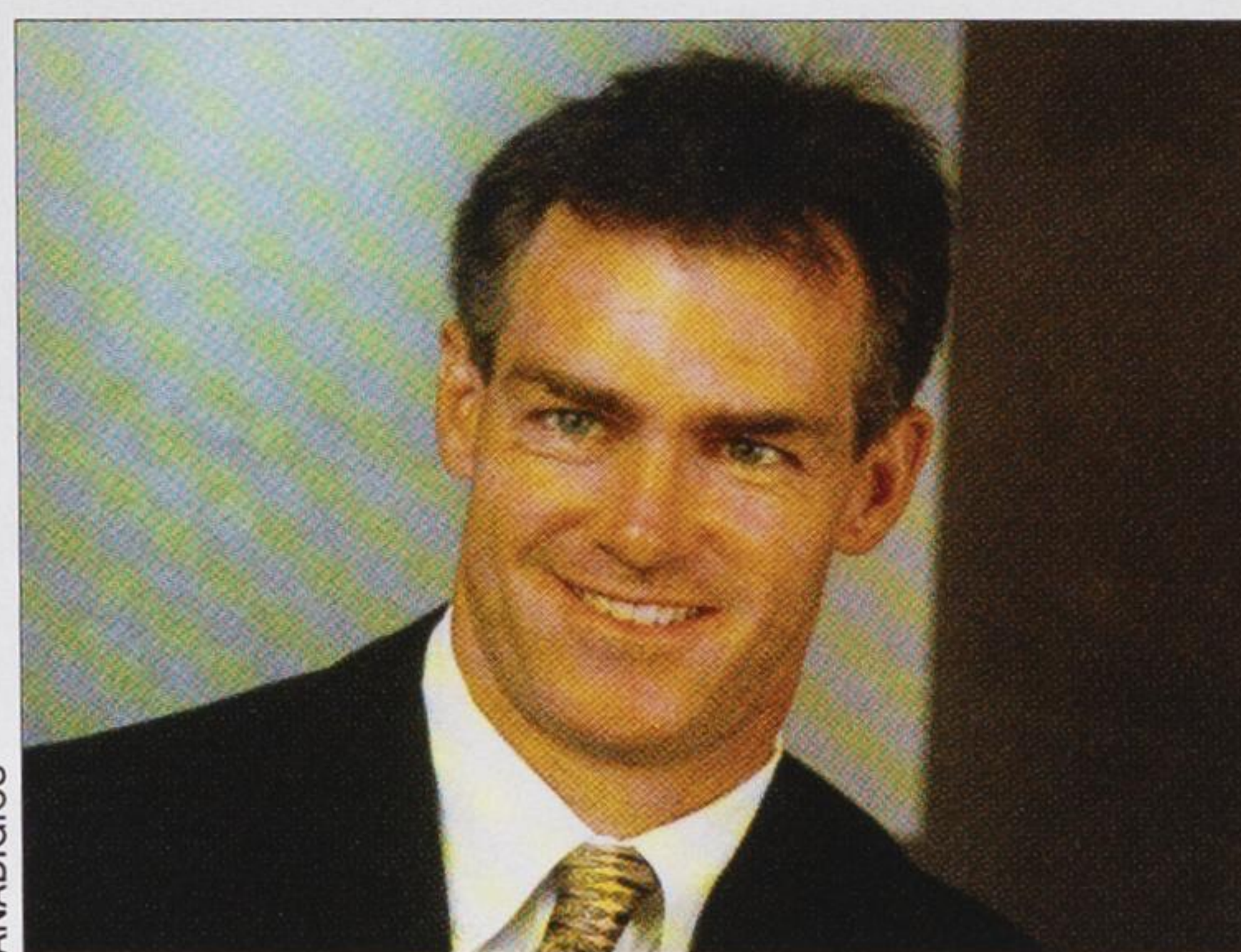
● See "Portfolio" on p36.

Anadigics plans to cut costs as loss increases

RFIC maker Anadigics has posted revenue of \$21.2 million for the quarter ending April 3, 2004, up \$5.1 million on the comparable period in 2003. Despite the increase in sales, the company continued to pile up a loss. Increases in sales and marketing spend, research and development, and general costs combined to wipe out the extra revenue.

The company made a \$12.8 million loss in the quarter, up from \$12.2 million in the same period last year. Anadigics also made a loss of \$12.1 million in the traditionally strong final quarter of 2003. As a result, the company is to initiate a cost-cutting strategy starting in the current quarter. The strategy is set to affect operations throughout the company, including research and development activity.

CFO Tom Shields said: "We will implement



Shields aims to save \$8 million this year.

an operating expense reduction initiative that targets total annual savings of \$8 million...by the fourth quarter of 2004." He added that the savings will come from outsourcing and

improved manufacturing efficiency.

However, with quarterly losses running consistently at \$12 million or more for the past two years (Anadigics has racked up a loss of \$106.7 million over the past two fiscal years), further strong increases in revenue would still be required to bring the company to the break-even level even if the anticipated \$8 million annual saving is realized this year.

As of April 3 2004, Anadigics held \$64.3 million in cash and cash equivalents, as well as \$45.1 million in marketable securities. On a more positive note, the company did see a strong increase in sales to the wireless LAN segment, with shipments up 32% on the previous quarter. In addition, the company managed six GSM design wins in the latest quarter.

TriQuint ups guidance on strong revenue

TriQuint Semiconductor has reported revenue of \$89.9 million for the quarter ended March 31, 2004. The company has adjusted its revenue forecast for 2004 upwards as a result. Revenues for the same quarter in 2003, and the seasonally strong previous quarter, were \$71.6 million and \$89 million, respectively.

TriQuint said that strength in its end markets continued to increase, with particular growth in base stations, wireless LAN, optical networks and cell phones. The company recorded a slight profit in the first quarter of a fiscal year for the first time since 2001. The associated operating income of \$1.1 million

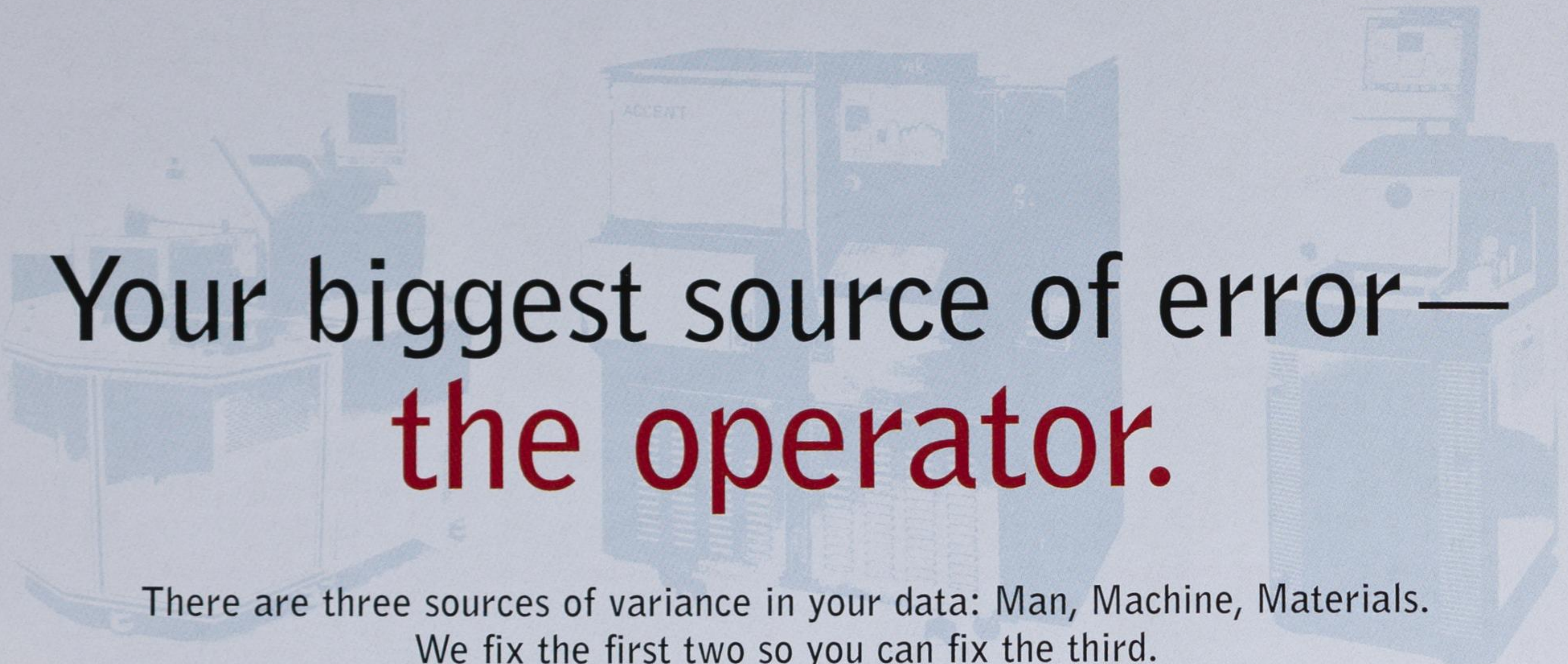
compares with an operating loss of \$15.1 million for the first quarter of 2003.

"Demand for our diversified portfolio of wireless and optical products has increased. I am very optimistic about the second half of 2004," commented TriQuint's president and CEO Ralph Quinsey. The company raised its guidance for fiscal 2004 on announcing the positive results. It now forecasts full-year revenue to be in the range of \$365–375 million, adjusted from the previous forecast of \$340–355 million. The company made an operating loss of \$74.4 million in 2003, but expects to make an operating profit for 2004.

Semiconductor sales give Motorola a boost

Strong sales of cell phone handsets and semiconductors boosted earnings at Motorola to \$8.6 billion for the quarter ended April 3, 2004. The overall revenue figure was 42% higher than the equivalent period last year. This was mainly due to strong handset sales, which were up 67% over the same period to \$4.1 billion.

The semiconductor products segment, which is in the process of being spun off into the separate company Freescale Semiconductor, also enjoyed strong growth. Sales were up 21% on 2003 to almost \$1.4 billion.



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Cree sets revenue, white LED records

By Tim Whitaker

Cree's excellent run of financial results continued with another record revenue figure of \$77.1 million for the first quarter of 2004, up 5.6% sequentially and up 28% on the equivalent period in 2003. The company also reported a quarterly profit of \$15.1 million. Looking ahead, Cree said that it expects its revenue to grow by 8–10% to \$83–85 million in the June 2004 quarter, which would take its total revenue for fiscal 2004 (ending June 30) to \$300 million.

Cree's president and CEO Chuck Swoboda said: "Our decision to invest aggressively in R&D is paying off as new high-brightness LED products are driving the growth of our business." LED sales were up 10% to \$62 million in the March 2004 quarter, with unit shipments growing by 7% and average sales prices (ASPs) growing by 3%. The ASP increase was due to growth in sales of Cree's highest-brightness products, its X-class devices, which now make up 20% of sales.

Swoboda said that white LEDs are in demand for backlighting keypads and screens in mobile phone handsets, as well as camera

flashes, while the automotive and display screen markets also account for significant sales of LEDs.

In its quarterly conference call, Cree emphasized the continuing importance of intellectual property (IP) issues in the LED industry. "We are now moving ahead with an aggressive campaign to notify companies of potential infringement issues," said Swoboda. "We believe there are a number of misconceptions about IP in the marketplace, so we continue to educate the chip manufacturers and their packaging customers."

Swoboda also said that Cree is in the final stages of releasing LED power chips on 3 inch wafers. "We are working through qualification on a product-by-product basis," he said. "Conversion will be ongoing over the next year and is important in long-term cost reduction."

Cree's first packaged LED, the 1 W XLamp, is being sampled to customers, and Cree's goal is to release the product by the end of the June 2004 quarter. Most of the necessary manufacturing equipment has already been installed at Cree's Durham, NC, facility.

The GaN substrate and epitaxy business

acquired for \$10.25 million from ATMI will also be relocated to Cree headquarters in Durham over the course of the next year. The target revenue from this business during the June 2004 quarter is \$1 million. Cree views the acquisition as providing "longer-term technology that will help our R&D in lasers and electronic devices".

Cree is still working to resolve several critical issues to achieve a 10,000 h, 30 mW laser diode. "We are at least three quarters away from having the manufacturing capability to supply devices with the required characteristics," said Swoboda, "but the volume market for these types of device is still a couple of years away." However, GaN-based electronic devices will hit the market sooner; Cree plans to start sampling its first GaN products by the end of 2004.

● Cree has demonstrated 57 lm/W of white light from one of its XB900 power LED chips operating at 350 mA, and also 142 lm from the same device operating at 1 A drive current. The company believes that these are the highest reported emissions from a high-power packaged LED chip to date.

Osram, Vishay agree license deal

Osram has signed yet another LED license deal, this time with Vishay Semiconductor GmbH, a subsidiary of Vishay Intertechnology, a global semiconductor manufacturer based in Malvern, PA. On payment of a license fee, Vishay will acquire the right to manufacture and sell white LEDs and surface-mount LEDs for high-current applications such as interior lighting in automobiles, as well as traffic signals and signs, advertising billboards and LCD screens. "Vishay is gaining a new opportunity to expand its white LED offering with new devices for the automotive industry," said Dieter Wunderlich, executive VP of semiconductors at Vishay.

The white LED technology licensed to Vishay was developed by Osram Opto Semiconductors, and combines a blue-emitting InGaN LED with a suitable phosphor. Osram has already licensed its technology to Rohm, Everlight, Lite-On and Samsung Electro-Mechanics, as well as reaching a patent cross-licensing agreement with Nichia.

However, Nichia is concerned that rivals may misinterpret the implications of this



VISHAY INTERTECHNOLOGY

Vishay has released a new family of power SMD LEDs with a specially designed leadframe profile that improves device heat dissipation.

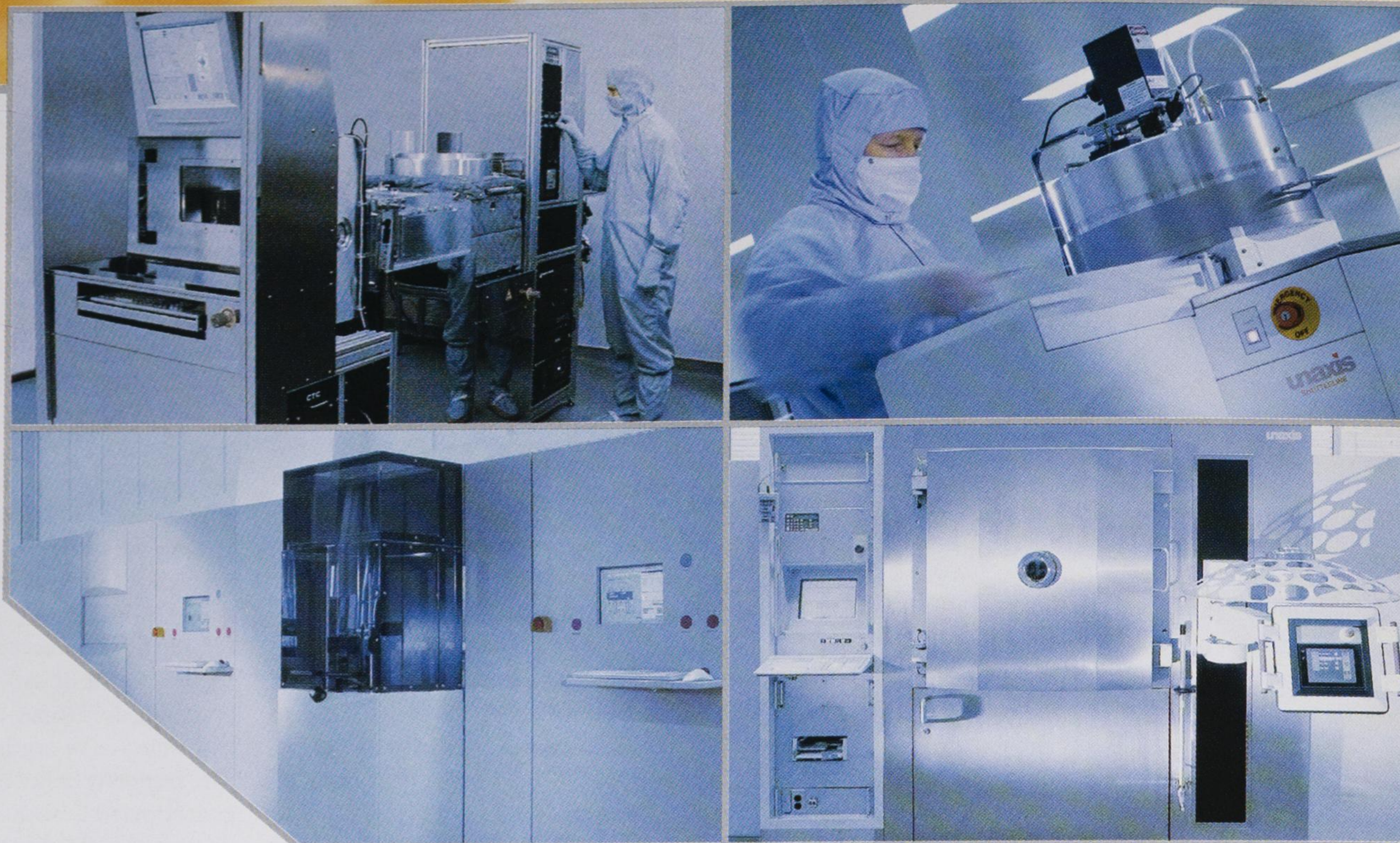
cross-license. In a statement on its website, Nichia commented on the recent license agreements between Osram and other manufacturers: "With regard to white LEDs, Nichia also holds valid and enforceable patents in many countries [and] any license granted under Osram's patents does not necessarily [imply a] license under Nichia's patents."

Seoul Semiconductor launches HB-LED

Korea-based LED packaging company Seoul Semiconductor has developed a high-brightness LED in conjunction with lighting company TridonicAtco, for use in technical and general illumination. The Alpha Power LED has been developed over the past year and is available in a range of colors, including white. Seoul Semiconductor hopes to achieve a market leader position in the future LED illumination market. The company is manufacturing the device by combining TridonicAtco's patented technology with its own packaging expertise. The companies have agreed that Seoul Semiconductor will manufacture the Alpha Power LED and have exclusive sales rights in Asia and the US, while TridonicAtco will retain exclusive sales rights for Europe and Australia.

Late last year, Seoul Semiconductor announced an agreement with the Solid State Lighting and Display Center (SSLDC) at the University of California, Santa Barbara, to license key technologies for manufacturing LEDs for illumination.

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UV LEDs reduce water bacteria levels

By Richard Stevenson

A US collaboration has reduced levels of *E. coli* bacteria in water by more than five orders of magnitude using 280 nm excitation from ultraviolet (UV) LEDs. The proof-of-concept experiment involved exposing a 1 ml sample of *E. coli*-spiked water to 50 μ W emission from two UV LEDs.

The experiment, conducted at the University of Maine, was directed by Hydro-Photon, ME. UV LEDs were provided by Shuji Nakamura's group at the University of California, Santa Barbara.

The technology is not restricted to the

sterilization of *E. coli*. "Anything with DNA or RNA will work," said Miles Maiden, president of Hydro-Photon. He added that the experiment, which was funded by the Office of Naval Research, was the first demonstration of a direct germicidal effect from UV-emitting semiconductors.

Hydro-Photon has developed portable mercury lamps emitting in the UV. However, these units were expensive, needing components to provide high-frequency, high-voltage sources for the lamp. LED sources of UV light offer many benefits over mercury lamps. They are "instant-on", potentially much cheaper, port-

able, and have a higher theoretical efficiency.

The global market for UV water treatment is huge, says Maiden. For example, practically all bottled water in the developed world is UV-treated prior to shipment. Hydro-Photon's next project, which also forms part of DARPA's SUVOS program (*Compound Semiconductor* May 2004 p20), involves developing inline water treatment for the armed forces.

A small module will form part of a portable hydration system similar to that used by many hikers. UV LEDs at the inlet and outlet of the device will emit instantly when water is extracted, providing sterilization.

Nichia not keen on Nakamura settlement

Eiji Ogawa, president of GaN-based LED and laser manufacturer Nichia, has said that the company will not consider an out-of-court settlement with Shuji Nakamura. That's according to a report in the Japanese business newspaper *Nihon Keizai Shimbun*.

Nichia and Nakamura have been embroiled in a row over intellectual property since shortly after Nakamura left the company in 1999. The researcher, who is now at the University of California, Santa Barbara, filed a lawsuit against his former employer in August 2001, but lost his original claim that he owned a disputed patent (patent "404") relating to a two-flow MOCVD technique.

However, a Japanese court ruling in February this year awarded Nakamura almost \$200 million in compensation for his work. Nichia has appealed that decision (*Compound*

Semiconductor March 2004 p5).

This ruling was based on the judge's interpretation of Nichia's potential profits from blue LEDs up until 2010, which were estimated at ¥120 billion (\$1.1 billion). However, Ogawa believes that such a prediction is impossible while Nichia is unable to precisely predict LED sales even for this year.

In an interview Ogawa reportedly said that Nichia is not even using patent 404 in LED production. Ogawa added that Nichia will argue in its appeal that the scope of the disputed patent was interpreted too broadly in the district-court ruling.

In response to Nakamura's comment that he was referred to as a "slave" while working at Nichia, Ogawa claimed that Nichia paid Nakamura an annual wage of nearly ¥20 million at the time he left the company.



California-based Coherent has introduced DuraLite, the first in a series of new laser diode products and the latest in its extensive family of field-proven laser-diode bars. The first available DuraLite product is this 810 nm 50 W bar, an environmentally sealed and lensed conduction-cooled package. It is ideal for integration into graphic arts and direct-diode materials-processing applications, says Coherent.

Buyout signals end for Nova Crystals

By Tim Whitaker

Gemfire, a Californian company that develops planar optical circuits, has acquired a portfolio of technology relating to avalanche photodiodes (APDs) from Nova Crystals of Halifax, Canada, a now defunct optoelectronic component manufacturer.

The technology developed by Nova Crystals uses a proprietary wafer-bonding technique to combine the high detection sensitivity of InGaAs with the beneficial manufacturing properties of silicon.

Gemfire says that the APD technology,

which can be manufactured using planar silicon processes, will complement its recently acquired passive planar lightwave circuits (PLC) operations and existing polymer PLC waveguide products. The detectors operate at telecom wavelengths, allowing Gemfire to develop integrated planar WDM solutions. They can also be designed to operate in Geiger mode for single-photon-counting applications.

Richard Tompane, president and chief executive officer of Gemfire, said: "This technology not only allows cost-effective integration of detectors into PLCs for increased functionality, but also enables Gemfire to serve customers – addressing market opportunities such as quantum key cryptography."

The technology acquisition comes several

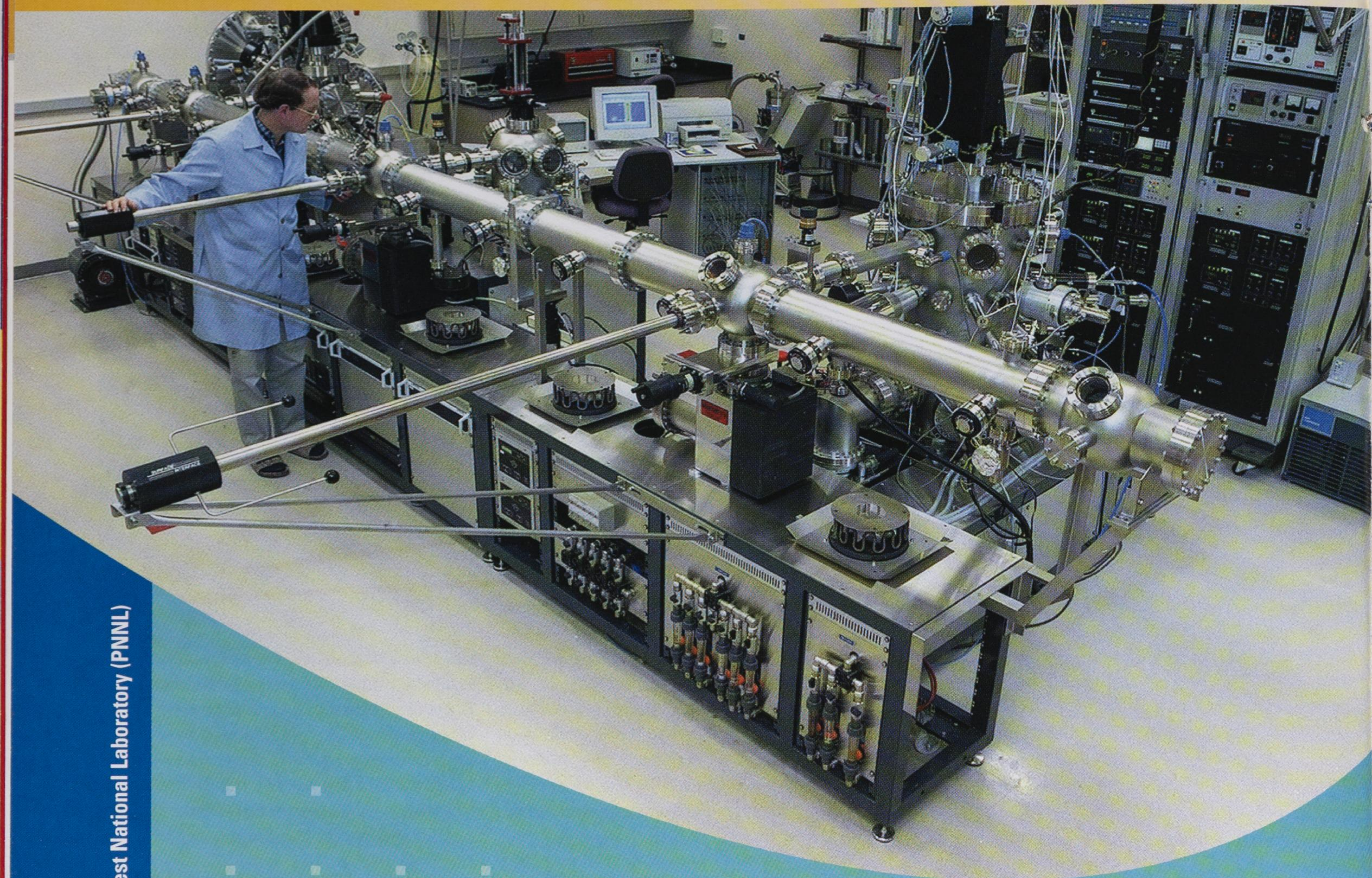
months after Nova Crystals' manufacturing equipment was sold by auction. Among the items offered were two Emcore D180 MOCVD reactors, two Bede X-ray systems, a JEOL field-emission SEM and various steppers and etchers.

In addition to InGaAs-on-silicon detectors, Nova Crystals had dabbled with various other devices – including high-brightness LEDs and long-wavelength (1.3 μ m) VCSELs – without commercial success. The firm was founded in September 1998 to commercialize technology developed at Cornell University.

A move to a new 40,000 sq. ft facility in San Jose helped to burn through some of the \$31.25 million that Nova Crystals raised in its third financing round in October 2000.

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INSTRUMENTS

Sb-based detectors enable video-rate imaging in the millimeter-wave spectrum

Zero-bias InAs/AlGaSb detectors and a host of other III-V components are at the heart of a camera that is expected to dramatically improve mm-wave imaging systems. **Tim Whitaker** reports.

HR L Laboratories has developed InAs/AlGaSb detectors operating at zero bias that could enable an order-of-magnitude improvement in the sensitivity of mm-wave imaging systems. The research organization, which is based in Malibu, CA, has already produced and delivered several hundred thousand InAs/AlGaSb diodes to Trex Enterprises, which is developing an advanced version of its passive mm-wave camera.

The HRL diode is expected to help enable the practical implementation of mm-wave imaging for a range of future military and commercial applications. The mm-wave spectrum allows detectors to “see through” obstructions much more effectively than other imaging bands such as the infrared. Prototype mm-wave cameras are already being developed to detect concealed weapons or to act as a navigational aid when visibility is poor.

The Sb-heterostructure devices developed by Joel Schulman, David Chow and colleagues at HRL are superior to existing device types in terms of zero-bias and high-frequency operation. At present, the diodes operate up to the W-band (75–100 GHz), but have the potential to extend well into the sub-mm (>300 GHz) wavelength range. The diodes are grown by MBE, which allows them to be produced in large quantities and with the flexibility to tailor the layer structure to optimize the desired figure of merit for a given application.

Interband tunneling

HRL’s diode operates on the principle of interband tunneling between the valence and conduction bands of adjacent semiconductor regions. The principle is the same as that in Esaki tunnel diodes, in which the required energy offset is achieved with a very heavily doped p-n junction. In the Sb-heterostructure devices, also pioneered by Leo Esaki at IBM

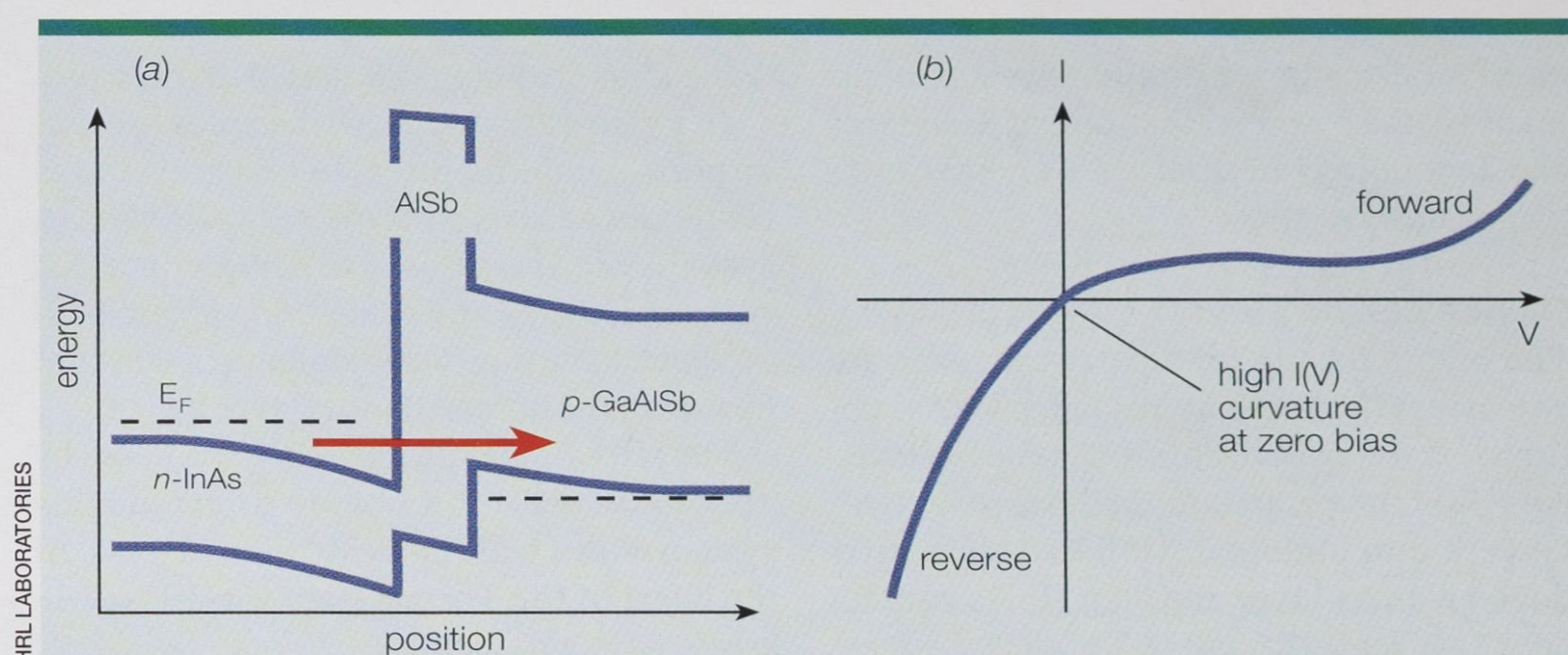


Fig. 1. (a) Band structure of the Sb-heterostructure detector diodes developed by HRL. The Type II band line-up between n-InAs and p-AlGaSb achieves the condition for interband tunneling without heavy doping. The AlSb barrier thickness controls the overall current flow. (b) The InAs/AlGaSb diode has a high curvature in the $I(V)$ characteristic at zero bias.

in the late 1970s, tunneling takes place between the conduction band of an n-type InAs layer and the valence band of a p-type AlGaSb layer, which are separated by a thin AlSb barrier (figure 1a). Related heterostructures were explored in the early 1990s for their negative resistance properties, although not for the zero-bias behavior exploited here.

The Type II bandgap line-up between InAs and AlGaSb results in the most attractive feature of such devices, namely a high curvature in the current-voltage characteristics at zero bias (figure 1b). This allows the device to function, at zero bias, as a square-law detector, in which the power (voltage squared) of the incoming signal is converted into a proportional DC offset.

In comparison, high-frequency (above 10 GHz) Schottky diodes must be biased in order to lower their junction resistance, or require input signals significantly higher than the sub-mW level. Other device types have other problems; germanium-based Esaki

diodes are limited to operating below 40 GHz and cannot be made in large quantities, while planar doped barrier devices work well up to W-band but are very difficult to produce reliably and reproducibly.

As a consequence of enabling zero-bias direct detection, the Sb-heterostructure device eliminates the need for local oscillators or bias currents that add complexity, power consumption and noise. Also, since $1/f$ noise is proportional to bias current, a significant improvement in signal-to-noise ratio can be expected using Sb-heterostructure devices in place of Schottky diodes in practical system applications. In addition, the tunneling nature of the current transport virtually eliminates the influence of temperature on detection sensitivity; this is a major issue with Schottky diodes, where the current has an exponential dependence on inverse temperature.

HRL says that its Sb-based devices lead to an order-of-magnitude improvement in the noise-equivalent power, the key figure-of-

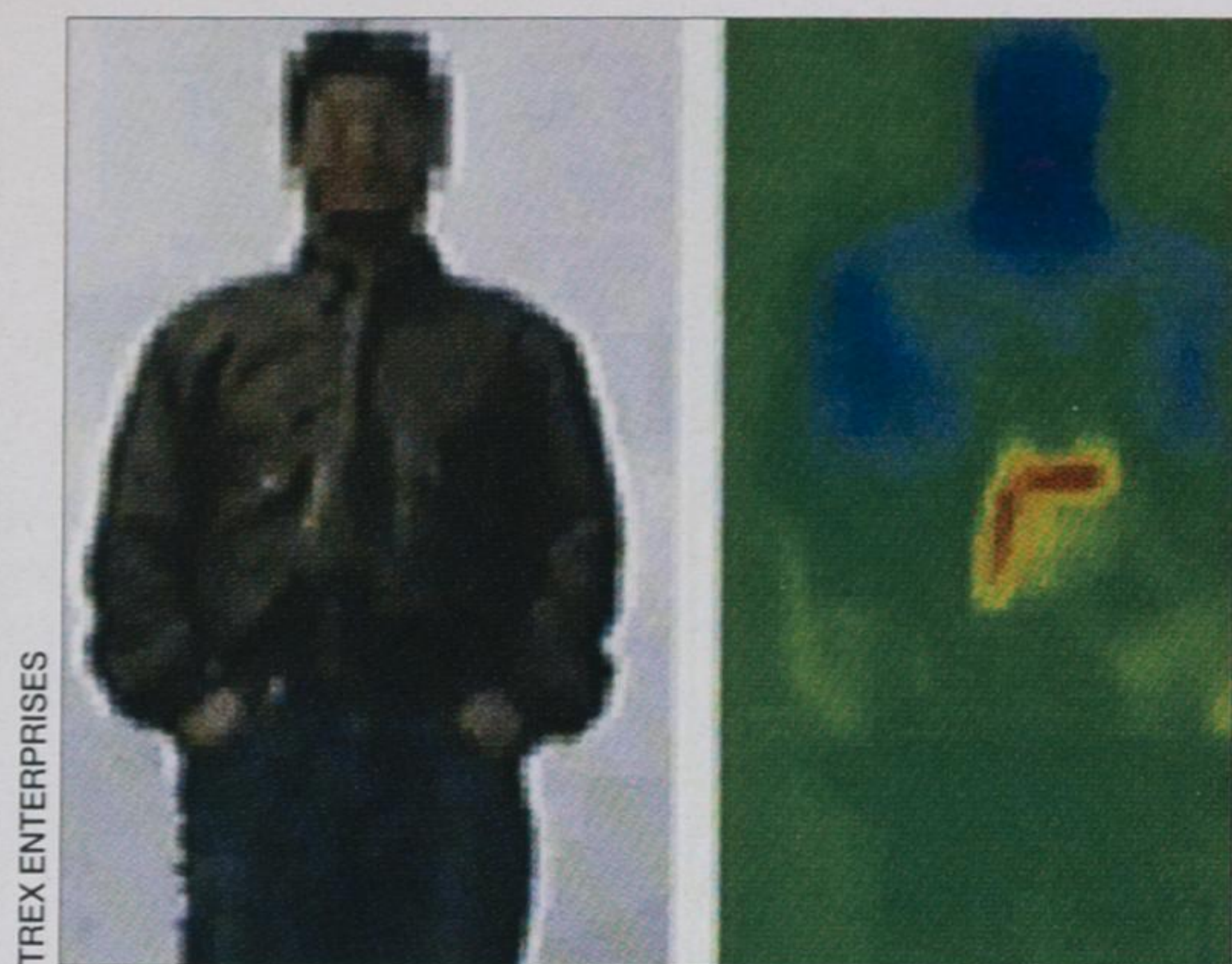


Fig. 2. A mm-wave camera can see metallic objects through clothing, such as the metal gun seen through a leather jacket here.

merit for detector sensitivity. Measurements made by the National Institute of Standards and Technology in Boulder, CO, have confirmed these results.

Device performance

The layers for the Sb heterostructures are grown by MBE on semi-insulating GaAs substrates, and consist of an n^+ InAs contact layer, a p^+ GaSb layer, an undoped $Al_{0.12}Ga_{0.88}Sb$ layer, a thin undoped AlSb barrier, a low-doped n-InAs layer and an n^+ InAs contact layer (Meyers *et al.* 2004). The devices made for Trex Enterprises have $2\mu m \times 2\mu m$ active areas defined using I-line stepper lithography.

In test circuits, record voltage responsivities of up to 8000 mV/mW have been recorded from 75 to 93 GHz, with input powers from -50 to -30 dBm (0.01–1 μW). Tests were also carried out using an actual camera frequency-processor board with 128 tuned channels; 72% of detectors had responsivities at or above 6000 mV/mW, while 3% of channels were above 10,000 mV/mW (Schulman *et al.* 2004).

As the Sb-heterostructure diodes are simple to grow and fabricate, these results indicate the potential for large-scale arrays operating at W-band and above and providing low-noise, zero-bias, square-law detection.

Phased-array imagers

The test results described above were performed by HRL in collaboration with Trex Enterprises, a San Diego, CA, company that has been involved in the development of passive mm-wave cameras for more than 10 years. Millimeter-wave imaging detects radiation that is emitted or reflected passively to some degree by all objects. The wavelength is such that the radiation passes through clouds, fog, clothing and some building materials.

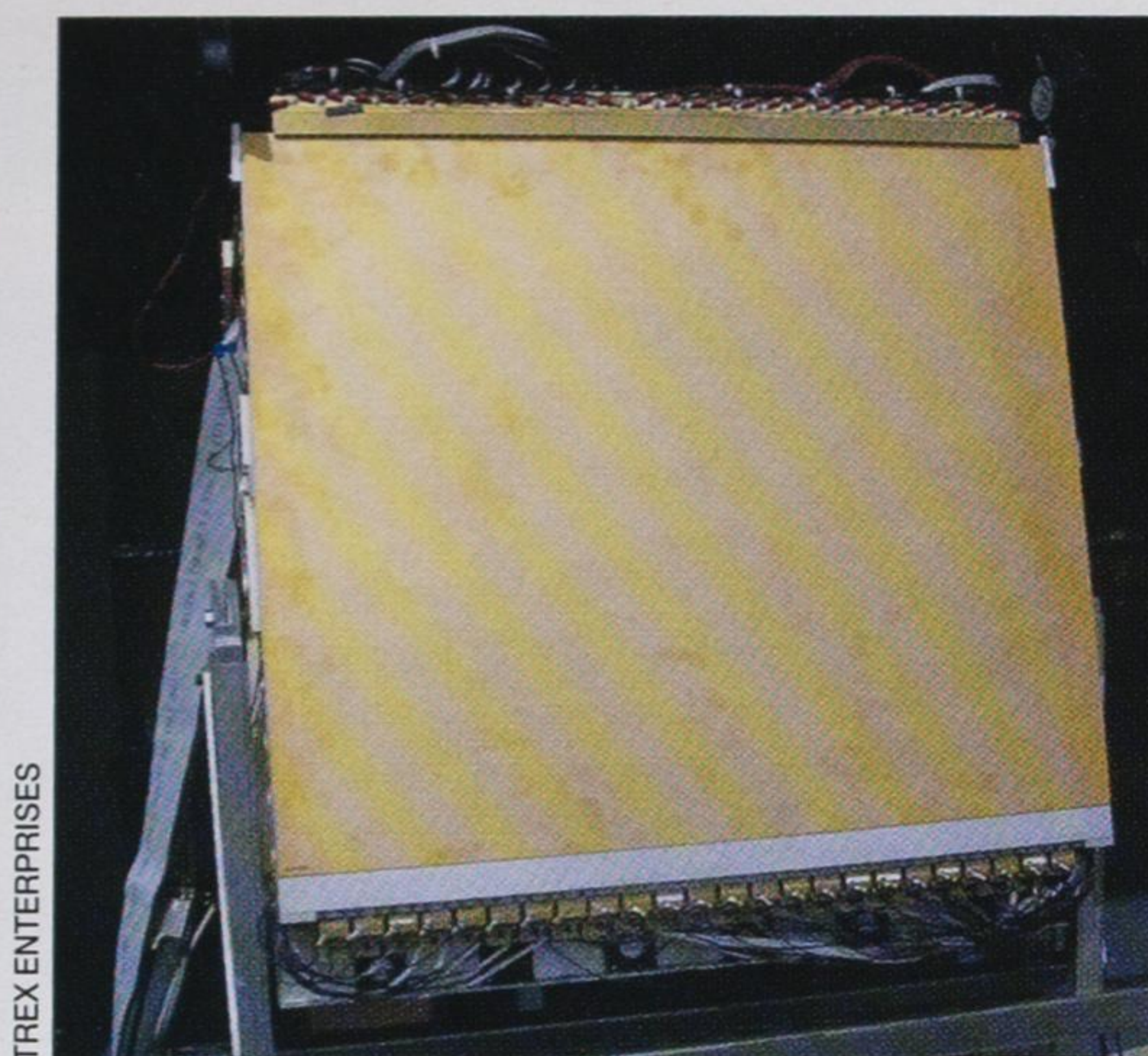
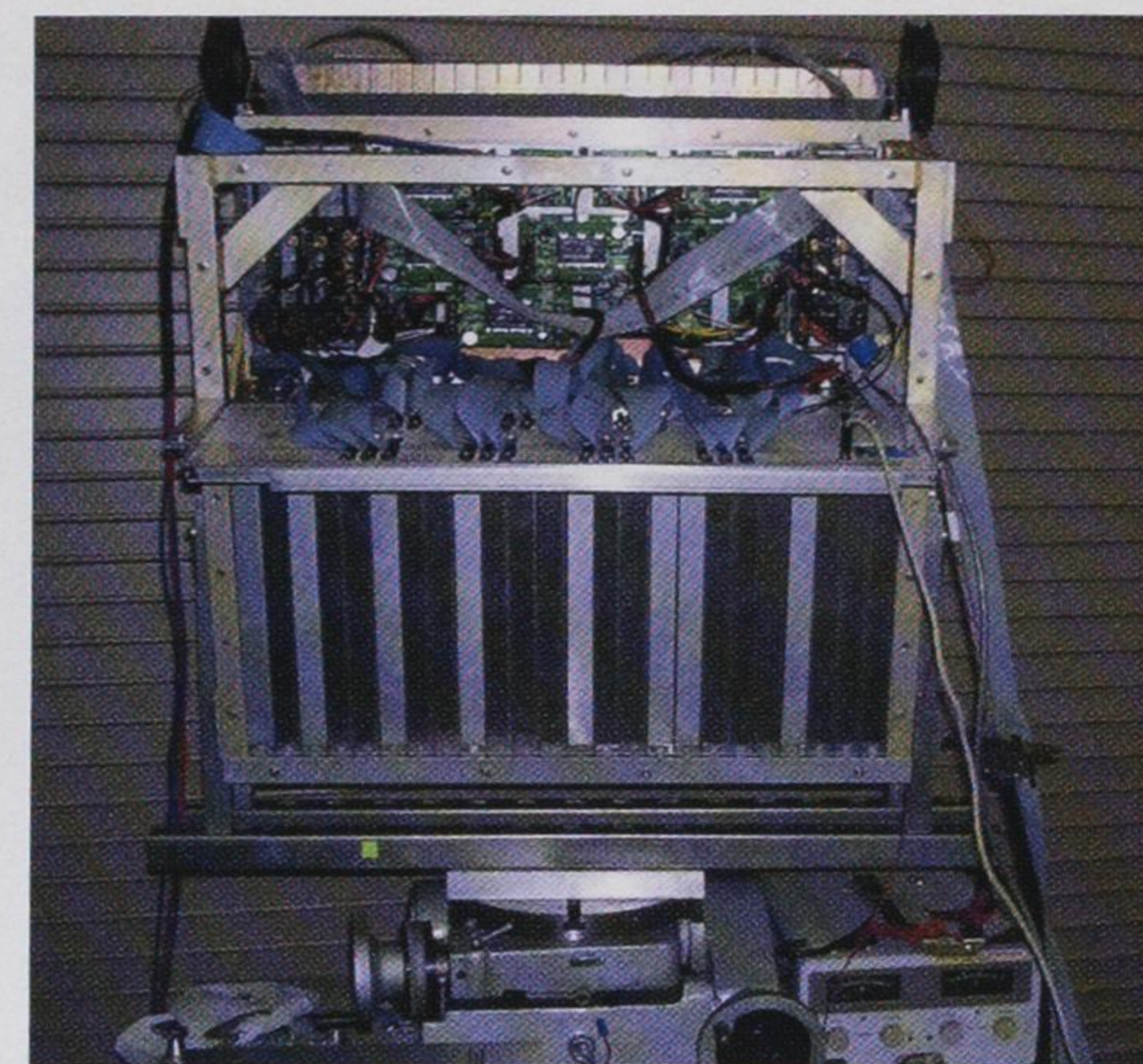


Fig. 3. Front and rear views of Trex's real-time mm-wave imaging system.



Systems are being developed that can provide video-rate imagery of scenes such as airports, enabling pilots to taxi and land in conditions of severely restricted visibility. The systems can also be used to detect concealed weapons, drugs and other contraband – all of which have mm-wave signatures that contrast with the human body (figure 2).

The HRL diodes are being incorporated by Trex into a real-time, phased-array imaging system with a wide $20^\circ \times 30^\circ$ field of view. At the heart of the Trex system is a 192×128 array, with a detector diode at every pixel, meaning that the imager contains almost 25,000 detectors in total. Prior to detection, the signals must be amplified, so the system also contains more than 1000 low-noise amplifiers (LNAs). The LNAs used by Trex are InP-based devices also manufactured by HRL on a 0.1 μm process and operating at 75–94 GHz. The systems also contain AlGaAs pin diode switches, supplied by M/A-COM, which toggle the input signal to the LNAs between the scene being viewed and a matched resistive load that acts as a reference.

The sensitivity of the HRL diodes is a key factor in improving system performance, according to John Lovberg, CTO of Trex. “The costliest components in the system are the amplifiers, so the more sensitive the detector diodes, the less money we need to spend on the LNAs,” he said.

The HRL diodes also enable direct detection in the W-band, rather than requiring down-conversion to X-band as in previous iterations of the phased-array imaging system. “The first system was very large and weighed around 2000 lb, but the latest imager is much smaller and weighs around 150 lb,” said Lovberg. “The HRL diodes enabled us to build the phased-array imager in a compact package that

can be flown on a helicopter.” The sensor is shown in figure 3 (Martin and Kolinko 2004).

Packaging the amplifiers and assembling the detector circuit boards, passive delay lines and other elements is currently all done manually, making the system cost very high. “We’ve built two systems so far, each costing around \$1 million,” said Lovberg. “With automated assembly and a reduction in component costs, particularly for the amplifiers, we expect this can be reduced to around \$200,000.”

The phased-array systems, providing video-rate imagery at 30 frames/s, are likely to be used in applications such as aircraft landing. Trex has also built mechanically scanned systems, which do not provide real-time images but are much smaller and less expensive, partly because they contain only 128 detectors and three amplifiers. “These systems could sell for less than \$10,000, for portable security applications such as weapons detection,” said Lovberg.

Advances in semiconductor technology have enabled the new architectural design of the phased-array imaging sensor. “As this continues to happen we’re also looking at higher frequencies, such as 140 and 220 GHz,” said Lovberg. “Hopefully some day we’ll push into the terahertz region, which is becoming a hot area for the detection of explosives.”

Further reading

C Martin and V Kolinko 2004. *SPIE Proc.* **5544**.

R G Meyers *et al.* 2004 *IEEE Elec. Dev. Lett.* **25** (1) 4.

J N Schulman *et al.* 2004 *IEEE Microwave & Wireless Components Lett.* **14**(7) (in press).

Joel Schulman of HRL can be contacted at schulman@hrl.com.



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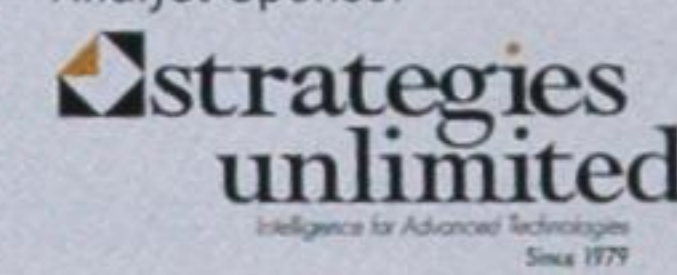
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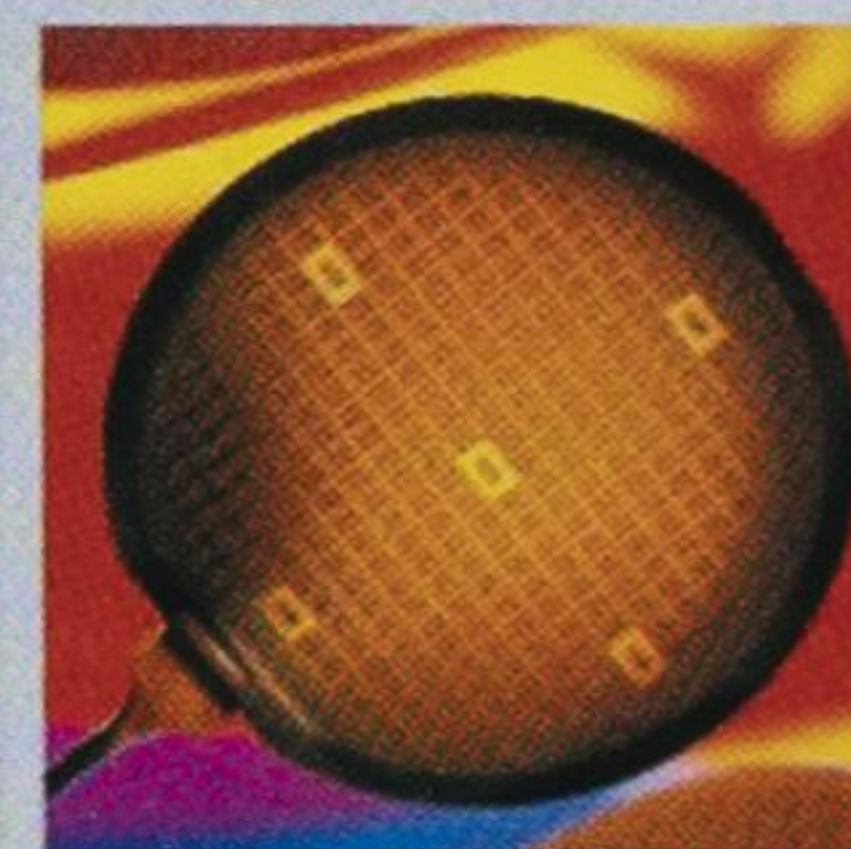


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Compound semiconductor device

With increasing electronic content and applications in cars, the automotive industry offers great potential for III-V device manufacturers.

Richard Stevenson reports.

Detroit auto giant General Motors predicts that global car sales will reach a new record of 60 million vehicles in 2004, a rise of 3% on the previous year. Sales of semiconductor components within the automotive industry were valued at \$12.6 billion in 2003, according to market analyst company Strategy Analytics. Today, electronic content equates to approximately 25% of the costs of car production, and market research firm Frost & Sullivan expects this figure to rise to 40% by 2010. Opportunities to take a cut of this revenue have not escaped the notice of the compound semiconductor industry, with a wide variety of products attempting to penetrate the automobile market.

Predictably, silicon dominates the automobile semiconductor market, but several applications use compound semiconductors. Many of today's cars contain CD players and use LEDs for various interior lighting applications, while some also have optical communication systems driven with LEDs. Luxury models may have DVD players, and advanced driving features such as automotive radar, based on GaAs technology (figure 1). In the future, cars may even include photocatalyst-based air purifiers containing ultraviolet LEDs (*Compound Semiconductor* May 2003 p19), and in-car communication using laser diodes. Although these luxury model products will become commonplace, changes will not occur overnight. Unlike the consumer electronics sector, where new product cycles unfold quickly, penetration of the automotive industry takes approximately seven years.

Growth in auto LED market

The most prominent area that has already been penetrated by compound semiconductors is LED lighting. Sales of LEDs to the automotive sector reached \$392 million in 2003 and will grow about 15% this year to around \$450 million, says Strategies Unlimited. The

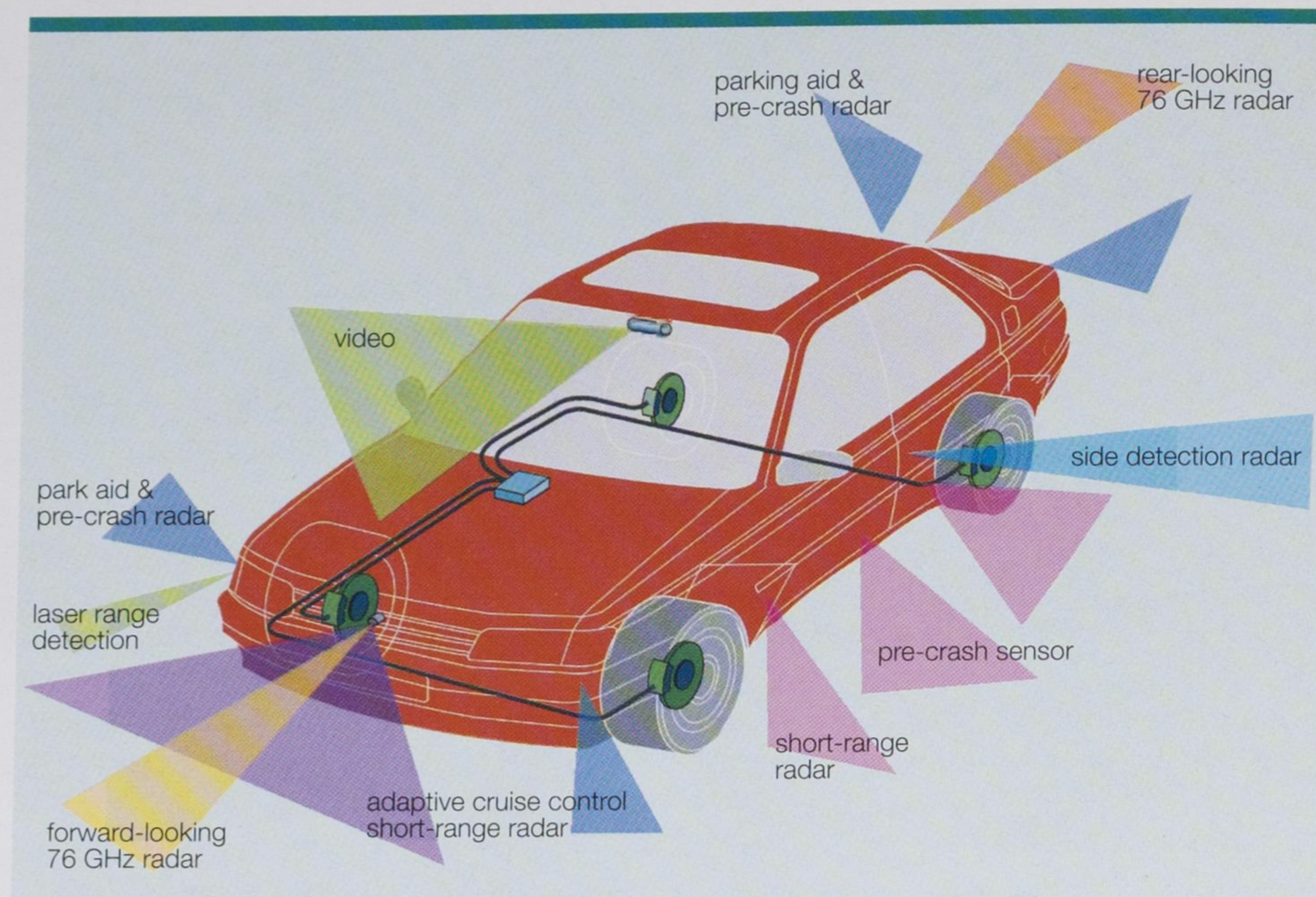


Fig. 1. An example of the range of driving aids that are available on luxury cars such as the Mercedes-Benz S-Class. The autoradar systems employ GaAs-based MMICs.

industry uses a wide range of LEDs for a whole host of applications. For example, the Audi A3 contains 210 LEDs, with nearly half used for dashboard lighting, followed by radio, climate control, switch and other applications. While LEDs are widely used for interior lighting and displays, they are yet to replace incandescent sources in car headlamps.

Ron Steen, director of lighting R&D at Schefenacker, based in Germany, calculates that today's total headlamp market is 100 million units. He predicts that LED headlamp sales will only reach 1 million units in 2010. This view is shared by Burkard Wördenweber (recently R&D director at Hella KG Hueck & Co, based in Germany). "Commercialization of LED headlamps is still a long way away from the technical and financial goals," said Wördenweber. He believes that hybrid lamps containing both LEDs and other sources will be the next step, and that developments will first emerge in Asia.

Recent advances have seen LED-based daytime running lamps appearing on a variety of concept cars, and more recently on a production vehicle, the Audi A8 6.0. "Today the car industry realizes the advantages that LEDs offer mainly in one application, the center high-mounted stop lamps [that are usually

placed above the rear windscreen]," said Wördenweber. "In order for LEDs to spread to the other signal lighting functions, automotive manufacturers have to acknowledge the overall savings possible through 'packaging' (e.g. thin rear lamps). In addition, the designers have to realize the advantages that LEDs offer, such as longer lifetimes, 'cold-light' sources and fast rise times."

In-car communication

LEDs are used as the light source for in-car fiber-optic communication systems, based on a data bus protocol known as media-orientated system transport (MOST) bus systems. These systems are already fitted in over 20 production vehicles, including models manufactured by Mercedes, Porsche, Audi, Citroën, Renault and BMW. Infineon currently has 95% of the market share for MOST transmitters and receivers, although the company has just announced the sale of its fiber-optics business unit to Finisar, a US manufacturer of optical subsystems and test gear. Suitable for data rates of up to 50 Mbit/s, the transmitter is based on a 650 nm LED. The systems connect in-car electronic devices such as CD and DVD players, car navigation systems and video-gaming consoles. MOST systems offer high

es offer new driving experiences

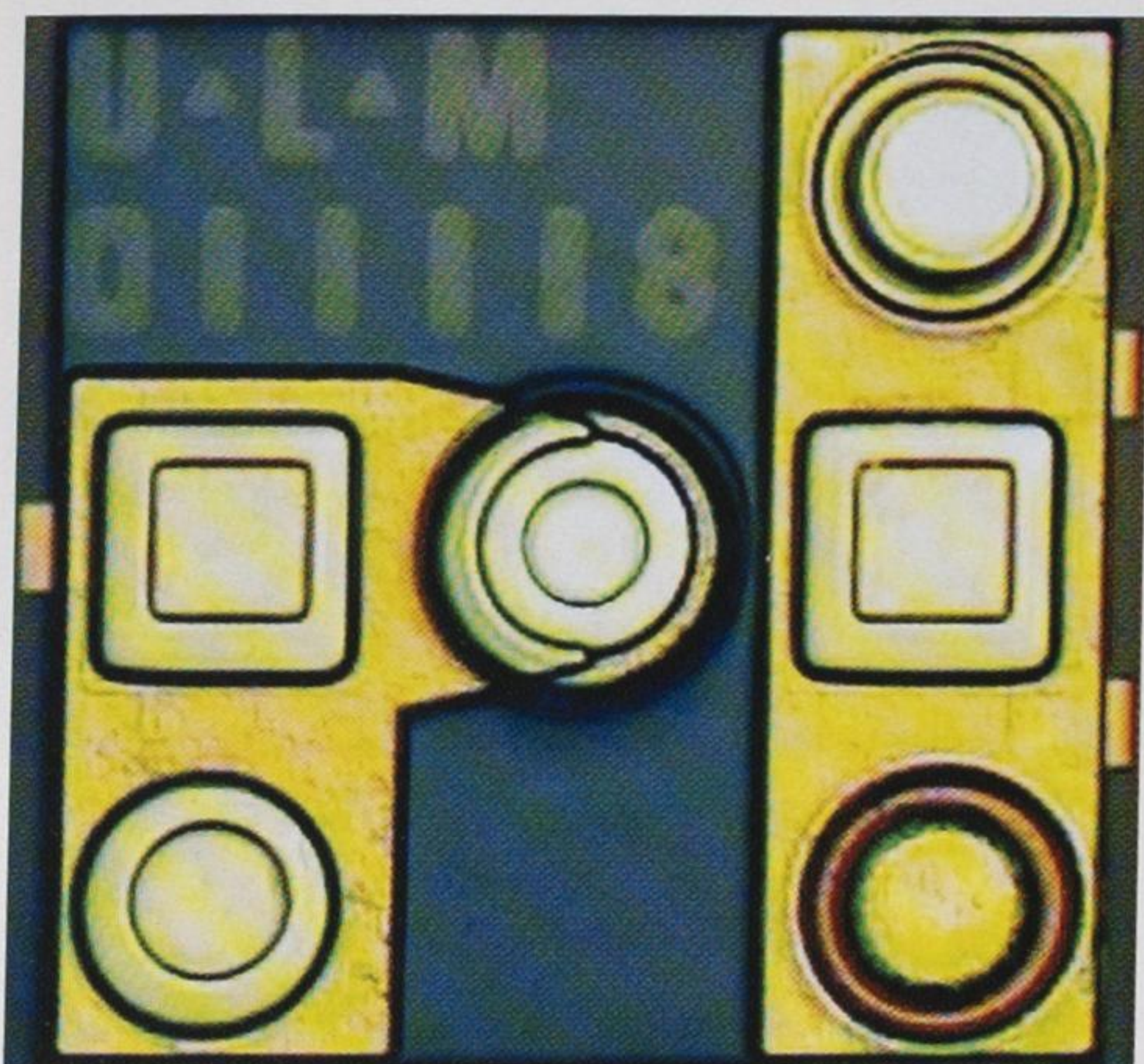


Fig. 2. An ULM Photonics GaAs VCSEL.

operating bandwidth, increased transmission security, low weight, immunity to electromagnetic interference, and ease of handling and installation.

Today's MOST systems use 650 nm LEDs and inexpensive plastic optical fiber (POF). However, with the ever-increasing number of gadgets and systems present in cars, such as real-time video cameras for reversing, faster data transmission rates are required. Next-generation systems will comply with the IDB-1394 protocol, the automotive version of the IEEE-1394 standard, also known as FireWire, which targets higher-speed data transfer rates of up to 400 Mbit/s.

At least two different transceiver solutions are under development targeting the IDB-1394 standard. ULM Photonics, based in Germany, is investigating the combination of optical fiber and 850 nm VCSELs, capable of data transfer rates in the region of at least 1 Gbit/s (figure 2). Firecomms of Ireland is instead using resonant-cavity LEDs (RCLEDs), emitting at 650 nm, and POF. Burghard Schneider, the general manager of ULM Photonics, aims to have VCSEL-based systems in cars by 2009. "In addition to low transmission speeds, existing LED-based MOST systems deliver poor performance at higher temperatures," he explained. "Above 105 °C, a typical ambient temperature for automotive applications, POF transmission degrades and LED power output is low."

ULM Photonics has invested a great deal of effort in researching VCSEL reliability, including 85% humidity and temperature shock tests. Schneider believes that the com-

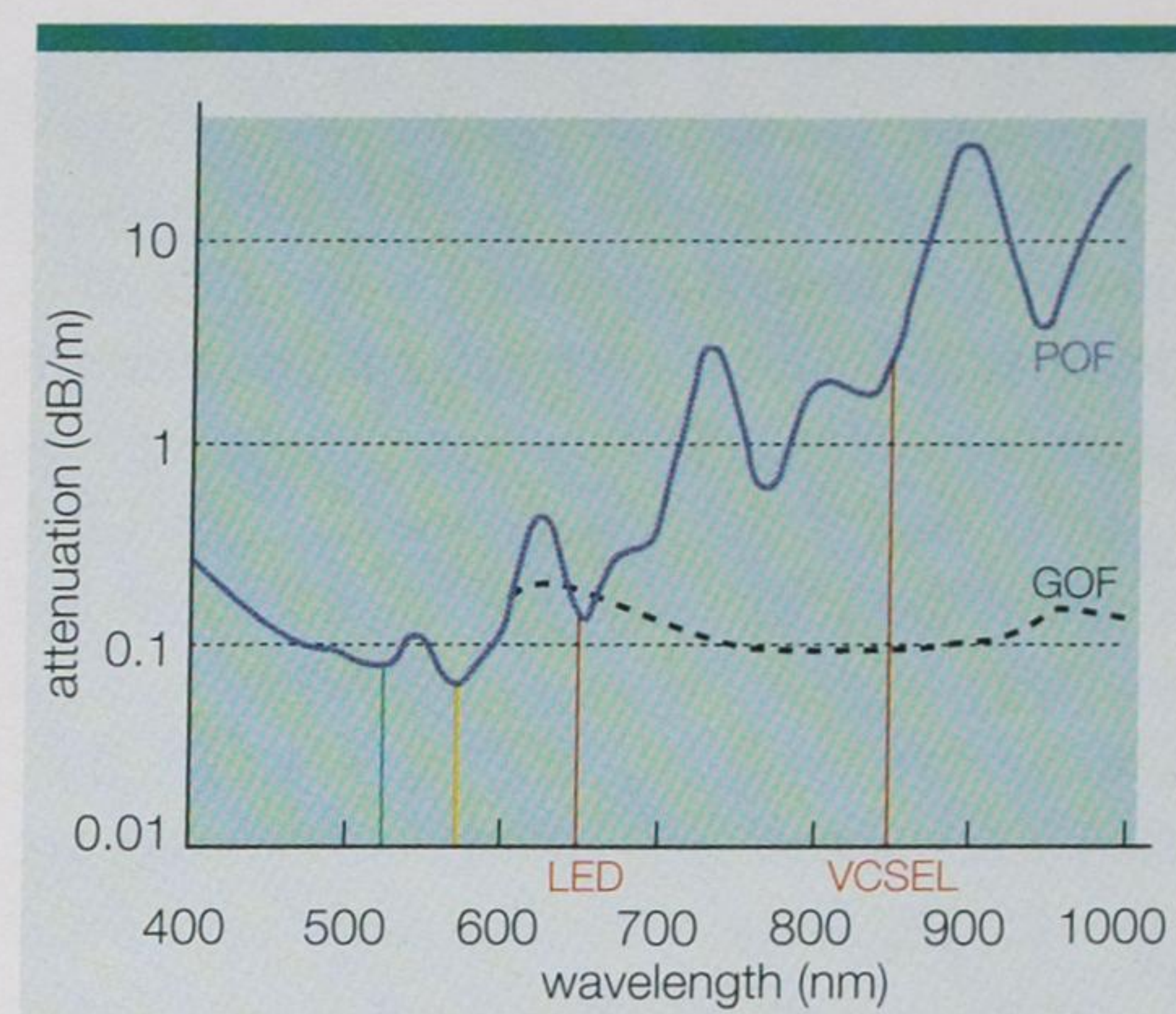


Fig. 3. A comparison of the absorption properties of POF and glass optical fiber.

pany is capable of producing VCSELs that do not require hermetic sealing, yet will still exhibit excellent temperature behavior with good stability over time. Although the device lifetime required for the car industry is only 12,000 h, failure of any device is unacceptable.

Schneider explains that at a wavelength of 850 nm, two fiber options are available for straightforward coupling: either polymer-clad silica fibers with a 200 μ m diameter core, or a multi-core glass fiber (with 400 individual fibers) with a total core diameter of 1 mm. The price of a VCSEL-fiber module is strongly dependent on light coupling, so straightforward coupling available with either of these wide-diameter core fibers keeps costs low. However, at the moment cost still appears to be too high. Schneider said: "VCSEL prices need to fall to 10% of their current value in order to penetrate the car market."

ULM Photonics is competing with alternative systems for achieving the IDB-1394 standard that use 650 nm RCLEDs and POF. It is confident, however, that a highly conservative car industry demanding proven device performance will choose the relatively well established 850 nm VCSELs over 650 nm RCLEDs. This is not the view of Declan O'Mahoney, CEO of Firecomms, who says that since VCSELs are unproven in the car environment, the choice of the light source for communication remains wide open.

Firecomms is a spin-off of the National Microelectronic Research Centre in Cork, Ireland, and was established in March 2001. It has invested a high proportion of its efforts in 650 nm RCLEDs. These devices have sev-

eral advantages over LEDs for data communication, including small surface-emitting areas, reduced spectral widths, and higher transmission rates of ~350 Mbit/s.

The company has spent the last two years improving the key parameter, RCLED lifetime. It has produced many proof-of-concept systems targeting the IDB-1394 standard, including examples with RCLEDs operating at 250 Mbit/s coupled to 1 mm core diameter POF. O'Mahoney said: "Although RCLEDs used in home network applications can be butt-coupled directly to POF, for car applications devices operate at typically 95 °C. Device self-heating is an issue at these temperatures, and so optimized package design including an integrated lens is used to improve performance."

Firecomms has developed red-emitting devices, but it is possible that future generations of POF communication systems will also use green sources. Shorter wavelengths result in less absorption (figure 3), which is beneficial for industrial networking over distances of hundreds of meters or more. However, O'Mahoney believes that green RCLED technology is unlikely to be used in automotive applications in the foreseeable future.

Automotive radar

Another application for compound semiconductor devices in cars is automotive radar. Research began as far back as 1973, although the market had to wait until 1998 before autoradar was fitted to production cars such as the Mercedes-Benz S-Class. According to Asif Anwar of Strategy Analytics: "The technology is still limited to luxury cars, with radar forming part of a safety package including other functions such as pre-crash seatbelt tightening and braking assistance." Anwar believes that if volumes increase, production costs will fall, although car manufacturers need to lead the way by introducing technology to the mid-price market. Japan is already witnessing this, with Honda offering autoradar on its new Accord, a mid-price car in the domestic market. "In addition, the VW group, which already offers autoradar on its luxury Phantom model, is considering marketing it as an accessory to the Golf platform, which includes the VW Golf, the Audi A3, the Seat Ibiza and the Skoda Octavia," said Anwar.

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Current autoradar falls broadly into two categories. Short-range radar (SRR) systems are used mainly for parking, reversing or "stop-go" driving in heavy traffic, and operate at 17–24 GHz and distances of up to about 25 m (figure 4). SRR systems cost about \$1000, while long-range radar (LRR) systems are about twice as expensive. LRR has a range of up to ~150 m, and operates at 77 GHz. It is designed to assist the driver's road position at higher speeds, and is marketed under names such as "adaptive cruise control". Early LRR systems used InP Gunn diodes, but today the majority of systems use GaAs MMICs, with the remainder using GaAs Gunn diodes. However, companies such as Infineon are developing SiGe-based alternatives. Anwar believes that "in the next 5–6 years we will see developments of hybrid systems containing both SiGe and GaAs components."

There are other reasons apart from cost to prevent SRR from penetrating the car market. Anwar explains: "There are two forms of SRR, either narrow band using a focused beam, which can be used for blind-spot detection, or ultra-wide band (UWB) SRR, which has several sensors around the vehicle." 24 GHz UWB SRR has a bandwidth of 5 GHz, which interferes with the work of radio astronomers and meteorologists. It also faces competition from the camera-based parking systems popular in Japan, and ultrasonic parking aids used in North America. Anwar believes that LRR technology will come to dominate the application: "If autoradar manufacturers could get the costs down, cars could then just use 77 GHz technology, but it could be 8–10 years before this happens."

One company producing GaAs MMICs for autoradar, as well as other markets, is United Monolithic Semiconductors (UMS), based in France and Germany. Since October 2001 its GaAs MMICs have been used in LRR systems for Mercedes. UMS is working with other automotive equipment manufacturers, such as CONTI/ADC and Autocruise, and currently produces more than 30,000 chipsets per year. However, product development manager Marc Camiade only expects to see steady growth in the uptake of LRR radar.

UMS is also producing GaAs MMICs for SRR. It has seen customer forecasts for more rapid growth of SRR than for LRR, and is aware of the bandwidth problems associated with the UWB variant. 24 GHz SRR was discussed by the European Conference of Postal and Telecommunications Administrations (CEPT) working group for frequency man-

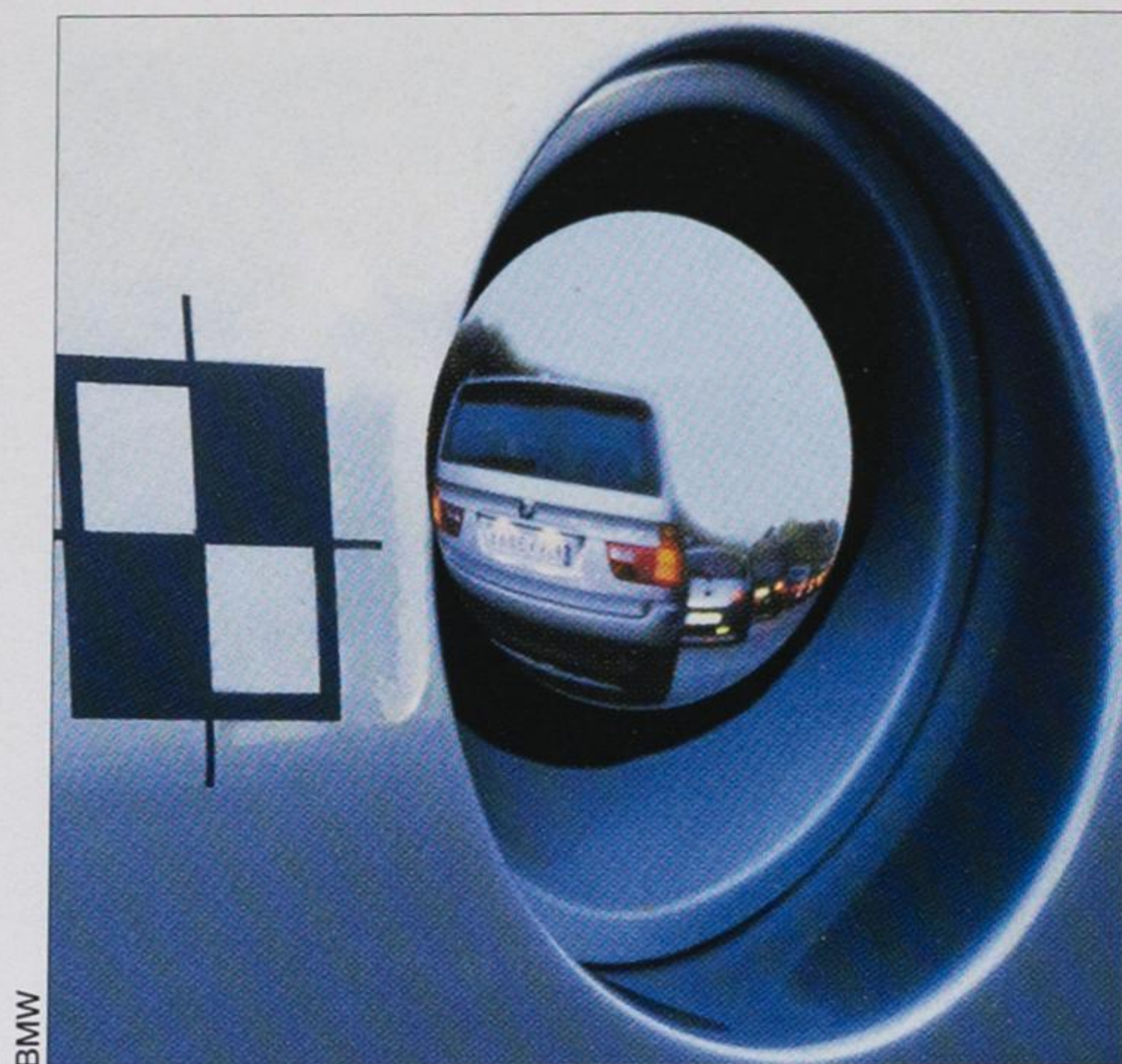


Fig. 4. BMW 5 Series short-range radar.

agement (WGFM) in April 2004. Astronomy, meteorology, telecoms and automotive representatives had "a heated debate on all sides", according to WGFM chairman, Jim Connolly.

"The agreed proposal is not a solution for the automotive industry," said Connolly. Measures proposed include capping penetration of SRR to 5.9% (with action taken if market penetration is higher), and a cut-off date for fitting 24 GHz SRR of 2012. Other ideas include mandatory automatic deactivation of SRR equipment to protect radio astronomy sites.

Not surprisingly, representatives of a country with a strong automobile industry objected to these proposals, which now go before the Electronics Communications Committee (ECC). If accepted by the ECC, the measures could then be adopted by the regulatory bodies in CEPT member countries.

Connolly believes that 24 GHz SRR is an interim solution. Looking to the future, UMS is starting to develop SRR at 79 GHz, sufficiently displaced from 77 GHz LRR to avoid interference problems. UMS is not expecting an instant transition to 79 GHz autoradar, because the 24 GHz variant is less expensive.

UMS believes that one key to reducing the cost is supplying chipsets, enabling autoradar systems to be put together as simply as possible. In the past, UMS has won business by supplying GaAs MMICs that replaced GaAs Gunn diodes without the customer having to change the radar design. An additional benefit of MMICs over Gunn diodes is the removal of a circuit-tuning stage, shortening the assembly process. UMS is aware of the competition that GaAs MMICs will face from SiGe-based devices. Today UMS uses GaAs technology and an in-house foundry, but in future it may incorporate silicon-based technologies using external foundries.

Korean manufacturers focus on white LEDs

A fall in the price of blue LEDs used in handset keypad backlights means that Korean manufacturers are looking to white LEDs and applications outside the cell phone market. **Hordon Kim** reports.

With Samsung Electric and LG Innotek announcing their collaboration last year, Korea's high-brightness (HB) LED industry seems to have good prospects. Both HB-LED chip and applications markets are thriving, while the market volume and the number of manufacturing players are increasing.

However, Korean manufacturers still lag behind the global leaders (headed by Nichia) in terms of base technologies, such as wafers and materials. This is a great hindrance to Korean firms' international competitiveness. Although packaging technology has been improved, and competes with that in Japan, epi-processing technology still lags well behind Taiwan's. About half of the wafers in Korea are imported from Japan, Europe and Taiwan.

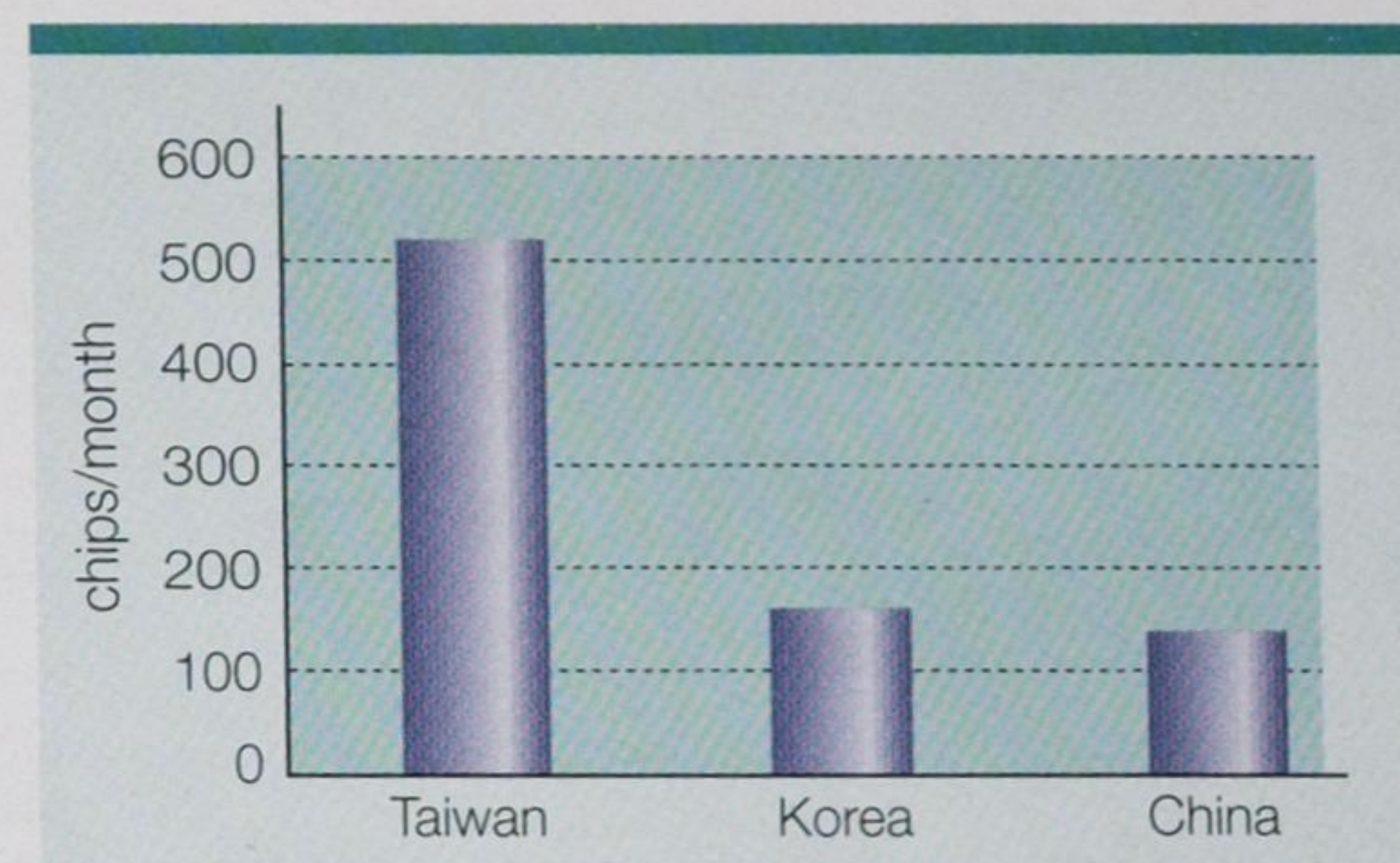
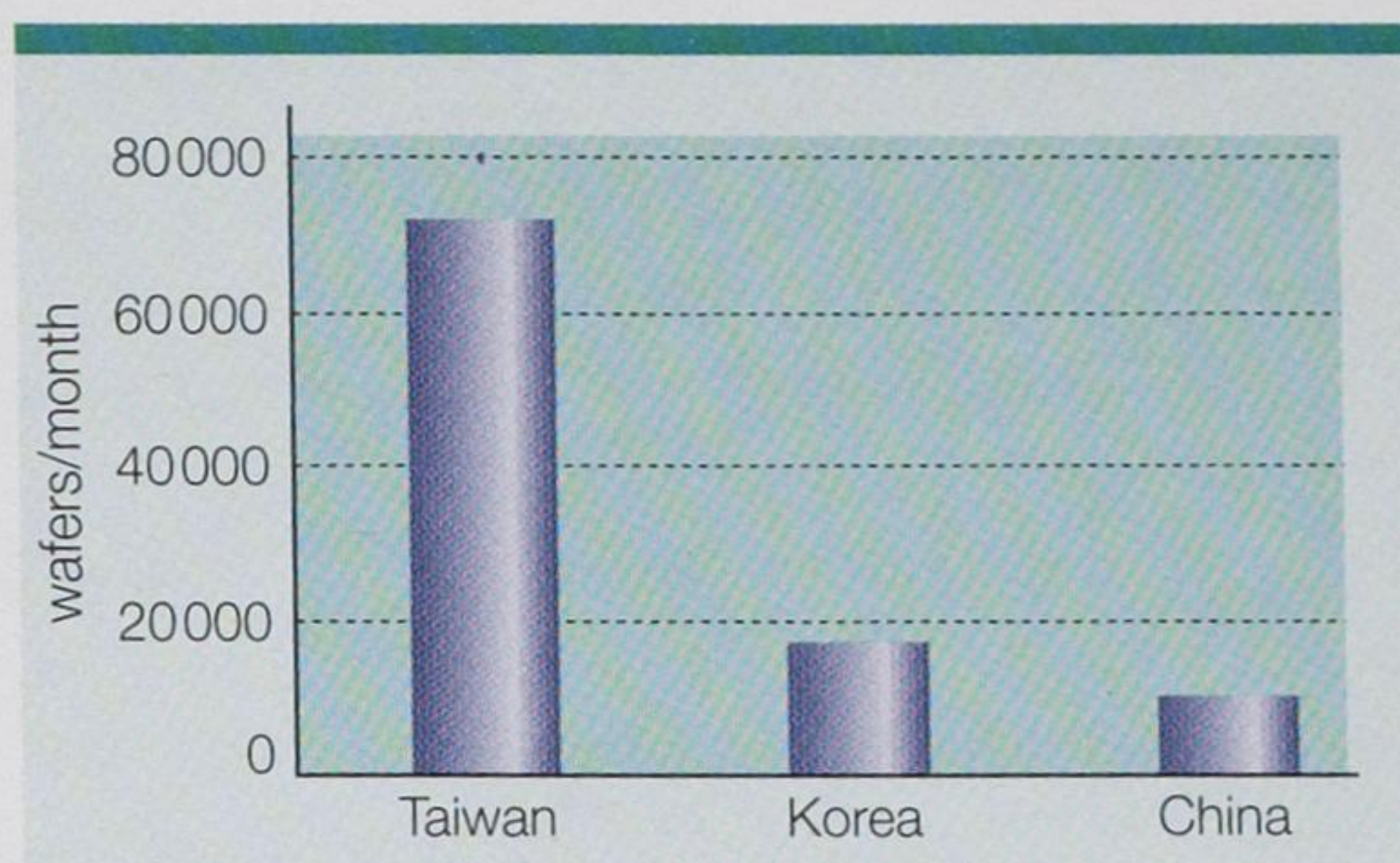
Investment has been heavily biased towards facilities, rather than technologies, which will impact the return on investment in the future. The dependence on imports for key manufacturing equipment is another barrier to break down. More than 80% of the HB-LED manufacturing equipment in Korea comes from Japan, while epi-growing equipment mostly arrives from Japan and Europe.

Increased competitiveness

With technological advances backed by steady mass production, however, Korean companies are becoming competitive on quality, price and delivery through techniques such as surface-mount (SMT) packaging.

Supplying local customers is key to the success of the Korean LED industry, with Samsung and LG comfortably in the top-tier of the global mobile phone manufacturing industry. Improved product quality has resulted in a series of purchasing orders for local companies. Lasemtech, for example, has secured a major contract with Samsung Electronics for its multicolor LED packages.

Lasemtech's product consists of blue, green



Korean manufacturers accounted for about 20% of GaN-based LEDs manufactured in Asia (outside of Japan) in 2003. In terms of epitaxial wafer manufacturing, Korea has a slightly lower share, at 16%. This year, a shift is expected away from blue devices towards white as competition from Taiwan and China continues to drive down the price of blue LEDs.

and red LED chips in one package. Having improved heat conductance by an order of magnitude over conventional devices, the company is now supplying Samsung with 330,000 LED packages a month.

Technological development is also being furthered through partnerships with foreign companies. LED packaging company Seoul Semiconductor is collaborating with the German lighting company TridonicAtco to develop HB-LEDs for industrial and automotive illumination applications.

The two companies presented details of the Alpha Power LED at the recent Light and Building International Trade Fair in Frankfurt, Germany. Assembled in an SMT package, the Alpha Power LEDs come in various colors, including white.

While Seoul Semiconductor will manufacture the Alpha Power LED and have exclusive sales rights in Asia and the US, TridonicAtco will retain exclusive sales rights in Europe and Australia. Applications include indoor/outdoor illumination, billboard illumination, traffic-signal lights and backlighting for large-area LCD screens. Monthly production capacity is 1 million pieces, and the companies forecast that their markets will more than double every year after 2004.

The keypad of mobile handsets has been a major driving force for Korea's blue HB-LED manufacturers, and this market is expected to keep sales at Korean companies booming for the next four to five years. The local market volume of blue HB-LEDs for mobile handsets is estimated at about \$178 million a year, according to industry sources.

Late last year, drastic price cuts of blue LEDs by Taiwanese suppliers forced Korean companies to go "upmarket" with more value-added products, such as those used for camera-phone flashes and backlight units.

Seoul Semiconductor has thrown down the gauntlet to industry-leading companies such as US-based Lumileds. According to its president Jeong Hoon Lee, Seoul's HB-LEDs feature 150 lm brightness, which he claims is more than a 25% improvement on Lumileds' devices (Lumileds' Luxeon V product offers 120 lm from a solitary source).

Meanwhile, Photron makes HB-LED lamps emitting more than 10 cd. Featuring a wide viewing angle of more than 40°, the lamps have various applications, and shipments are destined for the US. By employing SMT packaging, the need for hole-taping and lead-cutting processes has been reduced, improving productivity.

Wafer Test

1000 nm

MOSFET SiO_2

100 nm

LED GaN ZnO MOCVD

10 nm

HEMT HBT SiC SiGe MQW MOVPE

1 nm

MOS High K Low K VCSEL GaAs HSB HP QDE



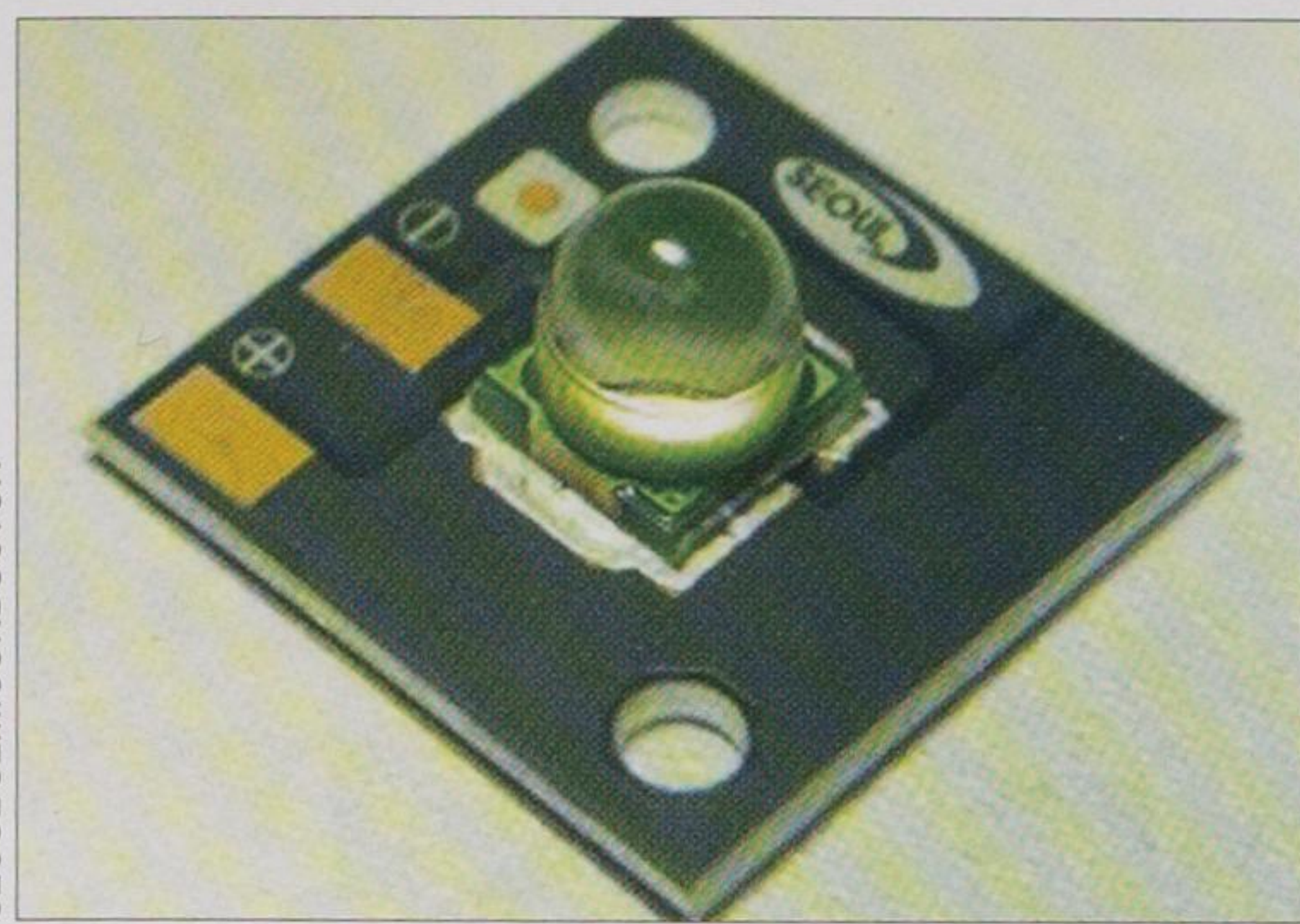
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The Alpha Power LED took less than a year to make, claim Seoul Semiconductor and TridonicAtco. TridonicAtco is a subsidiary of Austrian lighting firm Zumtobel AG, which is said to have sales of more than \$1.4 billion.

Illumination is one of the future applications markets targeted by Korean companies. EST, for example, is to widen its market share by replacing incandescent and fluorescent lamps with LEDs. The company is beefing up exports to the US. Plans are in the pipeline to set up an offshore factory in China late this year or early next year, according to the company.

While the falling prices of blue LEDs continue to shrink margins from mobile phone keypad backlights, companies are focusing more on applications of white HB-LEDs in the phone's LCD backlight unit and camera flash, as well as outdoor billboards and illuminations. Samsung Electro-Mechanics has already made a move into this technology and is shifting away from blue and seven-color LEDs.

At the same time, LG Innotek is doubling its production of white HB-LEDs to 100 million pieces a month – the same as Samsung Electro-Mechanics. LG Innotek's planning manager Y S Jeong noted: "While progressing toward highly reliable high-brightness LEDs, we are also cashing in on the development of high-brightness UV LEDs [at] two local R&D institutes."

From blue to white

As the applications market of mobile phones continues to grow domestically and abroad, some of the HB-LED manufacturers are switching into camera modules to penetrate the market further. Companies have already begun to diversify into flash and side-view white HB-LEDs, adopting flexible manufacturing to deliver customers' requirements.

Stiff competition for mobile phone HB-LEDs is also forcing Korean companies to diversify products and to focus on niche markets. Lasemtech's move to a new multicolor HB-LED package appears to have paid off,

and many other players are accepting small orders for diverse specifications.

Successful companies are striving to ramp up LED production to generate a stable supply. Lasemtech is now planning to move into mass production as it receives orders from Pantech & Curitel and Appeal Telecom (both Korea-based). Lasemtech president B W Yoon said: "We will expand the monthly production capacity from 9 million to 15 million multicolor LED packages in a few months."

Diversifying production

Other companies, such as SSI Semiconductor, are becoming specialist suppliers of all kinds of mobile handset parts and components, rather than simply concentrating on HB-LEDs. SSI has diversified its product range to include power amplifiers, LCD-driving ICs and CMOS camera modules.

At the cutting edge for both technology and price, Korean companies have also begun to target the local automotive market, which has been dominated by global players such as Osram, Agilent and Nichia. It is estimated that Korea's automotive HB-LED market will

reach \$726 million in the near future.

Samsung Electro-Mechanics is to launch white HB-LEDs for automotive dashboards during the second half of this year. Seoul Semiconductor also expects 2004 to mark the turning point for this market. Luxpia, meanwhile, is spurring the development of back-lighting LEDs for car navigation displays.

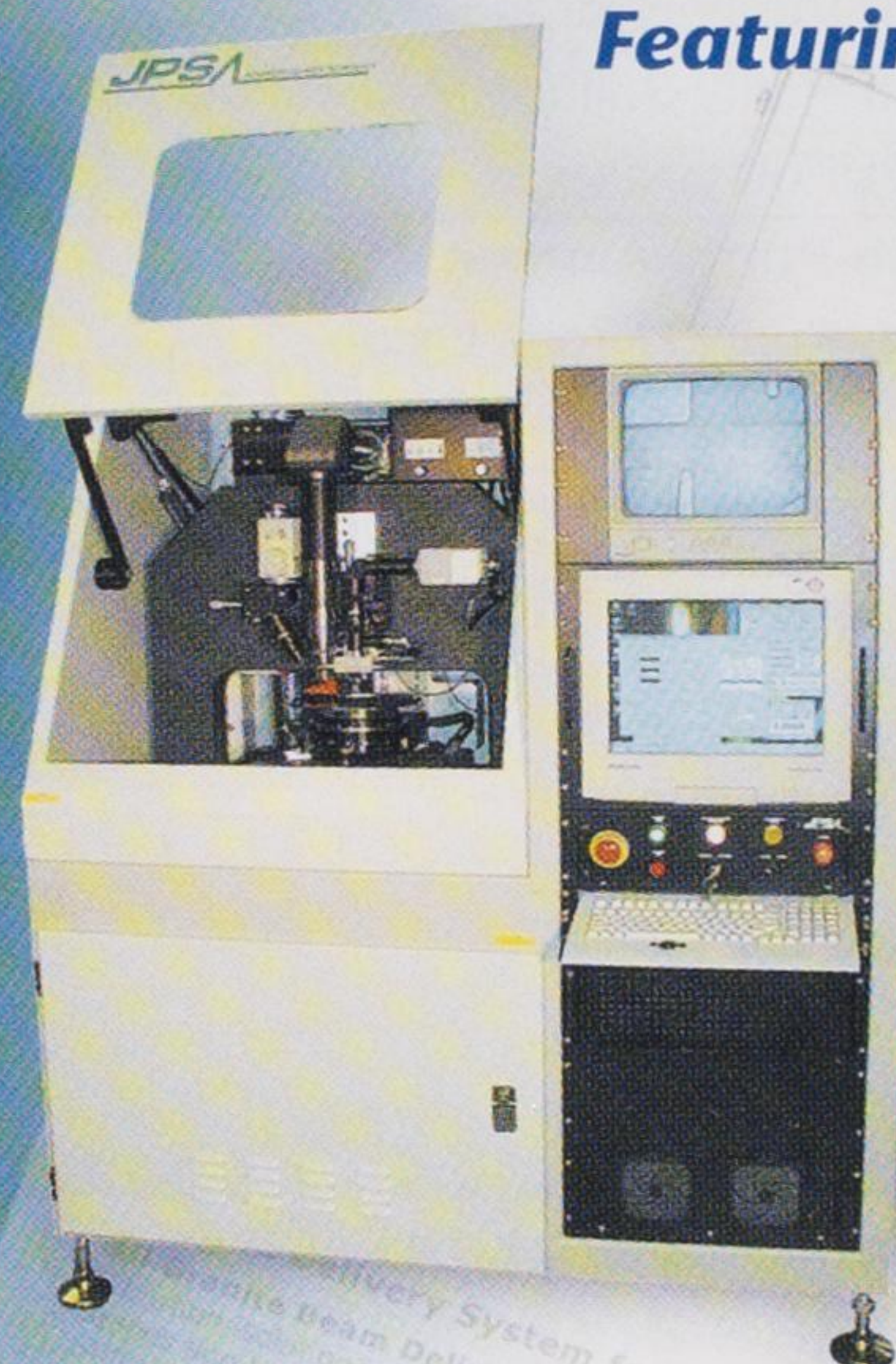
Chang Woo Engineering's Color Ring and Color Gen LED illumination systems feature remote-controlled LED lamp colors and a low power consumption of 5–7 W. A combination of LEDs and fiber-optic systems will be made available during the second half of this year.

Other Korean manufacturers are following suit. Luxpia has been focusing on white HB-LEDs since early this year. More than 70% of its 2004 sales are expected to come from its LCD backlight unit, which features RGB-based white HB-LED packages. Tripled production capacity, meanwhile, should boost this year's sales of backlight units based on white HB-LEDs at Lumimicron.

Hordon Kim is a freelance journalist based in Seoul, South Korea.

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	High-Purity HFC-32	CH ₂ F ₂
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	High-Purity FC-218	C ₃ F ₈
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Taiwanese companies ramp up MOCVD capacity

Increased demand for optical data storage applications and from Korean cell phone manufacturers wanting blue LEDs are the primary reasons behind a boom in III-V device manufacturing in Taiwan, as **Michael Hatcher** reports.

MOCVD systems are selling fast in Taiwan. In late March, for example, the LED manufacturer South Epitaxy, which was founded in 1999, ordered five new "GaNzilla" tools from equipment supplier Veeco. Even prior to this announcement, the number of commercial MOCVD machines installed in Taiwan had surged to 235 as demand for GaN-based LEDs increased.

It was only 11 years ago that the very first commercial MOCVD kit was installed in Taiwan, at the LED and HBT maker United Epitaxy Company (UEC). Since then, around 20 new companies that use the epitaxial growth equipment have emerged. And although LED manufacture is the mainstay of the local compound semiconductor industry, a number of Taiwanese companies are involved in making other devices (see table). Nine companies in the region make laser diodes, while seven manufacture HBTs, according to Taiwan's Industrial Technology Research Institute (ITRI). One company, Procomp, has an MBE machine as well as MOCVD capacity, giving it additional expertise in PHEMT manufacture on top of its capability in LEDs, laser diodes and HBTs. Another company, XPert Semiconductor, is offering 3–6 inch epiwafer foundry services exploiting its MBE expertise. Company president Pin Ho says that XPert is the only Taiwanese epi foundry operation boasting its own intellectual property, with others relying on "technology transfer" from Japan.

The overall Taiwanese optoelectronics industry is dominated by the displays busi-

Major compound semiconductor device manufacturers in Taiwan

Company	Device type made					
	LED	Laser diode	HBT	PHEMT	Photodiode	PIN
UEC	•		•			
High Light	•					
Union Optronics	•	•			•	
Epistar	•					
VPEC	•	•	•			
OIC		•				
Procomp	•	•	•	•		
Landmark		•			•	
Huga	•					
Unilight	•					
Kingmax	•	•	•			
Arima	•	•				
AET	•					
Forepi	•					
Tekcore	•	•	•			
South Epitaxy	•					
Highlink	•					
Epitech	•		•			
Nan Ya Plastics	•					
Kopin Taiwan	•		•			
Ledex	•					
Gigacomm		•				•

SOURCE: ITRI

ness, with this market accounting for more than 40% of revenue. By 2005, further dominance is expected. Within the III-V sector, LEDs made up 60% of the \$100 million revenue generated by MOCVD activity in 2002. Since then, manufacturing has ramped up, and the latest figures from Strategies Unlimited estimate the Taiwanese HB-LED industry to be worth a monthly revenue in excess of \$30 million. This equates to a monthly manufacturing capacity of 1.1 billion InGaAlP chips (equivalent to 110,000 2 inch epiwafers), and around 520 million GaN chips (72,000 2 inch epiwafers).

Despite the emergence of high-volume production in mainland China, Taiwan remains by far the biggest manufacturing center in non-Japan Asia. Strategies Unlimited's report suggests that 87% of InGaAlP epitaxial wafers made in non-Japan Asia were fabricated in

Taiwan last year, with China accounting for 10% and Korea 3%.

The region's GaN wafer production in 2003 was more balanced, with 73% produced in Taiwan and 16% in Korea, where there is more demand for blue keypad backlights from phone manufacturers Samsung and LG. About 11% of GaN wafers were produced in China. This year is expected to show continued expansion, with a doubling of GaN wafer and chip capacity predicted in Taiwan.

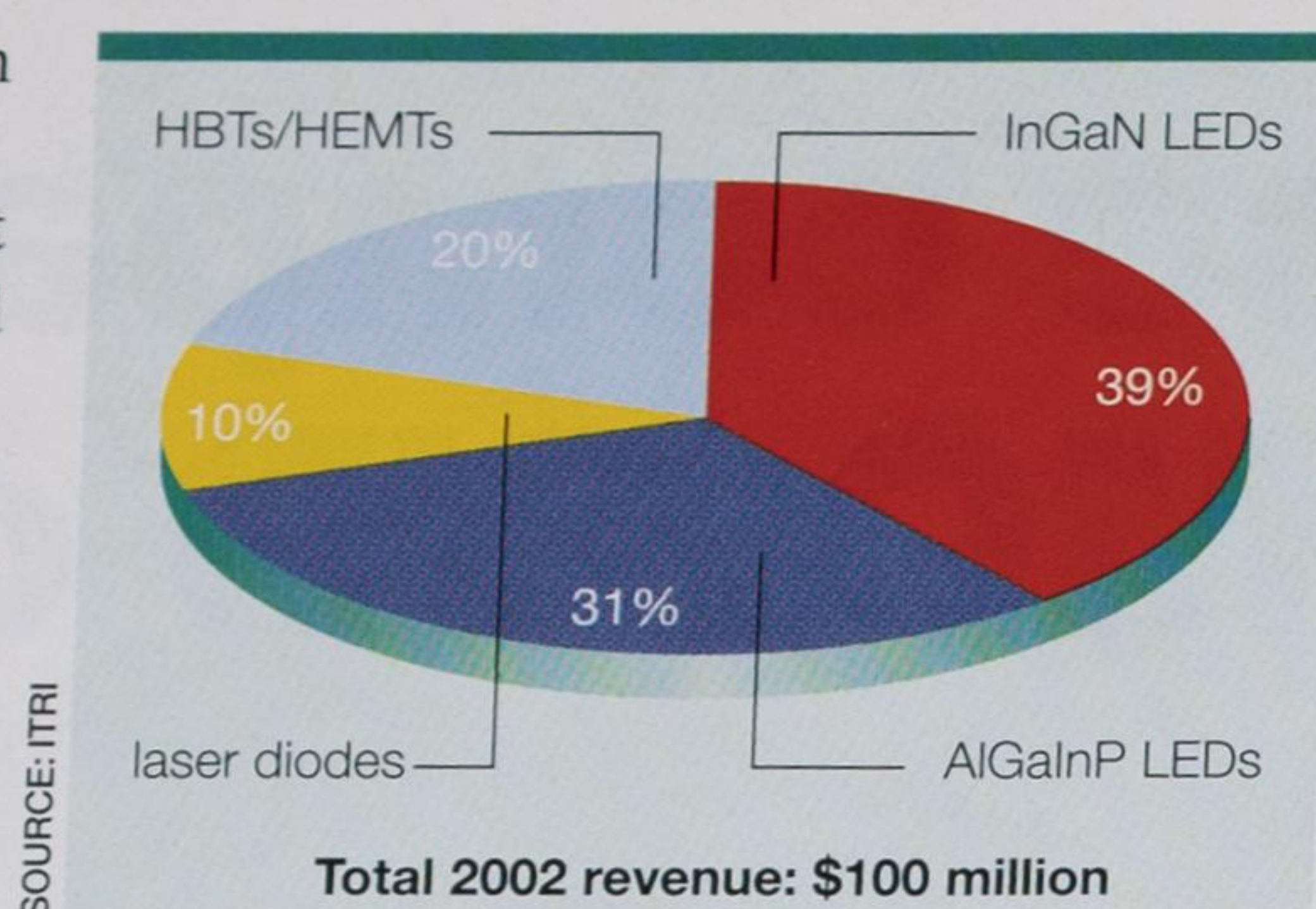
With demand for blue LEDs continuing its upward spiral, both Epistar and Forepi are increasing their manufacturing capacity. According to a report in the *Nihon Shimbun Keizai* business newspaper, Epistar is set to double its monthly production capacity to 120 million chips, and plans to install six more MOCVD machines this year. Meanwhile, Formosa Epitaxy (Forepi) is expected to

TAIWAN

increase production by 50% to 60 million chips per month.

Given its LED output, it is no surprise that Taiwan is investing heavily in a research and development consortium of 11 companies, focusing on next-generation lighting. In the first phase of this project, in 2003, NT\$10 million (\$0.3 million) was invested in the technology. This was increased to NT\$383 million for the second stage of the project, which runs until 2005. Epistar and Forepi are involved with the consortium in both epitaxy and device fabrication. Companies including Everlight, Kingbright and Lite-On are involved on the packaging and module side, while Opto Tech is focusing on lamp design and applications. The goal is to achieve 50 lm/W output products and 100 lm/W in the laboratory.

While Taiwanese companies are not normally thought of as leaders in terms of technological development, this also appears to have changed in the HB-LED segment. The results of a recent research project that was 20% funded by VPEC have led to 14 patents and 20 new manufacturing processes in the field of highly efficient LEDs, including some



InGaN-based LEDs are making up an increasing share of Taiwan's III-V industry revenue, thanks primarily to demand for cell phone backlights.

US patents. According to some of those involved in the project, this means that Taiwanese companies will now be able to compete with leading-edge companies such as Lumileds and Osram. Innovations include novel wafer-bonding techniques, flip-chip technology and new phosphors. For example, a wafer-bonding technique developed by Horng Ray-Hua and colleagues at the National Chung Hsing University that solves

thermal problems associated with AlInGaP LEDs is said to have been adopted by Osram.

Outside of the LED business, the ITRI is also heavily involved in dictating the next generations of optical data storage applications, being a member of the DVD Forum steering committee along with industrial heavyweights such as Matsushita, Sony, IBM and Intel.

Intellectual property issues are often part of the picture where Taiwanese companies are involved, and this is one issue that remains unchanged. Ongoing disputes involve Nichia, which has actions against Everlight (which has licensed Osram technology) and Epistar. The Japanese company has recently been at pains to stress that it will protect its intellectual property, with particular emphasis on Korean and Taiwanese manufacturers. "Any license granted under Osram patents does not necessarily mean license under Nichia patents," said the company.

If Taiwanese companies can avoid legal disputes with the likes of Nichia and continue to innovate, the region's compound semiconductor manufacturing industry will surely go from strength to strength.

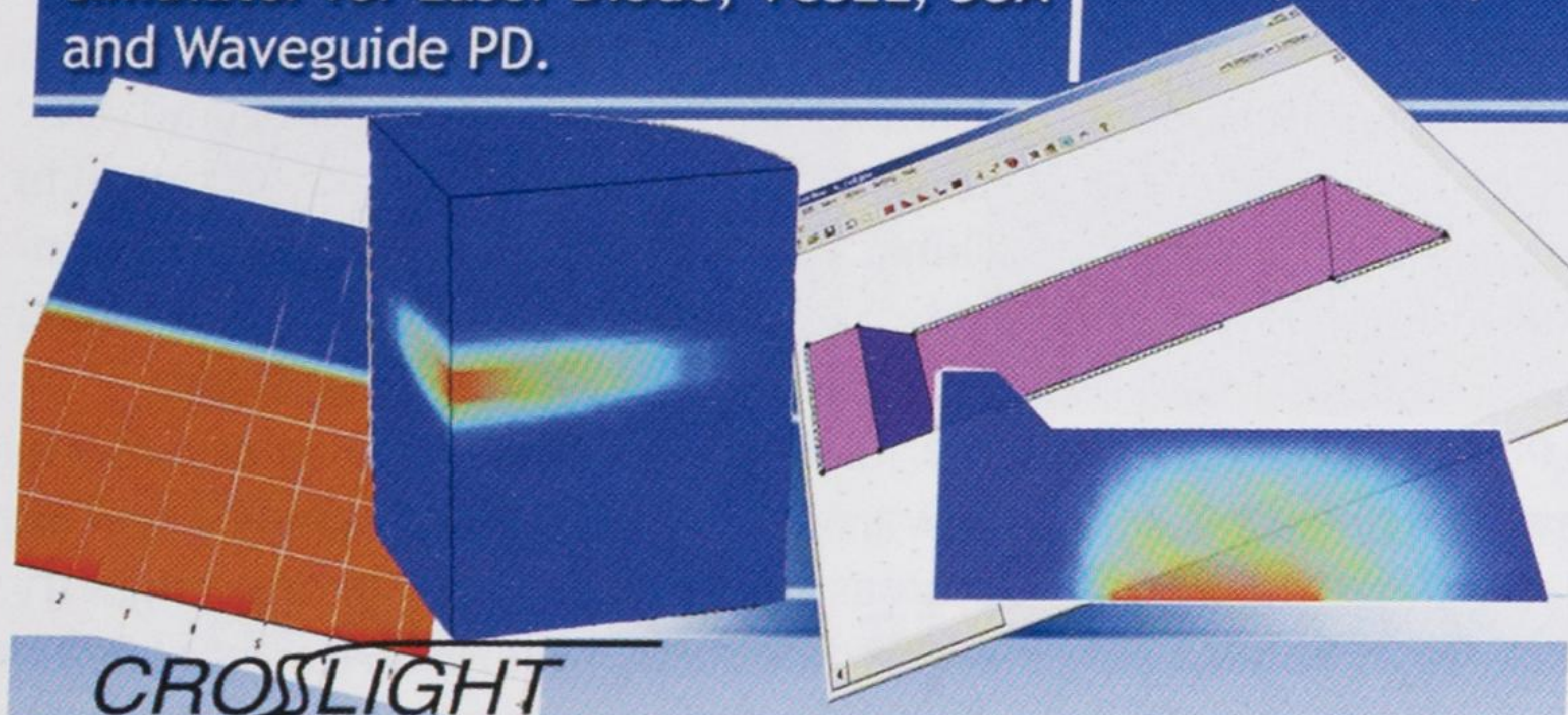
2/3D DEVICE/PROCESS SIMULATION SOFTWARE FOR COMPOUND SEMICONDUCTOR DEVICES

PROCOM: MOCVD reactor simulation software for binary/ternary/quaternary compounds

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Samsung and Toyoda Gosei unveil progress in violet lasers

As more companies develop commercially viable violet laser diodes, and both LEDs and lasers move into the UV, many improvements continue to be made at the device level, writes **Max Shatalov**.

The 5th International Symposium on Blue Laser and Light Emitting Diodes (ISBLLED-5) was held in Gyeongju, Korea, on March 15–19, 2004. A total of 242 papers, including 22 invited talks, were presented by participants from 19 different countries. The talks described ongoing research and development efforts in UV, blue and white LEDs, as well as in violet laser diodes. In the latter area, several companies demonstrated that their devices are almost ready for commercial production.

A number of major trends could be identified at the symposium: for high-power blue LEDs, participants spoke about the development of reflecting contacts, substrate removal by laser lift-off (LLO), and backside surface texturing. Other important topics included the development of GaN-free structures for high-power near-UV LEDs, and the key issue for deep-UV LEDs of reducing threading dislocation density (TDD) by lateral epitaxial overgrowth (LEO).

Developers of 405 nm laser diodes speaking at the conference were concerned with areas such as ridge geometry optimization and reliability. There is also a trend towards reducing threshold currents via lower TDD values, using the LEO technique or bulk GaN substrates.

Samsung targets Blu-ray

According to O Nam of the Samsung Advanced Institute of Technology in Korea, Samsung plans to supply 405 nm laser diodes for Blu-ray optical data storage systems by the end of 2004. For such consumer products, reliability issues are naturally of great concern. Laser diodes grown on LEO GaN (with a minimum TDD of $1\text{--}2 \times 10^6 \text{ cm}^{-2}$) had a threshold current (I_{th}) of 33.4 mA, a threshold voltage (V_{th}) of 4.25 V, and a slope efficiency of 1.53 W/A. The relative intensity noise (RIN) was less than -130 dB/Hz at 2 mW. The projected operational lifetime was 10,000 h at 30 mW output (53 mA, 4.67 V) and 235 h at



Fig. 1. Sensor Electronic Technology's UVTOP-340 LED is the first commercially available UV LED with peak emission at 340 nm, and is designed for biological and chemical sensor applications.

60 mW (84 mA). The Samsung team has also demonstrated a maximum CW power of 300 mW at 280 mA.

Laser diodes grown on bulk GaN substrates (with TDD of $7 \times 10^6 \text{ cm}^{-2}$) showed similar threshold characteristics ($I_{th} = 30.7 \text{ mA}$, $V_{th} = 4.22 \text{ V}$) but a lower slope efficiency of 0.85 W/A. Only 1000 h lifetime was estimated for 30 mW operation (64 mA, 4.88 V). According to the Samsung work, reliability is determined by magnesium diffusion under bias from p-type layers into the active region through the threading dislocations. This was confirmed by the comparison of reliability testing of laser diodes with different TDD values, followed by SIMS analysis. Samples with a lower TDD showed less magnesium diffusion and longer operating lifetime. Also, it was shown that epi-down bonding needs to be used for better thermal dissipation.

Violet lasers at Toyoda Gosei

Already a leading supplier of GaN-based LEDs, Toyoda Gosei of Japan is also developing 405 nm laser diodes for next-generation optical data storage. H Watanabe presented recent results for devices grown on both LEO GaN templates and bulk GaN substrates. Single-mode operation with an output

power of 30 mW at 65 mA was demonstrated for a device grown on a LEO GaN template with a TDD of about $2\text{--}20 \times 10^6 \text{ cm}^{-2}$. I_{th} was 36 mA and the slope efficiency was 1 W/A for ridge waveguide lasers with a width of 1.5–2 mm and length of 500–600 mm. RIN measured less than -130 dB/Hz at 2.5 mW.

Pulsed, single-mode operation at 150 mW was also demonstrated at 170 mA. Laser diodes grown on bulk GaN substrates, with a TDD of less than $5 \times 10^6 \text{ cm}^{-2}$, had an output power of 30 mW at 51 mA with a threshold current of 31 mA and 1.5 W/A slope efficiency. Under pulsed conditions, the devices had a projected operational lifetime of more than 7000 h at 60 mW.

Sharp uses MBE growth

Recently, a team at the UK-based Sharp Laboratories of Europe (SLE) became the first group to successfully demonstrate GaN laser diodes grown by MBE (*Compound Semiconductor* January/February 2004 p5). According to SLE's Jon Heffernan, the advantages of MBE growth for III-N lasers include the use of *in situ* monitoring techniques such as reflective high-energy electron diffraction and a significant reduction in ammonia flow. There is also no need for a post-growth anneal stage to activate the p-type dopant. Laser diodes with a 5 μm wide ridge and 500–1500 μm long cavities emitted at 395–405 nm with a threshold current of about 1.1 A (22 kA/cm^2 , 34 V) under pulsed operation.

ZnSe-based white LEDs

While most of the industry is firmly focused on GaN-based devices, Japan-based Sumitomo Electric (now part of Eudyna Devices) has been at the forefront of the development of ZnSe-based white LEDs, which operate without the need for a phosphor for down-conversion. T Nakamura presented recent results on reliability improvements of ZnSe-based LEDs. White emission with very stable



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color co-ordinates can be obtained by combining the blue emission at 485 nm due to band-to-band transitions and yellow emission due to deep level states. However, poor reliability due to electron overflow into p-regions is a known problem. By incorporation of an i-ZnMgBeSe/p-ZnMgSSe double cladding structure with a p-ZnMgSSe hole injector layer and suppression of the electron overflow, the operating lifetime (at 25 °C) was increased from 3000 to 10,000 h (figure 2). For 5 mm LEDs, lamp power of 8.1 mW was demonstrated at 20 mA and 2.5 V, corresponding to an external quantum efficiency (EQE) of 16.9%.

UV LEDs and lasers

Yu Bilenko of the US-based company Sensor Electronic Technology presented details of the first commercially available UV LED with peak emission at 340 nm, which has been developed for biological and chemical sensor applications. The UVTOP-340 LED is hermetically flip-chip packaged into a metal-glass TO-39 header with a UV-transparent window (figure 1). It has an output power of

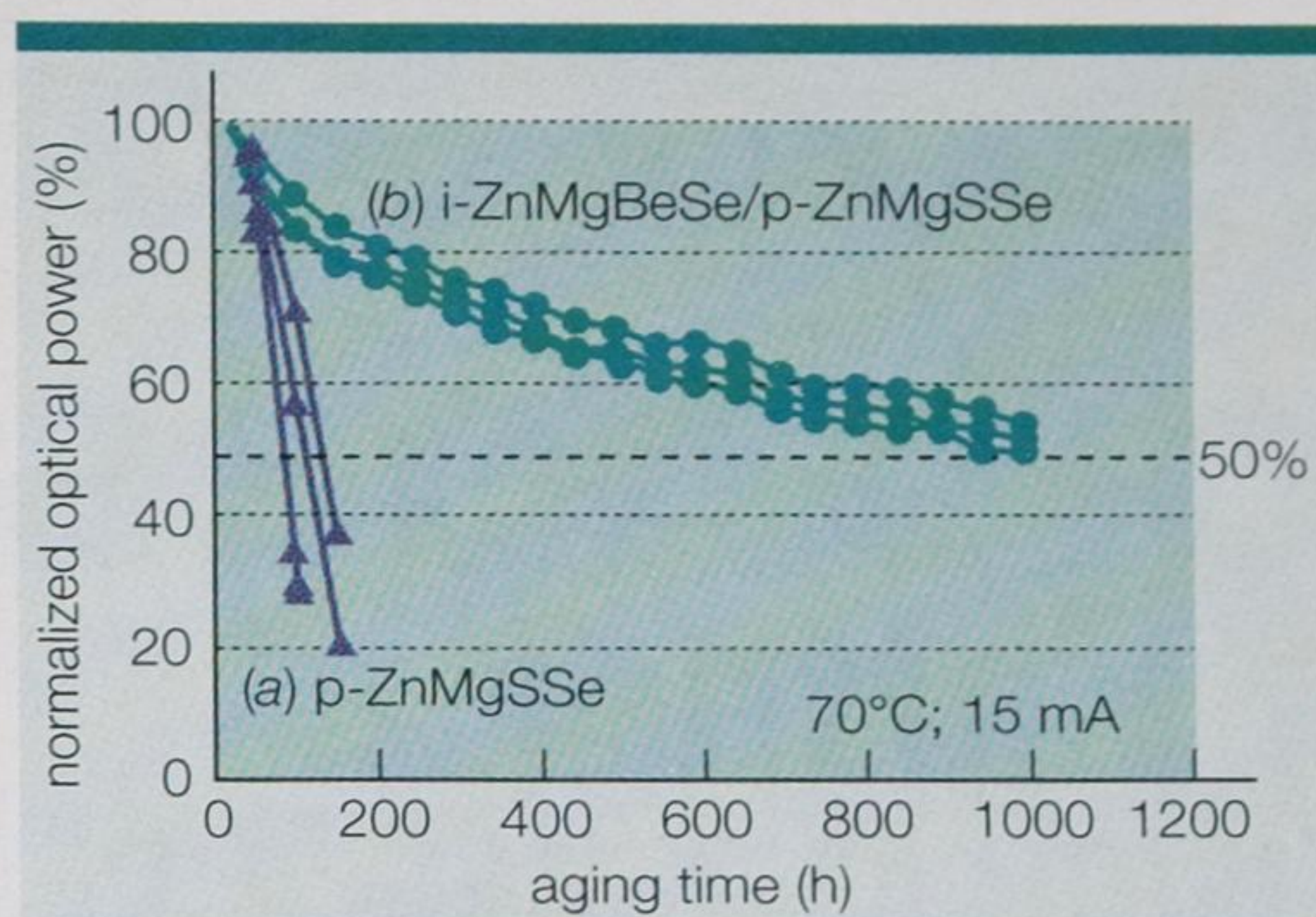


Fig. 2. Reliability behavior at 70°C and 14.3 kA/cm² of (a) a standard ZnMgSSe (E_g = 2.95 eV; thickness, d = 500 nm) structure and (b) LEDs with the i-ZnMgBeSe (3.1 eV, 20 nm)/p-ZnMgSSe (2.9 eV, 500 nm) double heterostructure.

up to 1 mW at 100 mA, with a projected operating lifetime of 2000 h. Bilenko also presented results of a joint project with the University of South Carolina, US, which has achieved sub-milliwatt and milliwatt operation of UV LEDs in the 250–340 nm range (*Compound Semiconductor* May 2004 p20).

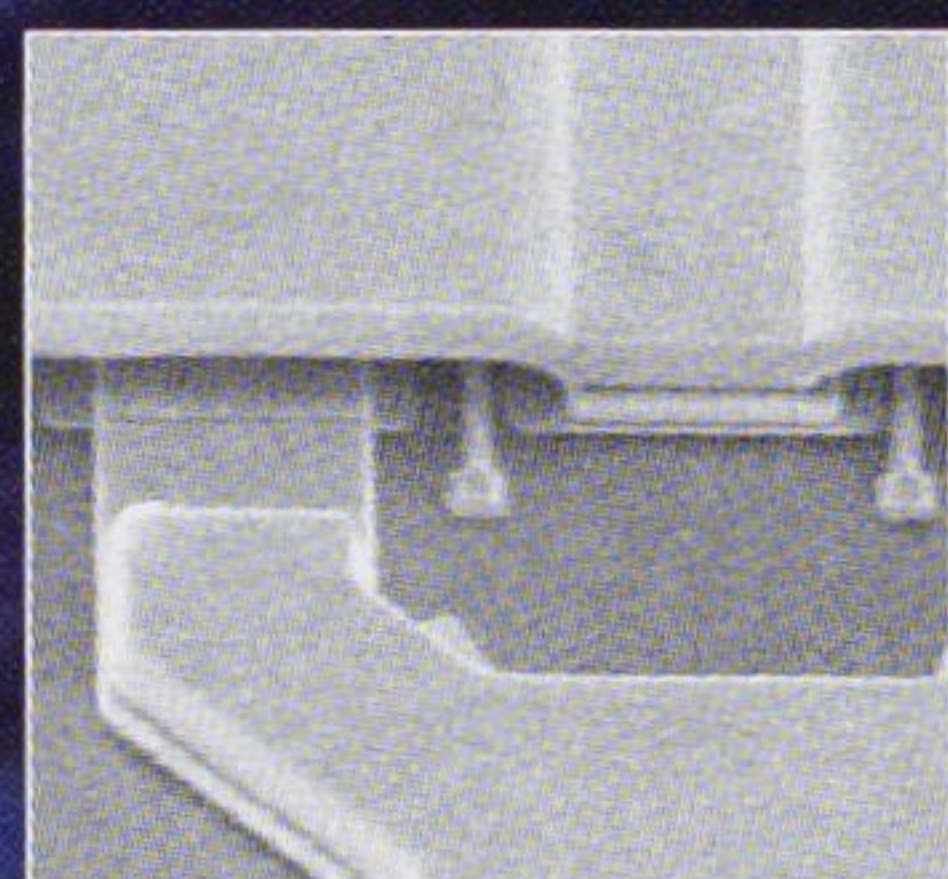
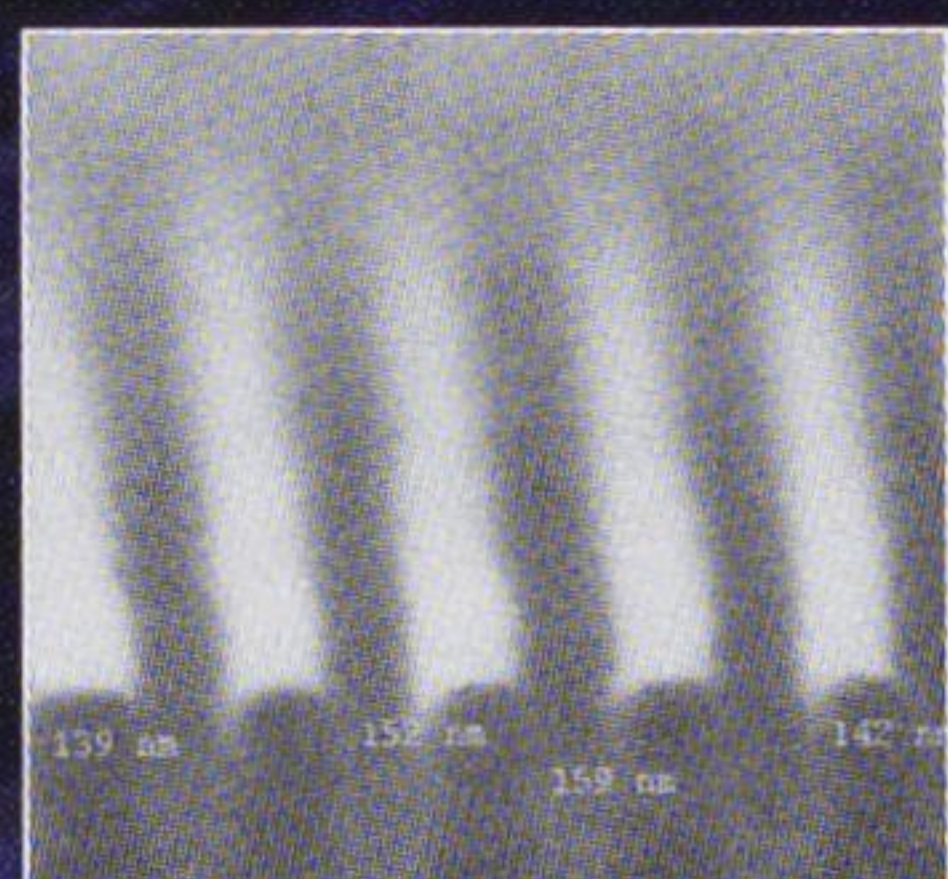
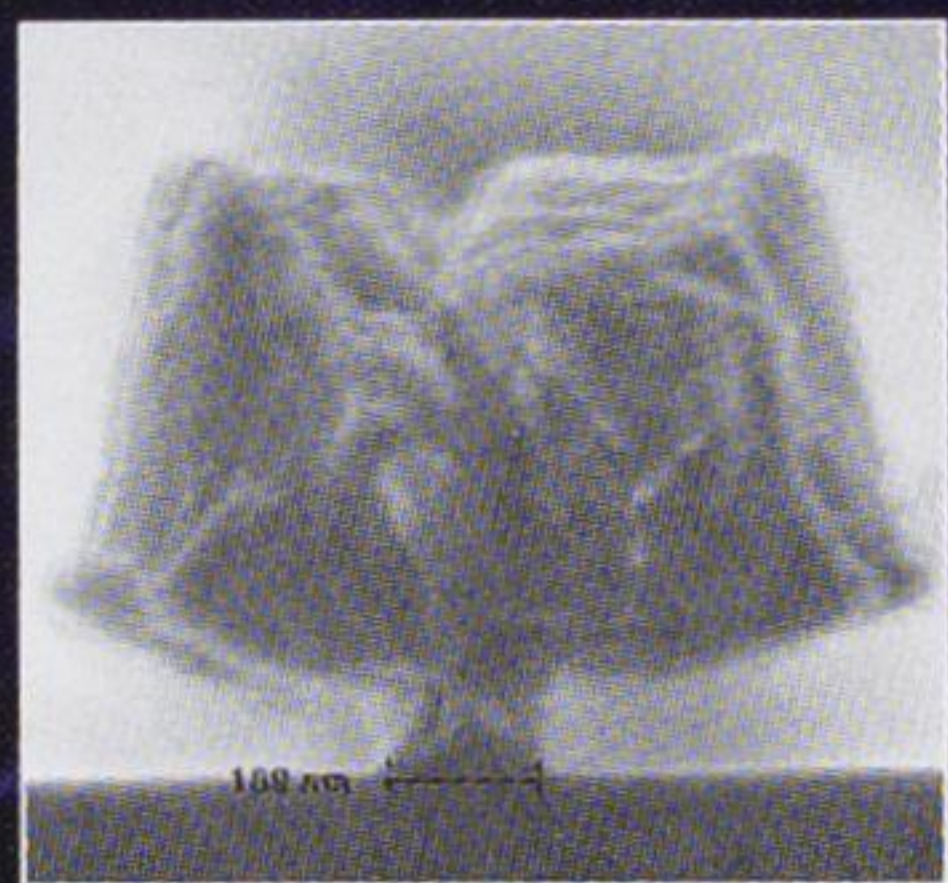
Meanwhile, Nichia's S Nagahama dis-

cussed advances in the development of UV LEDs with emission at 365 nm, which replicate the I-line of Hg-lamps. To achieve high LED output power several key issues were addressed: absorption in the LED structure; LLO of the sapphire substrate and backside surface texturing for enhanced light extraction; and reflecting contact schemes. After optimization, Nichia's UV LEDs exhibited an EQE of 21% under CW operation with an output power of 360 mW (500 mA, 5.0 V) and 24% EQE under pulsed operation at 410 mW (500 mA, 5.3 V).

Nagahama also described improvements in Nichia's UV laser diodes. The TDD in the laser structures has been reduced to 4×10^7 cm⁻² using LEO. Devices operating at 365 nm had a lifetime of 2000 h at 3 mW, with a 25 °C case temperature. The laser threshold current density at 50 mA was 3.6 kA/cm², with a threshold voltage of 4.8 V. Shorter-wavelength devices operating at 354.6 nm had a threshold current density of 14.3 kA/cm².

Max Shatalov is at the University of South Carolina. E-mail: shatalov@engr.sc.edu.

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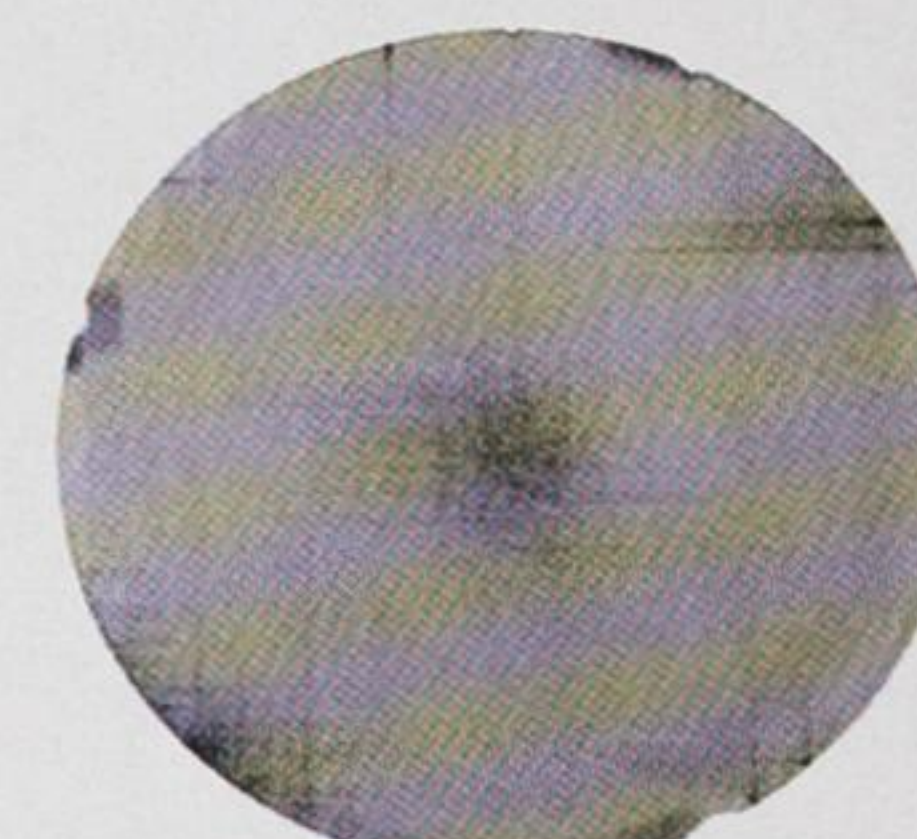
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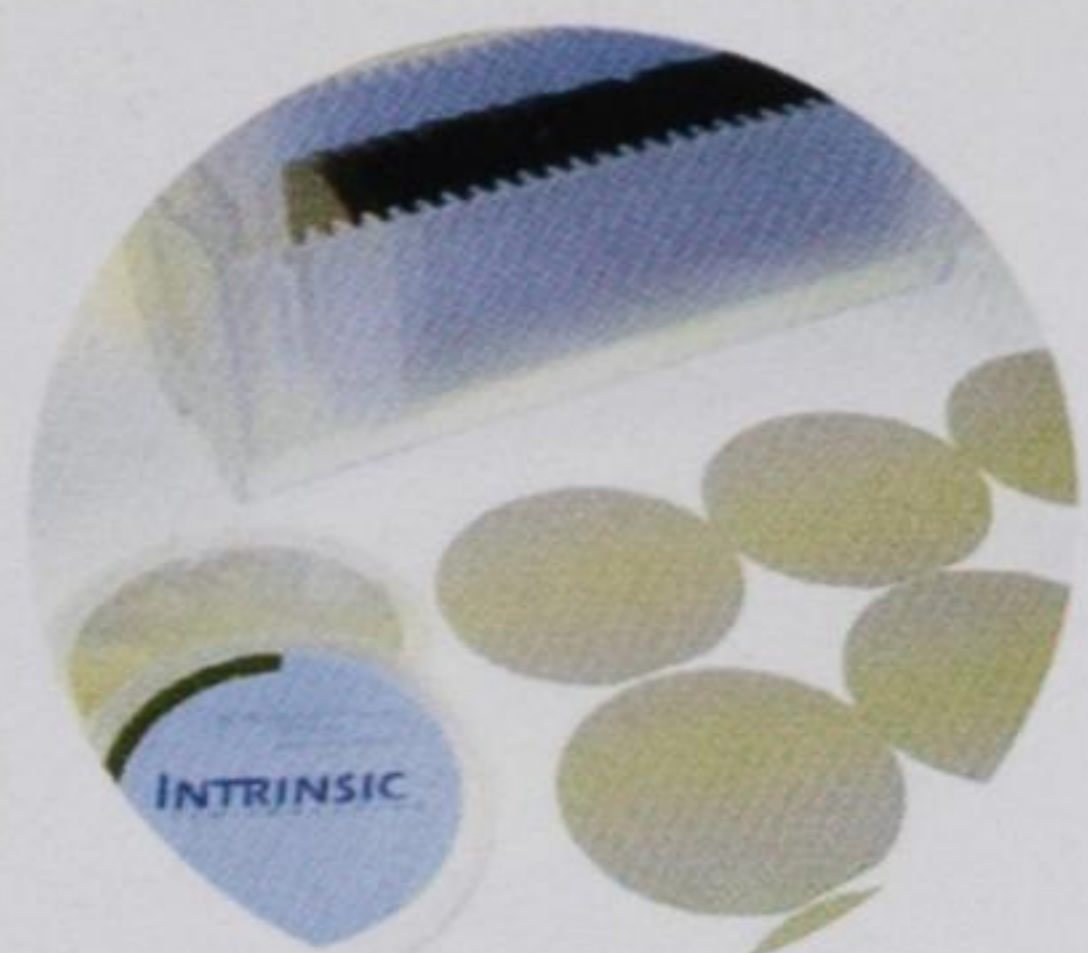
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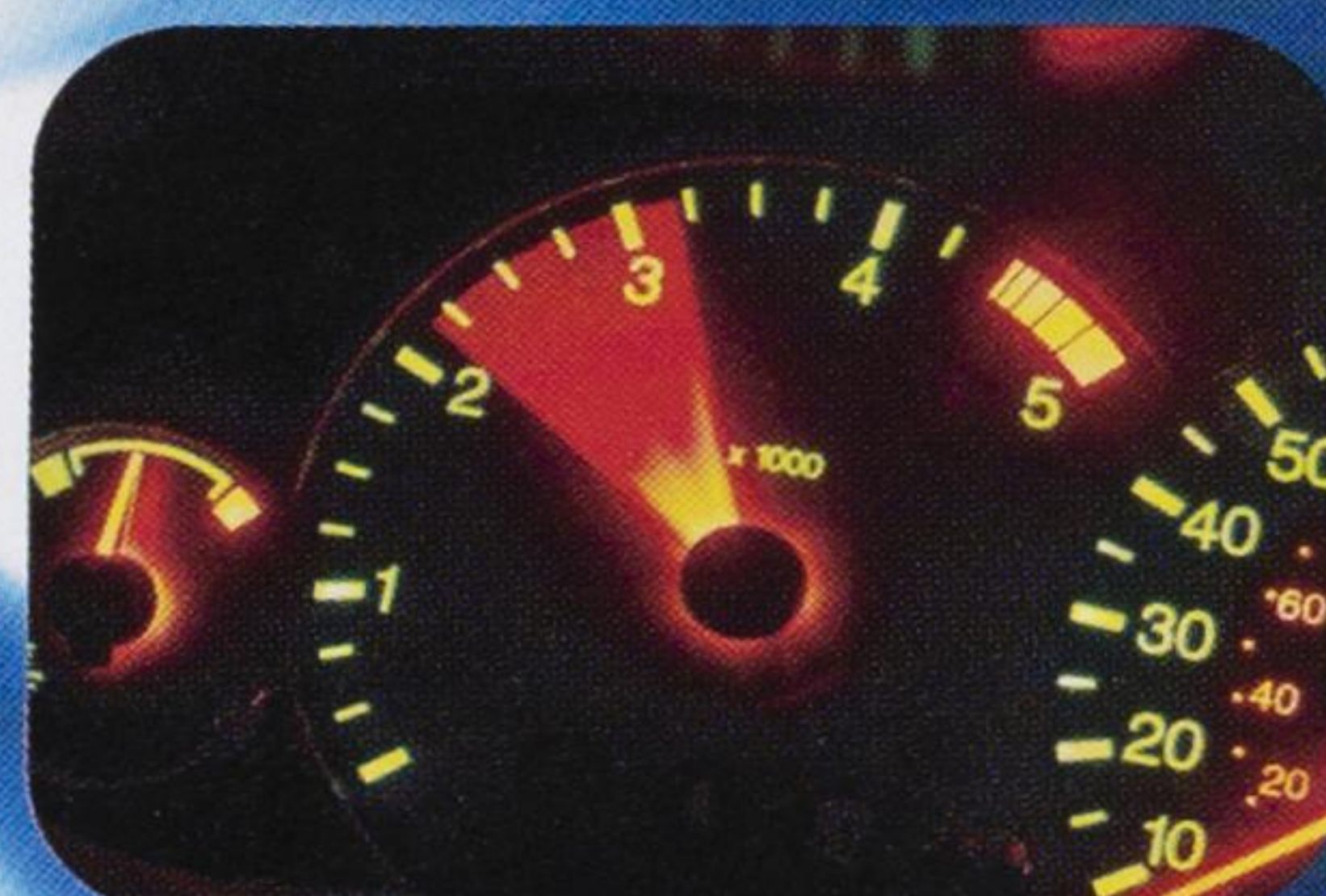
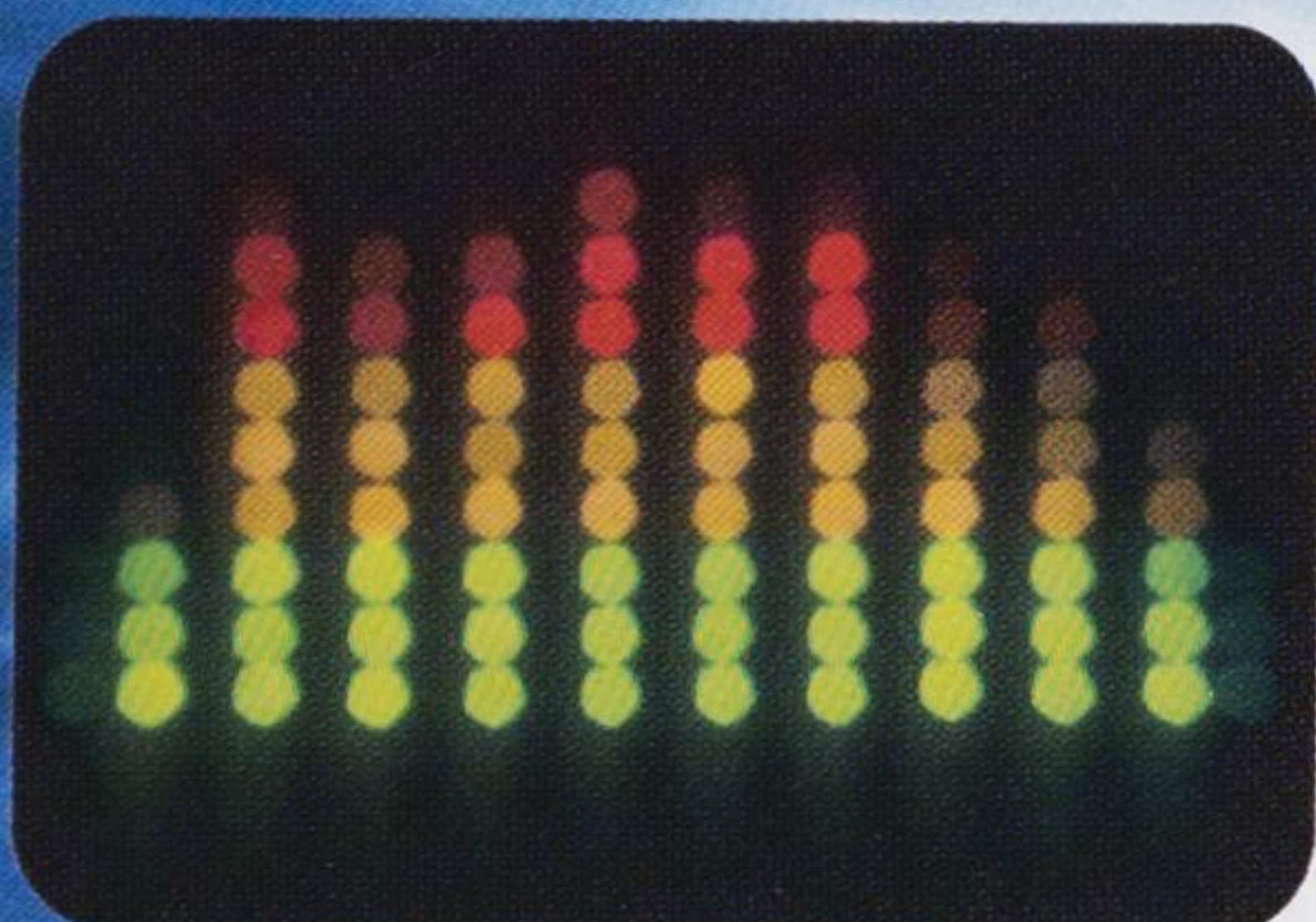
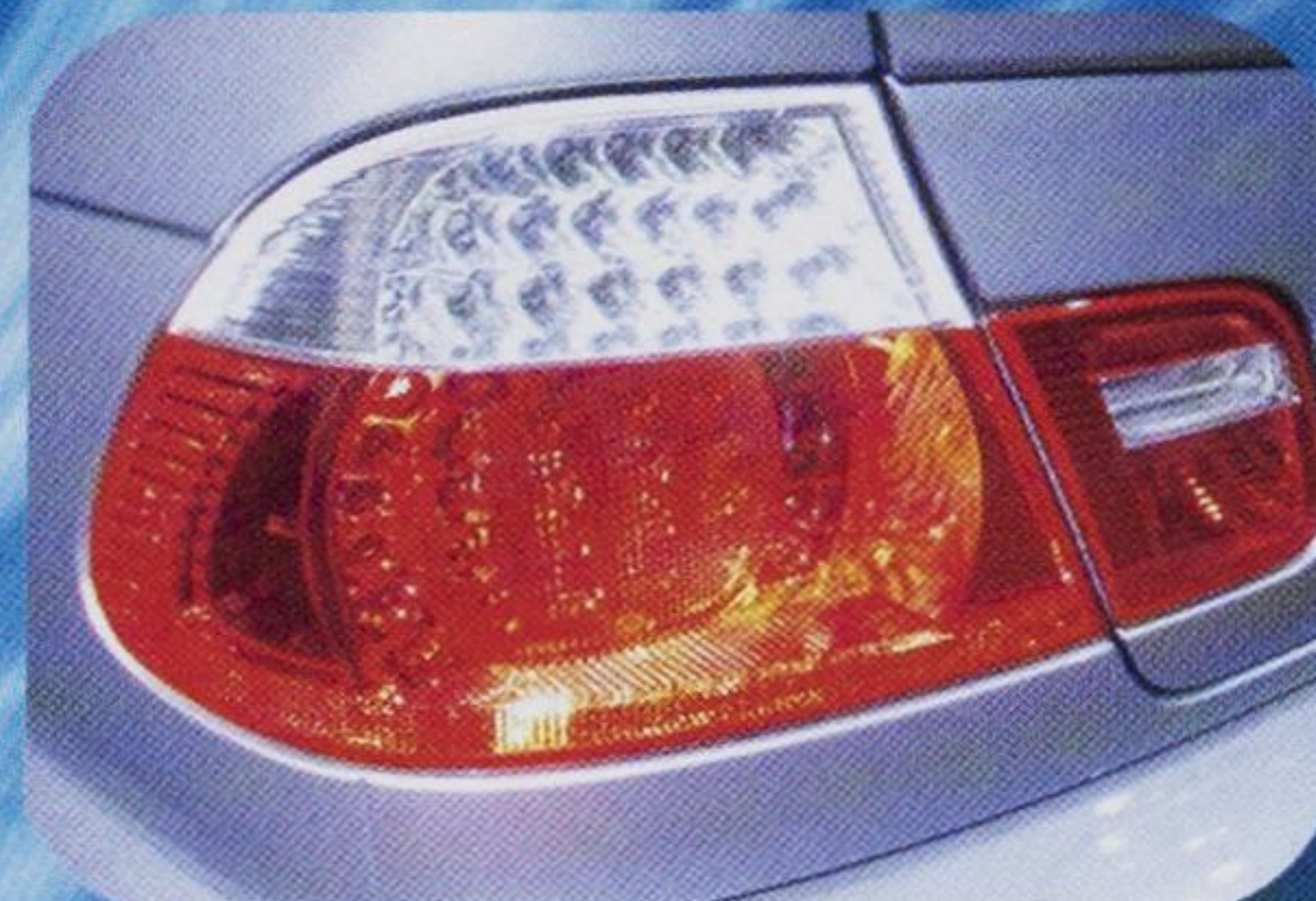
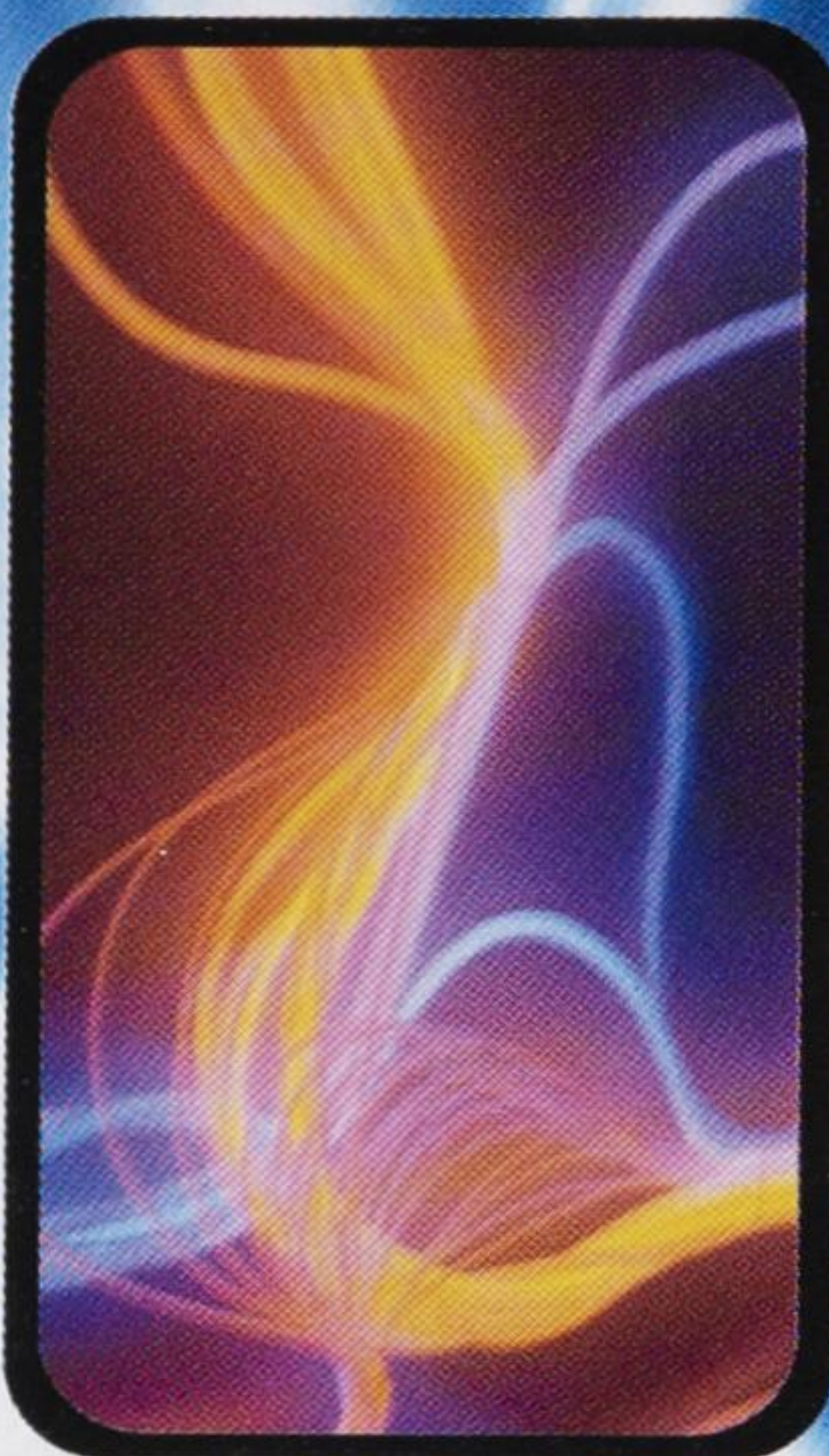
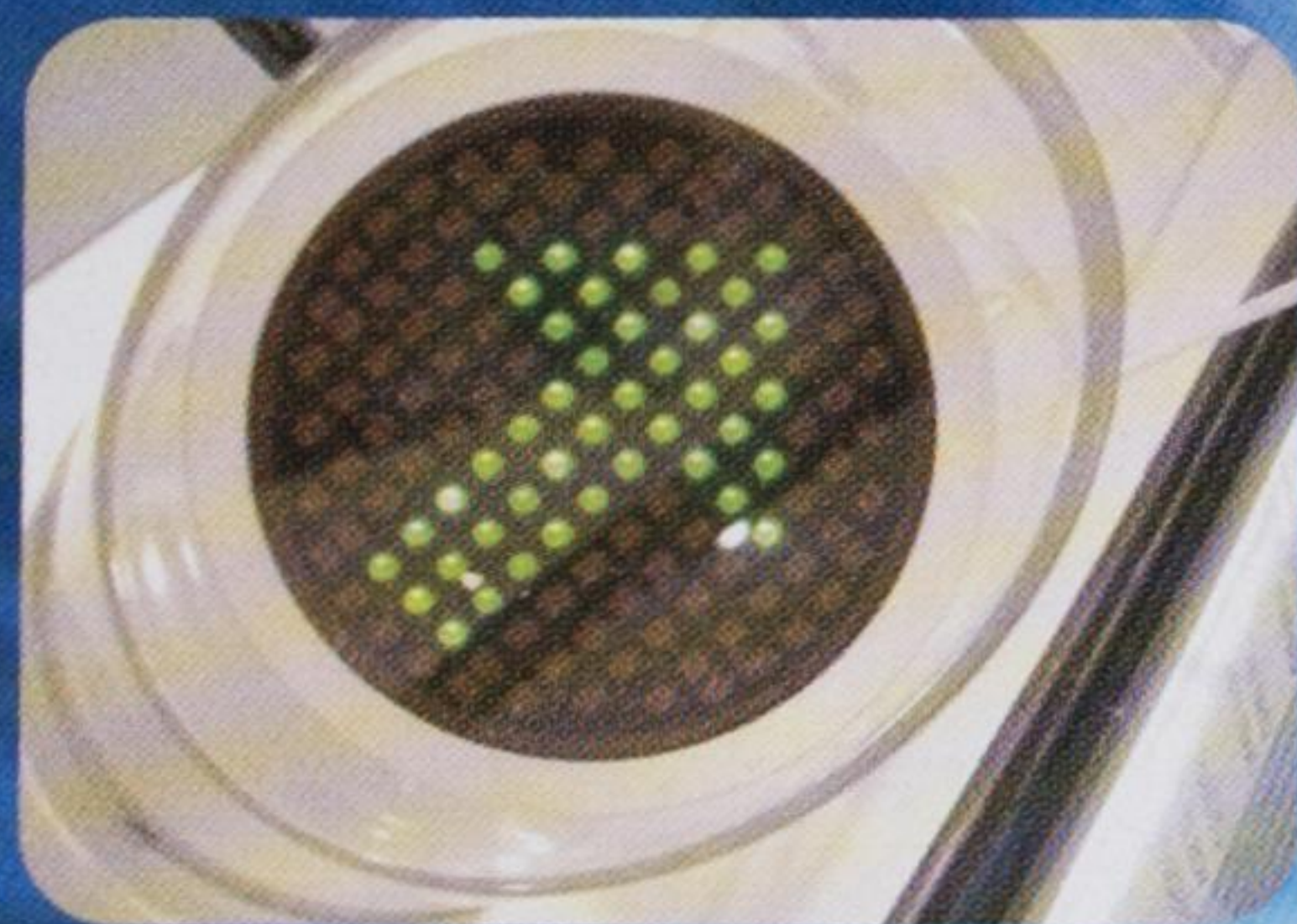
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Waveguide integration boosts laser diode yield

With many optoelectronics manufacturers set up during the telecom boom now looking to target industrial and military applications of lasers, **John Marsh** describes a technique that improves the manufacturing yield of high-power diode laser arrays.

The advantages of monolithic integration of semiconductor optoelectronic components include high yields, high performance and new functionality. Over the past 25 years, the main research driver for such integration has come from the telecom sector, but significant deployment is now taking place in other market sectors. These sectors range from high-volume industrial markets to lower-volume avionics and defense markets, with specific applications in printing systems, microwave photonic systems and optical signal processing. There is considerable crossover from telecom requirements into these other market sectors.

In the industrial market, there are strong commercial drivers for integrating high-power single-mode lasers into multi-element laser arrays. In many industrial systems, light from individually packaged lasers is coupled (usually by fiber) into an optical head (figure 1). In the assembly process, semiconductor lasers are cleaved and packaged individually, and then precision alignment of optical fibers is required in both the package and the head. However, if the lasers are integrated into a linear array, the output of the array can be used directly and the module effectively becomes the optical head. In this approach only one package is required, thereby reducing form-factor and cost and eliminating fiber pigtail-ing. Furthermore, the pitch of the emitters is fixed by lithography, rather than by mechanical fiber placement.

Manufacturing yields

For laser arrays to be viable, the manufacturing process must have a high yield, and every element must perform within a tight electrical and optical tolerance. Although fiber coupling has been eliminated, the specification on beam quality may be at least as demanding as that required for coupling to single-mode fiber. Meeting these require-

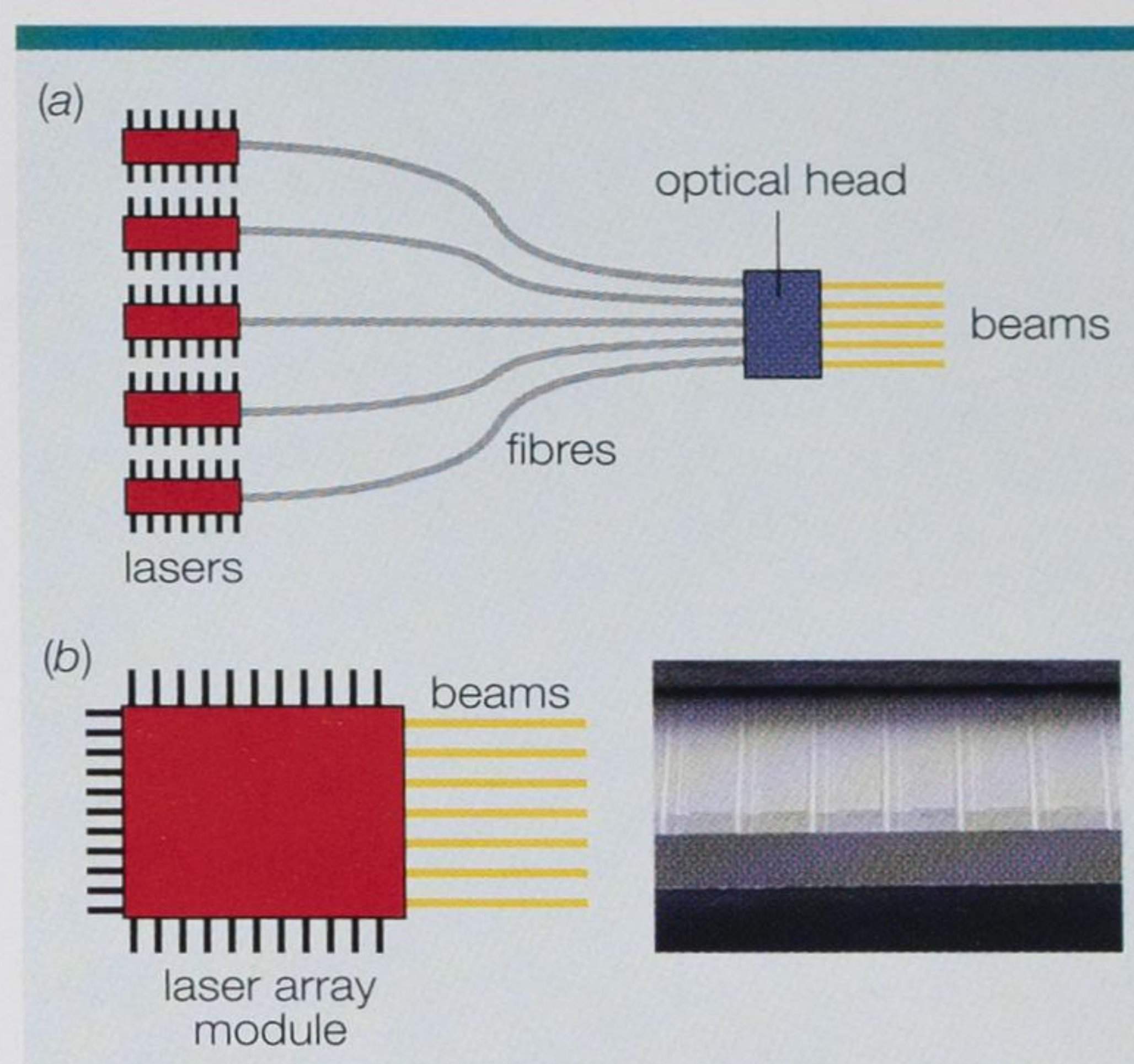


Fig. 1. Laser optical system (a) assembled using discrete lasers that are fiber-coupled into an "optical head" and (b) replacement with a single multi-element laser array. Inset: SEM of an array of individually addressable 980 nm lasers.

ments is a major challenge, as the application might require several hundred milliwatts of power in a single transverse mode from each element. The overall performance is similar to that of a state-of-the-art single 980 nm erbium-doped fiber amplifier pump laser of only a few years ago, and because the wavelength range of particular interest is 650–1000 nm, the array faces the same reliability and yield issues as 980 nm pump lasers. However, the challenge is magnified by the fact that there may be up to 100 elements in the array. In addition, the arrays demand more real estate than single devices, reinforcing the criticality of the yield figure.

Laser arrays are a good example of parallel optoelectronic integration, in that many identical elements are placed side by side. However, serial integration at the chip level is critical in meeting the performance and cost requirements. The inclusion of passive waveguides adjacent to the facets of the laser

cavities leads to good electro-optical performance, and also relaxes mechanical tolerances. These passive waveguides improve the yield in three different ways: the catastrophic optical damage (COD) threshold is raised, while the cleaving tolerance is relaxed, as is the packaging alignment tolerance.

Electro-optic performance

COD is the main failure mode of high-power semiconductor lasers operating in the 650–1000 nm wavelength range. Incorporating passive waveguides in the facet regions to form "non-absorbing mirrors" (NAMs) or "window lasers" is an established technique for raising the COD threshold. The use of NAMs leads to a direct increase in the COD threshold. The transparent passive waveguides in the facet region reduce the absorption of light at the facet, preventing the runaway process responsible for COD. Quantum well intermixing (QWI) is the most common technique for fabricating the passive waveguides (*Compound Semiconductor* September 2001 p63). In one QWI approach, point defects are created during sputter deposition of SiO₂. For simple uncoated devices, NAM lasers have a greater COD level than a standard laser by a factor of 2.6.

The passive waveguides also relax the cleaving and packaging tolerances. The facets of semiconductor lasers are formed by breaking the semiconductor crystal along a cleavage plane. This gives an extremely flat mirror, but the typical precision to which cleaving can be carried out is around $\pm 5 \mu\text{m}$. For conventional lasers, the cleave must be located less than 10 μm from the end of the gain contact, but in a laser with low-loss passive waveguides the cleaving position only needs to fall somewhere within the passive region. Angular variations in the cleaving direction have an even larger impact, especially for arrays. Using normal photolithography, the tolerance

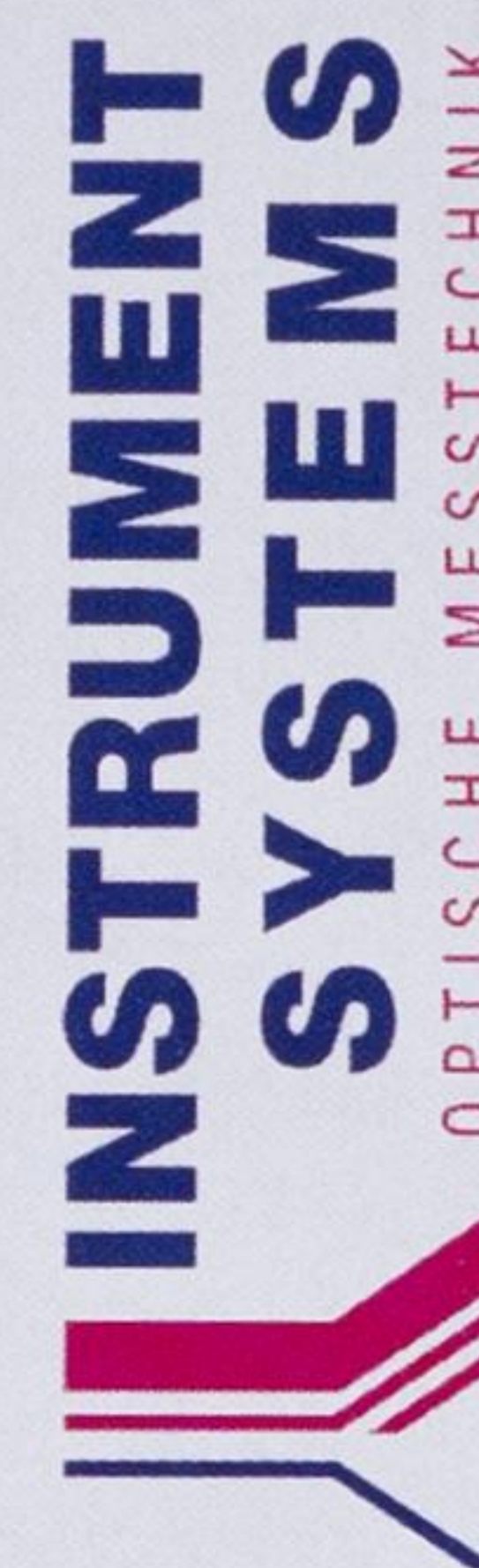
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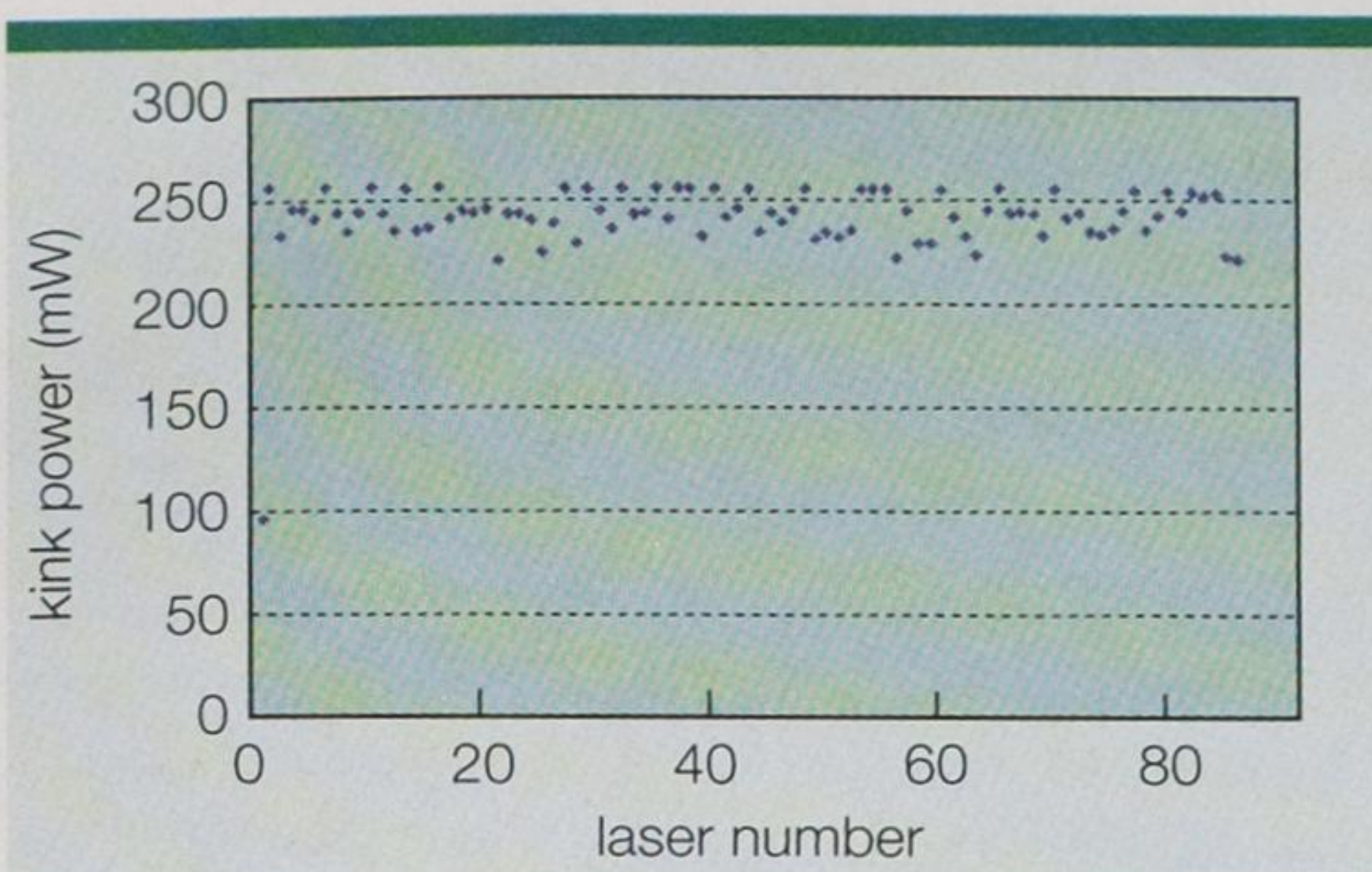


Fig. 2. A laser array developed by Intense Photonics features 86 consecutive emitters with a "kink power" (the power emitted in the laser's lowest-order transverse mode) of over 220 mW, ensuring that the power emitted can be usefully applied.

with which the laser waveguides can be aligned to the crystallographic planes is around $\pm 0.05^\circ$. Over a 1 cm facet length this introduces a further $\pm 9 \mu\text{m}$ of "run-out" in the cleave position. Finally, the passive waveguides relax the packaging alignment tolerances. Because little heat is generated in the passive section, the laser chip can overhang the heat sink.

Array performance

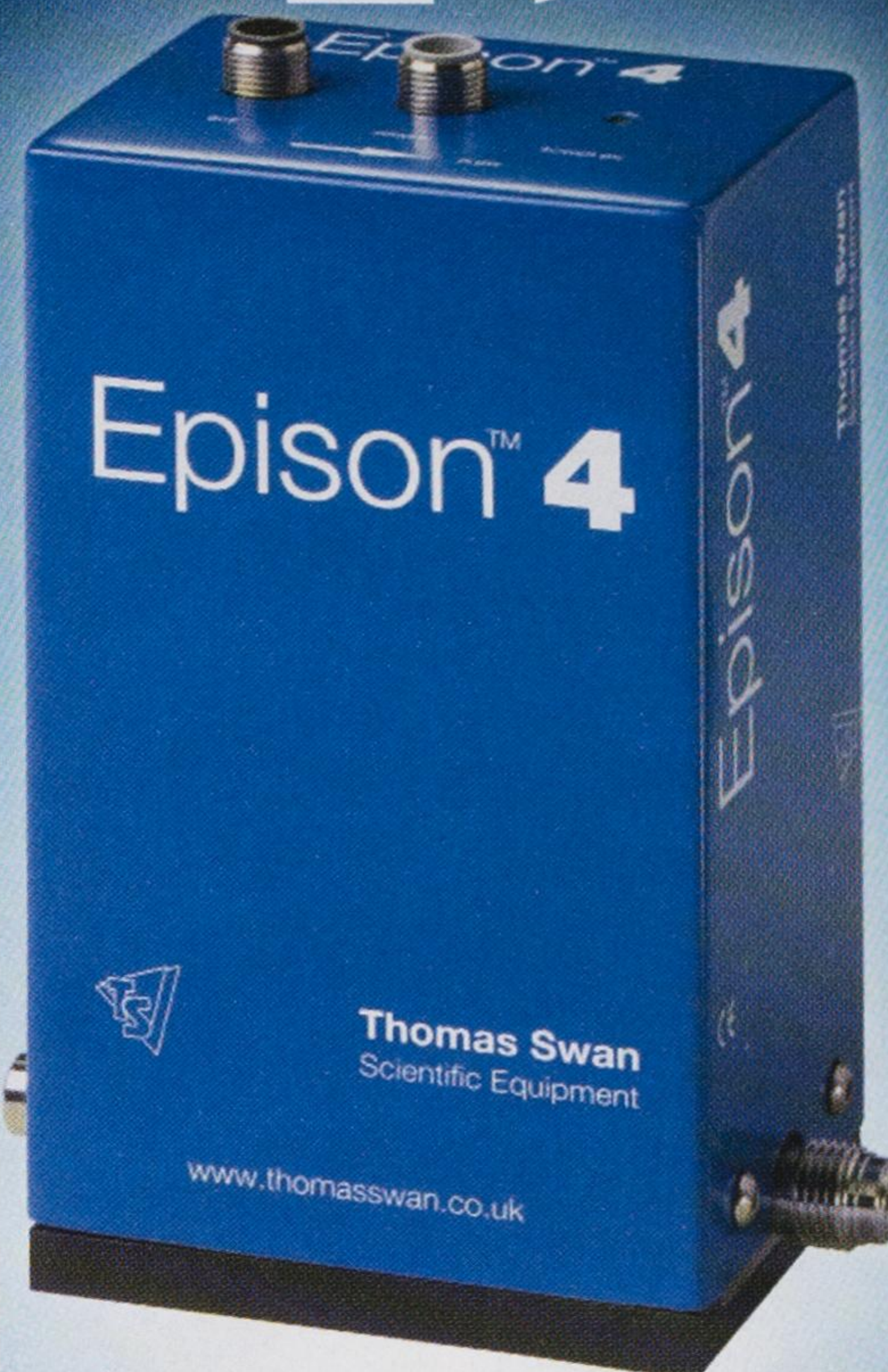
The performance and manufacturing yield of laser arrays is therefore increased substantially by integrating passive waveguides within the laser cavity; indeed, such integration is a prerequisite for achieving good yields. Laser arrays with extremely uniform characteristics have been demonstrated. Figure 2 shows the kink power of lasers in an array, in which 86 consecutive elements have a kink power of more than 220 mW – again comparable to the power of leading-edge 980 nm pump lasers. Kink power is a measure of how much laser power is emitted in the lowest-order transverse mode. It is important, because second-order output modes have a detrimental effect on the laser's far-field pattern and, consequently, the effectiveness of the tool for industrial applications. A correspondingly high level of uniformity is seen in parameters such as threshold current and slope efficiency. ●

Further reading

Marsh *et al.* Improved COD level from laser with non-absorbing mirrors *IEEE Photonics Technology Letters* **14** (10) 1394.

John Marsh is co-founder and CTO of UK-based optoelectronics manufacturer Intense Photonics. E-mail: john_marshall@intenseco.com.

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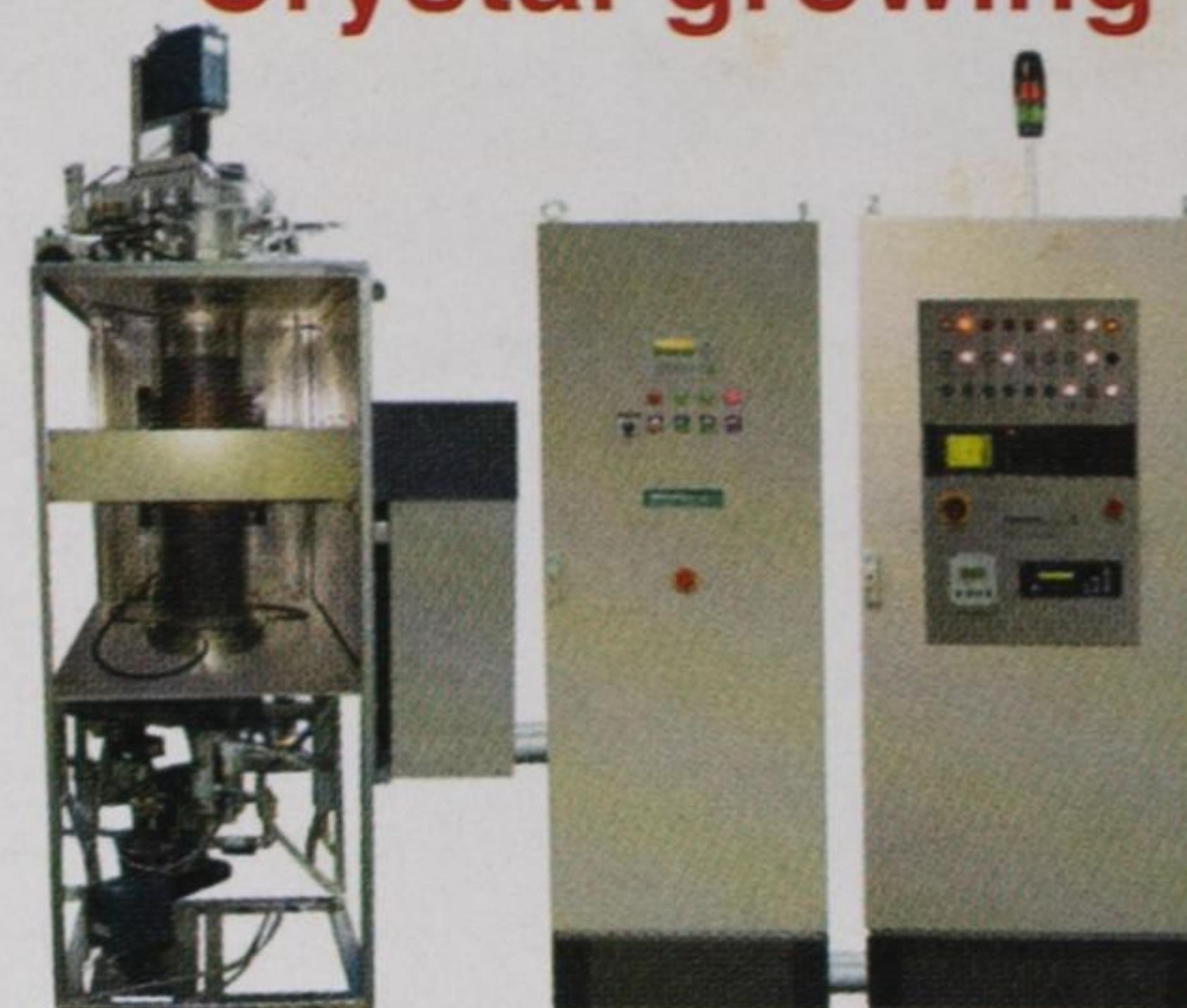


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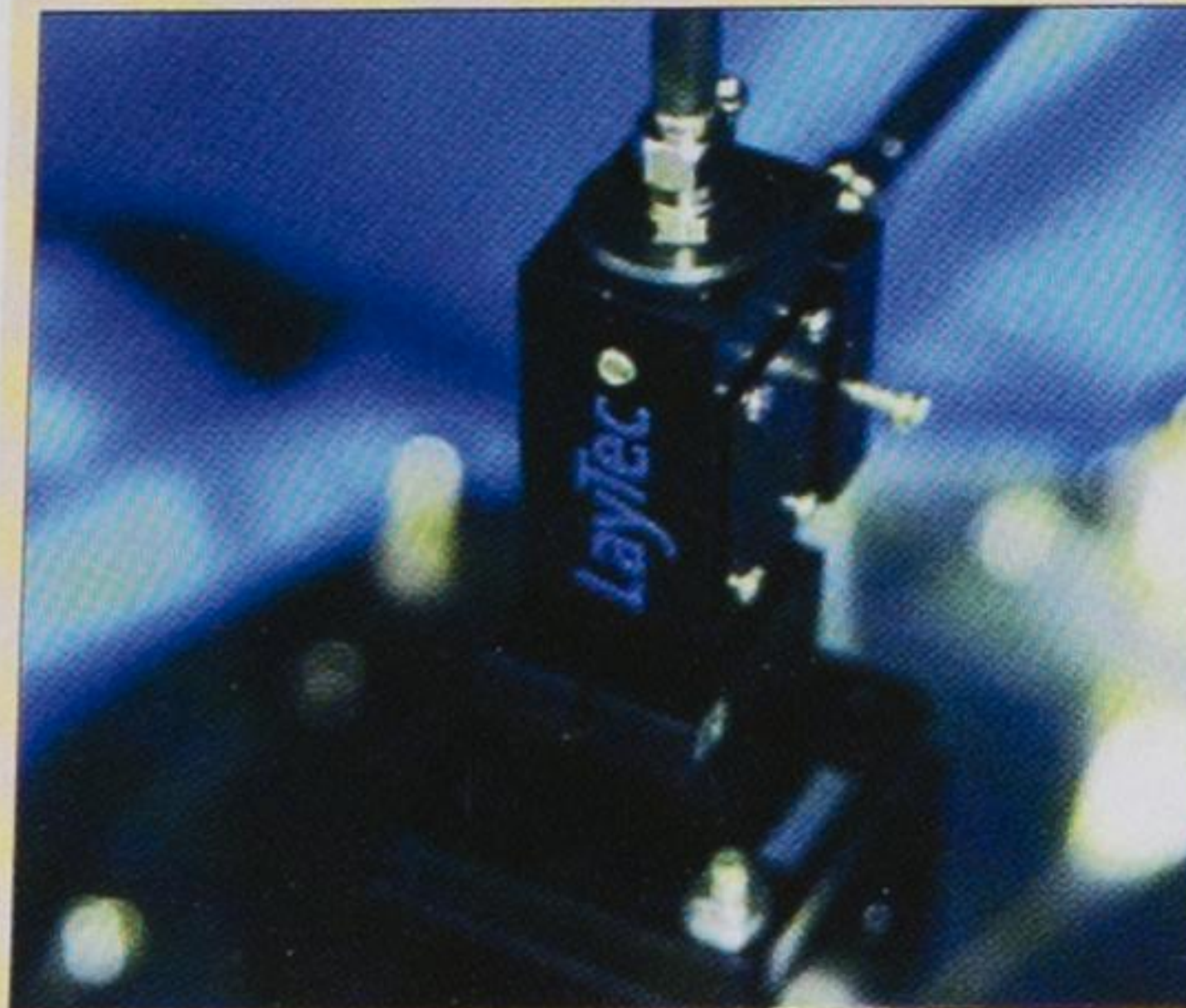


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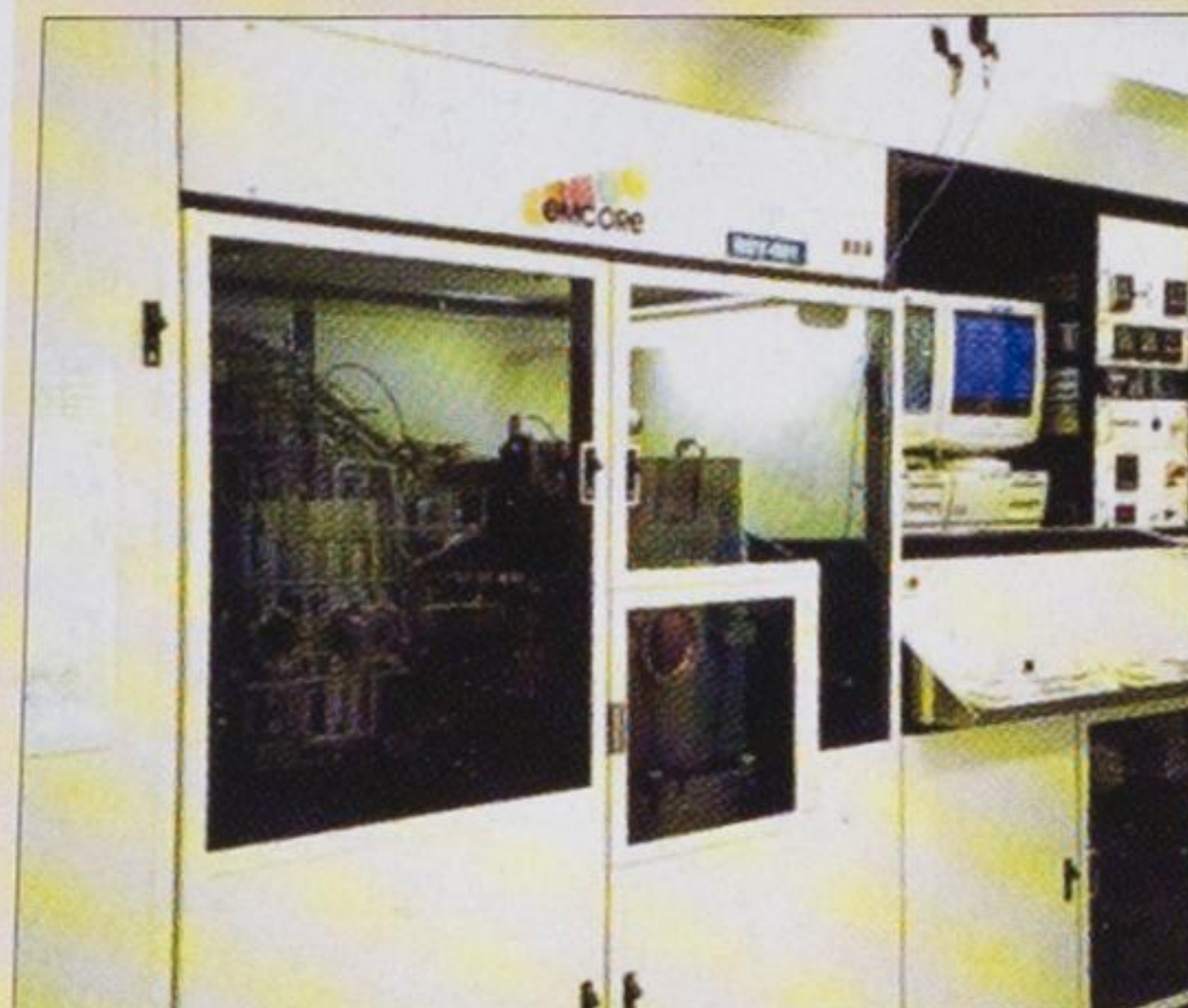
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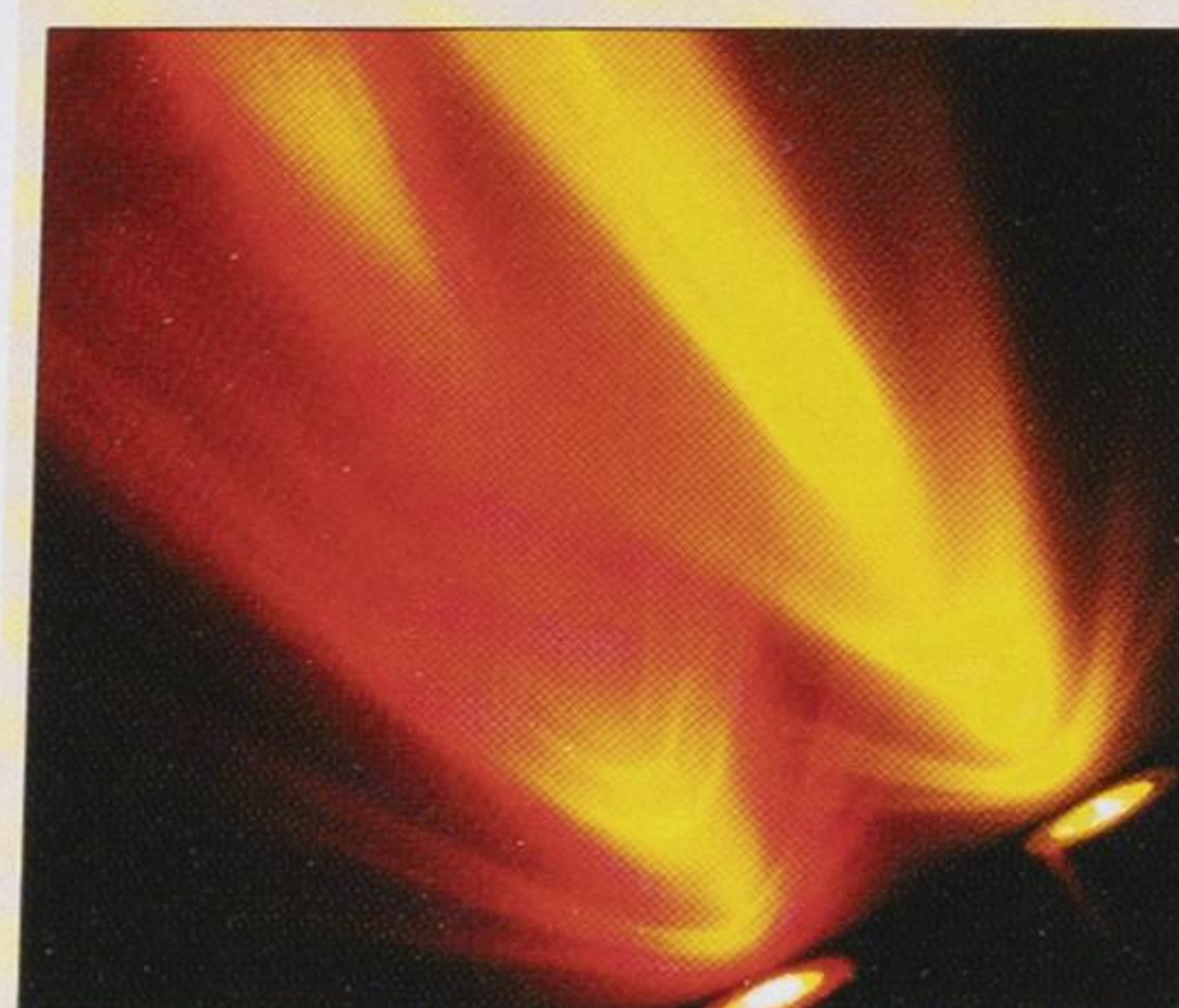
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UEC's new high-brightness glue-bonding AlGaInP LED processing chip ($350 \mu\text{m} \times 350 \mu\text{m}$) can achieve up to 45 lm/W at 625 nm and 20 mA driving current. The performance at 590 nm can reach up to 70 lm/W. Another new product is UEC's utilized metal-bonding process. This new technology can bond epitaxial structures to metallic or silicon substrates. The metal acts as the reflective substance to increase brightness. The $350 \mu\text{m} \times 350 \mu\text{m}$ chip can

reach 40 lm/W at 625 nm (60 lm/W at 590 nm) and 20 mA driving current; the $700 \mu\text{m} \times 700 \mu\text{m}$ chip can reach 50 lm at 500 mA; and the $1 \text{ mm} \times 1 \text{ mm}$ chip (at 500 mA and 1 A) can reach up to 50 and 80 lm respectively.



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Veeco bags \$10 m MOCVD deal

Fujian Quanzhou Sanan Group, a manufacturer of high-brightness (HB) LEDs based in Fujian Province, China, has placed an order in excess of \$10 million for a number of Veeco's GaNzilla MOCVD systems.

The company will manufacture blue, green and white LEDs. It is another sign of the strength of the HB-LED industry in Asia. Only last month, Taiwanese LED manufacturer South Epitaxy ordered five GaNzilla

tools, while a recent report from Strategies Unlimited suggested that Asian manufacturers (excluding those in Japan) produced 40% of the world's GaN-based LED chips in 2003.

Xiu Cheng Lin, president and CEO of Fujian Quanzhou Sanan, said: "With this significant expansion of our production capacity, we are taking a major step towards achieving our stated goal – becoming the leading supplier of LED materials in China."

Riber eyes OLEDs with Addon acquisition

MBE machine supplier Riber has acquired fellow French company Addon. Addon makes components for both MBE machines and organic LED (OLED) display manufacturing.

"Some components supplied by Addon were not part of Riber's components portfolio," said Riber in a statement. "These components have become necessary in order to master the MBE epitaxy process in new areas." New areas specifically referred to

include nitride-based epiwafers for microwave devices and blue-violet laser diodes, as well as ultra-thin oxide films for high- κ insulators.

But the main reason for the acquisition appears to be the potential for exploiting Addon's components that are used in OLED manufacturing. These are similar to those used in MBE machines, and Riber said that the acquisition would allow it to diversify into what is regarded as a growth market.

Trikon set to cut staff levels again

Trikon, the wafer fabrication equipment supplier based in Newport, UK, has announced a loss of \$6.5 million for the quarter ending March 31, 2004.

Revenue for the quarter was \$6.8 million, up from the \$5.1 million reported for the same quarter of 2003. To reduce costs by an estimated \$4–4.5 million per year, Trikon will implement several initiatives, with the largest saving resulting from headcount reduction.

Bob Chappell, Trikon's CFO, revealed that Trikon will also switch its emphasis from long-term projects, such as low- κ dielectrics, to supplying more established markets.

Trikon is continuing to closely manage its working capital. Cash and cash equivalents on March 31, 2004 stood at \$29 million, down from \$31.6 million on December 31, 2003.

GaAs and InP markets currently account for only around 10% of Trikon's business, and the company does not expect to see a significant upturn in this segment until 2005.

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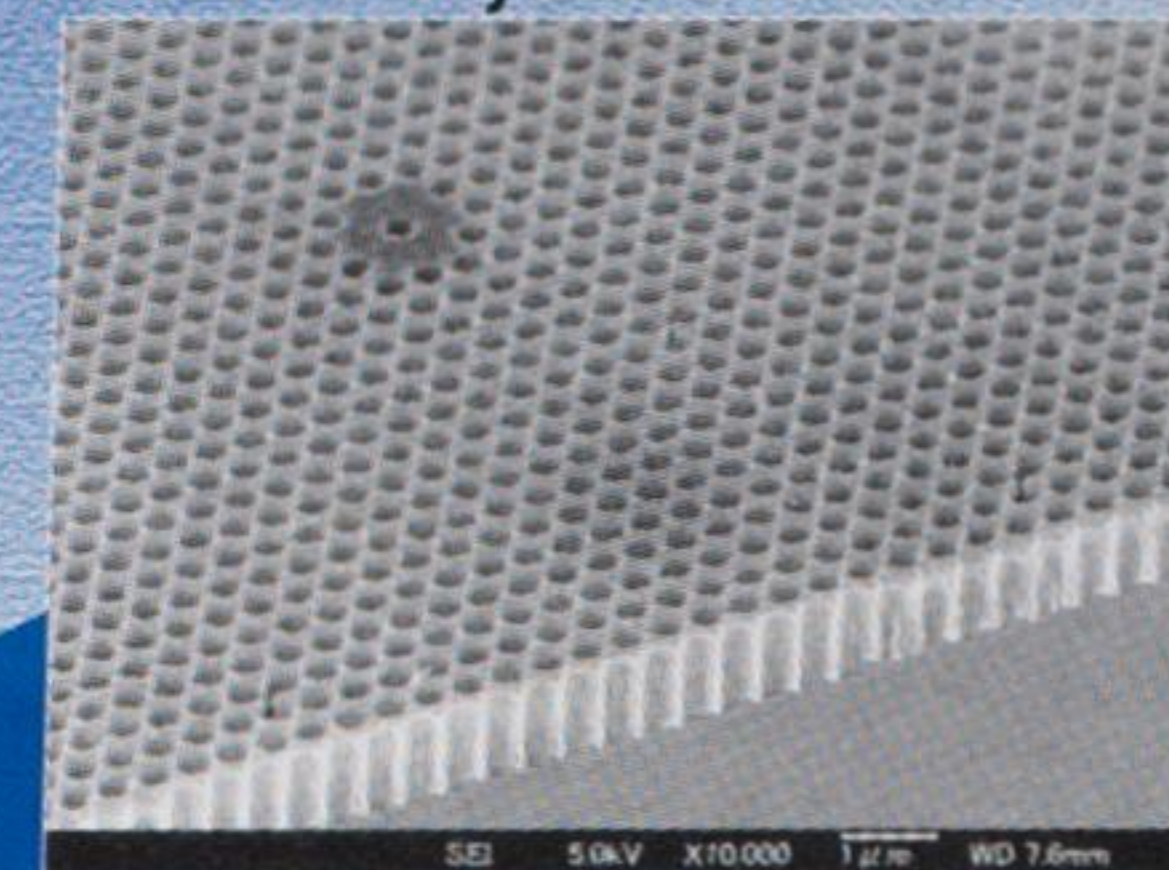


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Mixed fortunes for manufacturers as wireless market strengthens

While RF Micro Devices has recorded a healthy profit for fiscal 2004, and TriQuint and Skyworks make steady progress, Anadigics is planning to cut costs in a bid to reduce its loss.



After the traditionally strong final quarter of the calendar year, the first quarter of a new year often results in slumping revenues for GaAs manufacturers. But while the strengthening cell phone market (Nokia's weak results were more than made up for by strong sales at both Motorola and Samsung) is driving revenue and even profits upwards at some GaAs IC companies, others appear to be lagging behind. RF Micro Devices (RFMD) certainly appears to be riding the current wave of optimism in the wireless sector. Despite making a slight loss in the most recent quarter, the Greensboro, NC, company posted a profit of \$30 m for its full fiscal year 2004.

With plenty more products and design wins in the pipeline, 2005 looks like being an even better year for RFMD. Full-year revenue came in at \$651.4 m, up almost 30% on the fiscal 2003 figure. CFO Dean Priddy said that he was "even more optimistic about fiscal 2005", with the company expecting further gains in its share of the power amplifier (PA) market. Overall, RFMD predicts double-digit top-line growth next year as it moves towards its goal of \$1 bn revenue in 2007.

The cellular business continues to dominate RFMD's sales: in the most recent quarter, this segment accounted for \$152 m, with the wireless connectivity group contributing \$7.4 m, and \$4 m coming from the infrastructure business. While its cellular segment goes from strength to strength, the company has admitted that its foray into the wireless LAN (WLAN) market hasn't gone quite according to plan.

However, RFMD CEO and president Bob Bruggeworth predicted that next year will be a big one for Bluetooth and WLAN, with double-digit growth expected in the company's wireless connectivity division. Although margins are generally regarded as low in the WLAN segment, Bruggeworth said: "We see ways to make a lot of money [in the WLAN market]."

With current fab utilization at around 90%, RFMD is transferring manufacturing to its 6 inch GaAs wafer facility, with over half of its production now on this line. However, the 4 inch facility will not be discontinued, with future GaN device production expected to join the current GaAs HBT and PHEMT manufacture.

Of the other big GaAs IC players, Skyworks and TriQuint appear to be making solid progress. TriQuint broke even in the most recent quarter, and has upped its guidance for the full year ahead. And although Skyworks reported a loss of \$4.4 m on the quarter, this was due mainly to a substantial write-down charge related to technology licenses acquired prior to the merger between Alpha Industries and Conexant. Skyworks president and CEO David Aldrich is in a buoyant mood, predicting an "exceptional" year for the company.

However, volumes at Anadigics are not in the same league as its top-tier rivals, and the New Jersey-based company continues to make a loss. Despite posting \$21.2 m revenue, an increase of \$5.1 m (32%) over the same quarter last year, increasing costs saw the company make a \$12.7 m operating loss. These resulted from last year's acquisition of both RF Solutions' PA product line for WLAN applications, and the Tavanza CDMA PA product line. Further costs have been incurred with new applications centers in Korea and Taiwan, while fab utilization stands at just 30%.

Anadigics said it was now planning to implement a raft of measures, including some outsourcing, to cut \$8 m in costs this year. When contacted by *Compound Semiconductor*, CFO Tom Shields was tight-lipped on the exact nature of the cuts, refusing to comment on any likely effect on headcount.

There has been some progress, however, particularly in the WLAN market, where Shields says the company is the leading supplier of InGaP HBT PAs. This segment saw a 32% increase in revenue sequentially, bringing in \$3 m. Shields added that "significant progress" has been made in the GSM segment, with a series of design wins and production orders for Anadigics' PAs. GSM revenue tripled in the most recent quarter.

Although Anadigics looks strongly positioned in these markets, it needs a 50% boost in sales to make its estimated break-even quarterly revenue target of \$33 m. Shields believes this is possible by the end of this year.

With the market in buoyant mood, Shields may be proved right, but Anadigics looks to be facing an uphill task given the strength of its competition.

April quarter revenues for GaAs manufacturers

Company	Symbol	Revenue (\$m, year change %)	Net profit/loss (\$m)	Share price on May 11 (52 wk range)
Anadigics	ANAD	21.2 (+32%)	-12.7	4.54 (2.09-9.11)
Celeritek	CLTK	8.6 (+6.2%)	-0.2	3.30 (3.13-9.10)
RF Micro Devices	RFMD	163.4 (+18%)	-0.86	7.15 (4.96-12.51)
Skyworks Solutions	SWKS	183.5 (+17%)	-4.4	8.78 (5.73-12.68)
TriQuint	TQNT	89.9 (+1%)	0	5.50 (3.48-9.93)

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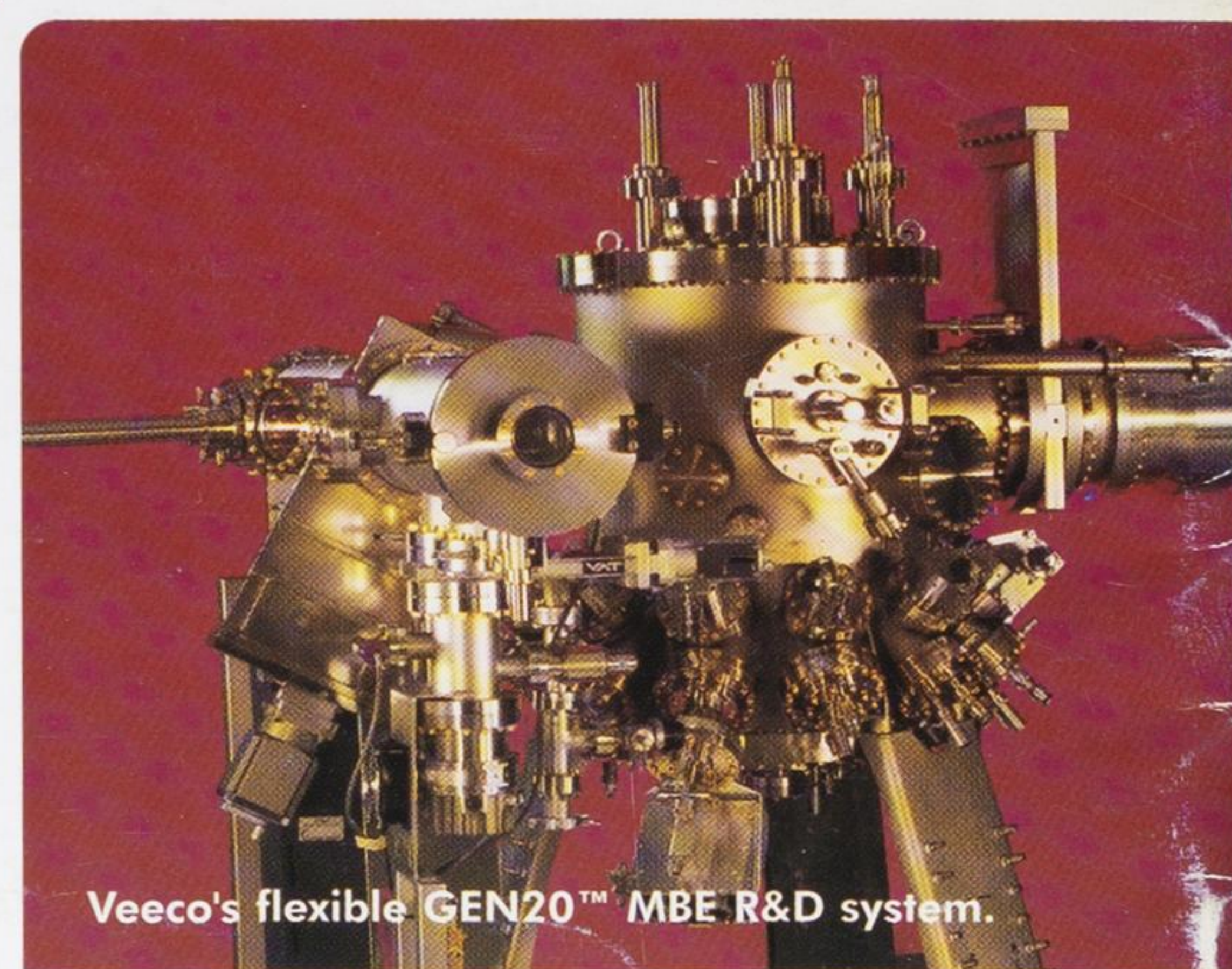
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